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PRODUCT SERVICE SYSTEMS FOR HOUSEHOLD WASTE PREVENTION

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ABSTRACT

Waste prevention is the prioritized waste management option within EU waste policy. There is however a scarcity of research on and policy measures for waste prevention. Improved resource productivity in consumption practices may prevent waste. Literature suggests that Product Service Systems (PSS, 'a marketable set of products and services capable of jointly fulfilling a user's needs' (Goedkoop *et al.* 1999)) have potential for increased resource productivity compared with self-servicing (households owning material artefacts and using them to perform household tasks themselves), and therefore potential for waste prevention. However, the potential of PSS is uncertain due to a lack of well-reported quantitative assessments. Moreover, the potential is predicated on particular behaviours of self-servicing households and PSS providers concerning their choice and management of material artefacts. This research, therefore, aims to assess the utility of the PSS concept for achieving household waste prevention in the UK with a view to informing policy-makers. Three objectives address the aim, namely to: identify attitudes towards PSS adoption and behaviours concerning choice and management of material artefacts which influence the waste prevention and wider environmental performance of PSS; the waste prevention potential of experimental PSS; identify the environmental potential of experimental PSS.

An exploratory mixed-methods research design was used to address the objectives, comprising focus groups, interviews, a survey, document studies, development of a model for waste prevention assessment and a simplified life cycle approach using life cycle indicators. The context was a national property development firm and households on new housing developments built by the firm. Experimental PSS, for potential provision by the property development firm were developed for four household tasks to enable the assessments, namely garden maintenance, home improvement, house cleaning and laundry.

The households, the property development firm and its supply chain expressed reluctance towards adopting PSS. Reported behaviours concerning choice and management of material artefacts partly confirmed and partly diverged from the propositions in the PSS literature. For almost all propositions, there were diverging behaviours. PSS for all household tasks except house cleaning had some although modest waste prevention potential. PSS led to increases in some types of emissions in most of the assessed scenarios. Increased emissions mainly arose from the transport for the delivery of PSS. Due to the increase in some emissions, it is uncertain whether PSS qualifies as waste prevention according to the legal definition. The waste prevention and environmental potential depend on the organisation of PSS. Moreover, the behaviours of service providers in particular are uncertain.

Despite the modest potential for household waste prevention PSS could have a role as one in a suite of waste prevention measures. However, due to the uncertainty of the potential it might be inappropriate for policy-makers to promote adoption of PSS currently. Adoption of household services provided by local service providers may however increase. Policy-makers should consider promoting the environmental sustainability of both self-servicing households and of commercial household services. Policy-measures are proposed. The PSS concept is critiqued and the term PSS rejected. It is suggested PSS are services.

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PUBLICATIONS

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GLOSSARY

AP	Acidification potential
EP	Eutrophication potential
FM	Facilities management
GWP	Global warming potential
Household waste	Waste is 'any substance or object which the holder discards or intends or is required to discard' (Official Journal of the European Union 2008, p.9). In this thesis, household waste is understood to be waste emanating from households
Geographical density of demand	Relatively large number of households adopting PSS in a limited geographic area, to reduce the transport distances and the time staff spend travelling rather than performing the PSS,
LCA	Life cycle assessment
Material artefact	A man-made object (Lathouri 2011) (product); the term includes the notion that social activity, knowledge and values have shaped the structure of the material artefacts (Lawson 2010).
PAH	Polycyclic aromatic hydrocarbon
Product Service System (PSS)	'a marketable set of products and services capable of jointly fulfilling a user's needs'(Goedkoop et al. 1999) .
Rebound effect	Efficiency gains being off-set by increased consumption (Sorrell & Dimitropoulos 2008).
Result-oriented PSS	A PSS in which the service provider owns and uses the requisite material artefacts and produces a result for the customer. The customer buys this result.
Self-servicing	The household owns and uses the requisite material artefact to produce a result (in the case of the present research, a result for a household task, such as mowing the lawn to produce a neat lawn).
SLA	Service level agreements
Upstream; downstream	In life cycle assessments, product (or service) life cycles are divided into life cycle stages from raw materials extraction, materials and parts production, assembly, sales, use, waste management (and distribution in between those stages). The term 'upstream' refers to life cycle stages before the stage in focus, and the term 'downstream' refers to life cycle stages after the stage in focus. If the focus in a study or discussion is on the use phase, then upstream refers to raw materials extraction and production stages. Likewise, downstream then refers to waste management which comes after the use stage.
Use cycle	The period of use before the owner discards a material artefact. If the material artefact is collected for reuse or remanufacturing and is put to use again in someone else's ownership it is said to have multiple use

	cycles
VOC	Volatile organic compounds
Waste prevention	‘measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste including through reuse of product or the extension of life span of products; (b) the adverse impacts of the generated waste on the environment or human health; or (c) the content of harmful substances in materials and products’ (Official Journal of the European Union 2008, p.10). Waste prevention refers to preventing some waste from arising. This leads to a reduction of the total waste arisings. Waste prevention does not refer to a elimination of all waste.
WEEE	Waste electrical and electronic equipment

1 INTRODUCTION

1.1 INTRODUCTION

This chapter sets out the background to the research the research problem and its research and policy relevance. The aim, objectives and research questions and scope are set out against this background. Finally the structure of the thesis is presented.

1.2 BACKGROUND TO THE RESEARCH

It is widely accepted that production and consumption patterns need to change to protect the environment for current and future generations (Defra, 2011a; OECD, 2008; UNEP, 2011). If more output could be generated with the same amount of input of material resources (that is, if resource productivity increased), environmental burdens may be reduced across the life cycle, from extraction of material to waste generation and waste management. Waste generation is one of the issues of concern within sustainable consumption and production. Preventing waste from arising in the first place is the waste management option favoured by waste policy (Defra, 2007) at least in theory. Nevertheless, there is a scarcity of research on waste prevention (Cox, et al. 2010). Policy measures in the waste area have to great extent concentrated on landfill, energy recovery and recycling. With the Waste Directive 2008 (Official Journal of the European Union, 2008) and the requirement on EU member states to put in place national programmes for waste prevention plans by late 2013, waste prevention is likely to receive greater policy attention. An evidence base is needed for policy measures for waste prevention.

Waste prevention has a synergetic relation to resource efficiency and productivity, whereby improved resource productivity in production and consumption practices are thought to be able to prevent waste from arising in the first place (Ekvall, 2008; Lilja, 2009). The idea that services may improve resource productivity is the subject of a growing literature (Meijkamp, 2000; Heiskanen & Jalas, 2003; Halme, *et al.* 2004) and might, therefore, also be of utility for waste prevention research. Product Service Systems (PSS) is a type of service which has been defined as 'a marketable set of products and services capable of jointly fulfilling a user's needs' (Goedkoop, *et al*. 1999). The underlying idea in the PSS literature is that when service providers own material artefact[1] and use it or make it available for use to fulfil the customers' needs, service providers have incentives to extend the use-lives of material artefacts and thus maximise their use-value. This is thought to lead to increased resource productivity (Stahel, 1997). If this is the case PSS could also lead to waste prevention.

[1] A man-made object (Lathouri 2011) (product); the term includes the notion that social activity, knowledge and values have shaped the structure of the material artefacts (Lawson 2010).

PSS and similar service concepts have been the focus of research for instance in continental Europe. However, PSS has not been researched in terms of its potential for achieving waste prevention. There is also a scarcity of research on PSS in the UK, particularly concerning PSS offered to households. This thesis reports the findings of a PhD project that was based on a government funded research project on achieving household waste prevention.

The project upon which this PhD thesis is based formed part of a Department for Environment, Food and Rural Affairs (Defra) research programme on household waste prevention. The project drew on previous research concerned with Product Service Systems (PSS) waste, resources and technology assessment undertaken by Cranfield University. The research was undertaken by a multi-disciplinary team including those from social science, design, economics and environmental management. The research was conducted in collaboration with a national house builder, through which access was gained to representatives of its functions and households on its new housing developments. The lead representative of this firm was a member of the research team.

The three-year project was conducted between 2005 and 2008. The research project comprised several objectives. The first two objectives were concerned with understanding potential PSS performances and developing experimental PSS in light of these insights. Subsequent objectives involved assessment of the experimental PSS to gauge their social, economic and environmental potential. The social and economic assessment comprised qualitative elements to identify criteria which influence the adoption of PSS, and attitudes towards adoption, e.g. criteria related to cost, price and profitability were part of these criteria. The social and economic assessment also included an analysis based on the Analytical Hierarchy Process (AHP).

The author of this PhD thesis had the role of Research Assistant in the project. The author led much of the research, refined and implemented the overarching methods set out in the original project plan as necessary, in particular the qualitative investigation and the assessment of waste prevention potential and environmental assessment. Life cycle study of management of municipal solid waste was the author's specialist area in the project and therefore it formed the basis of the PhD.

More specifically, The focus on the household waste stream was specified by the contract since the Defra research programme focused on household waste prevention. The author selected the household waste fractions under study.

Collaboration with the property development firm was specified by the project. It participated in the bid. The focus on experimental PSS was determined by the contract since those PSS were not currently offered on the market. The author selected the household tasks under study and led on the development of the experimental PSS.

The criteria-oriented approach to exploring adoption of PSS was defined by the contract in order to feed into a multi-criteria analysis that was a part of the Defra project but not the PhD thesis. The use of both focus groups and interviews was specified in the contract. The author developed the application of the methods for the purpose of the project and executed those.

The author decided on the focus on behaviours of households and service providers concerning their choice and management of material artefacts, realizing its role in PSS and waste prevention. The author found the combination of focus groups, individual semi-structured interviews to be fruitful to these research questions as well. The author decided on the use and development of a survey questionnaire as a complementary data collection instrument to explore the research questions concerning the aforementioned behaviours. The author also developed and executed the method for the assessment of waste prevention and environmental potential.

1.3 RESEARCH PROBLEM

Practical approaches to household waste prevention are needed. However, in order to determine the extent to which they merit policy support, research on such approaches are also needed. PSS is one such possible approach that has been thought promising. However, the extent of the potential of PSS to improve resource productivity and by extension waste prevention is debated in the literature. The bolder claims of the early conceptual literature of improvement potentials in the order of factor 4-10 (Stahel, 1997) have been contested by subsequent research suggesting more modest potentials (Heiskanen & Jalas, 2003; Tukker & Tischner, 2006). The environmental assessments in the literature provide limited clarification on the issue, and therefore the early conceptual claims can neither be seen as confirmed, nor refuted. Some of the assessments can be thought of merely as based on reasoning associated with service concepts. Other assessments are reported in a manner which prohibits insight into methods and data used, and thereby the fairness of the results.

According to the PSS and similar service concepts, gains in resource productivity and waste prevention from PSS are predicated on certain behaviours of service providers and self-servicing households respectively. Examples of such behaviours are the choice of certain specifications of material artefacts, use patterns and replacement rates of material artefacts, skills of use, maintenance and repair. Such behaviours are embedded in social contexts which may offer more or less support for the ideal behaviours. Therefore, it is important to study the phenomenon and its potential in a particular context and in the country from which the particular policy interest stems. In addition, literature on PSS identified a limited willingness to adopt PSS as a potential barrier for any gains to be realised.

The ability of PSS to improve resource productivity in business to consumer markets and thus to achieve household waste prevention, remains uncertain. The present research seeks to link the question of adoption of PSS, and behaviours of supply chains and households in the context of contemporary urban households in the UK, and assess the resultant waste prevention potential, with a view to informing waste policy.

1.4 AIM AND OBJECTIVES

This section enumerates the aim and objectives formulated in light of the literature review that identified a theoretical and policy relevant research problem.

1.4.1 Aim

The aim of the research is to assess the utility of the PSS concept in achieving household waste prevention in urban areas of the UK. The purpose is to inform policy decisions.

1.4.2 Objectives

Based on the literature review, a number of objectives were developed to direct the enquiry in pursuit of the aim. These objectives were:

1. To identify attitudes towards PSS adoption and behaviours concerning choice and management of material artefacts which influence the waste prevention and wider environmental performance of PSS
2. To identify the waste prevention potential of experimental PSS
3. To identify the environmental potential of experimental PSS

1.4.3 Research questions

For the first three objectives, a number of research questions were developed that articulated important facets of the objectives and guided the analyses.

Objective 1

1. What attitudes do households and service providers hold towards adopting the experimental PSS?
2. How do households and service providers conceive of the different factors thought to influence adoption of the experimental PSS?
3. How do households and service providers respectively reason and behave concerning their choice, ownership and management (use, maintenance, replacement and disposal) of material artefacts?
4. How do these behaviours compare with the behaviours proposed by the literature review?

Objective 2: to identify the waste prevention potential of experimental PSS developed for different household tasks

1. Do the household tasks hold the same potential for household waste prevention?
2. How do the attitudes and behaviours of households and service providers with regard to adoption of PSS and choice and management of material artefacts affect the waste prevention potential through result-oriented PSS?
3. What is the scale of the potential for household waste prevention potential through the result-oriented PSS?
4. Do result-oriented hold as great potential as has been suggested by previous research?

Objective 3: To identify the environmental potential of PSS developed for different household tasks

1. Are there any trade-offs between household waste prevention and other emissions over the life cycle?
2. Are there any trade-offs between different types of emissions over the life cycle?
3. What is the scale of the changes in emissions?
4. Do PSS for different household tasks have the same environmental potential?

1.5 SCOPE OF THE STUDY

The term PSS is adopted in this research. Similar service concepts like eco-services which share many of the same notions of resource productivity are also included. The focus in this research is on a particular type of PSS, namely result-oriented PSS (provided through the formal private sector economy). In result-oriented PSS, the service providers own and use material artefacts to produce a result for the customer. An important assumption in the PSS concept is that the PSS customer gives up ownership of material artefacts when using PSS. Since the focus in this research is on household waste prevention, the focus is also on PSS provided to households in order that households possess fewer material artefacts. Thereby household waste may be prevented. After initial research, four household tasks were selected, namely garden maintenance, home improvement, house cleaning and laundry. While use-oriented PSS (such as renting or sharing) was also considered after the initial stages, it was later deselected for reasons explained in appendix A.

New housing developments in urban areas in England, house-builders and households associated with these, formed the context of this research. Research was undertaken in collaboration with a property development firm. Experimental PSS (henceforth just PSS) were developed in this project for hypothetical provision by the property development firm to households on new housing developments built by the firm. In other words, the PSS assessed are not actually provided. This research does not cover PSS in the sense of servicizing manufacturing firms.

While household waste, (solid waste emanating from households[2]) is the focus of this study, the corresponding commercial waste arising from PSS is also taken into account in order that household waste is not merely shifted to another waste stream. The waste fraction of WEEE (waste electrical and electronic equipment) was selected for the present research, as set out in appendix A. The definition of waste prevention comprises the amount of waste, hazardous substances, and the impact of waste on the environment and human health. Hazardous substances were considered in the selection of focal waste fraction. The research comprises both an assessment of potential prevention of amounts of direct waste, and a simplified life cycle approach assessing emissions and mid-point environmental impacts of PSS.

[2] For the legal definition, please see chapter 2.

The research covers a variety of behaviours of households and (potential) PSS providers (henceforth service providers[3]) and other actors across several life cycle stages. In addition to PSS literature, the research draws on research related to each of these stages and type of behaviours. This related research stems draws on a variety of theoretical areas. In this research, theory is used as a heuristic devise. A single grand theory is not adopted in this research.

1.6 RESEARCH PERSPECTIVE

This thesis adopts a realist perspective, which holds that reality exists independently of human perception of it, that reality transcends the observable, but nevertheless, it is possible to gain knowledge about it. This perspective acknowledges that concepts are fallible and theoretically laden (Easton, 2002), and shaped by human cognitive abilities (Minger, 2004). Therefore, knowledge about the world is transitive. Reality is stratified into for instance molecular, biological, psychological and social levels, with each new stratum emerging from the underlying ones, but with faculties and properties that cannot be reduced to the previous strata. For instance, mind may be emergent from biological matter but the powers of agents, springing from their minds, cannot be reduced to the biological matter (Willmott, 1997). Agents are reflexive and therefore it is impossible to create closed social systems with stable conditions. The conditions are potentially changing due to the reflexivity of agents. Institutions may enable demi-regularities and cause pseudo-closed conditions. However, the usefulness of probabilistic prediction is rejected due to the impossibility of closed conditions in the social world (Danermark, *et al.* 2003). Therefore, the research focus with this realist perspective is on understanding the generative mechanisms underlying the phenomenon under study. To this end, the use of both qualitative and quantitative methods may be beneficial. However, the interpretation and generalisation of results will be based on an understanding of the phenomenon and potential underlying causes and theoretical transfer of this understanding to other contexts, rather than on statistical probability. This is further discussed in chapter 3.

1.7 THESIS STRUCTURE

The thesis is structured as follows.

Chapter 2 Literature review: This chapter provides a state of the art view of waste prevention and PSS along with related concepts pertaining to service. Definitions and ideas of PSS and identified and critiqued. Key debates in the PSS literature are reviewed. Frameworks for exploring supply and demand side adoption are collated from PSS and related literatures. A list of propositions on behaviours thought to lead to

[3] The participating property development firm and its supply chain did not provide PSS for household tasks and the assessment of adoption in chapter 4. The local providers of household who provided data for the waste prevention assessment were not PSS providers in the context under study. Therefore, the term 'service providers' is used to refer to potential providers of PSS.

resource productivity is produced to enable qualitative testing and as input the later assessments of waste prevention potential.

Chapter 3 Methodology

Chapter 3 describes the research methodology used in this research. The research design is identified considering the novelty of the research area, the type of research questions, the purpose of the research and approach to theory. An exploratory mixed-methods design was chosen. The rationale for the choice of the context of the study is presented. The methods used to develop the experimental PSS, to explore attitudes to adoption and behaviours of households and service providers, to assess the potential for waste prevention and to assess the environmental potential of PSS are described. The descriptions cover the types of data needed, the methods for data collections and analysis and assumptions. In the case of the assessment of waste prevention potential and environmental assessment, the choice of method, variables and equations are also set out.

Chapter 4 Attitudes towards adoption of PSS, and choice and management of material artefacts - results

Chapter four reports the attitudes towards PSS adoption among participating households, the property development firm and its supply chain, collected through interviews and focus groups, and analysed using coding and clustering based on the factors influencing adoption that were identified in the literature review. This contributes to the fulfilment of objective 1. The results on behaviours of households and service providers reported in interviews and focus groups concerning choice and management of material artefacts, are presented and compared with the propositions in the PSS literature. This contributes to the fulfilment of objective 1 and informs the scenarios for waste prevention and environmental assessment reported in chapter 5 and 6.

Chapter 5 Waste prevention potential – scenarios, results and discussion

Chapter 5 presents the basic cases and scenarios of self-servicing and PSS that are assessed, and then presents and discusses the results of the waste prevention assessment. The assessment model devised in chapter 3 was used to conduct the assessment. The input values for the variables for self-servicing were collected from households using a survey questionnaire. Input values for PSS was collected through interviews with service providers. This chapter fulfils objective 2. The results also feed into the environmental assessment in chapter 6.

Chapter 6 Assessment of environmental potential – scenarios, results and discussion

Chapter 6 presents and discusses the results of the environmental assessment. The same scenarios on choice and management of material artefacts as in chapter 5 were used. Additional secondary data on material compositions and energy use were described for each household task. The equations described in chapter 3 were used to generate the results.

Chapter 7 Reflections on the policy implications of the research

Chapter 7 critiques and rejects the PSS concept, and suggests that the term service be used instead. Reflections on the results of the research suggest that policy-makers should not seek to stimulate adoption of PSS at the present time, but should seek to promote improved resource productivity in both self-servicing and commercial household services. Reflections on adoption considers the possibility that there may be adoption of household services, but then from a different type of suppliers to the ones in this study. This forms the context for the subsequent reflections on policy measures to promote the resource productivity and environmental potential of both self-servicing and household services.

Chapter 8 Conclusions and recommendations

This chapter presents the conclusions of the study. It shows that the research aim and objectives have been met. Key findings for each objective and also the implications of those findings are summarised. Conclusions from the critique of PSS concept are summarised. The generalizability of the findings and the contributions to knowledge are presented and areas for further research are identified.

2 REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter reports the main findings from the literature review. An initial literature review was completed and added to as the research progressed. The literature review helped identify relevant literatures and state-of-the-art in the PSS domain and related literatures of relevance. Furthermore it identified gaps in the literature and helped focus the research. The literature review also provided a basis for the comparison of results from the present research to those of previous research. Below is a summary of key points in the chapter.

- There is a scarcity of research on waste prevention, and few comparable quantitative studies.
- Waste prevention, resource productivity and services are identified as related topics, and thereby increased service production and consumption a potential route to waste prevention.
- There is no closure on the definition of PSS and similar concepts. Several terms have similar definition. However, the definitions differ for instance with regard to whether they include environmental potential. Arguments for how PSS differs from services or other business offerings are not convincing. Rather than relying on the definitions only, the present thesis turns to a set of shared notions of how PSS is said to lead to resource productivity.
- Different types of PSS were reviewed. The literature suggested that result-oriented PSS thought to hold the greatest potential for resource productivity.
- The notion that PSS hold potential for increased resource productivity and reduce environmental impacts is predicated customers and service providers behaving differently as a result of incentives arising from service providers' ownership of material artefacts. However, the proposed difference in behaviours assumed that service providers and customers (before adoption) respond differently to ownership of material artefacts.
- Those proposed behaviours concerned the choice of material artefacts in terms of their specifications, use patterns, maintenance and replacement practices. The behaviours proposed by the literature were collated to be tested qualitatively in the research reported in chapter 4 and to inform the waste prevention assessment and environmental assessments reported in chapter 5 and 6 respectively.
- The environmental potential of PSS compared with some reference case termed for instance 'traditional sales' or 'status quo' was a key debate in the PSS literature. However, waste prevention was not the focus of those studies.
- Authors that conducted quantitative assessments used for instance expert ratings on ordinal scales, or simplified life cycle approaches. However, reporting of methods and system boundaries was opaque, impeding judgement of the results. There is a need for structured and transparent environmental assessments of PSS. Life cycle approaches are appropriate.
- Comparison of results of existing environmental PSS research is very difficult, both due to the opaque reporting, and the use of a variety of emissions and

impact categories. Thus more research is needed to establish the environmental potential of PSS, and also the potential for waste prevention.

- Notwithstanding the limited possibility of judging the results of the environmental assessments of PSS, several authors suggest that claims of improvements of factor 4-10 are unrealistic. Improvements are more likely to be between factor 1.7 to factor 2. PSS may also lead to increased environmental burdens. Especially additional transport in PSS may offset any environmental improvements.
- Adoption of PSS (firms providing PSS and customers buying PSS) was identified as a challenge to realise potential environmental benefits of PSS. Factors acting as drivers and barriers for adoption were collated. On the supply side, the adapted AMR framework for technology transfer by Cook (2002) was found suitable for organising factors from other studies as well and as an analytical framework for the qualitative research reported in chapter 4. On the demand-side, Gröönroos' service quality dimensions (Schneider & White, 2004) was used to organise factors from other studies. It was extended by factors from for instance the theory of household production and was deemed suitable for analysing qualitative research reported in chapter 4 in pursuit of objective 1.

2.2 WASTE PREVENTION

The possible utility of the PSS concept in achieving waste prevention was the starting point for this thesis. This section reports on the review of literatures related to waste and waste prevention. It defines waste and household waste in order to establish the focus for the present research; it illustrates the amount of household waste generated in the UK as an indication of the scale of the problem and serves as a basis for comparison of the size of the waste prevention potential of PSS (outcome of chapter 5); it sets out the household waste fractions and their relative shares to serve as a basis for the selection of household waste fractions and household activities for development and assessment; it shows there are differences among households in the amount and type of waste generated. This serves as a background to the sampling of households for the present study; it demonstrates the policy and research relevance of waste prevention. Finally, it establishes the link with resource productivity and thereby with Product Service Systems as a potential way to achieve waste prevention.

2.2.1 Definition and origins of waste

Waste, according to the legal definition, is "any substance or object which the holder discards or intends or is required to discard"[4] (Official Journal of the European Union,

[4] Exclusions from this legal definition are for instance gaseous effluents emitted into the atmosphere, faecal matter, waste waters and other wastes covered by specific regulations, such as radioactive waste (Official Journal of the European Union (2008). Furthermore, exactly what constitutes waste has been subject to debate and court rulings. Broadly speaking, the debate concerns whether or not an object is discarded as waste and whether an object has ceased to be waste and become a resource for economic re-utilisation (Defra 2011d).

2008, p.9). Such unwanted 'substances' or 'objects' arise from activities in a range of sectors such as agriculture, construction, commerce and industry and households (Defra, 2011d). Figure 1 shows that construction and demolition waste makes up the largest waste stream (as percentage by tonnes), closely followed by mining and quarrying waste (not subject to control under the EU Waste Directive (Official Journal of the European Union, 2008). Commercial and industrial waste are also sizable waste streams, followed by household waste, making up 9% of the total annual waste in the UK in 2004, or some 30 million tonnes.

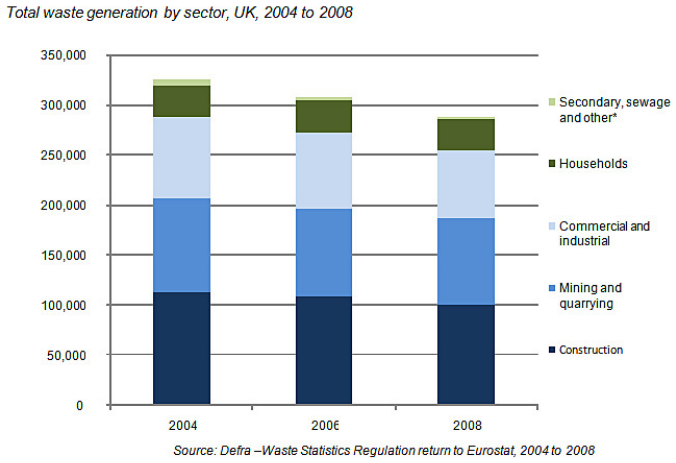

Figure 1 Annual waste arisings by sector 2004-2008 (Defra 2011d)

This thesis is concerned with household waste. Here, household waste is understood to be solid waste (in accordance with the legal definition of waste), emanating from households, and falling within waste fractions recorded for household waste, such as by (Burnley, 2007). These comprise for instance paper, card, glass, plastic, WEEE (see appendix B). These waste fractions relate to a range of material artefacts that households purchase to satisfy different wants and to support the performance of different household tasks, such as house cleaning, entertainment, food preparation and storage. When the households dispose of those material artefacts, they become waste. Household waste generation, both with regard to the total amount of waste generated by households, and the composition of this waste, differs across geographical areas depending on their socio-economic standings (Emery, *et al.* 2003). Relatively more affluent households generated more waste than those relatively less well-off, for housing of the same size in terms of average number of bedrooms (Emery, *et al*. 2003).

The waste fractions reflect common properties of the waste. The relative concern over the waste fractions depend on for instance the amount of waste, usually measured in tons, but sometimes also volume, and also the content of harmful substances.

2.2.2 Waste – an environmental, health and policy problem

Waste is a cause for concern over sanitary, health and environmental issues and squandering of natural resources. The focal point of these concerns has shifted over

time. From being an issue of sanitation, solved by waste collection and disposal to landfill (Olofsson, 2004) other issues such as squandering of natural resources, remedied by resource recovery (Secretary of State for the Environment; Secretary of State for Industry, 1974) and environmental and health effects of waste and different waste management methods (Enviros, 2004) have come to the fore. The exact environmental impact depends both on the type of waste, the type of waste management and contextual factors.

The legal definitions of waste are in place to lay down responsibility for waste management to ensure sanitary issues, environmental and health hazards are handled properly. A range of waste policies are also in place to this end, many of which stem from EU legislation, implemented at the national level. Examples of such policies are the Landfill Regulations (UK Statutory Instruments 2002) seeking to mitigate negative effects of landfilling through a range of technical provisions, and also to divert biodegradable waste from landfill; the Landfill Allowance Trading Scheme (LATS) (UK Statutory Instruments, 2005) is an economic mechanism to support diversion from landfill; producer responsibility for packaging, waste electrical and electronic equipment, and end-of-life vehicles, placing financial responsibility for collection and recycling on producers, and also setting quantitative targets for recycling (UK Statutory Instruments, 2010; UK Statutory Instruments, 2005; Official Journal of the European Union, 2003b); waste incineration legislation, requiring operators to acquire permits to ensure technical standards are met that minimise negative impact on human health and the environment (Environment Agency, 2001). Research suggests that most waste policy initiatives have concentrated on the less preferred waste management options in the waste hierarchy (which will be presented in the next section) and that new policies are required to target the most favoured level of the waste hierarchy, namely waste prevention (Mazzanti & Zoboli, 2009).

EU policy has laid down a general principle for favoured waste management options to minimise environmental impacts of waste and waste management (EC 75/442/EEC). This rule of thumb, known as the waste hierarchy[5], was refined in the recently revised waste directive (2008/98/EC), due to be implemented in member states by December 2010. This waste hierarchy is also central to the Waste Strategy 2007 (Defra, 2007). Figure 2 below illustrates from top to bottom the most to the least preferred waste management options. The validity of the waste hierarchy as a rule of thumb has been confirmed by research. It is however also recognised that it does not hold true under all conditions. For instance, the environmental benefits of recycling depend on what materials are replaced by the recycled materials and also on the properties of the materials that are recycled and how clean and well segregated they are. The

[5] While the validity of the waste hierarchy as a rule of thumb has been confirmed by research, it is also recognised that it does not hold true under all conditions. Therefore the revised waste directive (2008/98/EC) also recognises that departure from the hierarchy may be necessary (Official Journal of the European Union, 2008).

environmental benefit of energy recovery depends on what energy sources are replaced by the energy recovery (Sahlin *et al*. 2004). Therefore, the revised waste directive (2008/98/EC) also recognises that departure from the hierarchy may be necessary (Official Journal of the European Union, 2008).

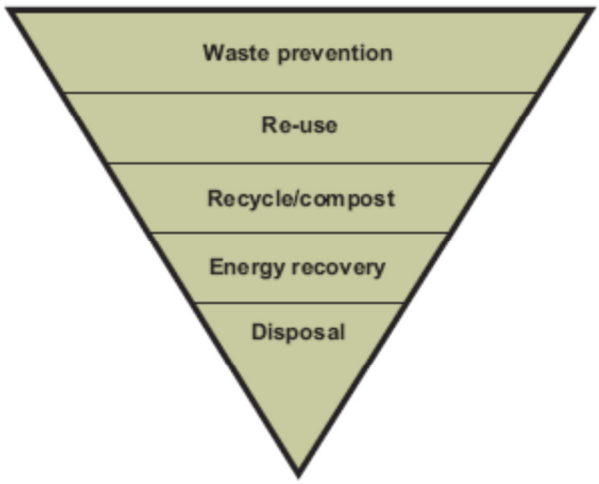

Figure 2 Waste hierarchy (Defra 2007, p.9)

According to the waste hierarchy, waste prevention is the most favoured option. Waste prevention is defined as "measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of harmful substances in materials and products" (Official Journal of the European Union, 2008 p. 10)[6].

2.2.3 Waste prevention – research gap

Despite prevention being the most favoured waste management option since the 1970s, it is the least researched option (perhaps along with re-use). Literature searches on landfill yields a large number of matches. Likewise, incineration has received much research attention, for instance on the behaviour of different compounds in the incineration process (Wheatley & Sadhra, 2004; Zhang, *et al*. 2008; Paoletti, *et al*. 2001; Victorin, *et al.* 1988; Vogg, *et al*. 1986), management/utilisation of residues (Sabbas, *et al*. 2003; Müller & Rübner, 2006; van der Sloot, *et al.* 2001). Similarly, recycling has been the concern of research both with regard to technical aspects of recycling processes for different materials, households' attitudes to recycling and participation in schemes (Clausen, 2004; Clausen, 2004; Lupi, *et al*. 2005; Pascoe &

[6] Waste minimisation is a similar term. Contrary to waste prevention, waste minimisation also comprises recycling and energy recovery (OECD, 2004 p. 67).

O'Connell, 2003; Shent, *et al*. 1999; Darby & Obara, 2005; Wilson & Williams, 2007; Read, 1999; Martin, *et al.* 2006; Emery, *et al*. 2003).

In contrast, waste prevention research is still in its infancy, in particular household waste prevention. A literature search for "waste prevention"[7] yields a considerably smaller number of hits. Many of those articles, especially from the 1970s and 80s are not about solid waste, but about treatment of gas from industrial processes. Furthermore, the articles about solid waste often concentrate on source separation, collection and recycling and composting of waste, especially towards the end of the 1970s and in the 1980s (Birch & Jackson, 1979; Burnt, 1979; Mieszkis & Thomas, 1979; Pieters & Verheyen, 1979; Scharf, 1981). It is not until the 1990s and 2000s that waste prevention in its current meaning rises to relative prominence in the literature. Some of this research is on commercial and industrial waste (Laner & Recherberger, 2009; Lilja 2009) and a little on household waste prevention (Read, *et al*. 2009; Salhofer, *et al.* 2008).

Examples of household waste prevention exist but are scarce in the literature. Examples of waste prevention activities from research as well as from tool kits tend to comprise home composting and stopping unwanted mail (paper and card household waste) (Salhofer, *et al.* 2008; Gray, 2009). It could be argued that composting is a treatment option for waste that has already been generated. Prevention of organic kitchen waste would entail purchasing the right amount of food to avoid throwing food away that has gone off while in storage, or not finishing cooked food. In other words, prevention of organic kitchen waste would be achieved through changes in household consumption behaviour. The use of services, such as nappy laundering services, is also mentioned as an opportunity for household waste prevention (Gray, 2009).

Ekvall *et al.* (2009) propose a number of ways in which waste prevention may be achieved across life cycle stages and sectors. These include as resource efficient industrial processes, reducing the amount of material used in a product unit (e.g. product light-weighting, product life extension through for instance design for durability, changing consumption patterns. Such prevention of some waste from arising, may lead to a reduction in the total waste arisings. Tonglet *et al.* (2004) point out that waste prevention (or minimisation to use their terminology) through point of purchase requires different messages and strategies compared with promotion of recycling and promotion of repair and reuse).

Literature on quantitative environmental assessments of waste prevention is also very scarce (Gentil *et al*. 2011). There are a couple of exceptions. Gentil, *et al.* (2011) carried out an environmental assessment of municipal solid waste systems with and without waste prevention of unsolicited mail, beverage packaging, vegetable waste and meat waste, including the production stage of those materials. The reference flow was one tonne of these waste and the assessment assumed constant consumption levels. Olofsson (2004) assessed the changes in greenhouse gases of municipal solid waste generation of

[7] "waste prevention", Scopus, 342 matches

systems comprising shares of material recycling, biological treatment, energy recovery and land-filling, with one system including waste prevention. However, his assessment does not take into account waste prevention measures as such, it only applies a reduced amount of waste going through the waste management system. Therefore, the net effect of a measure, as the impacts of the practice before and after waste prevention is not included.

To sum up, there is a research gap in waste prevention, as was also identified by Defra, who launched their research programme on waste prevention (Cox, *et al*. 2010), which provided funding for project underlying the present thesis. This is highly relevant in light of the requirements by the Waste Directive (2008/08/EC) for member states to present waste prevention plans. Services are mentioned as one possible waste prevention measure.

2.2.4 Waste prevention and resource productivity – related topics

Increasingly, waste prevention is viewed as an issue of resource efficiency and productivity (Ekvall, 2008; Lilja, 2009; Defra, 2007; OECD, 2004). In broad terms resource productivity refers to the maximisation of material or welfare yield from each unit of resource input, and by implication reducing the share of unwanted output per resource input, that is waste or other emissions. In this way, resource productivity and waste prevention are related issues. In addition, most of the environmental savings from waste prevention in a life cycle perspective are brought about from savings at the production stage when less material is produced (Ekvall, 2008).

Terms such as eco-efficiency, material efficiency, resource efficiency and resource productivity are often used interchangeably to denote this idea. Dahlström & Ekins (2005) have sought to define and differentiate the terms. They propose that:

- *Resource efficiency* is "a ratio of two identical resource variables" such as material output by material input (M_o/M_i)
- *Resource productivity* is "a ratio of two different variables", notably with a numerator indicating some sort of welfare measure, and the denominator the resource input (Y_o/M_i)
- *Resource or pollution intensity* is " the inverse of resource productivity, or the production of some undesirable factor by some other factor", such as the material intensity of output (M_i/Y_o) or pollution intensity of output (P_o/Y_o)
- *Eco-efficiency* is "the inverse of pollution intensity", (Y_o/P_o)

Different definitions of relative dematerialisation also correspond with some of these productivity, efficiency and intensity definitions and indicators. What Cogoy, (2004) refers to as relative dematerialisation appears to correspond with material intensity of output. Pollution intensity of output appears to be an indicator of dematerialisation, according to Spangenberg, (2001). Furthermore, in accordance with Spangenberg, (2001) it should be noted that pollution may be of many different species, such as CO_2, NO_x, or SO_x. These pollution species, or emissions, often occur at the same time, and trends differ for these.

The author understands that in relation to waste prevention, waste may for instance be denoted as a type of pollution ('production of some undesirable factor'). Consequently, waste prevention could be considered as reducing pollution intensity (P_o/Y_o), either over time or for two alternative production or consumption options, where Y_o, may be for instance a monetary term, or an expression for some other type of useful outcome of production or consumption. In relation to waste prevention, which refers not just the amount of waste but also harmful substances and environmental impacts of waste and waste management, (P_o/Y_o) could also refer to the pollution from substances emitted from the waste or waste management. Alternatively, waste could be equated with the material in a product which will later become waste. Thus waste would equal M. The relative resource productivity (Y_o/M_i) of two alternative consumption options would also indicate a waste prevention potential.

It could also be inferred that the higher the resource efficiency ratio (M_o/M_i), for instance of an industrial process, the less waste is generated. Actions to increase this efficiency may then be viewed as waste prevention.

2.3 SERVICES AND RESOURCE PRODUCTIVITY

This section further focuses the research topic to a particular service concept and its potential to achieve resource productivity, and thereby waste prevention. Further, it describes and critiques this concept (PSS or rather a set of mechanisms encompassed in (literature on) this and other terms), and arrives at a set of proposition for qualitative testing in the primary research that is the concern mainly of objective 1, which in turn feeds in to objectives 2 and 3. To this end, this section first identifies a number of different definitions of services (section 2.3.1). These may be relevant in different situations, why it is not possible to select a single definition for use in the thesis, but several uses will occur in the thesis. Second, the author identifies three different (often confounded) strands of ideas pertaining to services and resource productivity, and chooses one for further investigation, namely, the one concerning use value and pertaining to PSS (section 2.3.2). Third, different definitions of this idea are reviewed and critiqued and PSS selected for further use in this thesis (section 2.3.3.1). Fourth, different types of PSS are identified in the literature and described and critiqued. These are thought to differ in their potential for improved resource productivity, due to differing behavioural incentives thought to follow on from different institutional arrangements (section 2.4.1). Fifth, these behavioural mechanisms are elaborated on and critiqued. These mechanisms are concerned with the choice and management of material artefacts on the part of households and PSS providers respectively, and are central to the thought on how resource productivity may arise from PSS (section 2.4.2). Indeed, they are central to the research conducted in this thesis to fulfil objective 1, and to feed into the waste prevention assessment (objective 2). Importantly, the author exposes hidden assumptions on the behavioural mechanisms. Sixth, key debates in the literature on PSS are identified. These are environmental performance of PSS, drivers and barriers for adoption of PSS, and design of PSS. The review of these debates reveal gaps in the knowledge on and methods applied for establishing the environmental performance of PSS. Furthermore, it proposes a number of factors that may act as drivers and barriers for adoption of PSS, adoption of PSS being a prerequisite for the realisation of any gains in resource productivity, waste prevention and environmental

benefits. Finally, a concluding summary is offered in which key points for the further research are presented.

2.3.1 Definition of services

Like so many other terms, 'service' is a term with many different meanings, both in everyday language and in various academic and professional disciplines. These definitions include:

- Service sectors as defined by national accounts
- Acts of performance using material artefacts
- Utility
    - Provided by a material artefact
    - Provided by acts of performance using material artefacts
- (Alleged) service characteristics: intangible, heterogeneous, inseparable and perishable

Heiskanen & Jalas (2003) note that services may refer to for instance service sectors (consequently as defined by national accounts), or the utility provided by a product, or a task performed by human labour, or to a company's offerings to its customers. In Services Management literature, services have been defined as "an act of performance offered by one party to another. Although the process may be tied to a physical product, the performance is essentially intangible and does not normally result in ownership of any of the factors of production" (Lovelock, *et al.* 1999, p. 6). Authors often define services by characteristics thought to distinguish services from products, namely: *intangible*, *heterogeneous*, *inseparable* and *perishable* (Schneider & White, 2004). These characteristics were derived from classical and sometimes neo-classical economics. The identification and assertion of characteristics distinguishing services from products was an effort by early services marketing scholars concerned with justifying their new research field, when challenged by other marketing schools (Clemes, *et al*. 2000). This definition of services is still commonplace, in spite of convincing arguments that the characteristics do not set services apart from products, but are features of both products and services to varying degrees depending on the product or service. The characteristics give rise to different sets of management issues regardless of whether they pertain to products or services. For a comprehensive critique, see Gadrey (2000).

While recognising the need to be able to refer to different although similar notions of services, this thesis favours the definition of service production put forward by Gadrey (Gadrey 2000, p.384), building on the notion of services as a set of economic and social relations:

"The economic production of services is reckoned to take place in developed capitalist systems in the following two cases:

(a) when an organization A, which owns or controls a technical and human capacity (this latter can also be denoted by the term "competencies"), sells (or offers without payment in the case of non-market services) to an economic agent B the right to use that capacity and those

competencies for a certain period in order to produce useful effects on agent B himself or on goods C that he owns or for which he is responsible.

(b) when a household himself employs a wage earner to look after his goods or his own person (or possibly person towards whom he has a duty of care: children, parents . .”

Following from this definition of service production, a definition of service would be:

> *the use, or right of agent B to use the technical and human capacity and competencies of the organisation A, for a certain period in order to produce useful effects on agent B himself or on goods C that he owns or for which he is responsible.*

In this definition, the human competence essentially refers to the actions or labour by the service provider, but presumably also comprises skills.

From this definition (as well as the one by (Lovelock, *et al.* 1999) it is clear that material artefacts are included in services and service production. Nevertheless, in this thesis the need remains to sometimes refer to the activity (human capacity) component of services and material artefacts separately.

2.3.2 Services and resource productivity – strands of ideas

This section presents a brief overview of different, although often convoluted, strands of ideas on how service consumption may contribute to resource productivity. The author recognises that the ideas may not be as separable as is suggested below and that the authors behind them may not adhere to such pure views of the ideas. Nevertheless, it was deemed useful to highlight some key differences between them, since the solutions to achieve resource productivity (and waste prevention), and associated assessment differ among them. The present research focuses on the last one of these strands of ideas.

2.3.2.1 Macro-analyses

One strand of thought relates to the definition of services as service sectors in national accounts. It stems from environmental assessments of national accounts, through for instance combined Input-Output – Life Cycle Assessment approaches or other environmental methods (Moll, *et al*. 2005; Wier, *et al.* 2005). In such assessments, consumption categories classed as service sectors, such as education, insurance and kindergartens have sometimes been found to have less environmental impacts than some other production/consumption categories (Wier, *et al*. 2005). A similar argument goes that with economic growth up to a certain (varying) level of GDP, pollution of some species increase, where after it decreases at higher levels of GDP (World Bank, 1992). In accordance with this argument, a change in household spending towards increased service consumption has been thought beneficial for the environment[8]. The

[8] This concept is called the Environmental Kuznetz Cuve (EKC)

growth of employment in the service sector has also been found to follow a stable pattern of coincidence with growing income per capita (Schettkat & Yocarini, 2006).

From this stance, it could be inferred that all that is needed for improved environmental conditions is economic growth, and the growth in the service sector over recent decades (Schettkat & Yocarini 2006; Wölfl 2005) would seem to suggest that many of the environmental problems would already have found alleviation. Mazzanti & Zoboli, (2009, p.220) however, found that in terms of waste generation, "wealthier and more service oriented economies produce more waste per capita", and thus question whether services are always better for the environment.

2.3.2.2 Service consumption, well-being and dematerialisation

Another idea appears to relate to the definition of services partly as the utility of a material artefact or act of performance (the utility being 'well-being' in a broad sense), and partly to service sectors in national accounts. It stems from a long-standing, although contested, critique of materialistic consumption. This critique, on the one hand, suggests that materialistic consumption exceeds legitimate human needs to satisfy hedonistic desires in a manner which is environmentally damaging. On the other hand it recognises psychological and social needs that may be legitimate, but notes that economic growth has not been matched by a growth in life satisfaction (Jackson, *et al*. 2004). Materialistic consumption is a violator or pseudo-satisfier of the real psychological and social needs underlying well-being. Therefore, the critique goes, pursuit of well-being is better served by other means than materialistic consumption (*ibid.)*. This critique resonates with an argument for a change in household spending from current budget categories to consumption of service categories that are high in 'well-being' intensity and low in material intensity (Femia, *et al*. 2001).

This argument is similar to the one in the previous section, in that shifts in spending between consumption categories might alleviate negative environmental impacts arising from consumption and production. The former one suggests that this will be achieved through increased economic growth. This position from economics is largely silent on the issue of human needs and the legitimacy of those, and instead prefers to speak about preferences and demand (Jackson, *et al*. 2004). The argument in the present section stems from certain branches of needs theory with moralistic undertones. It implies that in order to achieve a more resource productive society, consumers need to change their consumption fundamentally. As an example, consumption of household appliances, food or cars could be substituted by consumption of cultural experiences (or indeed a walk in the park), and that this might result in greater well-being. It also suggests that economic policy must direct economic development in a way that supports the delinking of economic growth from environmental impact (Femia, *et al*. 2001). The argument does not suggest *how* those services might lead to increased resource productivity, but presumably, it relies on the same empirical observation of environmental impacts of some service sectors in national accounts. Alternatively, it may adopt the (somewhat flawed) assumption that services are intangible and perishable (the alleged services characteristics definition of services, please see section 2.3.1).

This argument has not gone unchallenged. One criticism is that it fails to recognise the symbolic cultural and even spiritual meaning of material artefacts to human beings

(Jackson, *et al*. 2004). Another potential criticism relates to the nature and measurement of "well-being" or "happiness". While on the one hand those with greater income tend to report greater happiness than those with less income at a point in time, happiness remains constant in spite of increased income in a cohort (Easterlin, 2001). Various explanations for this paradox have been proposed. One explanation is that humans adapt to negative or positive events such that a after a temporary increase or decrease in happiness, happiness settles around average. Another explanation may be that as income increases or decreases, so do expectations. The change in aspirations is thought to lead to happiness staying average while material well-being has increased. Despite increased standard of living, self-reported well-being tends to be fairly constant (Rojas, 2007). Therefore, it may be difficult to corroborate the effectiveness of a pursuit for changed consumption patterns and an increased subjective feeling of happiness and well-being.

2.3.2.3 Use value and resource productivity of services

Another idea relates to the notion of service as the utility or 'use value', or 'service yield' rendered by a material artefact (Meijkamp, 2000; Femia, *et al*. 2001; Mont, 2004b; Roy, 2000; Stahel, 1997). This is similar to the idea in the previous section, which referred to 'use value' in terms of satisfying a social or psychological need[9] that could equally well be satisfied by consuming for instance a cultural experience, as purchasing a material artefact. The strand of idea presented in this section, takes a more instrumental view of 'use value' as functional output produced by material artefacts (Meijkamp, 2000; Mont, 2002; Stahel, 1997). For instance, the use of a vacuum cleaner yields clean surfaces and the use of a car yields mobility. Essentially, the proponents of this view suggest that a shift from selling and buying material artefacts, to selling the utility, or service, offered by the material artefacts, would extend the uselife of the material artefacts, and thereby the use value per material input. This corresponds with the definition of resource productivity suggested by Dahlström & Ekins (2005) as reported in section 2.2.4: useful outcome by material input.

The concept of increasing resource productivity by focusing on the use value (i.e. service yield) of material artefacts arose as a reaction to "Industrial Economy". It was argued that the industrial economy focused on producing and turning over more material artefacts with relatively less resource (Meijkamp, 2000). This was considered detrimental for the environment, especially as it ignored the use and use value of the material artefacts (Manzini & Vezzoli, 2002). Literature suggests that the value of services derives from improved utilisation of goods rather than the monetary value at the exchange of ownership of at the point of sale (Stahel, 1997). Literature, as related by for instance Meijkamp (2000) suggests that optimisation of production has already

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- [9] underlying internal forces that drive our action (non-negotiable; failure to satisfy has detrimental effects on the health of the individual).

- External environmental requirement for achieving an end (concentrates on *feeling* of safety, contentment etc.)

- Justified requirements for performing behaviour.

taken place to an extent that now limits the profitability of production of material artefacts for sale as in the "industrial economy". Instead, it is argued that the sales of use value offers greater potential for business profit, as well as greater potential for improved resource productivity. This was essentially thought to extend the uselife of material artefacts in two main ways:

- Extending the use life in each use cycle (e.g. material artefact specification, maintenance),
- increasing number of use cycles, and materials recycling (closed loop and open loop/cascading recycling)

In addition, literature also suggests that service provision leads to more intensive use of the material artefact, requiring sooner replacement, by a material artefact assumed to consume less resources in the use-phase due to improvements in produce development thought to occur (Heiskanen & Jalas, 2003). This is thought to occur through a change in ownership of the material artefacts, from self-servicing households or firms, to service providers. The service providers are thought to have greater skills and incentive to extend the uselife of the material artefacts in their ownership.

As stated at the beginning of this section, this idea relates to the definition of services as 'use value' or 'service yield'. It also draws on the observation that service sectors have increased in economic importance over recent decades. In addition, as subsequent sections will elaborate, it details to greater extent *how* resource productivity is thought to come about through rearrangements of the human activities and control over material artefacts, which relates to the definition of services as technological and human capacity (or acts of performance, using physical products). In this respect, this idea takes a micro-level approach. It is somewhat ambiguous as to the requirements of policy measures to achieve the shift to services and associated resource productivity. On the one hand the literature implies that the incentives for resource productivity are more or less intrinsic to services, and also notes that the growth in service production and consumption is already underway. On the other hand it sometimes suggests that both the shift to service consumption and achievement of resource productivity requires policy intervention.

The present thesis concentrates on this idea of services and resource productivity, and therefore, issues set out in brief in this section will be further elaborated in subsequent sections.

2.3.3 Service concepts relating to use value and resource productivity

Service concepts related to use value and resource productivity have been published under different names, while drawing on largely the same literatures and ideas. This section briefly discusses some of these terms, definitions and typologies used for these concepts. It goes on to elaborate the key ideas on the mechanisms for achieving resource productivity thought to be offered by these concepts, including for instance changes in choice and management of material artefacts. After that, key debates in the literature pertaining to these concepts are reviewed.

2.3.3.1 Definitions

A variety of terms are used to refer to the concept outlined above. Examples are Product-Services, Product-Service Systems, eco-efficient services (Tukker & Tischner, 2006), functional sales (Mont, 2004b; White *et al.* 1999) relating to the provision of a function rather than a product, and servicisation referring to an increased bundling of material artefacts and service offers (White, *et al.* 1999). A variety of definitions are listed in Table 1 below.

Table 1 Definitions of product-service systems and related service concepts (Tukker & Tischner, 2006, p.25)

PSS definitions and connected terms	Source
The configuration (quantity and quality) of products and services supplied to meet the demand for well-being may be described as a product-service mix or product-service combination	(Manzini, 1996); (Goedkoop, *et al.* 1999).
A product-service system is defined as 'a marketable set of products and services capable of jointly fulfilling a user's needs	(Goedkoop, *et al.* 1999, p.18)
(Behrendt et al. 2003)PSS is a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customers' needs and have a lower environmental impact than traditional business models	(Mont, 2004b)
Eco-efficient services are systems of products and services that are developed to cause a minimum environmental impact with a maximum added value	(Brezet, *et al*. 2001)
An eco-efficient service is one that reduces the environmental impact of customer activities per unit of output. This can be done directly (by replacing an alternative product-service mix) or indirectly (by influencing customer activities to become more eco-efficient)	(James, *et al*. 2001)
A product-service system can be defined as the result of 'an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands'.	(Manzini & Vezzoli, 2002)
A pure product system is one in which all property rights are transferred from the product providers to the client on the point of sale… A pure service is one in which all property rights remain with the service provider, and the clients obtain no other right besides consuming the service. A product-service system is a mixture of the above. It requires that property rights remain distributed between client and provider, requiring more or less interaction over the life time of the PSS.	(Hockerts & Weaver, 2002)
A product-service system consists of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.	Initial definition used in SusProNet

Overall, the definitions seem to be aligned with the definition of services as the combination of human and technological capabilities (or acts of performance and material artefacts) as set out in section 2.3.1. Most definitions share the notion that these services or product-service systems should meet customer needs and/ or maximise value. Differences in the definitions include for instance whether or not environmental performance is specifically mentioned. Some authors only refer to the combination of products (material artefacts) and services, and satisfying customer demand (Goedkoop, *et al.* 1999; Manzini & Vezzoli, 2002).

Those using terms like eco-services or eco-efficient services, include environmental performance in their definitions (James, *et al*. 2001; Brezet, *et al*. 2001). Many of those using the term product service systems do not refer to environment (Goedkoop, *et al.* 1999; Manzini, 1996; Manzini & Vezzoli, 2002; Hockerts & Weaver, 2002). Mont (2004b) is an exception, including environmental performance as well as supporting networks and infrastructure in her definition. Tukker & Tischner, (2006) use further distinctions: product-service, product service systems, eco-efficient product-services and product service systems, and sustainable product-services and product-service systems. The product-service is the offering necessarily including a combination of material artefacts and human capacity. Product-service systems, Tukker & Tischner (2006) suggest include the infrastructure and value network. Eco-efficient PS and PSS are PS and PSS that have a minimum of negative environmental impact.

As to the 'system' part of the 'Product Service System' term, the literature is relatively vague on what 'systems' refers to and it is silent on whether it refers to any particular systems theory. One suggestion of what the 'system' part might include is infrastructure and network of supporting actors (Mont, 2004b; Roy, 2000). An additional reference to systems is the life cycle impacts of all products and services brought together to provide value to customers (Mont, 2004b).

Mont (2002) argues there is a difference between services and Product Service Systems. PSS, she argues, are purposively eco-designed systems that have lower environmental impacts. Several authors (Cook et al. 2006; Halme et al. 2004; Mont 2002) argue that environmental improvements do not happen automatically, but through purposeful actions. On the other hand, Bartolomeo *et al.* (2003) suggest that eco-designed services were not successful in the market, whereas PSS that were successful on the market were eco-efficient by coincident. Nevertheless, the overall description of PSS appears to suggest that certain mechanisms inherent in services are thought to offer incentives for improved resource productivity. It is not clear why eco-designing self-service systems should be less efficient than eco-designing service systems.

Mont argues that the previous definitions of PSS are the same as any product or service or offer. The same goes for (Tukker & Tischner 2006). Mont addresses this by redefining the concept to include infrastructure, and better environmental performance than "traditional business models".

The 'traditional' seems to refer to 'business as usual', the reference case against which a change to PSS is suggested to offer an improvement. The PSS concept arose out of a critique against industrial economy (Meijkamp, 2000), and the possibility of manufacturing firms expanding their sales offerings with service packages. It was

thought if they retained ownership of the material artefacts, rather than selling them, incentives would arise to design and manage material artefacts in a more resource productive way than if the manufacturer's income was generated from unit sales. However, the term traditional is imprecise and carries connotations of relating to the past, inherited customs (see for instance Merriam Webster's definition of tradition). Then the business models or consumption patterns in question would depend on at what point in time one is looking. As will be shown in section 2.4.4.2 household services were customary in the first half of last century. Other authors use the term 'status quo' to refer to the reference case (Halme *et al.* 2004). The author of the present research suggests that 'self-servicing' is a better term for describing the reference case against which PSS are compared. In the context of households, self-servicing is (unpaid) labour in the household by a household member used to create value from resources such as consumption goods, purchased with the salary a household member has earned in the labour market (Gershuny, 1979).

The reference to supporting networks and infrastructure (Mont, 2004a) would appear to be a necessity for all business offerings and not exclusive for product-service systems /eco-efficient services. The explicit reference, however, helps to highlight systems thinking that is essential for environmental concerns, in order to ensure fair comparisons between different ways of achieving the same results. In addition, if the focus is on promoting change, either from a business management perspective, or policy perspective, it is useful to bear the supporting networks and infrastructure in mind as these may be fundamental to the delivery of the services/PSS. Therefore their inclusion in the definition may be justified.

The inclusion or exclusion of the environmental performance of the services is interesting and also somewhat problematic. The reason for the above body of literature to be concerned with services is the perceived environmental potential of services compared with self-servicing agents using material artefacts in their own possession. Thus, if there was no environmental component involved, the topic might be left to business management and economic disciplines. The problem, however, with including environmental performance in the definition, is that it is very difficult to identify and verify services that consistently perform better than self-servicing across different contexts. Several authors have found that the environmental performance can only be determined from case to case (Manzini & Vezzoli, 2002; Behrendt, *et al*. 2003; Heiskanen & Jalas, 2003). The author's view is that the environment or term 'eco-efficient' is included as an analytical and/or management device to research or seek to improve the environmental performance of services. It should not be taken to be a 'label' of the environmental performance of a service.

Few definitions explicitly address the allocation of property rights of the material artefacts (Hockerts & Weaver, 2002). It would appear that implicitly, product ownership residing with service provider is integral to the concept of most of the aforementioned authors.

The author finds it problematic that the term PSS (and many other terms) and their definitions are so all-embracing to the majority of business offerings in all sectors that the analytic and communicative ability of the term is much weakened. Furthermore, the service definition by for instance Gadrey (2000) referred to in section 2.3.1, and similar

service definitions such as by Lovelock, *et al.* (1999) comprises both human and technical capacity, which was understood to include both material artefacts, labour, knowledge, skills and infrastructure, that is, a system of products and service activities.

While the definitions of PSS and similar terms are open-ended, they share a number of ideas on how resource productivity may arise that may clarify the concept better than the definitions do. The next section addresses this. In order to refer to previous literature where other terms are used, for the sake of simplicity, these will be referred to as PSS.

2.4 PRODUCT SERVICE SYSTEMS (PSS)

2.4.1 Types of PSS

A variety of types of PSS are proposed in the literature. They are derived from case studies, often representing a number of present-day commercial phenomena in light of potential for improved resource productivity through service production and consumption (Cook, *et al*. 2006). A wide spectrum of heterogeneous types exist (Behrendt *et al*. 2003), making modelling difficult. Below is one typology (Cook, *et al.* 2006; Roy, 2000; Tukker, 2004). These types differ in terms of the agents controlling the technical capacity (to use the term in the service definition by Gadrey (2000) and responsible for different stages of the life cycle. Due to these differences, the types are also thought to differ in terms of the incentives for resource productivity offered to the agents, and consequently the extent of the environmental potential (Behrendt, *et al*. 2003). This will be further discussed below.

With *product oriented PSS*, the customer owns the material artefact, and a service such as a warranty or maintenance contract is offered that may contribute to prolonging the uselife of the material artefact.

Examples of *use oriented PSS* are sharing, renting and leasing. In the case of renting and leasing the service provider owns the material artefact and the customer pays for the use of the material artefact. In the case of sharing, the material artefact is jointly owned by a group of users or an organisation, and the users take turns using it.

With *result oriented PSS* the service provider owns the material artefacts and uses it to provide the customer with a particular result. In the case of house cleaning for instance, the service provider of a result oriented PSS owns the cleaning equipment, performs the cleaning and the households pay for the result which is a clean house. The PSS literature tends to suggest that the levels or attributes of the result are the focus of the specification of the PSS, rather than the material artefact or usage.

The different types of PSS are set out in Table 2 with regard to whether the customer or service provider is responsible for ownership, labour and end-of-life management of the material artefact.

Table 2 Types of PSS and distribution of responsibilities

Type of PSS	Ownership	Labour/human capacity	Maintenance	End-of life management
'Traditional consumption'	Customer	Customer	Customer	Customer
Product-oriented PSS	Customer	Customer	Service provider	Customer
Use-oriented[10] PSS	Service provider	Customer	Service provider	Service provider
Result-oriented PSS	Service provider	Service provider	Service provider	Service provider

Some authors place the types of PSS on a continuum from more tangible to less tangible (Behrendt, *et al*. 2003; Tukker, 2004; Halme, *et al*. 2005). This perception of tangibility does not appear to be based on a systems analysis of the total resource and energy requirement of the service compared with 'traditional sales', but rather on a misconception about services as intangible, mentioned in section 2.3.1.

The purpose of the typologies in the literature is often unclear. The typologies or classifications lack a range of potentially important aspects both in terms of design and management of the services and in terms of environmental profiles (Mont, 2004b). Therefore, the author suggests that this and similar typologies in the literature are blunt tools with limited ability to support analysis. It may, however, be viewed as a way to start structuring and refining a concept, with a long way yet to go – if, indeed, it is a way to pursue. On the one hand, if a multiplicity of cases give rise to the same analytical abstractions that form a consistent framework, a 'totalising' concept may be helpful. If, however, cases are forced into a strait jacket of categories that restrict analytical ability, then a totalising concept is not very useful. If the case studies suggest that a great number of additional sub-categories are needed to make up a useful analytical tool, it may also be that other categories are more appropriate than the ones set out above.

2.4.2 Behaviours thought to generate resource productivity

Section 2.3.2.3 set out in brief some basic notions of how resource productivity might arise through service production and consumption, that is, through extension of material artefact uselife either in one use cycle or by adding use cycles. This section elaborates on these in light of the different types of PSS.

For *product-oriented PSS*, the ownership of the material artefacts remain with the self-servicing agent, while the PSS provider carry out maintenance and repair and consultancy on the use of the material artefact (Tukker, 2004). The PSS literature

[10] Sometimes referred to as "enabling platforms" (e.g. Vezzoli et al 2003 (UENP)).

proposes that product oriented PSS extend material artefact use-life through the maintenance or advice on operation of material artefacts that is the core of this type of PSS (Manzini & Vezzoli, 2002; Tukker, 2004). Some authors also suggest that material artefact take-back at the end-of-life might be classified as product-oriented services, increasing the number of use-cycles of the material artefact (Tukker, 2004). This type of PSS is thought to offer a limited degree of improved resource productivity, since the manufacturer/service provider does not own the product and therefore is thought have limited incentives for sustainable design (Tukker, 2004).

For *use-oriented* and *result-oriented PSS*, such as renting or communal use, the ownership of the material artefact is thought to reside with the PSS provider. It is proposed that 'the distribution of ownership of goods has considerable influence on the volume and speed of the material flow in an economy' (Behrendt, *et al*. 2003, p.8). Essentially, although implicitly, this is premised on the assumption that PSS providers are economically rational agents, and that the economic benefits arising from maximising the use of the material artefacts and minimising running costs are paramount to any other business considerations. Self-servicing households (or self-servicing firms for that part) appear to be thought to not respond to rational motivations to maximise the utility of the material artefacts and minimise running costs.

For *use-oriented PSS*, the literature sometimes suggests that the designer/manufacturer of the material artefact is also the service provider (Baines, *et al.* 2007). This assumption probably stems from the observation that many manufacturing firms are increasingly bundling their offers with service components (White, *et al*. 1999; Roy, 2000; Meijkamp, 2000). Thus, the service providers, who in some types of use-oriented services, retain ownership of the material artefacts, are thought to have incentives to design material artefacts with longer use-lives, and which are easy to remanufacture or recycle (Baines, *et al.* 2007). In this way resource productivity would be achieved since fewer resources are needed per unit of valuable output. It is however, also recognised in some of the literature that the service provider is often a third-party organisation separate from the manufacturer (Tukker, 2004). In this case, the literature suggests, the economic incentive for eco-designed material artefacts is weakened, compared with manufacturers who maintain ownership of their material artefacts and use them in service provision.

The literature also suggests that use-oriented PSS leads to fewer material artefacts being used more intensely, thus leading to resource productivity, not least in a life cycle perspective (Behrendt *et al*. 2003; Cook *et al*. 2006; Tukker, 2004). This increased intensity of use is thought to lead to material artefacts reaching absolute obsolescence sooner, allowing sooner replacement (with newer more efficient models) (Heiskanen & Jalas, 2003; Behrendt, *et al*. 2003).

Furthermore, PSS providers, owning the material artefacts, are thought to have incentives to reuse, recycle or remanufacture the material artefacts and thereby extend their uselives by increasing the length of a use cycle and adding more use cycles (Behrendt, *et al*. 2003). This assumption seems to stem from the literature concentrating on manufacturers turning service providers, in other words going from transferring the ownership of material artefacts to keeping ownership of them. This is thought to

strengthen their producer responsibility for the end-of-life artefacts (Behrendt, *et al*. 2003; Cook, *et al.* 2006).

Result-oriented PSS are thought to encompass the same differences between self-servicing behaviour and PSS provider behaviour as use-oriented PSS, namely concerning the choice and specification of material artefacts influencing (or not) the design stage of the material artefacts; increased intensity of use of material artefacts through PSS compared with self-servicing; producer responsibility for end-of-life material artefacts since the ownership is thought to reside with PSS providers. Result-oriented PSS are thought to comprise further incentives for improved resource productivity over self-servicing.

From the above it is clear that the mechanisms behind the potential for resource productivity – and waste prevention – of PSS rests on differing behaviours between service providers and self-servicing agents. These behaviours may be divided into different life cycle stages of the product/service: choice and ownership of material artefacts (that is, sale and upstream life cycle stages), use and management of material artefacts, and replacement and disposal of material artefacts. They seem to draw on a simple view of economies of scale, for instance regarding the skills of specialised service providers compared with self-servicing firms or households. For further discussion of economies of scale, see section 5.5.1.

2.4.2.1 Choice and ownership of material artefacts

Households are thought to choose material artefacts that are over – or underspecified for the job and/or have limited durability (Halme *et al*. 2004). PSS providers on the other hand are thought to choose the most efficient material artefact to perform the job, and possibly this is of professional grade (Bartolomeo *et al*. 2003; Halme *et al*. 2005; Cook *et al*. 2006). In the case of use-oriented PSS, such as renting or leasing, households may still choose inappropriate specifications for the task at hand, even if the PSS provider offers the appropriate the specifications.

The idea behind PSS appears to rest on the assumption that households or firms that start using PSS stop using self-servicing and no longer own the material artefacts for the job. Indeed, this form of production and consumption is sometimes called ‘consumption without ownership’ (Hirschl *et al*. 2003). Some authors, however, recognise that not all PSS substitute ownership of material artefacts entirely (Meijkamp, 2000; Schrader, 1999). The PSS literature is silent on the question of whether self-servicing households own one or more units of each type of material artefact, and whether they give up ownership of one or all units in the case of using PSS. Furthermore, the PSS literature is premised upon the assumption that service providers use material artefacts that are in their ownership, rather than using material artefacts provided by the households in the ownership of households.

Literature looking at ownership of numbers of units of material artefact finds that ownership of multiple units is common, and also that the different units within a household may be used for slightly different purposes with different use patterns and therefore also have different specifications (Steffens, 2003).

Some literature on ownership concentrates on ownership of household durables as time-saving devices for self-servicing (Kim, 1989; Bittman, *et al*. 2004; Gershuny, 2004). This literature, however, does not offer much advice on the tendency to give up ownership of material artefacts when using household services. Another strand of literature is concerned with how consumers value the acquisition of a material artefact and giving up ownership of the corresponding material artefact respectively. This literature suggests that consumers experience greater pain at loosing something that they have in their possession, than they enjoy gaining it if they have not previously owned it (Carmin & Ariely, 2000; Novemsky & Kahneman, 2005; Brenner, *et al*. 2007). This tendency manifests itself in consumers setting a higher price when selling a material artefact than they would pay to purchase it if they had not owned it. While this literature does not offer firm advice on households' willingness to give up ownership of material artefacts when starting to use a service, it indicates that this willingness may be limited.

2.4.2.2 Use and maintenance of material artefacts

It is sometimes assumed in the PSS literature that consumption of for instance energy during the use-phase shows up on the service providers bill, thus offering an incentive to the service provider to design or choose material artefacts that use little energy (exerting pressure through the supply chain on manufacturers) (Heiskanen & Jalas, 2003; Manzini & Vezzoli, 2002). This implies that were the incentive there for the service provider, they would act on it, while the customer is not driven by the motivation to consume as little energy as possible. In other words, the firms are assumed to be driven by rational cost minimisation motives, and that cost minimisation in this respect is paramount to other business considerations. Households (or self-servicing firms) on the other hand, seem to be thought to have other overriding concerns than cost minimisation.

In addition, service providers are thought to be more skilled and therefore to perform the task and use the material artefact more efficiently than self-servicing agents (White *et al.* 1999; Halme, *et al.* 2004; Cook, *et al*. 2006). This appears to be based on an assumption that new generations of material artefacts consume fewer resources in the use phase (e.g. energy and water). This may not be the case for all types of products. Whether it would be the case in a total service economy depends on the extent to which service providers are rational in that respect and have no other motives affecting their product specification, leading them to choose over-specified material artefacts, even if each new material artefact in itself were more efficient.

Related literatures offer scarce advice on use of material artefacts, in particular in relation to that of professional service providers. However, literature suggests that there is great potential for households to reduce energy consumption arising from the use of material artefacts to perform household activities, by changing behaviour (Wood & Newborough, 2003). This supports the notion that households are not as efficient as possible. However, it cannot be inferred that they are more or less efficient than professional service providers.

Maintenance theory concerned with firms' maintenance of equipment, recognises that repairs may span from minimal repairs rendering the material artefacts 'as bad as old' to perfect repairs rendering the material artefacts 'as good as new' (Doyen & Gaudoin,

2004). Similarly, households' maintenance and repair activities range from minor maintenance to full refabrication, with varying degrees of competence (Gregson et al. 2009). Thus, while there is some evidence for the assumption that all households do not maintain material artefacts properly or skilfully, the behaviours of firms may not differ greatly from those of households.

2.4.2.3 Replacement and disposal of material artefacts

While material artefacts owned by self-servicing agents are idle much of their available time, the PSS literature suggests that use-oriented and result-oriented PSS lead to intensified use of material artefacts. This increased intensity of use is thought to lead to material artefacts reaching absolute obsolescence sooner, allowing sooner replacement (with newer more efficient models) (Behrendt, *et al*. 2003; Heiskanen & Jalas, 2003).

Furthermore, PSS providers, owning the material artefacts, are thought to have incentives to reuse, recycle or remanufacture the material artefacts and thereby extend their uselives by increasing the length of a use cycle and adding more use cycles (Behrendt *et al.* 2003). This assumption seems to stem from the literature concentrating on manufacturers turning service providers, in other words going from transferring the ownership of material artefacts to keeping ownership of them. This is thought to strengthen their producer responsibility for the end-of-life artefacts (Cook, *et al.* 2006; Behrendt, *et al.* 2003; Roy, 2000). Implicitly, it seems households are thought to discard of their obsolete material artefacts through the waste management system, and that this leads to less reuse and recycling than in the case of PSS. Households are also thought to dispose of material artefacts due to changes in fashion (Halme, *et al*. 2005), also known as psychological obsolescence (Cooper, 2004).

Literature on material artefact obsolescence and replacement supports the idea in the PSS literature review that material artefacts in households often fall into disuse (being replaced, disposed of or kept) prior to absolute obsolescence (Cooper, 2004; Harrell & McConocha, 1992). Thus, households are not always economically rational with respect to increasing the use value of their material artefacts as much as possible. However, some forms of relative obsolescence may also be viewed as economically rational. The tendency towards absolute and relative obsolescence depends on the type of material artefact. What is more, maintenance theory suggests that firms are concerned with the cost optimisation of maintenance and replacement (Hartman, 2004; Jackson & Pascaul, 2008; Kijima, *et al.* 1988). This would seem to correspond to economic rather than absolute obsolescence. Maintenance theory also recognises that repairs may span from minimal repairs rendering the material artefacts 'as bad as old' to perfect repairs rendering the material artefacts 'as good as new' (Doyen & Gaudoin, 2004).Therefore, the question remains open as to whether households and service providers behave differently.

Related literatures on maintenance and replacement of material artefacts, both among firms and households differentiate between the cumulative use of the material artefact and its age in terms of the duration from the material artefact was taken into use and until it is replaced or scrapped (Hartman, 2004; Bayus & Gupta, 1992). In this thesis, this is referred to the operational age of a material artefact, versus its chronological age. Kijima et al. (1988) also point out that repairs may rejuvenate a material artefact to a virtual age, that is its state prior to breaking down ('as bad as old', minimal repairs).

Literature on material artefact obsolescence and throwaway behaviour suggests that households exercise a number of alternative options to disposing obsolete material artefacts as waste, such as keeping, selling, swapping (including trading in), giving away to kin or charity (Cooper & Mayers, 2000; Harrell & McConocha, 1992). Material artefacts discarded as waste, may take different waste management routes, including landfill, incineration, recycling and reuse. Even waste taken to civic amenity sites by households, may take different actual waste management routes. Therefore, no exact data on proportions of waste taking different waste management routes are available.

2.4.2.4 Summary of propositions and assumptions

Table 3 below summarises the propositions in the PSS literature on behavioural mechanisms thought to be present in PSS and to lead to resource productivity.

Table 3 Propositions in the PSS literature on behavioural mechanisms for improved resource productivity through PSS

Tentative propositions in the literature	References	Life cycle stage
The manufacturing firm also provides the services. Recognised in the literature that services are sometimes provided by third-party service providers.	(Bartolomeo *et al* 2003); Halme *et al.* 2004);	Adoption
Ownership of material artefacts by the service providers makes manufacturers act on the incentive to design more durable products. Recognised in the literature that this incentive is weakened when services are provided by third-party service providers.	(Bartolomeo *et al* 2003); Cook *et al.* 2006; Halme *et al.* 2004	Ownership; eco-design
Service providers choose the most efficient material artefact to perform the job (perhaps professional grade).	(Bartolomeo *et al* 2003); Cook *et al.* 2006; Halme *et al.* 2004; Heiskanen & Jalas, 2003)	Choice of material artefact
Households choose material artefacts that are over or underspecified for the job, have limited durability	Halme *et al.* 2004	Choice of material artefacts
Households own only one unit of each type of material artefact (underlying assumption)	*implicit*	Ownership of material artefact
Households who use services do not own the corresponding material artefact (assumption: give up ownership when starting to use a service).	*Implicit*	Ownership of material artefact
Service providers own the requisite material artefacts, rather than using material artefacts provided by the households.	Explicit/implicit	Ownership of material artefacts
Service providers have greater skills than self-servicing customers, and thereby use material artefacts more efficiently	Cook *et al.* 2006; Halme *et al.* 2004; Heiskanen & Jalas, 2003 citing White *et al.* 1999).	Use and maintenance

The manufacturer-service provider has the incentives to reduce resource use during the use-phase since reduced energy use during the use-phase will benefit the service-provider financially, i.e. resource use during the use-phase shows up on the service provider's bill.	Manzini & Vezzoli, 2002; Heiskanen & Jalas, 2003	Use and maintenance
Service provider maximise the use-life of their material artefact (UNEP) UNEP)	Cook *et al.* 2006;	Use and maintenance
Households replace well-functioning material artefacts due to changing fashion	(Halme et al. 2005)	Replacement and disposal
Increased intensity of use leads to material artefacts reaching absolute obsolescence sooner, allowing sooner replacement (with newer more efficient models).	Heiskanen & Jalas, 2003;	Replacement and disposal
Service providers (often being the manufacturers) remanufacture or recycle the material artefacts at their end-of-life	(e.g. Manzini & Vezzoli, 2002)	Replacement and disposal

Early conceptual research (Stahel, 1997), while stating that policy intervention may be required, also seems to suggest that the service business model in itself contains the incentives for different actors to bring about this resource productivity and resultant environmental improvement. More recent research recognises that the service model does not in itself lead to resource productivity and environmental improvements, and emphasise the need to configure the whole system of products, service activities and infrastructure to seek to achieve environmental improvements (Behrendt *et al.* 2003).

However, the assumptions underlying these possible incentives go unscrutinised. Upon careful consideration of the literature, it would appear that the mechanisms for improved resource productivity enumerated and discussed above, hinge upon a number of hidden assumptions concerned with behaviours and differences in behaviours of key actors. However, these behaviours, thought to be activated by incentives inherent in service production and consumption, have not taken into accounts any other contradictory or reinforcing incentives and motivations in the context that might influence the behaviours of the key actors. A few implicit assumptions about behaviours are proposed in Table 4 Further assumptions and propositions in the PSS literature below.

Table 4 Further assumptions and propositions in the PSS literature

Assumptions in the literature	**Authors**
Firms want to prolong their relationship with their customers	(Manzini & Vezzoli 2002)
In the case of result-oriented services, contractual agreement is based entirely on the results without reference to the means by which the results are produced.	(Bartolomeo et al. 2003; Cook et al. 2006)
There are no additional conflicting incentives or driving forces in the service provider firms to confound or offset the incentives extend the uselives of the material artefacts	implicit

Households are not rational in an economic sense	implicit
PSS increases utilisation of material artefacts	(Bartolomeo et al. 2003; Cook et al. 2006; Halme et al. 2004)
Service providers are economically rational	

Finally, an explicit assumption in the PSS literature is that result-oriented PSS are thought to offer great opportunities for the service providers to be innovative in the way they deliver the result, since the focus is on the result and not on how it is achieved. The service provider is thought to have incentives to search for innovative ways to achieve the results in a way that substantially reduces the material input, thus leading to improved resource productivity (Tukker, 2004). Therefore, the literature suggested that result-oriented PSS have the greatest potential for environmental improvement (Tukker, 2004).

While many propositions were present in the same publications and likewise in many different publications, not all were present in the same publications, neither all publications. Not all of the publications used the term PSS. Nevertheless, the references they draw on are often the same, indicating that they are drawing on essentially the same idea. The literature usually expressed those propositions in cautious terms not stating with absolute certainty that behaviours would arise in accordance with the propositions under all circumstances. However, since the achievement of resource productivity rests on those behaviours arising, there is a need to further test qualitatively whether the propositions are being fulfilled under certain circumstances. Some of the literature also indicated that this may not always be the case. This also warrants further qualitative testing of the propositions in order to refine the concept.

2.4.3 Environmental assessment and performance – A key debate

Resource productivity and environmental improvement thought to ensue from PSS, was at the heart of the PSS concept, and sometimes integral to the definition of PSS (section 2.3.3.1). The environmental performance of these 'PSS' compared with 'traditional sales' was one of the key topics in the literature. As discussed in section 2.3.3.1, the reference case for comparison was not always clear.

Some authors in the PSS literature did not conduct quantitative environmental assessments, but merely discussed potential environmental performance of PSS at a conceptual level (Stahel, 1997; White, *et al*. 1999; Roy, 2000). Many of the studies that presented quantitative environmental potential of PSS were consumer services rather than business-to-business services (Behrendt, *et al.* 2003; Halme, *et al*. 2005; Hirschl, *et al*. 2003; Meijkamp, 2000; Mont, *et al*. 2006). The majority of the consumer services under study were use-based services such as car sharing, renting of sports equipment, communal washing, renting/leasing power tools and other electric and electronic equipment (Behrendt, *et al*. 2003; Hirschl, *et al*. 2003; Meijkamp, 2000; Mont, *et al*. 2006). Many of the studies comprised a number of PSS within the same study, and about a third of the studies reviewed had a number of participating research organisations from several different European countries.

Studies that reported some form of quantitative environmental assessment had slightly different intentions. One was to identify existing services that have superior environmental performance, recognising that not all services do (Bartolomeo, *et al*. 2003; Goedkoop, *et al*. 1999). Another one was to assess the environmental impacts of existing consumer services (Hirschl, *et al*. 2003). Waste and waste prevention was not the focus of any of these studies.

Life cycle thinking was demonstrated and sometimes life cycle methods were applied. This seems appropriate given that the concept is based around environmental benefits across the life cycle, and the risks for trade-offs and shifting burdens when production and consumption changes, and since products and services are involved at all stages of the life cycle, and that a substitution in the use stages does not mean a total improvement in resource efficiency. Simplified LCAs and expert scoring (Goedkoop *et al.* 1999; Halme, *et al*. 2006) of environmental performance were the predominant methods for quantitative environmental assessment. Some presentations of quantitative information on the environmental potential of PSS drew heavily on secondary sources for instance (Behrendt, *et al.* 2003; Wong, 2004). Heiskanen & Jalas (2003) reported quantitative environmental potentials as a review of evidence.

Some of the quantitative environmental assessments of PSS concentrated on a single indicator for environmental performance, such as primary energy use (*e.g.* Jalas, 2002; Hirschl, *et al.* 2003), or aggregations of different types of environmental impacts into a single indicator (Goedkoop, 1999). Meijkamp (2000) included a variety of emissions and impact categories and to some extent referred to changes in individual emissions. However, to great extent he referred to environmental savings in terms of an aggregated single environmental indicator. Behrendt *et al.* (2003) referred to different environmental impacts although not in a structured manner, depending on the availability from cited studies, such as (Meijkamp, 2000). Mont (2004c) included emissions of CO_2, nickel and cadmium for drill rental and sharing, and emissions of CO_2, hydrocarbons and nitrogen oxides for lawnmower rental and sharing. Sometimes reductions in resource use or emissions were expressed as factor improvements, such as factor 4 or factor 10 (Roy, 2000; Heiskanen & Jalas, 2003; Tukker, 2004). If the same amount of resource (or emission) now could serve for instance ten households instead of one, the improvement would be factor ten. This means that a reduction of resource use or emissions corresponds to a factor 10 improvements, a 50% reduction corresponds with a factor 2 reduction *et cetera.* Early conceptual literature suggest improvement potentials in the range of factor 4 to factor 10 (Roy, 2000) whereas later reviews of evidence suggest more moderate potentials of factor 2 or less (Heiskanen & Jalas, 2003).

Rebound effects were recognised to be important for the environmental consequences of a change from 'traditional' consumption to PSS (Bartolomeo, *et al*. 2003). The rebound effect means that when for instance money is spent or saved, or time is spent or saved, time or money may be spent on other activities which also have environmental impacts and the net environmental effect depends on these consequences of changed behaviour patterns. Rebound effects were not assessed in the environmental assessments reviewed.

The reporting of the environmental assessment in the studies in this review was found to be lacking, both in terms of description of the systems and changes assessed (often these

issues were only implied), details of the methods used and their application. This reporting deficit prohibits judgements about the quality of the assessments, interpretation of the results and their applicability to wider contexts. One may conjecture that this reporting deficit, at least in part, is due to various types of resource constraints, such as restrictions that publications put on for instance number of words, in combination with the type of projects undertaken, often involving a large number of services, sometimes in many different countries.

What were the results of the environmental assessments in the literature? The environmental performance of PSS differs from PSS to PSS, and depends on the specific design and circumstances (*e.g.* Heiskanen & Jalas, 2003). The variety of emissions and impacts, types of PSS and system boundaries combined with the opaque reporting, makes it very difficult to compare the results of the reviewed studies. Overall, however, the results of the environmental assessments suggest that the earlier claims of factor 4 to factor 10 are unrealistic for many services (Halme, *et al*. 2006; Heiskanen & Jalas, 2003; Behrendt, *et al.* 2003; Hirschl, *et al.* 2003; Mont, 2004b). Wong (2004) suggests that improvements are typically of a magnitude of factor 1.7-2. Behrendt, *et al* (2003) also claim that the environmental performance of traditional consumption with environmentally adapted products may exceed that of some PSS. Tasaki, *et al*. (2006, p.9) made a similar remark based on the findings of their assessment of the leasing of household electrical and electronic equipment: "whether a system shortens or extends the life time of products was a key factor […], not whether the system itself was a lease system or a possession system". In some instances the lease system was more material intense even if all the lease products were reused. Goedkoop, *et al* (1999), whose assessment was based on an expert panel judging the environmental improvement or deterioration on an ordinal scale, were generally positive about the environmental improvement of the PSS, although due to the ordinal scale used, factor improvements cannot be extrapolated.

In the light of hitherto established realistic magnitudes of environmental improvement of 'PSS' compared with self-servicing, 'PSSs' do not perform much better than the improvements measures, such as eco-design and cleaner industrial processes that the literature criticised as insufficient (Roy, 2000). However, given the opaque reporting of the environmental assessments, it is difficult to conclude with any certainty whether this level of improvement is correct, too low or even to high. To sum up, the environmental potential of PSSs remain an open issue. Since various waste strategies propose services as a waste prevention measure, research is needed to further investigate the potential of services. Furthermore, from the point of view that service production and consumption is increasing in many developed countries, research to establish environmental performance and inform and promote environmental improvement is warranted.

2.4.4 Supply and demand-side adoption– a key debate

Another key topic in the PSS literature was the uptake of PSS among potential service providers and customers, that is, for firms to provide PSS and for customers to buy PSS. A wish to improve the state of the environment undergirded the PSS literature. On the one hand, an observed increase in services in the market indicated a market trend that could be harnessed in order to achieve the environmental benefits thought to reside in the ownership structures and their incentives with PSS. On the other hand, much of the

literature is also concerned that the adoption of PSS has not extended widely enough[11]. Therefore, a quest for drivers and barriers to the uptake of PSS has had a prominent place in the literature on PSS and similar service concepts (Mont, 2002). For any potential environmental benefits to arise there has to be supply and demand of PSS.

Adoption among suppliers and customers has been assessed through primary surveys (Schrader, 1999), use of data from secondary surveys (Behrendt, *et al.* 2003; Wong, 2004), and primary focus groups and interviews (Cook, *et al.* 2006; Mont, *et al.* 2006).

Previous research identified or developed different parameters for commercial performance and rated PSS on those parameters on a variety of scales. The overview suggests that the largest number of services that have been assessed were from continental Europe and Scandinavia. Primary studies of PSS in the UK are relatively sparser. The UK studies of PSS on the consumer market were of electronic services such as peer-to-peer file-sharing and online gaming, renting and leasing of consumer electronics and sports clothing (Wong, 2004). In other words many of the services were use-oriented and associated with leisure pursuits. There is a relative gap in the research on result-oriented services. Both existing and hypothetical PSSs were represented in the research (Schrader, 1999; Besch, 2005; Halme, *et al.* 2005; Mont, *et al*. 2006).

The assessments either comprised expert/researcher scoring of perceived performance of the PSS (Goedkoop, *et al*. 1999; Halme, *et al*. 2005), or qualitative and quantitative investigations of attitudes (Cook, *et al*. 2006; Schrader, 1999). In one instance approximate prices were developed for hypothetical PSS to establish profitability of the PSS (Mont, *et al*. 2006).

The literature sometimes referred to drivers and barriers and sometimes to factors. The author prefers the latter since some factors may be both driver and barrier depending on their presence, absence or performance. For examples of this, please see Table 5 . The author advocates an understanding of the term ‘factor’ as important ingredient, and not in a strictly mathematical and statistical sense.

2.4.4.1 Supply-side adoption of PSS

Key factors appearing in the literature are presented in Table 5. It should be noted that all factors are not present in all studies. The factors derive from studies of different markets in different countries, of different PSS. Where similar factors appear in different studies these factors have been aggregated. Furthermore, the author changed the wording of some of the factors. For instance, regulation of what services housing organisations are allowed to provide was changed to ‘industry regulation’ in an attempt to organise and draw out the essence of the factors. Since the research field is young and factors have been largely inductively derived, the general applicability of the factors is not well established.

[11] since there is a difference between authors as to whether environmental improvements are a part of the definition of PSS, or whether PSS equates to service, there is also a difference here in whether they refer to uptake of services or uptake of services that are more environmentally beneficial

The literature does not usually distinguish between factors affecting uptake of services in general and services that have proved to be environmentally beneficial. In some cases it is possible to distinguish between the two, and in some cases the factors for uptake and environmental benefits are so closely interrelated that a separation is not meaningful. The reader may wish to consider what the factor is primarily a driver/barrier for; for services in general or for eco-efficiency of services.

Table 5 presents factors in the literature proposed to affect supply side adoption of PSS. The author has grouped these factors according to a modified version of the factors proposed by (Cook, *et al*. 2006), so as to accommodate factors identified in the literature.

Drawing on an innovation and technology transfer framework, the factors in Cook *et al* (2006) were:

- availability of PSS concept,
- market conditions
- legislation,
- corporate competence,
- strategic orientation,
- organisational structure,
- product portfolio.

By availability of the PSS concept Cook, *et al* (2006) referred to the presence of the knowledge set about PSS in industrial context where representatives from industry may encounter them. By market conditions, Cook, *et al* (2006) referred to a number of competitive pressures faced by manufacturing firms, such as diminishing returns on economies of scale of mass production and instead opportunities to seek economies of scope adding service components to the offerings, and seeking new opportunities when manufactured goods is being commoditised. Similar issues are pointed out by other authors (see Table 5). Geographical density of demand is another market condition affecting financial and environmental viability and therefore acting as a driver or barrier for PSS adoption (Besch, 2005).

Regarding legislation, Cook, *et al* (2006) refers to environmental legislation, in particular WEEE legislation introducing producer responsibility for electrical and electronic equipment. This was relevant for the manufacturing sector under study in Cook's *et al.* (2006) research. Other authors in the reviewed literature point to additional types of legislation acting as drivers or barriers to the adoption of PSS. Examples are industry regulation, investment regulations and labour regulations. Therefore, Table 5 includes legislation, labelled in a broader sense as policy and regulation to encompass these additional areas thought to affect adoption of PSS.

By corporate competencies, Cook, *et al.* (2006) refer to skills set of personnel for new tasks, such as maintenance and repair of goods, as well as financial competencies to manage new types of transactions. Similar notions of competencies are the skills set of personnel in general (Bartolomeo, *et al.* 2003) and skills in relation to core business and the risk of undermining the skills base if the business is too diversified. In other words, corporate competences may be both a driver and barrier to adoption of PSS.

In relation to the strategic orientation of a firm, Cook, *et al.* (2006) found that firms that sought increased differentiation, innovation towards economies of scope, and sought to gain competitive advantage through legal environmental requirements were more receptive towards PSS adoption.

As regards organisational structures, Cook, *et al.* (2006) found that hierarchical organisational structures were not conducive to receptivity to PSS adoption. Instead, they found that matrix structures enabled problem solving and creation of service solutions to customers, and made the firms more receptive to PSS adoption. Mont (2002) also pointed out the internal relations between departments as a factor affecting PSS adoption.

Furthermore, Cook, *et al.* (2006) found that certain properties of the existing product portfolio of firms facilitated receptivity to PSS. Where the firm already included service components in its offers; where existing products were sufficiently high value to finance the competence building for increased service offerings, and where the tangible products (material artefacts) could easily be disassembled and upgraded to meet demands for new technology and fashion, receptivity increased. In line with this, Bartolomeo, *et al.* (2003) suggested that the presence of innovative technology in firms acted as a driver for eco-efficient producer services. Mont (2002) suggested that there might be a conflict between products designed for traditional use and for functional sales. Thus, research suggests that a firm's existing product portfolio may facilitate or hinder adoption of PSS.

In addition to these groups of factor, the author has added groups of factors to accommodate factors identified in the literature. These groups were costs and finances, networks and value chain, customer demand, and natural environment.

Table 5 Supply side factors influencing PSS adoption

Market conditions
• E.g. response to changes in the market and to competition on price and mature markets) (Besch, 2005; Cook, et al. 2006; Hirschl, et al. 2003; Mont, 2002). New possibilities for growth in mature markets (Mont 2002), • Organisational willingness to change (Mont, 2002) • Time to market (Mont, 2002) • Geographical density of demand (Besc,h 2005)
Policy and regulation
• Environmental legislation (absence – barrier, presence driver) (Cook, et al. 2006; Besch 2005; Mont 2002) • Industry regulation (Halme et al. 2005) • Regulatory framework to stimulate investments (Mont 2004a) • Labour regulation (affecting availability and cost of labour)
Corporate competencies
• Corporate competencies (Cook et al. 2006) • Core competencies vs. diversification (risk of over-diversification) (Mont 2002) • Skills set of personnel (Bartolomeo et al. 2003)
Strategic and organisational issues

- Strategic orientation(Cook et al. 2006) view of core business (Halme et al. 2005)
- Organisational commitment (Bartolomeo et al. 2003; Mont 2002)
- Organisational structure (Cook et al. 2006)
- Internal relations between organisational functions (Mont 2002)

Product portfolio

- (whether or not services already in the portfolio)(Cook et al. 2006)
- Innovative technology (presence is driver of services) (Bartolomeo et al. 2003)
- Conflicts between products designed for functional sales and traditional use (Mont 2002)

Financial issues

- Labour cost (Bartolomeo et al. 2003; Halme et al. 2005; Mont 2002)
- Cost of resources (Mont 2002)
- Financial risk (Besch 2005)
- Supplier and customer awareness of cost structure (Mont 2002)
- Financial savings (Mont 2002)
- Uncertainty/certainty of cash flow (Mont 2002)
- Infrastructure (Halme et al. 2005) and infrastructure costs (Bartolomeo et al. 2003) (low cost – driver, high cost barrier)
- Geographic density of customers (Besch 2005) (cost and environmental impacts. Low density – barrier, high density driver)

Networks and value chain

- Cooperative networks (Cook, *et al*. 2006; Halme, *et al*. 2005)
- Relationship and conflict of interest between actors along the value chain (Mont, 2002)

Customer relations and customer demand

- Customer demand (Besch, 2005; Mont, 2002)
- Relationship with customers (Bartolomeo, *et al*. 2003; Halme, *et al*. 2005)

Natural environment

- Ease or difficulty with which environmental criteria can be balanced with other customer criteria (Mont, 2002)

There appears to be an implicit assumption in the literature that existing firms are going to change their business model from manufacturing and sales of material artefacts to increased service provision. It would also seem possible however, that firms already providing services simply increase their market share and that the change is not mainly within firms, but between firms. A starting point for the concept was that many manufacturing firms increasingly bundle material artefact offers with service components, that the manufacturer is also the service provider in PSSs and therefore that the firm needs to change its operations on a number of accounts (Cook, 2002). This is no doubt the case in many instances, but it is far from the whole truth on the concept. Some authors also recognise that often third party firms are the service providers and that therefore the incentive to design material artefacts for recycling and remanufacturing may be weakened in such circumstances.

2.4.4.2 Demand-side adoption

This section reports the review of PSS literature concerned with demand-side PSS adoption and related literatures on service adoption and service quality management. The way of identifying factors for and attitudes to adoption used in much of the PSS literature may be viewed as a truncated version of the theory of planned behaviours (Hamlin, 2010). This theory comprises subjective norm and perceived control, in addition to attitude towards behaviour as inputs to the consumer decision. The theory is widely used, both in its full and truncated form. However, it is criticised in academic research. First however, is a brief account of fluctuations in the use of domestic services over the last centuries, and factors influencing those fluctuations.

The use and provision of waged domestic service was common in the late Victorian and early Edwardian eras (Delap, 2011) although with an uneven geographic spread (Gregson & Lowe, 1994). 'Servant-keeping' was broadly associated with middle-class identities of privilege and status, although not all middle-class households employed domestic workers and some working class households did (Delap, 2011).

Over the last century, the use of domestic services has fluctuated for a variety of reasons comprising both structural factors and ideals. At the beginning of last century ideals of domestic privacy rose, while 'mistresshood' (servant-keeping) increasingly became associated with idle luxury, 'parasitism or arbitrary forms of authority' (Delap, 2011, p.193). Certain lighter tasks in the households, such as mending socks and trimming hats, became acceptable for middle-class women to do, whereas 'rough work' such as scrubbing floors, heavy cleaning of knives and pans, were still seen as tasks for servants.

The higher taxation and inflation during and just after World War One, meant that fewer households could afford residential servants (Delap, 2011). Instead, daily domestic helps were hired to help with heavier tasks. In the inter-war period, owner-occupation of homes increased in the middle-classes. However, the homes became smaller and less spatially segregated. This increased potential friction with domestic workers and contributed to ideals of domestic privacy. In addition, marriage bars restricted married women from employment in many professions, and placed women more firmly in the domestic domain which contributed to the normalization of the housewife identity.

After the Second World War, better paid higher status employment became available, the school leaving age increased and more employment opportunities became available to women. This reduced the availability of labour for domestic services. Nevertheless, the employment of casual help continued, although provided by somewhat older women often of migrant status and on a part-time and informal basis (Delap, 2011). In the 1980's and 1990's the labour market was deregulated and mobility of labour increased at the same time as the number of married women in full-time employment rose. In addition, material inequalities grew. This contributed to increased use and provision of domestic services in the UK. Postwar rhethorical idealization of housewives never fully resonated with experiences of housewives despite the spread of 'labour saving' household appliances. Together, these factors enabled the increase in domestic services in the UK in the 1980's 1990's. According to an account by Gregson & Lowe (1994) nanny and house cleaning services were supplied by individuals responding to

advertisements by private households, specialized recruitment agencies or the increased number of firms specializing in the supply of those services. These accounts focus on how institutional changes have shaped domestic services, and not on factors motivating individual households to adopt or not adopt the services.

Models on consumer behaviour typically draw on a wide range of theories, formulating conceptual premises and causal relationships between dependent and independent variables (Lindhqvist, 2005). Some theories emphasise factors internal to the consumer, such as attitudes, values and habits. Other theories are concerned with external drivers such as fiscal and regulatory incentives, institutional structures and social norms (*ibid.*). There is a controversy in this research field between simplicity and complexity. More complex models incorporating a large number of variables and relationships are criticised for being too complex for practical testing and application, whereas simpler models are criticised for missing important causal influences for consumer decisions (*ibid.*). More ambitious models seeking to reconcile internal and external factors and accounting for unconscious biases, symbolic and affect components tend to become complex. Jackson (2005) however points out that there are different purposes for modelling consumer behaviours, justifying the use of models of different levels of complexity. One purpose may be to provide heuristic devices that enable the identification of certain areas of importance for influencing specific behaviours.

In this thesis, the findings from PSS literature are used as heuristic devises for exploring household adoption of the experimental PSS. Below, Table 6 Factors influencing demand-side adoption of services and PSS summarises factors influencing adoption, from services management (service quality dimensions and perceived risks in service purchases), household production literature and PSS literature. After that, a brief account is given of related literatures.

Table 6 Factors influencing demand-side adoption of services and PSS

Service quality dimensions	**Perceived risks in purchasing services** (Lovelock *et al.* 1999)	**Household production**	**PSS**
	Financial risk (monetary loss, unexpected costs)	Cost and price (Pålsson, 2004; Gershuny, 2005)	Cost and price: Initial investment; Tax deductions and subsidies (Halme, *et al.* 2005; Mont, 2004); Relative prices of purchasing, renting and repairing (Hirschl, *et al.* 2003); Customers knowledge about total costs of ownership (Mont, 2002; Schrader, 1999); Willingness to pay (Halme, *et al.* 2005); Transaction costs (Bartolomeo *et al.* 2003).
	Social risk (how others think and react)	Social norms and bonds (Fernandez & Sevilla Sanz, 2006; Williams & Windebank, 2000)	
Professionalism and skills	Functional risk (unsatisfactory performance) Physical risk (damage to possessions or person)		
Attitudes and behaviours	Psychological risk (personal emotions and fears)	Enjoyment (C. C. Williams & Windebank, 2000)	
Accessibility and flexibility	Temporal risk (wasting time, consequences of delays)	'time famine'	Time efficiency (availability, planning, fetching, returning) Behrendt, *et al.* 2003); Time-frame for decision-making (Bartolomeo *et al.* 2003); Life style and demographic change (Halme *et al.*2005); flexibility of leisure time (Hirschl, *et al.* 2003). Flexibility and convenience (Hirschl, *et al.* 2003; Schrader, 1999). Availability (Schrader, 1999) of delivery at home (Behrendt *et al.* 2003).
Reliability and trustworthiness Recovery Reputation and credibility			
		Socio-demographics (Sullivan & Gershuny, 2001)	Socio-demographics (Schrader, 1999)
			Ownership of material artefacts Importance/culture of ownership (Behrendt *et al.* 2003; Mont, 2004; Halme, *et al.*

	2005); Product ownership as status symbol (Halme, *et al.* 2005); Customer involvement in product (Hirschl, *et al.* 2003); fashion and design (Besch, 2005); Whether service offers additional features/product range (Behrendt *et al.* 2003; Mont, 2004); Frequency of use of a product; special occasions (Behrendt *et al.* 2003); Availability of space at home (Behrendt *et al.* 2003; Schrader, 1999)

Service quality dimensions have been developed in services management research seeking to identify what factors people look for in service delivery (Schneider & White, 2004). The set presented in Table 6 above were Grönroos' service quality dimensions. The professionalism and skills dimension refers to whether the employees, physical resources and systems of the organisation have the knowledge and skills to solve customer problems in a professional way. The attitudes and behaviours dimension refers to whether the service employees (contact persons) show concern for customers and interest in solving their problems in a friendly and spontaneous way. The accessibility and flexibility criterion refers to whether the service (e.g. its location, operating hours, employees, operational systems) is designed so that customers can access the service easily and so whether the service providers can adjust to the demands and wishes of a customer in a flexible way. Reliability and trustworthiness refers to whether the customers feel that they can rely on the service providers, its employees and systems to keep promises and perform with the best interest of the customer at heart. Recovery refers to whether the customers trust that whenever something goes wrong or something unpredictable happens, the service provider will immediately take steps to find an acceptable new solution. Reputation and credibility refers to whether the customers believe that the operations of the service provider will give good value for money, that it stands for good performance and values that can be shared by customers and the service provider (Schneider & White, 2004).

The economic theory of household production is concerned with how unpaid work in the household by a household member is used to create value from resources such as consumption goods, purchased with the salary a household member has earned in the labour market (Anderberg & Balestrino, 2000; Freeman & Schettkat, 2005; Landefeld, *et al.* 2009). This is also known as self-service (Gershuny, 1979). An important application of the theory of household production as summarised above, is that spouses specialise in market labour and household production respectively, in accordance with their comparative advantage (Leeds & von Allmen, 2004). Traditionally, the spouse with the highest salary in the labour market undertakes paid work and the spouse with the lower income specialises in unpaid home production. This, according to economic theory, would lead to an efficient household distribution of production and consumption. Pålsson (2004), however, argues that the principles of the theory should be expanded to account for the possibility that it is more efficient for both spouses to work in the labour market and get a third-party service provider in to perform the household tasks.

Pålsson (2004), writing from a Swedish perspective with relatively high taxes which make it cost effective for very few households to use declared household services, advocates tax reforms to make household services fall below the *budget constraint* and be cost effective for a larger proportion of households[12]. A purely economic view suggests that demand for household services will increase as *prices* come down, the

[12] She also argues that this would generate jobs, reduce illness due to stress, make undeclared services declared, remove constraints on career opportunities for women who often take the larger responsibility for the home, and increase households' discretion as to how they allocate their time.

extent depending on the price elasticity of demand, and also the deadweight loss of tax will decrease (Mankiw, 2001). Gershuny (2005) also point out that the prevailing market prices for household services are likely to change when unpaid household production is introduced to markets on a larger scale.

The economic view, however, fails to take account of social norms. Empirical findings from time-use studies show that gender norms generate behaviours which counter predictions that are based on economic theory. When female paid work increases it was hypothesised that the time the female spouse spends on household work would decrease. Some findings suggest that this is the case, until she earns more than her male spouse. Females earning more than their male spouses spend more time on household work than working females who earn less than their spouses. Fernandez & Sevilla Sanz (2006) suggest that this behaviour might be an attempt to offset the violation of gender norms in terms of earning power, by conforming with gender norms related to household tasks.

Gershuny (2005) contends that occupational specialisation affects time use, and time use, in turn, affects consumption patterns. Sullivan & Gershuny (2001) expand on this, suggesting that 'time famine' may not be an across-the-board phenomenon, but rather associated with specific groups, such as 'professional dual-earner couples with dependent children' (p. 343). Therefore, the perceived need for, affordability and cost-effectiveness of consuming household services may be associated with particular socio-demographic groups.

In addition to commercial channels for household services, there are also informal channels. These are the concern of Williams & Windebank (2000) and Williams (2004). They found that a large share of households use informal channels, such as friends and kin to perform service activities without payment, but reciprocating in some way. Disadvantaged household (no-earner households) use these informal channels as much out of preference as economic necessity. These informal channels were a way of developing and maintaining social networks and were strongly dependent on reciprocity. Earner households were more inclined to pay friends and kin and used cost saving as a reason for this, as well as drawing on the skills of friends and kin. These findings partly reveal criteria for service performance, such as skills and cost, as well as enjoyment and satisfaction with outcome, and partly indication of criteria for uptake of commercial services. On the other hand, it is unlikely that no-earner households would be able to afford commercial household services and therefore this social role of the informal service provision may not affect the demand for commercial PSS.

2.4.4.3 Summary on factors influencing PSS adoption

Adoption was a key debate in the PSS literature, because if PSS does hold potential for resource productivity limited adoption might obstruct the realisation of this potential. This section has reviewed literatures on supply-side and demand-side adoption of PSS, and related literatures. A number of factors were identified both on the supply-side and demand-side. Below is a summary of factors that will be used to analyse attitudes to PSS adoption in the primary research for this thesis.

On the supply-side, the criteria in Table 1 Definitions of product-service systems and related service concepts (Tukker & Tischner, 2006, p.25)the list below were used, from the receptivity model by Cook (2006) and modified by the present author to accommodate further factors in the PSS literature:

- information in the external environment
- market conditions
- customer demand and customer relationships
- regulatory framework
- natural environment
- corporate competence
- strategic orientation
- organisational structure
- portfolio of offerings
- cost, revenue and profits
- network and supply-chain

On the demand-side, the criteria that will be used for analysing the primary research on households' attitudes to adopting PSS, are based on the service quality dimensions, and in addition to those, cost and price since financial factors were important both in the PSS literature and in the literature on household production. Socio-demographic aspects are considered in the sampling for the primary research. Ownership of material artefacts will be considered, but not as a factor for adoption of PSS as such, but whether or not households are willing to give up ownership of material artefacts when using PSS. This was an implicit assumption in the PSS literature concerning the behavioural mechanisms for resource productivity. Finally, environmental impacts were not a prominent factor in the literature, but will be included in the present research in order to explore whether that seems to influence the attitudes towards adoption of PSS.

- Cost and price
- Professionalism and skills
- Attitudes and behaviours
- Accessibility and flexibility
- Reliability and trustworthiness
- Recovery
- Reputation and credibility
- Enjoyment
- Environmental concerns

In addition, the different types of perceived risks in service consumption may offer further insights (Table 6).

2.4.5 Design – a key debate

Design of PSS was another recurring theme in the PSS literature. Many authors share the idea that existing design models for design and eco-design of material artefacts are a useful starting point for PSS as well, and that these model can be extended/adapted to fill current gaps in the design of PSS (Aurich, *et al.* 2006; Brezet *et al.* 2001; Maxwell & van der Vorst, 2003; Morelli, 2006; Tukker & Tischner, 2006). These authors represent different areas of application, and therefore have slightly different ideas of what is needed and currently lacking.

A new design approach was said to be needed for optimising the design of material artefacts and services associated with industrial investment goods in order to satisfy customer demands and improve the cost-effectiveness of the offerings (Aurich *et al.*

2006). The proposed model took an engineering design approach directed at the operational level. Aurich's (2006) service development process more or less mirrors and links to a generic process for development of material artefacts, in linear stages comprising: idea generation/ demand identification, concept development/feasibility analysis, product construction/concept development, product detailing/service modelling, prototype development/realisation planning; manufacturing preparation/service testing.

Brezet *et al.* (2001) suggests that services need to be eco-designed in order for their environmental potential to be realised, but that there is lacking evidence of how this may be achieved, and under what conditions. Brezet *et al.* (2001) too propose the use of conventional product development stages, supplemented with an introductory 'exploration' stage.

Another need was workable tools for developing sustainable material artefacts and services in manufacturing firms (Maxwell & van der Vorst, 2003). Maxwell & van der Vorst (2003) addressed the strategic rather than the operational level of firms and identified a number of business functions that need to be involved: marketing, PR, finance, production, product development, environmental and social management, health and safety, quality assurance and purchasing in addition to supply chain partners. The above approaches all seem to be geared towards manufacturing firms that are 'servicing' their offerings.

Morelli (2006) adopts a different perspective on PSS design. His starting point is that of stakeholder interaction; profiling stakeholders and generating maps of their interaction by way of modelling tools and narrative tools.

The literature reviewed on design of PSS will inform the development of the experimental PSS that will subject to exploratory assessments in this research.

2.4.6 Policy recommendations in the PSS literature

Some of the existing studies on PSS and related concepts conclude with policy recommendations in the form of a few sentences or paragraphs rather than in-depth analysis of policy measures, or indeed proposing specific policy measures to achieve their policy recommendation.

Many of these authors recognise that the environmental potential of PSS is uncertain but they draw different policy conclusions. Goedkoop *et al.* (1999) suggests that policy should support 'business activities' *that have* a lower environmental load per unit. Similarly, Mont & Lindhqvist (2003) recognise that services can be environmentally 'problematic' but suggest that policy should promote PSS, which by Monts' definition are environmentally superior to 'traditional sales'. Halme *et al.* (2005) suggest measures both to improve the sustainability of 'sustainable consumer services' *and* to increase adoption. Tukker & Tischner (2006) did not conduct environmental assessments but reference some of the few existing ones. They suggest policies to promote adoption of PSS. Hirschl *et al.* (2003) remark that efficiency gains are remarkably smaller than expected but that 'innovative use regimes' should be encouraged together with design for environment and 'favourable climate for complex innovation' (p. 881). Bartolomeo

et al. (2003) conclude that policies to support eco-efficient services are inappropriate due to the uncertain environmental performance of service, but that policies that internalise environmental external costs. Goedkoop *et al.* (1999) recommended policy support for benchmarking several industrial sectors, implicitly assuming that the lower environmental load is constant over time. Heiskanen & Jalas (2003) suggest further research into policy interventions themselves to establish which measure are useful to increase the environmental performance of services.

PSS could be viewed as a part of sustainable consumption and production. In their 2003 framework for sustainable consumption and production, Defra & DTI (2003) focus on market failures and corrective fiscal and information measures. Examples are the climate change levy, landfill tax, grants for fuel efficient and clean vehicles, loans for investment in energy efficient equipment, business support programmes, funding programmes to stimulate technological innovation, promotion of eco-labelling, green public procurement. In recent years, the Department for the Environment, Food and Rural affairs has commissioned research and gathered an evidence base on influencing behaviour (Defra 2011b). This has broadened the scope of academic disciplines from which the understanding of stimulating behaviours is drawn. In its sustainable lifestyles framework, (Defra 2011c) recognise that a range of both situational and behavioural factors influence practices and behaviours. They also recognise the need for a suite of measures that may differ across groups in the population and the need for engaging with business, civil society, communities and individuals.

2.5 CHAPTER SUMMARY AND CONCLUSIONS

This section summarises the messages from the literature review for the justification of the research topic, scope of the research, formulation of objectives and research questions and issues to address in the development of the methodology for the research.

2.5.1 Justification for the topic and research problem

The review of literature confirmed the need for research into household waste prevention and PSS. Waste and waste management is coupled with environmental and health issues, which waste prevention could potentially alleviate. Waste prevention was found to have suffered both a lack of research and policy attention in spite of its position as the favoured waste management option by waste policy. A conceptual link between waste prevention, resource productivity and services was identified, and in particular a service concept known as Product Service Systems (PSS).

However, the waste prevention potential of PSS had not been the focus of PSS research as such. Nevertheless, service consumption and PSS have been suggested as ways to achieve waste prevention although there was little research to bear out this suggestion. The resource productivity and environmental performance of PSS was found to be uncertain, and also argued to be context dependent. Much of the research on PSS concerned use-oriented PSS in Scandinavia and continental Europe. While result-oriented PSS was claimed to hold the greatest potential for resource productivity, there was a scarcity of assessments of result-oriented PSS offered to households in a UK context. Therefore, research is needed to assess the waste prevention and environmental

potential with a view to informing policy-making other decisions for instance by firms, as well as further research.

2.5.2 Focus and scope of the study

In addition to establishing the research topics and problems, the review of literatures also served to refine and bound these topics and problems. The scope of this research was presented in chapter 1.

2.5.3 Objectives and research questions

The review of literature identified key issues concerning the potential for PSS to bring about household waste prevention. This led to the development of research objectives and research questions.

Willingness to adopt PSS, both among companies that could potentially provide PSS, and among potential customers was identified in the literature as a challenge. Adoption is a prerequisite for any potential benefits to be realised. Factors influencing the inclination to adopt PSS were identified (2.4.4). There was a scarcity of research on adoption of result-oriented PSS in the context of PSS provided to households in the UK.

PSS was thought to provide incentives for behaviours pertaining to the choice and management of material artefacts, *e.g.* specifications of material artefacts, maintenance and replacement rates. These behaviours, the PSS literature posited, would bring about increased resource productivity. By extension then, they would bring about waste prevention. However, the review of literature revealed that many of these proposed behaviours rested on assumptions rather than empirical findings. In order to learn more about these behaviours and what they mean for the waste prevention potential of PSS, and particularly in the context of PSS for UK households, this was found to require research. The behaviours proposed by the literature on these behaviours were listed in (2.4.2).

Together, the behavioural issues of adoption and choice and management of material artefacts formed the following research objective and research questions.

Objective 1 (results chapter 4): To identify attitudes towards PSS adoption and behaviours concerning choice and management of material artefacts which influence the waste prevention and wider environmental performance of PSS

1. What attitudes do households and service providers hold towards adopting the experimental PSS?
2. How do households and service providers conceive of the different factors thought to influence adoption of the experimental PSS?
3. How do households and service providers respectively reason and behave concerning their choice, ownership and management (use, maintenance, replacement and disposal) of material artefacts?
4. How do these behaviours compare with the behaviours proposed by the literature review?

The issue of the waste prevention potential of PSS was central to this research, and merited a research objective with associated research questions. The review of the

literature essentially suggested that the behaviours of service providers and customers (households) would amount to extended use-lives of the material artefacts in the case of PSS. The prospect and effects of the behaviours on the amounts of waste generated with PSS compared to self-servicing formed the basis for this objective. The literature suggested that the performance of PSS needs to be established on a case by case basis. This raises the question of whether or not different household tasks have different properties that cause their waste prevention potential to differ. Since the PSS literature was to great extent relying on assumed behaviours, the behaviours thought to lead to resource productivity and waste prevention warranted a research question. In order that the decision-makers gain an insight into the worth of investments for instance in policies or PSS, it is useful to get an indication of the scale of the waste prevention potential. The PSS literature suggested that result-oriented PSS hold the greatest potential for increased resource productivity. However, since the results on the potentials were uncertain, this warranted a research question.

Due to the limited prior knowledge on waste prevention, and highly uncertain performance of PSS it is unlikely that the answers to the research questions are definitive. Each research questions are more likely to be answered only in part. Nevertheless, the questions need to be posed.

Objective 2 (results chapter 5): To identify the waste prevention potential of experimental PSS developed for different household tasks

1. Do the household tasks hold the same potential for household waste prevention ?
2. How do the attitudes and behaviours of households and service providers with regard to adoption of PSS and choice and management of material artefacts affect the potential for waste prevention through result-orientedPSS?
3. What is the scale of the potential for household waste prevention potential through the result-oriented PSS?
4. Do result-oriented hold as great potential as has been suggested by previous research?

Environmental performance was a key concern in the literature. The literature did not offer any conclusive evidence on this issue. Early conceptual research made relatively bold claims that have been toned down by subsequent case study research. However, due to opaque reporting, these claims were also uncertain. It was also argued that the environmental performance of PSS is context dependent and need to be determined on a case-by-case basis. There was a scarcity of research on result-oriented PSS for household tasks in a UK context. Due to the wide scope of each type of PSS, and the fact that it was not specified what contextual factors may influence the environmental performance of PSS, it might be relevant to assess whether PSS for different household tasks perform the same, or whether there are differences even between those cases.

It was noted in the section on waste, that different waste fractions give rise to different environmental impacts. Furthermore, different materials also have different environmental profiles. Therefore it is useful to consider whether PSS for different household tasks, requiring different material artefacts hold the same environmental potential.

Some of the literature considered environmental potential with a single indicator, whereas others recognised that different types of emissions and impacts arise. The literature on resource productivity and dematerialisation recognised that there are different species of emissions that these show different trends. In this research it is

deemed appropriate to explore whether potential waste prevention occurs at the expense of other environmental impacts, and whether there are any trade-offs between different types of emissions. Given the variations in the claims of the scale of the environmental potential of PSS, the scale of the potential merits a research question. Uncertainty and limited prior research means that it may not be possible to arrive at definitive answers for those questions. Nevertheless, the questions need to be asked.

Objective 3 (results chapter 6): To identify the environmental potential of PSS developed for different household tasks

1. Are there any trade-offs between household waste prevention and other emissions over the life cycle?
2. Are there any trade-offs between different types of emissions over the life cycle?
3. What is the scale of the changes in emissions?
4. Do PSS for different household task have the same environmental potential?

3 METHODOLOGY

3.1 INTRODUCTION

This chapter sets out the overarching research design strategy in light of a number of properties of the present research. After that, it details the research designs of the different parts of the research utilised to meet the objectives. Below is a summary of key points in this chapter.

- An exploratory mixed methods research design comprising both flexible and fixed design elements was selected due to the novelty of the research areas of PSS and waste prevention. The fixed and flexible designs offered complementary insights.

- The context for the research was a UK property development firm, its new housing development in the north and south and householders on those housing developments. Purposive sampling was used to recruit participants from multiple functions of the property development firm, its supply chain and householders.

- A flexible design using was used to develop experimental PSS for four household tasks, namely garden maintenance, home improvement, house cleaning and laundry. A flexible design was also to explore attitudes towards adoption of PSS, and choice and management of material artefacts. Focus groups and semi-structured interviews were used for data collection, alongside document studies. Coding and clustering of the contents of transcripts of audio recordings and summary sheets. Descriptions of the PSS resulting from the PSS development were presented at focus groups to enable discussions.

- A fixed design was used for the assessment of waste prevention potential and environmental potential respectively for the PSS. Functional units were identified to enable the comparison of self-servicing and PSS respectively, and thus the waste generated by the two options.

- The assessment of the waste prevention potential of PSS concerned direct waste only. The variables and equations used in the assessment were set out. The data for those variables for self-servicing were collected using a questionnaire completed by the focus group participants. Average values for each variable calculated. Supply chain participants form the property development firm could not offer data on the variables for the PSS. Instead, values were collected from other service firms, or reasoned where service firms could not offer data. The potential waste prevention was calculated and used as input in the subsequent environmental assessment using a simplified life cycle approach.

- Indicators of groups of resources used and emissions relating to different processes during the life cycle of the material artefacts and tasks were used to calculate emissions over the life cycle of self-servicing and PSS to compare the two.

- Assumptions and possible variations (scenarios) and their implications for the results were set out.

3.2 RESEARCH DESIGN

This section describes the research design incorporating the approach to types of data and sources, methods for data collection and analysis. It considers the purpose of the research and research questions to be answered, the research perspective the current state of the knowledge, the character of the topic and the theories used.

Robson (2002) suggests that there are two main types of research design, namely fixed and flexible ones. Fixed research designs are fixed before the main stage of data collection begins. Data are typically but not necessarily quantitative. Fixed designs are theory driven, as this is a pre-requisite for determining in advance what variables to study. Robson (2002) suggests that fixed designs are concerned with aggregations, group tendencies and general properties; in transcending individual differences. Examples of fixed research designs are experiments and non-experimental measurements of a number of variables. Robson (2002) suggests that experiments are suitable for explanatory research.

With a flexible research design, the design develops during the data collection, since initial stages of data collection and preliminary analysis will suggest further research needs to fulfil the research aim. Flexible research designs may be geared towards theory generation or in-depth understanding and interpretation of a single case or multiple cases. Examples of flexible research designs are case studies, grounded theory, ethnography (Robson, 2002).

According to Robson (2002) different types of research questions and research purposes[13] are particularly fitting for each of the research design strategies (Table 7 Research designs for different research purposes and questions).

Table 7 Research designs for different research purposes and questions

Research purpose	Types of research questions and research design strategies
Exploratory	*What (what is going on here); how, why* - **flexible** research design
Descriptive	*What questions (how many, how much, who, where)* - non-experimental **fixed** research design
Explanatory	*Why* - experiments (**fixed** design strategy)
Evaluation	*What is the worth of x*- Focus on outcome: fixed; focus on process: flexible

The use of both fixed and flexible designs into what is called 'mixed methods research' (Tashakkori & Creswell, 2007) may offer a better understanding of the research

[13] Here, the word 'research purpose' is used as Robson (2002) uses it. The author of this thesis interprets the term 'purpose' to be more to do with the aim and intention of the research).

problem. This may be achieved when fixed and flexible designs complement each other to elaborate and illustrate the issues at hand, and when the results from one method are used to inform the part of the research utilising another method. The understanding provided by mixed methods research may be better suited to inform theory and practice than the use of a single-design approach (Molina-Azorín, 2011).

An exploratory mixed method design was chosen for this research in light of the properties of the research. An exploratory approach was needed because waste prevention and PSS are relatively novel research areas. There was a particular scarcity of research on waste prevention and result-oriented PSS for English households. The research questions in this thesis (section 1.4.3) span both 'what' questions in terms of how many, how much, suitable for a fixed research design strategy, and 'what' questions in terms of 'what is going on here' suitable for a flexible research design strategy

In order to fulfil the research purpose of informing policy-makers on the waste prevention potential, the research needs to contain an element of aggregation and general tendencies. This corresponds to a fixed research design. At the same time, policy-makers may wish to be aware of households' and service providers' attitudes and behaviours to better understand where to target and how design any policy measures geared towards increasing adoption of PSS or improving the waste prevention potential and environmental performance of PSS.

An exploratory, context-bound approach means that the fixed research strategy called for by the quantitative nature of a part of the research topic, offers numeric descriptions and indicative orders of magnitudes. This is a useful complement to flexible designs and quantitative methods in generating an understanding of the phenomenon at hand (Danermark, *et al.* 2003). However, it should not be confused with statistical generalisation.

An exploratory context-bound approach also means that comprehensive definitive answers to the research questions are unlikely to flow from this research. Neither are the decisions-makers that this research seeks to inform likely to receive a fixed prescription. Instead, they will be provided with insights that they are able to consider in their own context, and to identity further issues that need to be addressed, and whether in the light of these insights they find it worth pursuing PSS. Additional questions are likely to be raised and further research needs likely to be identified. The research area is likely to have achieved some degree of further conceptual clarity.

Given the fact that the PSS research was found to be under-theorised (see chapter 2) the research was deemed to benefit from drawing on existing theories. Therefore, this research is theory driven as opposed to grounded, although the theories are heuristic devices, rather than grand theories. Fixed research design strategies are necessarily theory driven. Flexible research design strategies may or may not be theory driven (Robson 2002).

3.3 CHOICE OF CONTEXT FOR THE STUDY

The Defra research programme on from which this study received its funding was the reason for the focus on UK households. The PSS in this research were developed in collaboration with a property development firm building domestic homes as well as providing facilities management services to firms. New housing developments built by property development firms are likely to make up the majority of a large number of new homes developed as a result of a growth strategy for UK housing (Department for Communities and Local Government, 2011). Developing new homes and housing developments offers an opportunity to consider resource conservation and infrastructure to support it. New homes on new housing developments may also cater for new life-styles where services are increasingly consumed. Many of those new homes are likely to be purchased by those relatively more affluent socio-economic groups that Emery *et al.* (2003) identified as generating more waste than less affluent households. Moving house is likely to mark a moment of change at which householders reconsider their stock of material artefacts, service consumption and how they perform household tasks (New Economics Foundation & Defra, 2011). Thus, the presence of PSS in the range of after-sales offerings that may be opted for in the purchase of a house on a new housing development could offer opportunities for PSS production and consumption.

Table 8 provides an overview of the research objectives and the research questions, research design, types of data, data collection method, sampling strategy, data collection and data analysis related to each research objective. The table provides a 'routemap' through the study and shows how research questions were explicitly linked to choice of research methods.

Table 8 Overview of research design for the different research objectives, in light of the research questions and research design

Obj.	Research questions	Research design	Type of data	Data collection methods	Sampling strategy	Data collection	Data analysis
-	(development of experimental PSS for household tasks)	Flexible	Qualitative: oral expressions of attitudes and experiences transformed into text; Text and numbers in documents	Focus groups; semi-structured interviews; Document study	*Purposive sampling*: • Supply-side: ensure multifunctional participation from property developer in focus, and their supply-chain • Householders on new housing-developments provided by the property developer; homogeneity and variety sampling	*4 focus groups*: • Supply side: 2 groups with 6 participants (the same 6 on both occasions) • Households: 2 groups with 4 + 4 participants *14 Interviews*: • Supply-side: 8 respondents • Households: 6 respondents	Coding and clustering; preliminary set of codes from conceptual framework developed from literature review.
1	1. What attitudes do households and service providers hold towards adopting the experimental PSS? 2. How do households and service providers conceive of the different factors thought to influence adoption of the experimental PSS? 3. How do households and service providers respectively reason and behave concerning their choice, ownership and management (use, maintenance, replacement and disposal) of material artefacts? 4. How do these behaviours compare with the behaviours proposed by the literature review?	Flexible	Qualitative: Oral expressions of attitudes and experiences, transformed into text	Focus groups; semi-structured interviews; questionnaire; document study	The same as previous; + diverging cases of households	Data from the previous research activities. Additional data were also collected: *6 focus groups:* • Supply-side: 2 groups with 6 + 5 participants • Households: 4 groups with 10+7+4+5 participants *10 Interviews:* • Supply-side: 6 respondents • Households: 4 respondents *Questionnaire:* • Households: 21	Coding and clustering; preliminary set of codes from conceptual framework developed from literature review.
2	1. Do the household tasks hold the same potential for household waste	Fixed		Data from research activity carried out in pursuit of objective 2.	N/A	Product specifications, tests by consumer organisations, market research available in public domain	Equations with variables central to the PSS concept, with mean values from

	prevention ? 2. How do the attitudes and behaviours of households and service providers with regard to adoption of PSS and choice and management of material artefacts affect the potential for waste prevention through result-oriented PSS? 3. What is the scale of the potential for household waste prevention potential through the result-oriented PSS? 4. Do result-oriented hold as great potential as has been suggested by previous research?						questionnaire
3	1. Are there any trade-offs between household waste prevention and other emissions over the life cycle? 2. Are there any trade-offs between different types of emissions over the life cycle? 3. What is the scale of the changes in emissions? 4. Do PSS for different household task have the same environmental potential?	Fixed		Data from research activity carried out in pursuit of objective 3. Document study	N/A	Indicators of environmental burdens over the life cycle from 'MEEUP' Material compositions for material artefacts	Equations applying indicators to the results from the waste prevention assessment

3.4 RESEARCH PROCESS

This section describes the research process in which the different methods were applied to fulfil the aim and objectives of the research, as illustrated in Figure 3.

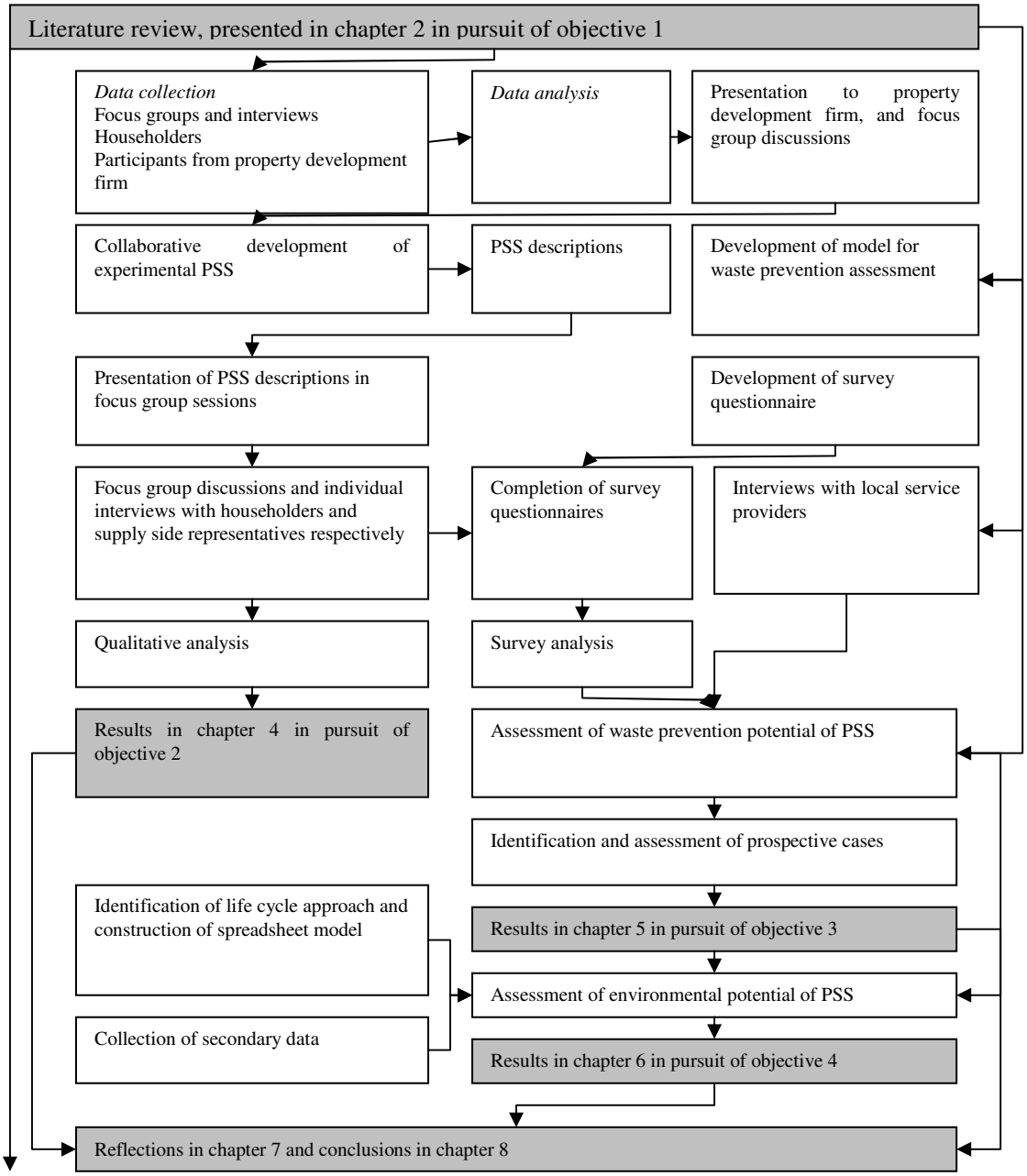

Figure 3 Map of research process

An initial literature review was conducted at the outset and continued throughout the research (see chapter 2). Focus group discussions and semi-structured interviews were conducted with participants from the property development firm and householders from new housing developments to inform the development of the experimental PSS that

were subsequently going to be assessed (see section 3.5.2). These qualitative data were analysed (see section 3.5.3). The results were presented to participants from the property development firm, and experimental PSS were developed in collaboration between the researcher, representatives from the property development firm and another member of the project team. The development of the experimental PSS is detailed in appendix A. The experimental PSS took the form of various types of descriptions. Narratives and storyboards and flashcards were used to present the experimental PSS to participating householders in order to explore their attitudes towards adoption of PSS and behaviours concerning the choice and management of material artefacts. The presentations were made at the beginning of focus group sessions and followed by focus group discussions. Individual semi-structured interviews were also carried out to the same end with the same participants (section 3.6.2). The PSS concept and brief descriptions of the experimental PSS were presented to supply-chain representatives from the existing supply-chain of the property development firm during a focus group session. This was followed by focus group discussions (see section 3.6.2). These qualitative data were analysed (see section 3.6.3). The results are presented in chapter 4.

A waste prevention model was devised to enable the waste prevention potential of a change from self-servicing to PSS to be assessed in pursuit of objective 3 (see section 3.7.2). A survey was devised to collect the input data for the model and to add further insights to the choice and management of material artefacts in pursuit of objective 2 (see section 3.7.3). Devising the waste prevention model and the survey preceded the focus group discussions that were carried out to explore the attitudes to adoption of PSS and choice and management of material artefacts, since the survey was handed to the focus group participants during the focus groups. The survey questionnaire was then completed and returned there, by mail or via telephone interviews. Service providers in local service markets were identified and interviewed to collect input values for the PSS in the model for waste prevention assessment. The survey data and interview data were analysed and entered into the spreadsheet model. Some of the input data for PSS drew on assumptions from the PSS literature, for reasons explained later on in this chapter. Scenarios were also modelled. The results are presented and discussed in chapter 5.

A simplified life cycle approach to environmental assessment was identified and a spreadsheet model was constructed (see section 3.8.1.2). Further secondary data on for instance material compositions of material artefacts were collected and entered into the spreadsheet model (see section 0). Life cycle impact indicators relevant to the materials and processes were entered, and calculations performed that were based on the results from the waste prevention assessment (see section 3.8.1.4). These calculations showed percentage savings (or increases) in environmental impacts of different environmental impact categories when life cycle processes pertaining to self-servicing and PSS were compared. The results are presented and discussed in chapter 6.

3.5 DEVELOPMENT OF EXPERIMENTAL PSS

New housing developments built by property development firms were considered a promising context for household waste prevention through PSS (see section 3.3). However, property developers did not offer such PSS. Therefore, experimental PSS needed to be developed to enable the assessments. This section sets out the method used to develop the experimental PSS (hereafter referred to as PSS). The development of the PSS is further elaborated in appendix A.

There are various models for new service development, which comprise similar stages although different in the exact numbers and the names the stages are given (Alam & Perry, 2002; Aurich, *et al*. 2006; Panesar & Markeset, 2008). Similar PSS development models are also presented by Tukker & Tischner (2006). Regardless of the exact name and number of stages, the models tends to comprise elements of idea generation and screening, demand identification, business feasibility analysis, service concept or more overarching process development to development of detailed operational processes, staff training, piloting and commercialisation.

The development of the PSS comprised the stages from idea generation and screening through to development of stopped at an outline level of service process development. Project resources did not allow for development of detailed operational processes for the PSS. Given the limited knowledge on PSS and waste prevention in this context, this level of detail was deemed sufficient to offer an indication of the scale of the potential for waste prevention and environmental performance. It was also deemed sufficient to allow service providers and householders to express their attitudes towards adoption of this type of service in line with the exploratory approach of this study.

3.5.1 Types of data needed

For there to be at least some potential adoption of the PSS, Householders' and the service firms' attitudes towards different types of PSS were needed, together with propositions from the literature review. Household waste fractions relevant for waste prevention, either due to the fractions share of total household waste, potential for harmful substances or other waste management challenges, needed to be identified. Therefore statistics on household waste was needed. Material artefacts in the different waste fractions also needed to be considered in order to determine what material artefacts and corresponding household tasks were suitable for the selected type of PSS. This also needed to be weighed against household tasks for which there was at least potential demand.

Information about sub-processes in the PSS delivery from customer booking and internal management processes on the parts of the property development firm was needed as well as the delivery of the PSS to the households. Furthermore, cost and price estimates from the property development firm were needed to identify pseudo-prices of the PSS. The pseudo prices would provide the householders with a rough estimate that would enable them to consider their willingness to adopt the PSS.

3.5.2 Data collection

3.5.2.1 Sampling strategy

A purposive sampling strategy was followed when recruiting participants for the focus groups and interviews (Coyne, 1997). Purposive sampling is deployed to ensure the typicality or interest in order to ensure information richness for the aim of the study (Krueger & Casey, 2000; Robson, 2002). The purpose of the selection of the supply-side representatives was to ensure participation from a variety of functions within the collaborating property development firm, and also their suppliers and customers, in accordance with recommendations from the service management literature (*e.g.* Panesar & Markeset, 2008). Consequently, this type of purposive sampling may be termed theoretical sampling. The functions included were facilities management, supply chain, customer services, environmental services and marketing functions.

A two-stage approach was used for the sampling of householders. First, housing developments were selected from the participating property development firm. Housing developments were selected to comprise both developments with houses and with apartments, and to be located both in the south and the north of England, to allow any regional differences to surface. The housing developments also needed to be of a reasonable size to offer the opportunity of sufficient demand for PSS to be viable, being embedded in urban areas.

Householders on these new developments were of interest to the research because they had recently moved house and thus were within a 'moment of change' which offers an opportunity to reconsider consumption patterns and other lifestyle choices. Householders were sought that would offer a degree of homogeneity within each group to offer a safe environment in which to share experiences (Barbour, 2005), but some variation between the groups to allow for a breadth of experiences and views as a whole. Thus, this was homogeneity and variety sampling (Coyne, 1997). Identification and recruitment of relevant respondents of each type was performed in collaboration with project partners in the collaborating property development firm. Marketing Officers in the sales and marketing office on the new housing developments asked the householders if they wanted to participate.

3.5.2.2 Focus groups

Three focus groups were organised with householders on the housing developments located in the North East (Newcastle), North West (Altringham), and South West (Swindon) of England. The former two focus groups were successfully completed. Due to poor response to the recruitment efforts in the South West, this focus group had to be cancelled. The participants from the North West were young to middle-aged professionals, two men and two women, of which three with children at home. The focus groups were held at 7 pm on week nights in facilities on the housing developments. Discussion topics were prepared to maintain the focus of the sessions. These topics sought to engage with every-day practices and habits of households (Söderholm, 2008), at a key moment of change representing an opportunity to reconsider habits. The participants were asked to consider the range of household activities/activities they undertook within or associated with their household on a typical

day of the week. With the aid of the facilitator, activities were clustered by participants into those relating to household activities, such as household maintenance, entertainment, home cleaning. The material artefacts and services used to support such household activities were then identified. Performance criteria and quality dimensions associated with the selection of these were elicited as well as attitudes to replacing existing consumption patterns with various types of PSS. While the scripted discussion topics scheduled data collection consistent with the semi-structured approach, new questions were asked to pursue lines of enquire as they emerged and the order of activities changed in response to focus group conditions. The sessions were audio-recorded and transcribed.

Two focus groups for the supply-side were organised. The first was held after results from primary data collection and analysis from the household focus groups were available. This procedure facilitated the researcher-aided iterative learning in the service development process. Six participants from five different functions attended. These functions were facilities management; supply chain management; customer services; technology consultancy; sales and marketing. Discussion topics were prepared, comprising a presentation of the PSS concept contributed by the research team, and similarities with ideas harboured within the focal firm. The results of primary data collection and analysis form the household focus groups were identified and discussed. The opportunities for different types of PSSs were discussed and performance criteria identified and discussed. The focus group was held at 10 am on a week day at one of the offices of the property development firm. The session was audio-recorded and transcribed.

A second focus group with the same participants was organised some months later, following further service development and pricing on the basis of the analysis of focus groups and individual interviews. Again, this offered an approximation of the iterative learning. Discussion topics were prepared and comprised a re-familiarisation with the concept, presentation of the selected, developed and priced services and discussion of those.

3.5.2.3 Semi-structured interviews

Individual semi-structured interviews were conducted in order to complement the focus group data. Individual interviews were used to get responses independently from the interactive situation in the focus groups. Consistent with the semi-structured approach, interview guides were developed based on the schedule used in the focus groups. Participants' responses were noted by the researcher in all instances. Three interviews were audio-recorded. Contact summary sheets detailing the key findings of the interviews were developed for each interview.

Individual semi-structured interviews with householders were carried out face-to-face and by telephone. Six interviews were undertaken with householders from a housing development in the North East. Participants from the focus group held in the North West were willing but unable to be interviewed due to personal commitments. Eight interviews were undertaken with participants from the supply-side. Seven participants were interviewed from different functions of the property development firm one interview was conducted with a participant from a supplier of material artefacts.

A face-to-face interview with a representative from Facilities Management was conducted for the purpose of developing pseudo-prices for the PSS. The pricing model utilised was identified and applied to the PSS developed following the analysis of the qualitative data. The pricing exercise was based on pricelists and spreadsheet models operated by the property development firm, in collaboration with a representative from the property development firm.

3.5.2.4 Literature and document study

Literature on household waste statistics was used (see appendix B). Documents on business processes were provided by the property development firm. A spreadsheet with the pseudo prices was provided by the property development firm.

3.5.3 Data analysis

The analysis of the qualitative data from focus groups and semi-structured interviews involved data reduction and display and generation of meaning in an iterative process (Miles & Huberman, 1994; Robson, 2002). The oral accounts made by the participants in focus groups and interviews were transformed into texts in the form of transcriptions of audio recordings and summaries of field notes (Miles & Huberman, 1994). A template approach to coding and clustering was used to further reduce and generate meaning from the texts (Robson, 2002), (see the first two rows, right hand column in Table 8). The content of the participants accounts were the focus of the analysis. A preliminary set of codes was developed from the conceptual framework. Text segments were coded according to those codes while the researcher remained open to the material and the possibility of new codes emerging and initial codes being redundant.

The qualitative data collected via focus groups and interviews were analysed using a coding and clustering method with a view to identifying themes, relationships and structures in the materials (Miles & Huberman, 1994; Robson, 2002). Transcripts and summary sheets provided the text to be analysed.

The data analysis and synthesis enabled the identification of types of PSS and household activities feasible and desirable for the context under study. It also enabled the understanding of issues pertaining to service delivery process such as assets (material artefacts), physical facilities, scheduling, and accessibility (*cf* Lovelock *et al.* 1999).

3.6 ATTITUDES TO ADOPTION OF PSS AND CHOICE AND MANAGEMENT OF MATERIAL ARTEFACTS

This section details the methods used for data collection and analysis to implement the research design strategy in pursuit of objective 1. Table 8 shows the methods used to meet each objective.

3.6.1 Types of data needed

In order to answer the research questions pertaining to objective 1 (see the first two rows in table 8) primary data in the form of participants' expressions of attitudes and experiences were needed. These qualitative data were collected in the form of oral expressions turned into text in the form of summary notes and transcripts of audio recordings. The expressions were open, that is, they were not restricted by fixed response options. Secondary data in the form of texts in documents provided additional information, on for instance contextual information on housing developments where participants lived and business processes for service bookings in the participating property development firm.

3.6.2 Data collection

This section describes the data collection methods used in pursuit of objective 1. The same overarching sampling strategy was used for all data collection methods for both objectives. Focus group methods and semi-structured interviews were used as data collection methods for both the objectives. In the following sections, the overarching method is described and after that, the specific application of the method to each objective is described. In addition, a survey was used as data collection method to meet objective 2.

3.6.2.1 Sampling strategy

The sampling strategy described in section 3.5.2.1 was also used for the research conducted in pursuit of objective 1.

3.6.2.2 Focus groups

A focus group method was chosen as one of the data collection instruments since the interaction among the participants in focus groups has the potential to reveal attitudes to goods, services, programmes and institutions (Carson, *et al*. 2001). This was deemed to be appropriate in order to answer the research questions for each of objectives 1.

Data from the focus groups and interviews conducted to inform the development of experimental PSS, informed research on objective 1 as well. Additional focus groups were also held to meet objective 1. One focus group was conducted with householders in North West England, and one with householders in South England. In addition, two focus groups with householders in urban areas of South West England, who did not live in new built houses, not on the same housing developments, and many of whom had not moved house recently. These households were sampled to provide diverging cases (*cf* Coyne, 1997) in order to get richer insights into behaviours in relation to PSS.

The participants from North West England were young to middle-aged professionals, four men and six women, of which four with children at home. The participants from South England were older middle-aged with grown-up children who had left the parental home. There were three women and four men. The participants in urban areas of South West England were retired; six females and two males. The focus groups in North West England and South England were held at 7 pm on week nights in facilities

on the housing developments. The focus groups in South West England were held during the day. Discussion topics were prepared to maintain the focus of the sessions. The topics concerned perceptions of service quality relevant for service adoption, ownership and non-ownership of material artefacts in a situation without and with PSS respectively, and rebound effects.

Two focus groups were held with supply-side representatives. The first one was held with six representatives from different functions within the property development firm, comprising facilities management; supply chain management; customer services; technology consultancy; sales and marketing. The second one was held with four representatives from the property development firm's external supply chain and two from the property development firm. The supply chain companies mainly represented large international Facilities Management firms. The topics concerned criteria for adoption, such as market conditions, customer demand, portfolios of offerings, corporate competence and profitability.

3.6.2.3 Semi-structured interviews

Semi-structured interviews were conducted for the same reasons as set out in section 3.5.2.3.

Individual semi-structured interviews were conducted via telephone with the participants in the focus group in North West England, and with service firms from large international firms and from local service firms and a trade association. The interviews with the householders were concerned with attitudes to adoption of PSS and choice and management of material artefacts. The interviews with service firms were concerned with their choice and management of material artefacts. The large international service firms that were already supply chain partners of the property development firm in focus of this study, did not currently offer services to the domestic market and therefore their responses concerned current practice in the business to business market, which may differ from what might be the case in PSS to households. The local service firms were not currently partners with the property development firm and therefore, were not part of the core context of this study. Nevertheless, they were able to offer insights into current practice in choice and management of material artefacts in local service markets.

3.6.3 Data analysis

The data analysis followed the same method as set out in section 3.5.3.

A preliminary set of codes was developed from the conceptual framework and propositions developed from the literature review (see section 2.5). The preliminary codes were tried on the texts, while the researcher remained open to the material and the possibility of new codes emerging and initial codes being redundant. This procedure was in line with Miles & Huberman (1994). The codes were then clustered as themes and relationships in the data were sought. The data analysis and synthesis enabled enabled the understanding of issues pertaining to service delivery process such as assets (material artefacts), physical facilities, scheduling, and accessibility (*cf* Lovelock et al. 1999).

3.7 ASSESSMENT OF WASTE PREVENTION POTENTIAL

This section sets out the method devised and used in pursuit of objective 2 namely to identify the waste prevention potential of PSS and answer the research questions set out in Table 8. This is the first one out of two assessments using a fixed design and quantitative data. It is concerned with direct waste and not wider resource use and emissions, nor other life cycle stages. The definition of waste prevention covers both the quantity of waste and 'adverse impacts of the generated waste on the environment and human health' (Official Journal of the European Union, 2008 p.10). Understanding potentials for household waste prevention in terms of amounts of waste may be of interest to policy makers, local authorities and house builders for instance for dimensioning of waste management capacities. Therefore an assessment is needed of the direct waste potentially prevented.

Prevention of potentially adverse impacts on the environment in a life cycle perspective is addressed in the second stage of the two-stage approach. The method for that assessment is set out in section 3.8 and the results presented in chapter 6. That assessment also addresses decision-makers' needs for awareness of any environmental trade-offs between direct waste prevention and wider resource use and emissions in a life cycle perspective. The waste hierarchy states that waste prevention is the most favoured waste management option as a rule. However, as explained in section 2.3.1 this rule of thumb is not always environmentally preferable in a life cycle perspective, but depends on what processes and practices are replaced by waste prevention. Therefore, a second fixed design quantitative assessment is carried out addressing additional resource use and emissions across the life cycle as described in section 3.8.

First, the type and scope of the assessment of waste prevention potential is set out. Then a simple model is developed based on the central tenets in the PSS concept (section 2.4.2). The model contains a basic form with values from primary and secondary data collection, as well as alternative scenarios. Setting out the variables and their relations enables the waste prevention potential to be assessed in quantitative terms. It also facilitates a critique of the concept since assumptions and limitations become more visible and serve as a basis for a qualitative sensitivity analysis (section 5.6.2). The method for data collection and analysis is described, followed by assumptions and their implications for the result of the assessment.

This assessment, including the quantitative and qualitative sensitivity analysis shows the scale of the potential for waste prevention. From the point of view of policy and decision-making, this enables actors to judge whether or not the concept is worth pursuing at all, whether it is worth expending resources on filling the knowledge gaps and if so what are the key issues to be addressed. If the provision and use of declared household services were to increase[14], the findings of this research direct attention to

[14] In Sweden households get tax rebates for using domestic help (Skatteverket 2011). News reports suggest that the UK Conservative party is investigating whether such a tax rebate could be introduced in the UK as well (Brant 2012; Ross 2012).

issues that may addressed by the decision-makers to facilitate waste prevention. From a research point of view, this assessment is an important component for furthering the understanding of the concept and its utility in terms of waste prevention. It also adds to the body of knowledge on methods for waste prevention. This fixed design quantitative assessment as a part of an exploratory context bound study facilitates theoretical generalization to other contexts (see further 3.9.2). However, it does not allow for probabilistic prediction. Indeed, the research perspective (section 1.6) questions the possibility of probabilistic prediction.

3.7.1 Type and scope of assessment

This waste prevention assessment is a *bottom-up* assessment, that is, it is a *micro-level* assessment based on individual observations rather than aggregated data such as national statistics, used in top-down methods (Energimyndigheten, 2006). A micro-level approach was deemed necessary for assessing a particular waste prevention measure (such as PSS). Micro-level approaches were also adopted in the sparse literature on waste prevention, such as Salhofer (2008). Top-down, or macro-level, approaches based on national statistics might be appropriate for for instance *ex post* evaluations of a country's fulfilment of its national waste prevention plan. However, they have limited ability to advice on the utility of different prospective measures to achieve waste prevention due to the limited possibility to disaggregate the data to the extent needed.

The assessment of the waste prevention potential of PSS compares the stock of material artefacts used to produce a certain result for the household tasks by self-servicing and PSS respectively (OECD, 2004). The household tasks subject to assessment are garden maintenance, home improvement, house cleaning and laundry. The stock of material artefacts is equated with the amount of waste generated and calculated using the variables drawn from the literature review as set out in section 3.7.2 and data collected in the survey described in section 3.7.3 as well as secondary data and data reasoned from interviews.

A comparative assessment requires that a fair basis for comparison of the options be established. A comparison of the stocks of material artefacts used to perform the household tasks by way of the options of self-servicing and PSS respectively requires a quantified unit to which to relate the amounts of material artefacts (*cf* Bauman & Tillman, 2004). In environmental assessment of a life cycle-type, equivalence of the function delivered[15] by the product or service under study is used as a basis for comparison. This is called the functional unit (Rebitzer, *et al.* 2004). This was also deemed appropriate for the assessment of the waste prevention potential of result-oriented PSS[16].

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[15] This is sometimes explained as the service performed by products, or the needs fulfilled (e.g. Rebitzer et al. (2004).

[16] Please note that the definition of result-oriented PSS refers to the type of PSS where the service provider owns the material artefact and uses it to produce the results, in contrast to use-oriented PSS where a firm owns the material artefact and the customer uses it to produce the result.

Establishing functional equivalence is known to be a challenge for several reasons (Bauman & Tillman, 2004). Any option for delivering a function (result) has a number of qualitative and quantitative attributes. It is unlikely that the options are equivalent in terms of all different attributes (Bauman & Tillman, 2004). Furthermore, each of the household tasks under study may comprise a range of sub-tasks with a variety of attributes or even sub-functions. For instance, garden maintenance may include lawn-mowing, weeding, pruning and trimming, making use of lawn-mowers, weeders, prunes, shears and trimmers to mention a few. Where a material artefact or service provides several functions, one function needs to be selected as the functional unit (Bauman & Tillman, 2004).

Another challenge is that the specifications of the attributes that form the functional unit need to be practicable for a research assessment. For instance, while it may be technically possible to measure the length of the grass of a newly mowed lawn, or the amount of particles left on a newly vacuum cleaned floor, the measurements of such specifications may not be practicable.

In the case of PSS, a particular challenge with the specification of functional units is whether or not the results achieved by self-servicing households and service providers respectively are actually equivalent. Furthermore, whether or not equivalence of results is enough for households to be satisfied with PSS is an open question. Results presented in chapter 4 indicate that some households may expect better performance of service providers than they do of themselves.

Given the difficulty of measuring the actual results of the self-servicing and PSS respectively, it is not possible to establish whether the results are actually equivalent. Nor would it be possible to establish the extent to which the results achieved by the service providers would actually be better, if better rather than equivalent results were the basis for comparison. Therefore, in this study the results of self-servicing and PSS are assumed to be equivalent either in actual terms or in their ability to fulfil householders' requirements. Further research could address the actual results of different household tasks as well as the detailed wants and perceptions of households concerning service providers' results.

The above means that proxy functional units are needed for the assessment of the waste prevention potential. In order to limit the potential functions and attributes provided within each household task, the household tasks included in the assessment are limited to the following sub-tasks:

- Garden maintenance - lawn-mowing
- Home improvement – tasks requiring the use of drill, such as putting up shelves
- House cleaning – vacuum cleaning
- Laundry – washing clothes and linen

The time that the material artefacts are in use per year to produce for the result for the household tasks was used as a proxy functional unit. This is an input parameter that

assumes the output (result)[17]. It enables the quantification of the stock of material artefacts used. Therefore, this proxy functional unit is relevant to assessment of the utility of this concept for achieving household waste prevention.

Table 9 Functional unit for each household task in the assessment of waste prevention potential

Household task	Functional unit
Garden maintenance	Total time of lawn-mowing for a household during one year
Home improvement	Total time spent using a drill for a household during one year
House cleaning	Total time of vacuum cleaning for a household during one year
Laundry	The total mass of laundry[18] for a household during one year

The functional unit for the household task of laundry is expressed as the amount of material processed by the material artefacts (washing machines) although this is later calculated as number of washing cycles using machines of different capacities (see further 5.2.4). In theory it would be possible to quantify for instance the surface area of the floors or lawns that are 'processed' by the vacuum cleaners and lawn-mowers respectively. However, the layout of the surfaces with furnishings or flowerbeds and shrubs influences the time that the material artefacts have to be in use to deliver the results of clean floors and neat lawns. Therefore, surface areas were not deemed to be adequate and workable proxy functional units for the assessment of the stocks of material artefacts required for self-servicing and PSS respectively.

Rebound effects are excluded from the model due to resource constraints. Rebound effects may occur if any potential waste prevention is off-set by alternative activities and consumption that households may engage in as a consequence of changing spending and time-use patterns following adopting PSS (*cf* Sorrell & Dimitropoulos, 2008). Identifying and understanding any rebound effects arising from the adoption of PSS is an important topic for further research.

[17] Please note that the term 'result-oriented PSS' refers to the type of PSS where the material artefact is owned and used by the service provider to produce the result, in contrast with for instance use-oriented PSS where the household uses the material artefact owned by someone else, to produce the result. The use of an input parameter as a proxy functional unit for this assessment does not change the definition of the term 'result oriented PSS'.

[18] The mass of laundry was calculated from the number of washing cycles of certain capacities. This calculation was necessary to enable the assessment of the stock of washing machines of greater capacities used for the PSS. Thus the functional unit for the household task of laundry is also based on the input of the use of material artefacts.

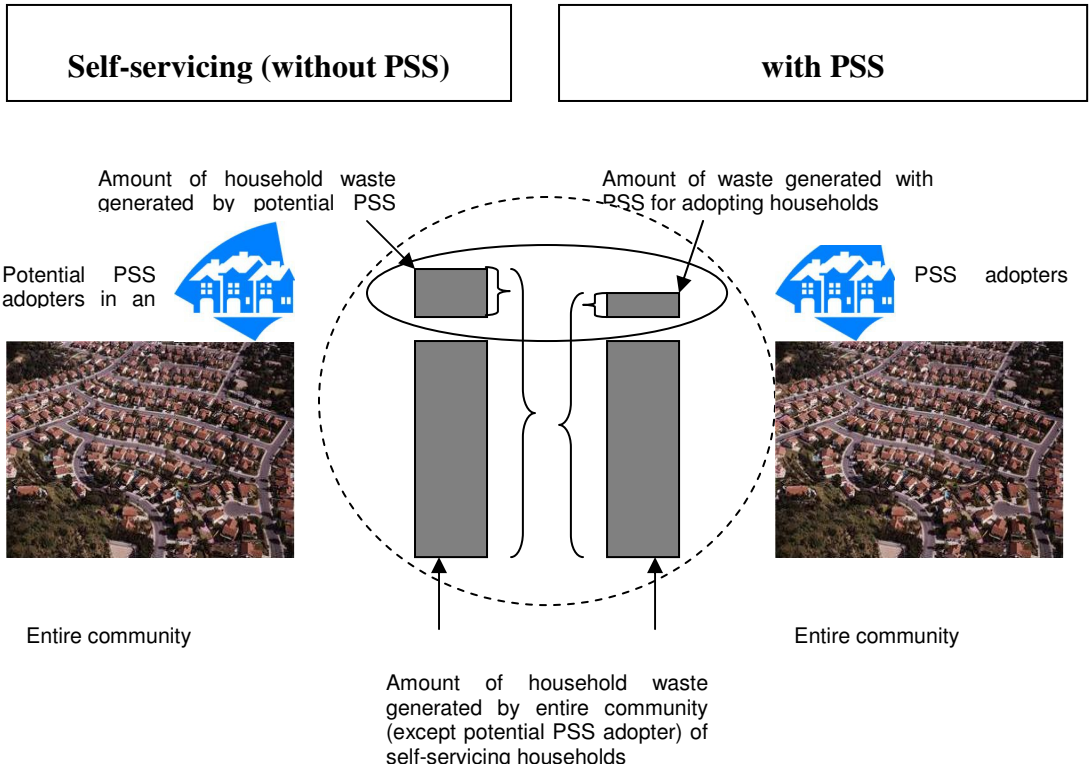

Figure 4 Illustration of waste prevention potentials when different rates of adoption in a community are considered

Geographical scope

The geographical scope concerns the geographical area under study for potential PSS delivery and the related household and service provider behaviour and data on the material artefacts required for the assessment.

Primary data were collected on the behaviour of households and service providers in England. The households were resident in three different regions in England, namely North East, North West and the South of England. Secondary data were collected on the relevant material artefacts typically used in England.

Temporal scope

A period of time needed to be established over which to calculate the stock of material artefacts used by a group of households and service providers respectively to perform the same household activities. A time span of ten years was chosen as it was deemed to be sufficiently long to allow for households to replace their electrical and electronic material artefacts, some of which may have uselives around ten years (Cooper, 2004). Primary and secondary data on certain aspects of household and service provider behaviours such as material artefact replacement, and data on material artefacts such as weight, referred to the current and past situation. It was perceived that households' account of for instance replacement of previous material artefacts would be more accurate than projections of assumed future behaviours.

Technological scope

The specification of the material artefacts chosen by households to perform self-service was identified from primary data. The material artefacts used by service providers were generally held to be domestic-grade in order to fit into the layout of households. For instance, a lawnmower used for large commercial or public lawns would be inappropriate for use in a domestic garden with small grassed areas in between shrubs, flowerbeds, patios *et cetera.* Thus, contrary to the PSS literature, significant difference in the specifications of the material artefacts chosen by households and service providers were not identified. Laundry was an exception to this, where the service provider used a laundrette size washing machine, which was between domestic size and industrial size. However, more research is needed to shed light on these practices.

3.7.2 Model

This section describes the model developed to enable the assessment of the waste prevention potential of PSS. The data collection method used to identify values for the variables is described in section 3.7.3, and the values are presented in section 5.2 and section 5.4.

The model compares the mass of material artefacts used by self-servicing households over the study period with the mass of material artefacts used by service providers to achieve the same result for the household over the study period. It is assumed that the mass of material artefacts used per study period equals the mass of waste generated per study period (see further section 3.7.4 on assumptions and limitations).

The assessment of waste prevention potential considers first the basic case for a single household. The basic case is comprised of the values for the variables collected or reasoned from the primary data collection. The basic case is assessed both in terms of absolute waste prevention (mass of waste prevented) and relative waste prevention (percentage of waste prevented). Absolute waste prevention is likely to be the measure of greatest relevance to waste policy, for instance when considering waste management capacities. Waste prevention in relative terms indicates where the greatest relative improvement potentials are. The PSS literature has mostly been concerned with relative improvements in resource productivity. Therefore, both absolute and relative waste prevention is included in this assessment.

After that, additional scenarios are considered.

- The basic case with alternative values for key variables
    - scenarios for choice and management of material artefacts
        - Mass of material artefacts
        - Uselife of material artefacts
    - Transport distance
    - Service volume
    - mass and uselife of material artefacts and transport distance together
- Community scale with different rates up adoption of PSS
- Community scale with different rates of households keeping ownership of the material artefact to perform intermittent self-servicing

The inclusion of the alternative scenarios indicates the waste prevention potential in contexts other than that of the present research. Likewise, it enables a judgement of the waste prevention potential if PSS adoption and certain behaviours are encouraged.

Table 10 sets out the variables used in the assessment of waste prevention potential. The variables are adapted from the propositions in the literature on choice and management of material artefacts (section 2.4.2.4)

Table 10 Variables in the assessment of potential for waste prevention

Variable name	Unit	Description	Relation to choice and management behaviours
t	years	Study period	-
w_{prev}	kg	Mass of waste prevented	-
$w_{prev\%}$	%	Percent of waste prevented	-
w_s	kg	Mass of waste generated by self-servicing households before adopting PSS	-
w_{sc}	kg	Mass of waste generated by a community of self-servicing households (before any adoption of PSS)	-
m_s	kg	Mass of one material artefact used by households for self-servicing before adopting PSS	Choice of material artefact (the mass for certain specifications of material artefacts)
a_s	number	Number of material artefacts used by households for self-servicing before adopting PSS	(Choice and ownership of material artefacts)
l_s	years	Uselife of material artefact used by households for self-servicing before adoption PSS (chronological uselife until obsolescence)	Use and disposal of material artefact
w_p	kg	Mass of waste generated by service provider (after adoption of PSS)	-
m_p	kg	Mass of one material artefact used by service provider (after adopting PSS)	Choice of material artefact (the mass for certain specification of material artefact)
a_p	number	Number of material artefacts used by service provider (after adopting PSS)	(Choice and ownership of material artefacts)
l_p	h	Uselife of material artefact used by service providers (after adoption of PSS) (operational uselife until obsolescence)	Use and disposal of material artefact
r_p	h	Time the service provider uses the material artefact to produce the *result* (after adoption)	Use (skills and efficiency of service provider)
m_v	kg	Mass of waste arising from the vehicle used by the service provider to deliver the PSS	-
a_v	number	Number of vehicles used by the service provider to deliver the PSS	-
d	km	Transport distance between service centre and housing development	
w_{sp}	kg	Mass of waste generated by households that keep ownership of material artefacts to perform intermittent self-servicing (after	-

		adopting PSS)	
m_{sp}	kg	Mass of material artefacts kept and used by households to perform intermittent self-servicing (after adopting PSS)	Ownership
a_{sp}	number	Number of material artefacts used by households to perform intermittent self-servicing (after adopting PSS)	Ownership
x	%	Percentage of households that have adopted PSS that keep ownership of material artifact for intermittent self-servicing (after adoption)	Ownership
h_{sn}	number	Number of households that do not adopt PSS in a community	-
h_{sc}	number	Number of households in an entire community of self-servicing households before adoption of PSS	-
w_{sn}	kg	Mass of waste generated by households in a community of households, that do not adopt PSS but keep self-servicing as before	-

3.7.2.1 Basic case: absolute waste prevention

Absolute waste prevention is the *mass* of waste prevented over the study period ($w_{prev}t^{-1}$) when an individual household or group of households change from self-servicing to PSS, allowing for any retention of self-servicing in addition to using PSS is

Equation 1 $$w_{prev}\,t^{-1} = w_p\,t^{-1} + w_{sp}\,t^{-1} - w_s\,t^{-1}$$

The total mass of waste generated by service providers w_p is

Equation 2 $$w_p t^{-1} = m_p a_p t^{-t} + m_v a_v t^{-t})$$

where m_p is the mass of the material artefact and the number of material artefacts a_p used to serve the group of households during the time period under study (eq x). a_v is the number of vehicles used to deliver the PSS to the group of households under the time period under study.

The number of material artefacts a_p used by the service provider is

Equation 3 $$a_p t^{-1} = r_p t^{-1} l_p^{-1}$$

Where r_p is the result[19] produced by the service provider, t is the study period, and l_p the uselife of the service provider's material artefact.

[19] As discussed in section 3.7.1 the amount of time used to produce the result is used as a proxy measure for the result in this study.

The total number of vehicles $a_v t^{-1}$ used is

Equation 4 $$a_v t^{-1} = dt^{-1} l_v^{-1}$$

Where d is the total transport distance, t is the period of study and l_v is the uselife of the vehicle.

The total mass of waste generated by households performing self-servicing intermittently in addition to using PSS, w_{sp} is

Equation 5 $$w_{sp} t^{-1} = m_{sp} a_{sp} t^{-1} l^{-1}$$

Where t is the period of time under study in year, m_{sp} is the mass of the material artefact that the household uses for the intermittent self-servicing whilst using PSS, a_{sp} is the number of material artefacts and l_{sp} is the uselife of the material artefact used for intermittent self-servicing. It is assumed that this material artefact used for intermittent self-servicing may be of a different specification and different uselife to the material artefact used for self-servicing when PSS is not used. This assumption is further explored in chapter 4.

The total waste generated by a self-servicing household ($w_{s)}$ over the study period (t) to produce the result (r) over the study period (t) is

Equation 6 $$w_s t^{-1} = m_s a_s l_s^{-1} t^{-1}$$

Where m_s is the mass of the material artefact used by the self-servicing household and a_s is the number of material artefacts, l_s is the uselife of the material artefacts and t is the study period.

3.7.2.2 Basic case – relative waste prevention

Relative waste prevention refers to a percentage change in waste generation comparing the mass of waste prevented with the mass of waste generated in the reference case. The relative waste prevention where the baseline is the group of potential PSS adopters is

Equation 7 $$w_{prev\%} \frac{w_{prev} t^{-1}}{w_s t^{-t}} * 100$$

3.7.2.3 Scenarios – different variable values for the basic case

The first set of alternative scenarios involves higher and lower weights of material artefacts for self-servicing households and service providers respectively than the values from the primary data collection. One scenario considers the possibility that households use material artefacts of lower weights and service providers use material artefacts of higher weights. This results in a smaller waste prevention potential than in the basic case with primary data, *ceteris paribus*. The other scenario considers the inverse of the

first scenario. The last scenario combines lower and higher weights of material artefacts with shorter and longer uselives for the material artefacts.

The second set of scenarios involves shorter and longer uselives of material artefacts for self-servicing households and service providers respectively than the values from the primary data collection. One scenario considers the possibility that households use material artefacts for longer, while service providers use material artefacts for a shorter period of time. This results in a smaller waste prevention potential than in the basic case with primary data, *ceteris paribus*. The other scenario considers the inverse of the first scenario.

3.7.2.4 Scenarios: communities of adopters – different rates of adoption

The literature review in chapter 2 and the research on households' and service providers' attitudes to adoption of PSS presented in chapter 4, indicated a limited willingness to adopt PSS. In order to assess the utility of PSS to achieve waste prevention, the assessment of waste prevention potential is scaled up to a community level where different shares of households adopt PSS. This is a simple linear scaling, assuming no threshold effects or other changes in the choice and management of material artefacts on the parts of households and service providers respectively.

The waste prevention w_{prev} in absolute terms for a community of households where only a share of the households adopt PSS is

Equation 8 $$w_{prev}t^{-1} = w_p t^{-1} + w_{sn}t^{-1} - w_{sc}t^{-1}$$

Where w_p is the waste generated by the service providers who perform PSS for the share of households in the community that adopt PSS, w_{sn} is the waste generated by share of households in the community that do not adopt PSS and w_{cs} is the waste generated by the community of self-servicing households before any adoption of PSS, and and t is the study period.

The total amount of waste generated by the service providers w_p for the households adopting PSS is

Equation 9 $$w_p t^{-1} = m_p a_p t^{-1} + m_v a_v t^{-1}$$

where m_p is the mass of the material artefacts used by the service provider, a_p is the number of material artefacts used by the service provider and t is the study period, m_v is the mass of the vehicle used by the service provider to deliver the PSS, a_v is the number of vehicles used and t is the study period.

The number of material artefacts a_p is

Equation 10 $$a_p t^{-1} = u_p t^{-1} l_p^{-1} h$$

Where u_p is the time the service provider uses the material artefact to produce the result, t is the study period, l_p is the uselife of the service provider's material artefact and h is the number of households.

The number of vehicles a_v is

Equation 11 $$a_v t^{-1} = dt^{-1} l_v^{-1}$$

Where d is the total transport distance t is the period of study and l_v is the uselife of the vehicle.

The total amount of waste generated by the share of households in a community that do not adopt PSS but adhere to self-servicing only is

Equation 12 $$w_{sn} t^{-1} = m_s a_s t^{-1} l_s^{-1} h_{sn}$$

The total amount of waste generated by a community of self-servicing households w_{sc} is

Equation 13 $$w_{sc} t^{-1} = m_s a_s t^{-1} l_s^{-1} h_{sc}$$

Where m_s is the mean mass of the material artefacts used by the self-servicing households, a_s is the number of material artefacts used by the self-servicing households, t is the study period, l_s and h is the number of households in the community.

The relative waste prevention $w_{prev\%}$ is

Equation 14 $$w_{prev\%} = \frac{w_{prev}}{w_{cs}} * 100$$

3.7.2.5 Scenarios: communities of adopters – different rates of ownership of material artefacts to perform intermittent self-servicing after adopting PSS

The previous section on different rates of adoption in a community of households assumed that the households that adopted PSS did keep ownership of the material artefact to perform intermittent self-servicing. However, the qualitative study reported in chapter four suggested some households would keep the material artefact and perform intermittent self-servicing. Therefore alternative scenarios are included that include this. In this scenario absolute waste prevention w_{prev} is

Equation 15 $$w_{prev} t^{-1} = w_{cs} t^{-1} - w_p t^{-1} + w_{sp} t^{-1} + w_{sn} t^{-1}$$

Where w_{cs} is the waste generated by the community of self-servicing household before any adoption of PSS, w_p is the waste generated by the service providers delivering PSS to the households in the community that adopt PSS, w_{sp} is the the waste generated by the share of households that have adopted PSS that keep ownership of the material artefact to perform intermittent self-servicing, and w_{sn} is the waste generated by the

households in the community that do not adopt PSS and therefore keep performing self-servicing as before.

The waste generated by self-servicing households that keep ownership of a material artefact to perform intermittent self-servicing w_{sp} is

Equation 16 $$w_{sp}t^{-1} = m_{sp}a_{sp}xht^{-1}l_{sp}^{-1}$$

Where m_{sp} is the mass of the material artefacts used by households that keep a material artefact to perform intermittent self-servicing while using PSS, a_{sp} is the number of these material artefacts, x is the share of the households adopting PSS that keep a material artefact and perform self-servicing intermittently, h is the number of households that adopt PSS, t is the study period and l_{sp} is the uselife of the material artefact.

The relative waste prevention $w_{prev\%}$ is

Equation 17 $$w_{prev\%} = \frac{w_{prev}}{w_{cs}} * 10$$

3.7.3 Data collection and analysis

In order to assess the waste prevention potential of PSS and answer the research questions pertaining to objective 2, numeric data were needed for the variables presented in the previous section (see section 3.7.2).

A questionnaire comprising some 20-25 questions per household task was developed to collect the data for the variables on households behaviours (self-reported behaviours rather than observed behaviours, and thereby hypothetical). In addition, secondary data, for instance on material artefact specifications such as weights and uselives, were collected from consumer and manufacturer websites in order to help specify questionnaire response options. An example of questionnaire is provided in appendix C. The questions referred to previous self-servicing behaviours as a proxy for future self-servicing behaviours.

In some instances, the questionnaire was used in telephone interviews. Primary data were recorded both in the questionnaire and via audio recording (with permission of the respondents), where feasible and appropriate. In the focus groups, the participants filled in the questionnaires while the researcher was present to answer supplementary questions as necessary. Many participants provided qualitative information alongside predetermined options.

The data from the questionnaires were entered into a spreadsheet and mean values calculated for the variables. These are presented in section 5.2.

3.7.4 Assumptions and limitations

The present research is based on a comprehensive literature review as well as primary research. To the extent possible with the resources at hand, primary research sought to

cover the data needs. Inevitably however, the model and data used within it rests on a number of simplifying assumptions, leading to certain limitations that the reader should bear in mind when considering the findings.

An overarching assumption concerned the data used on behaviours. Primary data originated from participants' expressed preferences and self-reports of events that had occurred in the past and were embedded in other related activities. This may lead to the reported behaviours on for instance frequency and duration of the use of material artefacts and replacement rates diverging from actual practice. In addition, behaviours in the future concerning households' and service providers' preferences for certain models of material artefacts may change as may technology. In order to assess the influence of such changes on the potential for waste prevention, scenarios are developed and assessed as described in section 5.4. Future research could model an even greater variety of possible technologies and behaviours. Future research could also explore tendencies for future behaviours and technology changes.

Some of the assumptions on household and service provider behaviours proposed by the literature were tested qualitatively in this research, whereas other assumptions remained untried and formed the basis for input data for the variables in the waste prevention model. Service provider behaviour in particular was based on assumptions.

Table 11 Assumptions on input data on ownership, choice and management of material artefacts, and the implications for the results of these assumptions

Assumption	Potential variation	Implication for results
It was assumed that service providers provide requisite material artefacts for PSS delivery. It was also assumed that service providers keep their material artefact until they reach absolute obsolescence.	Some providers of household services in local service markets in the UK use material artefacts owned by the households to perform the task. (However, the property development firm managing the PSS delivery might require their contracted service providers to own the material artefacts)	If the second of the assumption holds true, then the first assumption that service providers own the material artefacts mean that the waste prevention potential is greater than if the variation occurs that service providers use households' material artefacts. If the variation occurs that households' material artefacts are used by service provider, then PSS is likely to have no effect on amounts of household waste generated.
It was assumed that households own only one unit of each type of material artefact.	According to the literature (chapter 2) and primary data, households may own more than one unit of the material artefact.	If households own more than one unit of a type of material artefact it may affect the total amount of household waste generated by the self-servicing. If households owning more than one unit of material artefacts give up one unit, it may still lead to the same amount of waste being prevented by PSS. If households give up all units it might lead to greater waste prevention potential.
It was assumed that service providers choose material artefacts either towards the higher end of the consumer market or sometimes professional grade material artefacts. It was further assumed that this is reflected in somewhat heavier material artefacts than those used by households.	Professional-grade material artefacts may not be heavier than consumer-grade ones.	If the variation is true that professional grade material artefacts are used and this are lighter or no heavier than consumer-grade ones, then the results underestimate the waste prevention potential of PSS. Prospective cases cover the possibility that service providers use relatively lighter material artefacts while households use relatively heavier material artefacts.
Service providers were assumed to be more efficient at using the material artefacts to produce the unit of service delivered. This was assumed to be reflected in PSS taking somewhat shorter time to achieve the same result than for self-servicing households.	Service-providers may take as long as householders to achieve the same results.	If the possible variation is true rather than the assumption, then the results overestimate the potential for waste prevention.
Service providers were assumed to use their material artefacts to full capacity, that is, no spare material artefacts to accommodate peak demand were	Service providers may maintain a degree of over capacity to cover for peak periods and ensure security of operations.	If the possible variation is true rather than the assumption, then the results somewhat overestimate the potential for waste prevention. Effects of shorter and longer uselives

included in the assessment. Furthermore, it was assumed that service providers' material artefacts were used until they reach absolute obsolesence.		were assessed in the prospective cases.
The effects of maintenance of material artefacts were assumed to be reflected in the uselife reported by the respondents. Resource use and emissions from maintenance were not included in the study. The service providers often did not record their maintenance activities and so were not able to provide information on this. Households reported on repairs of material artefacts. They differed greatly in the extent to which they had their material artefacts repaired.	Some spare parts may be used in the maintenance of material artefacts, both by households and service providers.	Any spares used for maintenance and repair are deemed to have little effect on the overall waste prevention potential.
All material artefacts used by the households in the study become waste after one use cycle in that household, and are not purchased second-hand, or sold or given away when obsolescent.		

Additional assumptions concern the scope of the systems that were modelled (

Table 12).

Table 12 Assumption concerning the systems modelled, potential variation and implications for the results of these assumptions

Assumption	Possible variation	Implication for results
It was assumed that the result delivered by self-servicing and PSS would be the equivalent (see section 3.7.1).	Households may require better results of service providers than of themselves in order to adopt PSS (see further 4.2.1).	If the variation is true rather than the assumption, the results are likely to overestimate the waste prevention potential. This is a type of rebound effect where increased consumption off-sets reductions in resource use.
		The scale of the importance of additional material artefacts is unknown. For house cleaning, additional material artefacts are deemed to make up small proportion of material compared with the vaccum cleaner. For the other household tasks, the effect will depend greatly on the types of material artefacts used, and the choice and management of these artefacts of households and service providers respectively.

- Waste arising from other material artefacts than the main electrical ones used to perform the household tasks of garden maintenance, home improvement, house cleaning and laundry, were excluded for reasons explained in section 3.7.1. Neither was waste from auxiliary material artefacts, other than the vehicles, required by the PSS.

- Rebound effects and other second order effects were excluded since it was not possible within the constraints of this project to establish typical activities or consumption that households take up or give up for reasons of time or finances when switching from self-servicing to using PSS.

3.8 ENVIRONMENTAL ASSESSMENT

This section sets out the method used in pursuit of objective 3 namely to identify the environmental performance of selected household PSS. This objective is important in order to avoid that waste prevention is achieved at the expense of other environmental impact categories.

3.8.1 Types of assessment method

This section describes the type of environmental assessment undertaken to meet objective 3. The choice of method depends on the phenomenon under study and impacts of interest (Finnveden & Moberg, 2005). According to their diagram overview of environmental assessment methods (*ibid,* p. 1169), life cycle assessment is the relevant method where both environmental and natural resource impacts are concerned, emanating from products and services. This is consistent with approaches used in environmental assessments of (some) other studies of eco-efficient services and product service systems (please see chapter 2). Therefore, a life cycle approach was selected for the present study. Where trade-offs between environmental impact categories are of concern, methods concentrating solely on material inputs are of limited utility. The environmental assessment in this study is a complement to the waste prevention assessment to explore any trade-offs between waste prevention and other environmental resource use and emissions, and between different species of emissions.

3.8.1.1 About life cycle assessment (LCA)

Life cycle assessment is a technique for assessing the potential resources used and potential environmental impacts of a material artefact or service (or rather a function it provides) throughout its life cycle (Bauman & Tillman, 2004; Rebitzer, *et al.* 2004; Finnveden, *et al*. 2009). The product/service life cycle covers extraction of raw materials, production of materials and parts, assembly of material artefacts through to the distribution, use of material artefacts, and finally the disposal and waste management of material artefacts. A benefit of this method is that it helps to ensure that a measure to alleviate and environmental problem arising from one life cycle leads to overall improvement rather than merely being shifted to another life cycle stage, or at least it highlights environmental trade-offs (Finnveden, *et al.* 2009).

LCAs comprise a goal and scope definition, setting out the purpose of the LCA and the appropriate functional unit and system boundaries for the purpose (Finnveden et al. 2009). In the life cycle inventory (LCI), the resource and environmental flows associated with the product system are modelled and traced back to resources that have not previously been transformed by human beings, also called 'elementary flows' (Finnveden, *et al.* 2009).

In the life cycle impact assessment, the flows modelled in the LCI are related to environmental impacts (classes of environmental problems). The impacts are divided into a number of categories pertaining to human health, the natural environment and natural resources (Finnveden, *et al.* 2009). The actual impact depends on the conditions where the effect occurs, whereas LCAs are site-generic (Finnveden, *et al*. 2009).

Therefore, the impact categories are expressed as potentials rather than actual impacts. Examples of impact categories associated with emissions of air pollutants are global warming potential, acidification potential, and stratospheric ozone depletion. Examples of impact categories associated with releases to water are eutrophication potential and heavy metals. Results from the LCI are assigned to the impact categories, by way of the selected impact assessment method, and then multiplied by a characterisation factors (Carlson, *et al*. 2003). The results for different impact categories may be weighted to show the relative importance attached to those categories. The weights depend on social and political values attached to different types of impacts for a specific issue in a particular context. Therefore, methods to derive weighting factors are based in the social sciences, involving for instance stakeholder engagement or policy decisions and targets (Bauman & Tillman 2004).

The goal and scope definition, life cycle inventories and life cycle impact assessment are all subject to interpretation to identify, qualify and evaluate the choices and outcomes of these stages respectively (Carlson, *et al*. 2003). Like any other method, LCA is subject to judgement and choices made by the researchers (Hertwich, *et al*. 2000).

Many authors distinguish between attributional and change-oriented LCA, sometimes termed for instance descriptive and change-oriented LCA respectively (Ekvall, *et a*l. 2005; Finnveden, *et al.* 2009). An attributional approach records the environmental impacts that may be attributed to the product or service under study without consideration of second-order changes and consequences. Second order consequences are the effects resulting from changes in economy arising from the first order effects (Sandén & Karlström 2007). For instance, if households adopt PSS for garden maintenance and this leads to more petrol-powered lawnmowers being used instead of electric lawnmowers, first-order changes involve the resource use and emissions from the production of metals rather than plastics since petrol powered lawnmowers are composed of more metals than electric lawnmowers which are made up of mainly plastics. If these changes in the demand for plastics and metals respectively influence the prices and therefore supply and demand of other goods, then those changes in supply and demand, and associated emissions, are second-order changes.

3.8.1.2 Simplified life cycle approaches

An LCA is "an approximation of a vast and complex reality (Meijkamp, 2000, p.183). LCAs require large amounts of data and are therefore time consuming and expensive. Difficulties with data collection are exemplified by Thomas *et al*. (2005). For these reasons, practically all LCAs are to some extent simplified representations of the systems under study (Hochschorner, 2002). The choice is therefore not whether or not to simplify, but rather the ways and extent of simplification. Ways of simplifying life cycle assessments include removing upstream and/or downstream components partly or wholly; using specific entries to represent impacts, using specific entries to represent LCI, using 'show stoppers' or 'knock out' criteria, using qualitative or less accurate data, suing surrogate (proxy) data, limiting raw materials (Hochschorner, 2002).

Since the simplifications affect the results, the choices of simplifications need to be closely aligned with the goal and scope definitions of the study (Todd & Curran, 1999).

A simplification made here is that a part of the foreground system is modelled, and parts of it are excluded from the assessment. The foreground system is the part of the system that is central to a potential decision that the assessment seeks to inform (Bauman & Tillman, 2004). This assessment seeks to inform the decision mainly affecting the use-phase, namely whether to change from households owning using material artefacts to perform household tasks to service providers owning and using material artefacts to perform those tasks. Therefore the use-phase is the foreground system. As explained in section 3.7.1 only the main task using the electrical material artefact was included while other sub-tasks involving additional material artefacts were excluded. In the PSS the vehicle used by the service provider to get to the households is included whereas other potential material artefacts required to deliver the PSS are excluded. The parts of the foreground system that were excluded are within the dashed box of the use-phase in Figure 5.

The background systems are those parts of the system affected by changes in the foreground system (Bauman & Tillman, 2004). Only first-order changes in the background system are included. That means that the assessment takes an attributional approach rather than a consequential approach, due to resource constraints.

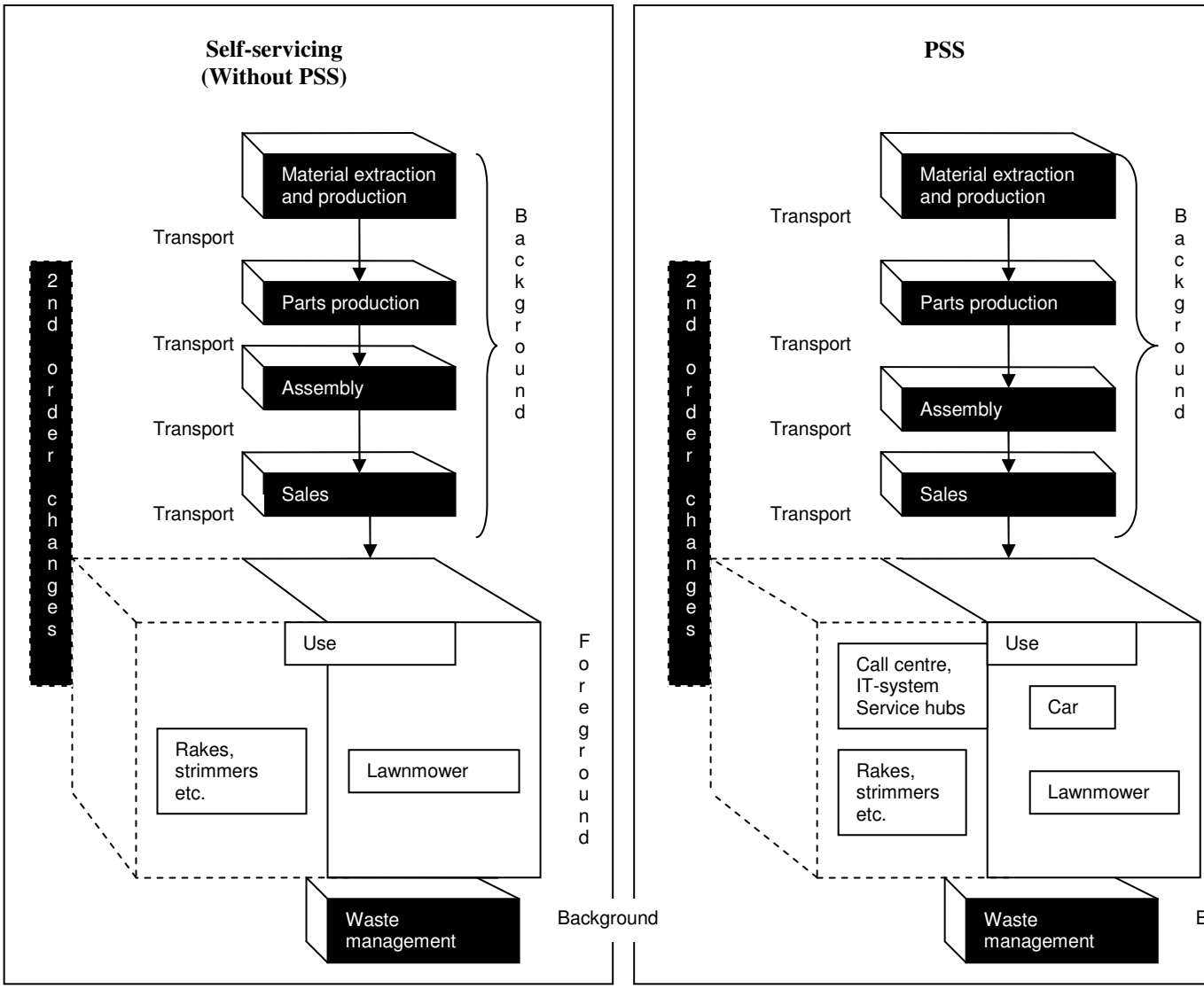

Figure 5 Illustration of self-servicing and product service systems respectively, and the foreground and background systems

A further simplification was the application of indicators for resource use and emissions to the materials in the material artefacts in this study which meant that no life cycle inventory needed to be collected in this study (see further 3.8.1.3). Thus manufacturing, production, assembly and waste management life cycle stages are accounted for. However, while the method behind the indicators is relatively well documented, it is not clear whether any unit processes or parts of unit processes of those life cycles were removed as a simplification in the development of those indicators.

Another simplification is that in a couple of instances proxy data or estimations were used for some input variables. A further simplification here was that a small percentage of the materials in the material artefacts were excluded from the assessment since the indicators of resource use and emissions did not comprise indicators for those materials (see section 3.8.1.4 below for further information on the indicators used). The

simplified life cycle approach by way of the life cycle indicators used is further elaborated below.

3.8.1.3 Indicators of resource use and emissions – a simplified life cycle approach

In this environmental assessment, indicators for resource use and emissions are used that relate to the mass of materials in the material artefacts and other processes over the life cycles of electrical and electronic equipment. The development of these indicators was commissioned by the EU and carried out by Kemna, *et al.* (2005) in support of eco-design of energy-using products. The LCI and LCIA stages are packaged to assist more wide spread use of environmental assessments using life cycle approaches.

These environmental indicators available in the public domain were deemed suitable since they were applicable to types of material artefacts in the present project, could be applied to the mass of material artefacts, energy use of the material artefacts, transport for service provision. They also provided approximate quantitative measures of the environmental potential of self-service and PSS, from raw materials extraction to disposal. The use of these indicators allowed for a reasonably comprehensive life cycle approach to environmental assessment of PSS (see chapter 2), with relatively limited resource expenditure on the assessment. Since a comprehensive method description for these indicators is also available in the public domain, it is a reasonably transparent method. The remaining of this section gives a brief summary of the method used by (Kemna, *et al.* 2005) to develop the indicators.

The 'indicators represent a simplified life cycle approach to environmental assessment. The main materials and processes involved with the life cycle of the relevant domestic energy-using products (EuP) were identified (Kemna, *et al.* 2005). Examples of materials are different metals of different grades and different plastics. Examples of other processes were final assembly and distribution. The processes and indicators used in this assessment are set out in appendix D. For each of the materials and processes, (Kemna, *et al.* 2005) retrieved life cycle inventories from a range of databases. These types of databases are typically used when LCAs are conducted. In retrieving LCIs from different databases, Kemna, *et al.* (2005) verified the consistency of the different sources. The European Commission, which commissioned the indicators, specified groups of emissions that the indicators should include in order to be relevant for the environmental policy objectives for energy using products. These groups of emissions were: climate gases expressed as global warming potential (GWP), acidifying emissions expressed as acidification potential (AP), eutrophication emissions expressed as eutrophication potential (EP) indicating ecological consequences (*cf* Baumann & Tillman, 2004). In addition, a number of emissions are included that may have both human and ecotoxicological effects, although they are not divided on that basis. These emissions are: volatile organic compounds (VOC), persistent organic pollutants (POP), polycyclic aromatic hydrocarbons (PAH[20]), heavy metals to air and water respectively,

[20] PAH may be classified either as a POP or heavy metal. VHK (2005) presented it as a separate indicator.

and particulate matter. In addition, gross energy use, water, waste categories reflected resource use.

Kemna *et al.* (2005) attributed the items of resource use and emissions in the inventories to the different groups of emissions. The extent of the contribution of the different inventory items to the groups of emissions or potential impacts were established by Kemna *et al.* (2005) using equivalence factors derived from legislation and regulatory guidelines. They also produced indicators for each group of resource or emission and for each key process in the life cycle of domestic energy using products. Table 13 shows an example of those indicators for the extraction and material production of the plastic ABS (Acrylonitrile butadiene styrene).

Table 13 Example of indicators of resource use and emissions associated with raw materials extraction and production of the plastic ABS and aluminium sheet respectively

Materials/ subprocesses Plastics per kg	Primary energy MJ	Waste Haz g	waste Non haz g	(Air) GWP kg	(Air) AP g	(Air) VOC g	(Air) PAH mg	Water (EP) mg
ABS	95	10	92	3,32	18	0	2	630
Aluminium sheet	193	No data available	360	10.35	67	0.07	97	5
Cast iron	10		315	1.06	3	0.12	No data available	26

For a table of the indicators used in this assessment, please see appendix D.

3.8.1.4 Application of indicators for environmental assessment

In order to calculate the environmental impacts of self-servicing and PSS respectively, the variables in Table 14 were used.

Table 14 Variables used in the environmental assessment

Variables	Unit	Meaning
$_k$	-	Categories of environmental burdens
i	-	Unit process, e.g. materials production or assembly
e_k	Various: MJ, g, kg, mg	Environmental burden of category k
e_{ik}	Various: MJ, g, kg, mg	Environmental burden of category k for a particular unit process i
u_i	Various: kg, n.o., MWh	Quantity of unit process i
$e_{k,p}$	Various: MJ, g, kg, mg	Environmental burden of category k for PSS p
$e_{k,s}$	Various: MJ, g, kg, mg	Environmental burden of category k for self-servicing s
E	%	Percentage saving or increase in environmental burden of the environmental impact category

The environmental assessment computes the total environmental burdens of self-servicing.

Equation 18 $$e_{k,s} = u_i \sum_i e_{ik}$$

Where $e_{k,s}$ is the environmental burden of category k for self-servicing, where u_i is the quantity of each unit process and e_{ik} is the indicator of environmental burden, that is, the environmental burden of category k for process i.

The environmental assessment computes the total environmental burdens of PSS as

Equation 19 $$e_{k,p} = u_i \sum_i e_{ik}$$

Where $e_{k,p}$ is the environmental burden of category k for PSS, u_i is the quantity of each unit process and e_{ik} is the indicator of environmental burden, that is, the environmental burden of category k for process i.

The quantity of each unit process was determined by the stock of material artefacts used for self-servicing and PSS respectively (in terms of mass) as calculated in the waste prevention assessment, and the material composition of the material artefacts. It was also determined by the number of material artefacts, and energy and fuel use during the use-phase, and the shares of each material deemed to be recycled, landfilled or go to energy recovery.

The percentage reduction (or increase) in the total environmental burden E for PSS ($e_{k,p}$) compared with the total environmental burden of self-servicing ($e_{k,s}$) was calculated as

Equation 20 $$E = 1 - \left(\frac{e_{k,p}}{e_{k,s}} \right)$$

The results for different types of emissions are not weighted in this exploratory research.

3.8.2 Data collection

In order to assess the potential resource use and emissions arising from PSS compared with self-servicing over the life cycle, numeric data on waste from the assessment of waste prevention potential were needed. In addition, secondary numeric data were needed on for instance material compositions of material artefacts, packaged volumes and energy use of material artefacts. Secondary numeric data were also needed on the resource use and emissions arising from different processes across the life cycle of the self-servicing and PSS respectively.

3.8.3 Assumptions and limitations

Many of the assumptions used in the assessment of waste prevention potential (see section 0 also affect to the environmental assessment since the outcome of the waste prevention assessment was used as input into the environmental assessment. In the environmental assessment, additional assumptions and limitations were made.

Where data on for instance material composition and material artefact uselife were not available, these were extrapolated from existing sources on similar material artefacts The documentation of the method and data sources used by Kemna *et al.* (2005) to develop the indicators, was comprehensive.

Unit processes were aggregated into materials or life cycle stages, or sub-groupings under life cycle stages. Therefore, the completeness of the environmental flows included in those materials or life cycle stages cannot be established. The indicators were however reviewed by international experts in the EU project within which they were developed. In addition, some properties of the indicators are stated in the methodology report.

3.9 TRUSTWORTHINESS, GENERALISATION AND RESEARCH ETHICS

This section reflects on the extent to which the results may be trusted and the extent to which the results may be generalised to context outside the one under study.

3.9.1 Trustworthiness

Trustworthiness of research is to do with whether the research is accurate, true and unbiased. Some disciplines (or rather research perspectives underlying disciplines) are also concerned with the ability of other researchers to arrive at the same results carrying out the same procedures at a different time. However, for the same reason that experiments were considered virtually impossible due to the prevailing open conditions in the social world, the possibility of this type of replicability is also refuted. This section focuses on validity and bias.

According to Maxwell (2002) validity in flexible research design strategies relates to:

- The factual accuracy of the description of what the researcher heard or saw (descriptive validity)
- The truthfulness to the meaning of an account intended by the respondent (interpretative validity)
- The accuracy of the concepts and relations among the concepts for understanding the phenomena under study (theoretical validity)

In accordance with Robson (2002), the majority of the focus groups and interviews were audio recorded (after obtaining consent from the respondents) in order to ensure descriptive validity. Many were also transcribed and for the rest summaries were made of the notes taken during the interviews or focus groups. Notes were also collected from other researchers attending the one focus group that was not audio recorded.

Interpretation of respondents' accounts is inevitably constructed by the researcher (Maxwell, 2002). Nevertheless, the author sought to strike a balance between the language used by the respondents and the theoretical abstraction in the reporting of the findings. Possible alternative interpretations of some accounts were also reported to ensure interpretative validity.

In line with Robson (2002) the author drew on a number of theories rather than a single one, to ensure theoretical validity. The author also remained open to the data while considering theoretical categories. In some instances this led to new categories, or relations between categories.

To guard against researcher bias, additional researchers were present at the focus groups and were able to interject questions to follow up on participants' remarks. In this way, the findings were not trapped in any preconceived ideas of one researcher. Findings were also discussed with colleagues throughout the study. The waste prevention assessment method was also sent to a group of experts for review.

3.9.2 Generalisation

Generalisation is concerned with relating the specific to the general in order to judge what may be or what could be (Kvale, 1996). There are different views on generalisation. One is concerned with the empirical regularity in larger populations based on a smaller number of empirical observations. This view is associated with fixed research designs and positivist research perspective. Theoretical generalisation is another form of generalisation, which is concerned with the ability of the theoretical insights of the research to be transferred to other contexts. Theoretical generalisation places the onus on the reader to judge whether or not their context is comparable with that of the original study (Sim, 1998). Sim (1998) points out that even cases deviating from empirical regularity, may be of importance for theoretical generalisation. Atypical cases may still inform decision-makers of what may be or what could be.

The dimensions of service quality used to explore attitudes toward adoption of PSS came from well-tried service management research in combination with previous research on PSS. Therefore, these dimensions may be theoretically transferred to contexts beyond the present study. However, caution should be observed in the generalisation of perceptions of the relative performance of different PSS against those criteria to other context. The importance of cost and price, flexibility and so on may be context dependent. As regards the behaviours of household and service providers some findings contradicted propositions in the literature. These findings may offer useful insights for theoretical generalisation.

The fixed elements of this research (the survey feeding into the waste prevention assessment as a part of objective 2, and the environmental assessment (objective 3) were all bounded in the case context of the research and purposive sampling was used in line with the selected research design strategy. Since random sampling was not utilised, the quantitative data may not be generalised in a statistical sense. Nevertheless, the assessment of scenarios, the resulting range of waste prevention potential and environmental performance allow theoretical generalisation beyond the specific context. Furthermore, the principles behind the waste prevention potential extend beyond the specific context. The principles behind the occurrence of the environmental trade-offs evident from the findings of the environmental assessment also extend beyond the context under study. How they play out in practice in other cases depend on changes in the systems in specific cases.

3.9.3 Research ethics

To ensure the research was carried out in line with good research ethics, the principle of informed consent was adhered to. Participants were informed of the aim of the research, use of the results and anonymisation of participants in publications. Consent forms were completed by participants to confirm they consented to participation.

3.10 CHAPTER SUMMARY

This chapter selected research design strategies, methods for data collection and analysis, method for the waste prevention and environmental assessments respectively.

An exploratory mixed method approach was selected, using both fixed and flexible research design strategies. Focus groups and semi-structured interviews were used to meet objective 1. Forward-looking, comparative, micro-level approaches were used for the waste prevention and environmental assessments. The environmental assessment also used a simplified life cycle approach by way of environmental indicators for environmental impact categories for different unit processes for electrical and electronic equipment. The subsequent chapters present the findings resulting from the application of these methods.

4 ATTTUDES TOWARDS ADOPTION OF PSS AND CHOICE AND MANAGEMENT OF MATERIAL ARTEFACTS - RESULTS

4.1 INTRODUCTION

This is the first of three chapters in which the results are presented and discussed. This chapter specifically addresses objective 1 of the research: to identify attitudes towards PSS adoption and behaviours concerning choice and management of material artefacts which influence the waste prevention potential and wider environmental performance of PSS. It also provides answers to the following research questions which were generated in chapter 2 to meet this objective:

1. *What attitudes do households and service providers hold towards adopting the experimental PSS for household tasks?*

2. *How do households and service providers conceive of the different factors influencing PSS adoption?*

3. *How do households and service providers respectively reason and behave concerning their choice, ownership and management (use, maintenance, replacement and disposal) of material artefacts?*

4. *How do these behaviours compare with the behaviours proposed by the literature review?*

The first part of the chapter reports the expressed attitudes (see section 3.6) of households and the property management firm and its supply chain towards adopting PSS or maintaining self-servicing and business as usual. Adoption of PSS was identified as a key debate in the literature reviewed (please see chapter 2.4.4). Adoption is a prerequisite for any potential benefits of PSS to arise. While the literature suggested a trend towards increased service production and consumption in western economies, it also suggested adoption of PSS presented a key challenge (*e.g*. Tukker & Tischner, 2006). First, results are structured according to the factors identified in the literature as drivers and barriers to adoption of PSS and services more generally to inform decision-makers on the need to address particular factors to stimulate PSS adoption[21]. Then the relative willingness to adopt PSS for different household tasks is discussed. In chapter 5 and 6 this will be related to the potential for waste prevention and changes in emissions for the different household tasks. If the willingness to adopt PSS for household tasks with limited or even negative waste prevention potential is greater than household tasks with higher potential, this affects the overall potential of PSS to achieve household waste prevention. This may inform decision-makers whether to focus on PSS for some household tasks only, to or indeed whether to pursue PSS at all.

[21] If the results in chapter 5 and 6 suggest that there is sufficient waste prevention and environmental potential to merit stimulation of adoption of PSS.

The second part of the chapter reports on households' and PSS providers' choice and management of material artefacts. The literature suggested that PSS would stimulate a number of behaviours that were thought to lead to reduced resource use for the same amount of, or increased business and customer value (see section 2.4.2.) The behaviours proposed by the literature were however to great extent based on assumptions. Theoretical literatures also suggested alternative behaviours to those in the PSS literature. The results of this research provide a qualitative testing of those propositions and enable a critique of the PSS concept (section 0). The findings also allow for a richer understanding of the behaviours represented by numeric values in the scenarios in chapter 5, in line with the mixed-methods rationale presented in chapter 3.2.

The literature review also identified a number of propositions concerning actor behaviours associated with the choice and management of material artefacts, (choice of material artefacts of certain specifications, use patterns and skills at using the material artefact, maintenance, replacement behaviours and reasons for obsolescence) both on the part of self-servicing actors, and PSS providers. Indeed, the waste prevention and environmental potential of PSS are premised on particular behaviours that PSS were thought to stimulate. PSS providers were thought to be economically rational actors seeking to maximise profit, and this was thought to be done through the choice and management of material artefacts (largely without other business considerations). Self-servicing actors were thought not to respond to economic incentives related to the ownership of material artefacts, for instance to choose the wrong specification for the task, and to replace material artefacts due to psychological obsolescence rather than absolute obsolescence. These behaviours proposed by the literature were however, to a great extent based on assumptions rather than empirical research.

Focus groups and semi-structured individual interviews were completed with householders and supply side representatives to explore the propositions from the literature review in relation to adoption of the PSS and the choice and management of material artefacts.

Below is a summary of key findings from this chapter:

- Both households and the property development firm and its supply chain expressed limited willingness to adopting PSS. The property development firm was somewhat more open to the idea than their external supply chain was.

- A summary of households' and firms' views of factors influencing adoption is presented at the end of section 4.2.1 and section 4.2.2

- Households were more positive towards adopting PSS for garden maintenance and home improvement, than house cleaning and laundry.

- The findings offered some support to the propositions in the PSS literature, but also divergent instances for all propositions on the choice and management of material artefacts.

4.2 ADOPTION

This section presents and discusses the results of the primary research on attitudes to adoption of the experimental PSS, in light of the frameworks derived from the literature (sections 4.2.1, 4.2.2, and 4.3). First, household adoption is considered and after that, supply side adoption.

4.2.1 Household adoption of PSS

At the present time, households were mainly performing self-servicing to complete various household tasks. As explained in the literature review (section 2.4.4.2) in this thesis self-servicing means household members performing unpaid work in the household using material artefacts to satisfy a need or create value for the household. For examples, a household member may vacuum clean using a vacuum cleaner to achieve hygienic and tidy home. Adoption of PSS would mean giving up self-servicing entirely or partly and paying for a commercial service provider to bring its material artefact to the household and use it to achieve the outcome. Descriptions of the PSS developed in this research can be found in appendix A (development of the PSS) and appendix E (user narratives).

This section reports on the results from the primary qualitative data collection and analysis pertaining to households' attitudes towards adoption of the experimental PSS. It also reveals not only householders' views on the experimental PSS but also on household services more generally.

Criteria for analysing household adoption of PSS were identified in the literature review. The criteria included cost and price, professionalism and skills, attitudes and behaviours, accessibility and flexibility, reliability and trustworthiness, service recovery, reputation and credibility, enjoyment and environmental impacts (see 2.4.4.3). Below, participants' attitudes towards adoption of PSS are reported in accordance with those criteria.

4.2.1.1 Cost/price

The cost/price criterion referred both to PSS and the purchase of material artefacts for self-servicing, and potentially the value of time used for self-servicing that could have been used for other pursuits (section 2.4.4.2).

Minimising the financial cost of accomplishing the household task was one of the most important criteria for whether or not to adopt PSS. Self-servicing was overall deemed to minimise the financial cost. The participants compared the price of the experimental PSS with the purchase price of material artefacts required for self-servicing. They viewed the price of the experimental PSS as unfavourable or even prohibitive, whereas material artefacts required for self-servicing were felt to be cheap and affordable. Participants did not generally consider the cost of their time spent on doing the jobs themselves. Absolute budget constraint was another issue. One participant expressed a dislike for cleaning and a preference for a cleaning service, but an inability to afford such services.

One participant who had used locally provided household services argued that the local service providers offered better value for money than the experimental PSS presented to the participants. Initial outlays for the purchase of material artefacts for self-servicing were also mentioned, especially for home improvement. On the other hand, initial outlays were deemed relatively small for many household appliances.

Therefore, the cost of using PSS instead of self-servicing was identified as a barrier to adoption for households.

4.2.1.2 Professionalism and skills

Professionalism and skills related both to households' skills at performing different tasks to the desired standard, and households' perception of service providers skills and resources to deliver the PSS to a desired standard (section 2.4.4.2).

Where participants felt they lacked the skills to complete self-service to a desired standard, in particular home improvement, they felt that the standard of the outcome would be decidedly better through the use of PSS. Skills would appear to vary between households. Furthermore, the perception of skills and the need for professional expertise may be partly influenced by customs and social norms. One participant used window cleaners and perceived that professional skills were required for window cleaning.

> "Obviously I have a window cleaner. That's normal isn't it?"

This norm may derive from a time when the design of windows made it difficult and hazardous for householders to clean windows located on higher levels above the ground. Modern houses such as those in the context under study (section 3.3) may have more modern designs that do not necessitate professional window cleaners with special equipment and skills. Nevertheless, the social norm may linger.

While in some instances service providers were perceived to hold greater skills than households, some participants would demand better results from service providers while they would be satisfied with lower standards if they did the job themselves. Also, some participants stated that service providers were unlikely to perform to the high standards that their own self-servicing produces. One participant even said:

> "I don't think if anybody else did it that it would be good enough for me".

Professionalism and skills are closely related to the standard of the outcome. Participants expressed that it was difficult to ascertain the performance of PSS before it had been trialled and would therefore like recommendations from peers who had tried the specific service provider. Participants also stated they would like to be able to change service provider if the outcome was not deemed to match the standard they required.

4.2.1.3 Attitudes and behaviours

Attitudes and behaviours referred to the service providers' care for the customers and willingness to solve the customer's problems in a friendly manner (section 2.4.4.2). This specific issue did not emerge in the focus groups and interviews. However, it may

be intermingled in households' responses concerning reliability and trustworthiness. Some participants emphasised they would like to have the same frontline staff[22] all the time, as they felt rapport is built with the person and not primarily with the firm. This rapport was mentioned in the context of trust and security, in other words, the factors of reliability and trustworthiness. The rapport with the person from the PSS provider might also comprise an aspect of care and friendliness with the customer. However, this would need to be confirmed in further research.

4.2.1.4 Accessibility and flexibility

Time was important to the participants and this was closely related to the accessibility and convenience dimension of service quality (section 2.4.4.2). Partly, this was to do with the time households had for household tasks or could release to do other things, by using a PSS. Partly it was to do with the timing of the particular service delivery. In general, ownership with self-servicing was felt to give greater flexibility than the use of PSS, since household tasks could be fitted in without much planning. Accessibility and flexibility was particularly important for washing, where speed of turnover would be imperative for PSS. This appeared to be particularly important for families with children who might soil bedlinen or who were engaged in sports and needed fast turnover of sport kits.

One participant said that when she lacked the time to keep up with ironing that had mounted up, she used an ironing service. Services may also be used to allow more time to be spent with the family for instance, rather than performing laborious household tasks.

The ability to choose to undertake household tasks spontaneously when the need and opportunity arose was a criterion that could work both for and against services. For the experimental PSS in the present research, it would be a barrier. However, for a car wash where you could drop in on your way whenever you liked, was felt to be more flexible than washing the car yourself at home.

The actual PSS needs to be available at times and places convenient for the households. In addition, participants suggested that if the PSS were offered in the immediate environment, for instance by the property development firm, they would be more likely to use it than if they had to search for the household service themselves, for instance in the yellow pages.

4.2.1.5 Reliability and trustworthiness

Reliability and trustworthiness referred to the service providers' ability to keep promises and act in the best interest of the customer (section 2.4.4.2). The reliability and trustworthiness factors were the most frequently recurring in the household focus group discussions and ones where the participants had the greatest concerns. Reliability and

[22] Customer-facing staff; the persons performing the tasks in the households.

trustworthiness comprised several issues. One issue concerned trust[23] in the service provider to turn up at the agreed time. Another issue was trust in the service provider to sustain the standard of the performance over time. Yet another issues was trust concerning letting the service provider into the house while the householders were out.

One aspect of reliability was the standard to which the service provider would perform the household task. Householders voiced a concern that the service provider's performance would not meet their expectations on the result. In this was also a sense that the service providers would be expected to deliver a higher standard than the self-servicing householder, otherwise some householders felt there was little point in buying PSS.

This concern may partly be down to the professionalism and skills of the service provider. However, it may also be an issue of the service provider's (or the customers' perception of the service provider's) willingness to act in the best interest of the customer and perform to high standards. This was a potential barrier to PSS adoption. Householders were also concerned about whether the service provider would sustain the performance over time. Participants voiced a concern that the standard of the performance would slacken over time. These concerns regarding reliability were potential barriers for PSS adoption. Households felt the needed to trial the PSS and see evidence of sustained performance in order to trust the PSS and continue using it.

Another aspect of reliability concerned the process of PSS delivery, namely the timely arrival and performance by the service provider. Households stated that they would have greater tolerance if they deferred self-service, than with delays on the part of the service providers. Fears of service providers failing to turn up on time might be a barrier for adoption of PSS.

An aspect of trust and trustworthiness concerned trust in letting service providers into one's home, which could allude to trust in the service provider's care and honesty regarding the property and belongings. Participants voiced concerns regarding letting service providers into their homes while not at home. On the other hand, they also preferred not be at home while the PSS was being delivered, since the point of using the PSS would be to save time which could be spent doing other things, perhaps away from home. This could be a barrier for PSS adoption.

Furthermore, it appeared that the issue of trust concerned both the service providing firm and its frontline staff. Regarding the firm, some participants felt that large firms would let consumers down, whereas trust was easier to establish in an individual with whom you developed a relationship. Other participants felt that whether it was a large or small organisation was of less importance as long as the frontline staff was trustworthy.

The participants also suggested that trust is built over time. This would mean that if the service providers were able to instil sufficient trust in the customers to begin with, the

[23] Trust is 'a feeling of security based on the belief that favourable and positive intentions towards welfare'(Nguyen & Mutum 2012) p. 407).

barrier to adoption of PSS may be lowered. Terms and conditions of the PSS contract between the household and service provider might enable initial trust to be built so that households dare to enter into the contract. For instance, the subscription permitted a period of trial, allowing time for the PSS provider to prove reliable and deserving trust. An opt-out clause might also be important if the service provider does not perform to the standard set out in the service level agreement. However, issues may arise over what qualitative specifications in service level agreements really amount to.

4.2.1.6 Service recovery

Service recovery refers to the service providers taking timely actions to find a new solution when the service provision has gone wrong (section 2.4.4.2). While this factor did not figure strongly in the primary research, participants were of the view that they would be let down by the service provider and that recourse would be difficult. This may be a barrier towards PSS adoption.

4.2.1.7 Reputation and credibility

Reputation and credibility referred to the service providers only, and not to self-servicing. The participants held different opinions as to whether a large or small service provider offered the greatest credibility. This might affect their willingness to adopt PSS provided by a large firm, such as the property development firm and its supply chain partners, rather than household services offered by small local service providers.

Some participants felt that a large service provider would provide a route for recourse if something went wrong and had a reputation to protect, whereas others felt that large firms were likely to let their customers down whereas small firms needed to care more for customer satisfaction. Some participants would trust local service providers who were seen around the development and thus were approachable. One participant said she would prefer a large firm in order to not have to complain to the frontline staff's face, but rather go through a centralised route if there was a problem. Many participants would like to have service providers recommended by peers who had used the service provider. There was a concern that new housing developments attracted rogue trades people and participants would be keen to avoid these.

Some participants also felt that rapport is built with the person performing the task rather than the firm. Therefore, it would be important that the same frontline staff attended to the same household. This may influence households' willingness to adopt the PSS in the context of this study, namely managed by the large property development firm rather than local independent service providers.

Since households were of differing meanings of whether large firms are credible, it was uncertain whether reputation and credibility would be a driver or barrier for household adoption of PSS supplied by the property development firm and its supply chain partners. The results from this research however, give some useful insights for the refined design and management of PSS.

4.2.1.8 Enjoyment

The enjoyment criterion mainly related to product ownership and self-servicing (whereas the enjoyment of freeing up time for other activities through the use of PSS may be expressed as other criteria such as flexibility and convenience). Participants enjoyed the look and feel of their belongings. Gardening and home improvement (self-servicing) was also particularly related to enjoyment. When money was scarce, allowing the use of only one or two PSS, the choice of household activity for self-servicing and service respectively was determined at least partly by relative enjoyment the household felt towards the different household tasks.

4.2.1.9 Environmental potential

The previous factors, except for 'enjoyment', were comprised in the framework of service quality dimensions influencing service adoption (see section 2.4.4.2). Environmental impact was added in the inquiry to identify participants' views on environmental protection and whether these might play a role for PSS adoption. Concerns for the environment did not feature strongly as a factor affecting attitudes to adoption of the experimental PSS. It was not mentioned spontaneously by the participants. When prompted, some householders remarked on the potential for present day commerce to affect environmental impacts for instance by energy efficiency of buildings and household durables (*e.g* fridges, washing machines) that are supplied with the new houses. The householders remarked that the new houses they bought are more energy efficient than older houses. However, that was not the main reason for choosing that particular dwelling, but rather a positive side-effect of buying a new-built home.

4.2.1.10 Household tasks

Householder attitudes to PSS adoption differed according to the household task under consideration. The relative importance of the criteria discussed above differed between the household tasks. PSS for the different household tasks were also thought to perform differently on the aforementioned criteria, and also in terms of different types of risks set out in the literature review in section 2.4.4.2. Table 6 in section 2.4.4.2 shows how these risks relate to the service quality dimensions and other factors influencing service adoption.

Garden maintenance

PSS for garden maintenance was felt by participants to have some benefits over other household tasks. For instance, it was felt to be more affordable as lawn mowing is only required for part of the year, during the growing season (the duration of which varies between locations). Garden maintenance was also found to be less sensitive to temporal risk in terms of precise timing of delivery than other services such as home cleaning and laundry. It did not matter much whether or not the grass grew for another few days before being cut. Therefore, the risk of inconvenience due to untimely service delivery was less of an issue. Furthermore, garden maintenance was felt to entail a limited degree of physical risk, in the sense that householders did not feel that security was as much of an issue since service providers do not enter into the house. Some participants however

enjoyed the activity of gardening and therefore, using the experimental PSS would entail a loss of sensory and psychological pleasure.

Home improvement

This was the household task for which perceived skills were found to play the greatest role. The qualitative data indicated that demand for the home improvement service largely arose from participants who perceived they lacked the requisite skills to achieve the outcomes they desire. For these participants, using self-servicing to perform home improvement entailed greater functional risk than using the PSS.

The cost of the home improvement service was less of an issue than the costs for the other household tasks. In contrast with the other household tasks, home improvement was a one-off service and not a regular subscription service. This made the total annual outlay affordable, not least in light of the perceived superior standard of the outcome. Among the participants were however also householders who took great pleasure in DIY and felt they had the skills to carry out home improvement themselves. They tended to have concerns over functional risk and have very expectations virtually impossible for PSS providers to meet.

These participants either rejected the use of PSS, or would use it if the job in question was very time consuming such that self-servicing would occur at the expense of spending time with the family. One participant with experience of using home improvement service providers from the local economy said that she would use a service rather than self-servicing, but felt that the experimental home improvement PSS was too pricey compared with services by local economy services providers that she was used to. In other words, PSS for home improvement would entail a financial risk. Propensity to adopt home improvement service depended on the judgement of own skills. While it might be cheaper to purchase the material artefacts to support self-servicing, this was not felt to be satisfactory by householders who felt they lacked the skills to perform.

House cleaning

House cleaning was a household task for which the enjoyment factor might act as a driver for adoption of PSS. Households expressed antipathy towards house cleaning.

"I hate cleaning. I would love to farm it out but I couldn't afford it"

It was also, however, the household task for which functional, physical as well as financial risk played great roles. While house cleaning was not perceived as a self-servicing activity requiring particular skills, householders were concerned about the standard of the outcome of the experimental PSS.

"I don't think if anyone else did it would be good enough for me".

With regard to the physical risk to their property, householders were anxious about letting service providers into their houses while away. At the same time, the temporal risk would be mitigated if the PSS was performed while the householders were away,

rather than at home. Furthermore, cleaning was a more urgent task than for instance garden maintenance, while not quite as urgent as laundry. Spills of for instance, liquid or foodstuffs would need urgent action which was felt to require ownership of material artefacts for interim self-servicing.

Overall, the attitudes to adopting the experimental PSS for house cleaning was tepid due to the costs, the concerns for security and standard of the outcome.

Laundry

There was relatively less interest in the laundry and house cleaning services compared with garden maintenance and home improvements. Temporal risk was a key worry with regard to the laundry PSS. Participants generally perceived that a laundry service would not be able to return washing quickly enough to correspond to the needs of an active family, as certain clothes such as school sports kits were required for specific times. Furthermore, self-servicing in the case of laundry was perceived to be relatively easy to do: just loading the machine and doing something else during the wash and dry cycles.

Furthermore, due to the large volume of laundry, all year around to meet a family's need for clean clothes and household linen, a subscribed PSS would be prohibitively expensive.

The findings on the factors influencing households' willingness to adopt PSS are summarised in Table 15.

Table 15 Summary of findings on the factors influencing households' willingness to adopt PSS

Factors	Summary of findings
Cost and price	Barrier to adoption of PSS. The cost was seen to be unfavourable or even prohibitive.
Professionalism and skills	Both driver and barrier to households' adoption of PSS, depending on how they perceive their own skills and those of the service provider.
Attitudes and behaviours	Neither driver nor barrier to adoption of PSS *ex ante.*
Accessibility and flexibility	Mainly barrier to adoption of PSS as self-servicing was viewed to offer greater flexibility. Could be driver for PSS if it frees up time to be spent on other things than laborious household tasks
Reliability and trustworthiness	Barrier to adoption of PSS. Trust comprised several issues such as trust in (sustained) results, trust in letting service provider into the home, trust in the service provider turning up at the agreed time.
Service recovery	Barrier to adoption. Households thought it would be difficult to get compensation if results of the PSS failed to meet service level agreements.
Reputation and credibility	Both driver and barrier to households' adoption of PSS provided by large firms. Some households thought large firms were more credible, and others emphasised the local reputation of small local firms.

Enjoyment	Both driver and barrier to adoption of PSS. Households enjoyed self-servicing for garden maintenance and home improvement more than for house cleaning and laundry.
Environmental potential	Neither driver nor barrier to adoption of PSS.

4.2.2 Supply-side adoption

This section reports on the qualitative results from the primary data collection and analysis pertaining to the property development firm and external supply chain firms' attitudes towards adoption of the experimental PSS (adding provision of PSS to their business-as-usual). It also revealed the participants' view on this type of service above and beyond the specific designs in the experimental PSS.

Business as usual for the participating property development firm (see section 3.3) was building housing and apartments on housing developments and selling them to householders. This entails short relationships with the customer, involving relatively large sums of money from one or two transactions. Business as usual also included selling 'after-sales products', such as pictures, mirrors, curtains to the house buyers after they had bought the house. For the facilities management branch of the property development firm, business as usual entailed providing facilities management services to other firms, usually through assigned supply chain partners that tended to be large national or international firms. This entails an on-going relationship involving relatively large sums.

On the supply-side, adoption of PSS means providing PSS to the households. For these existing firms providing PSS would mean adding a new branch to their existing business. This would entail a number of changes to business as usual. For the house-building branch of the firm, PSS would mean prolonging the relationship with its customers (an account manager from the often large client firms), and a large number of transactions involving small sums. For the facilities management branch, PSS adoption would mean on-going relationships with a large number of customers with many transactions involving small sums. As the results show, it might also mean a need to contract new supply chain partners. Furthermore, the profit margins may change. The decision to adopt PSS is likely to be taken at a senior level with the involvement of many business functions.

The literature review reported in section 2.4.4.1 identified a number of factors affecting supply side receptivity to adoption of PSS and thus changing business as usual. The author grouped these factors into a framework drawing on Cook *et al.* (2006) while modified to accommodate additional factors found in the literature. This section reports results from primary research exploring supply side adoption of the experimental PSS, in accordance with the modified framework. These factors in the framework are not mutually exclusive. Instead, this section shows their interrelatedness and how many issues may be multi-faceted and thus relevant to several of the different factors. In the following, the factors are presented along with the results from primary research. The results suggest that the framework was suitable for the analysis, while the factors were

fairly over-arching strategic management issues. The results suggested limited receptivity among supply-side representatives to adopt PSS.

4.2.2.1 Information in the external business environment

The literature review in chapter 2 suggested that availability of the PSS concept and associated knowledge set in a firm's external environment facilitated adoption of PSS. It also suggested intermediaries from for instance academia may help make this knowledge set available.

The research project team transferred the PSS concept into the property development firm. Participants from this firm associated the concept with the idea of concierge services from America and selling lifestyles rather than material artefacts. This idea had been discussed in the firm, not least as a way of exploiting the competencies in the Facilities Management division to offer value to the Construction division and providing 'mini-FM' services to the firm's housing developments. In addition, sustainable construction was understood to be topical. At a conference that one of the participants had attended, ideas similar to PSS had been discussed. Thus, information in the external environment was converging to make PSS delivery a potentially interesting option for the property development firm.

Some participants in the group of external suppliers related the idea of household services to phenomena that they knew from elsewhere, such as buying property abroad that included a package of services in the price or rent. One participant also mentioned a development where a managing agent managed cleaning, grounds maintenance and security services.

It is worth noting that some representatives from the property development firm struggled to remember the term PSS and what it was an acronym for and therefore also getting confused about the underlying concept about resource productivity. When reminded about the underlying concept, they understood it with ease. Therefore, a strict abidance by the PSS term might hinder the firm's internalisation of the underlying concept.

Some participants from the property development firm preferred to talk about lifestyle services. The author suggests that receptivity to information in the external environment might be facilitated if the firm uses a terminology that is proverbial to its members and meaningful to its customers. At the same time, if environmental benefits are sought, care needs to be taken that important aspects of the original concept are not forgotten and potential benefits lost.

4.2.2.2 Market conditions

The literature review in chapter 2 suggested that the market conditions facing a firm, for instance in terms of changes in competitive pressures, towards increased service offers could act as a driver for adoption of PSS. Furthermore, it suggested that in mature markets, PSS might offer new business opportunities.

The different divisions in the property development firm and the external supply chain firms faced different market conditions. The development division building and selling domestic houses operated in a mature but conservative risk adverse construction sector. The construction sector preferred tried and tested ideas and had not seen a trend toward increased service provision. Therefore, there were no competitive pressures in the market conditions driving adoption of PSS.

On the other hand, the market was seen as mature, and the representatives from the after-sales function within the housing development division were akin to the idea of PSS as a part of selling 'life styles' rather than just a house. This would be a way of seeking new opportunities in a mature market. Then again, these representatives also perceived ownership of material artefacts in the household to be a key aspiration among house buyers, and therefore limited willingness among households to use PSS and forego this ownership. This would be a barrier to PSS, although representatives from the FM function had greater confidence in the customer demand for PSS where PSS could be demonstrated to be reliable. Overall, the market conditions facing the property development firm were not a strong driver for adoption of PSS.

Participants from the group of external suppliers voiced some concerns about conditions in local service markets and competition from undeclared service providers. They saw a risk that such providers of undeclared household services could charge substantially lower prices by not paying insurances, health and safety standards. This competition, they felt could undermine households' willingness to pay for declared services. This was not an issue in the participants' current service provision to other firms, where customers were familiar with those costs and prices. Participants expressed a wish to achieve customer commitment to PSS for a longer period of time on dedicated housing developments, in order to avoid competition from local service providers. This would also generate volumes of geographically dense demand which was seen to be a prerequisite for financial viability of providing PSS.

Supply chain representatives did not appear to view PSS as an important avenue for strategic flexibility to meet changing market conditions. On the contrary, it appeared that their existing markets were still rich in untapped potential. The property development firm's FM division also saw rich business opportunities in their existing b2b markets.

4.2.2.3 Customer demand and customer relationships

The literature review reported in chapter 2 suggested that PSS enable prolongation of the firm's relation with its customers. Furthermore, it seemed to suggest that prolongation of the relationship between a firm and its customer would be beneficial and therefore a driver for PSS adoption.

For the housing development division of the property development firm, the relationship with the customer would change if the division started offering PSS as aftersales services. With the business as usual set-up, revenues arise from house sales

and to some extent sales of material artefacts – products as part of aftersales such as curtains and pictures. After that, remedial services[24] are offered under warrantee for a period of time and then the property developer withdraws and houses are sold on by the house owners. Contacts subsequent to that are for remedial actions by Customer Services under warrantee, and therefore incur costs that detract from the profit. The opinion within parts of the division is that prolongation of customer relationships could lead to costly problems rather than offering potential additional profit. Thus, they did not necessarily view a prolonged relationship with the customers as beneficial for the business. This is a potential barrier to PSS adoption.

On the other hand, representatives from the Aftersales group within the housing development division were more positive towards maintaining regular contact with households after the house sale, which PSS provision would entail. In addition, Customer Services experienced demand from households not only for remedial services, but also for other services for which the customers would be happy to pay extra. However, there was no system in place that allowed Customer Services to charge for such services. Thus, some functions within the firm saw potential business advantages of prolonging the relationship with the customer. However, in the light of the above, it was not perceived as unequivocally beneficial as proposed in the literature.

For the Facilities Management (FM) Division embarking on PSS provision to households would entail a different approach to customer relationships. With the current set-up, the FM division managed customer relationships through contract manager assigned for each contract. A contract typically required a three-year commitment from the customer. In the case of delivering PSS to households, the division would be required to deal with a large number of households, each of which would have a separate contract and contact. The sums of money in the transactions with each household would also be substantially smaller than the sums in the transactions with large business clients. This would have a number of consequences. The administrative systems of the FM division would need to be set up for transactions with a large number of households, which would entail costs. Also, in business as usual, complaints and any remedial action or compensation to the customer would be dealt with through the contract managers, who were relatively few in numbers. Any compensation is likely to be a smaller detraction from the revenues in the case of business as usual in contrast to PSS delivery to households. The price of the PSS to households is relatively small compared with the prices of the facilities management services provided to firms in business as usual. For compensations to households for failing to meet the service level agreement for a PSS delivery to be deemed sufficient by households, the compensation is likely to make up a larger share of the price of the PSS, than compensation to business clients.

Service level agreements (SLAs) were a recurring theme. Failing to live up to service level agreements may have detrimental effects both financially due to compensations to customers, and in terms of customer relationships. The risk of detrimental effects was

[24] Repairing defects in the houses under warranty

seen to be greater for PSS for households than FM services to business clients. . In the case of business to business markets, the supply chain representatives would deal with a smaller number of contract managers and negotiate an understanding of the SLAs and performance against those. Expectation management and non-quantitative SLAs (such as what would be done, rather than how clean it would get) were important aspects but were felt to be difficult to manage for household services. Due to the emotive nature of the issues, this had the potential to generate poor publicity. One participant suggested that the firm he represented was competent enough to ensure customer satisfaction given that the contract specification was right. A representative from the property development firm also suggested that client involvement would be needed in determining priorities in the service level agreements. These concerns were a driver for business as usual and barrier to adoption of PSS to households.

One participant, however, suggested that if the contract was right, then risk would be priced in and thus ceases to be a risk. Instead, the question was whether to take on the contract at all under the terms and conditions. After risk had been priced in the service may or may not be viable to sell. The supply chain firms would leave it to the contracting firm to work out the SLAs and other conditions and present to the potential contractors for consideration. In addition, the supply chain representatives would like the property developer to guarantee a certain volume of business, and thus pass the risk to the property developer. Another risk would be the reputational risk spilling over on house sales if the PSS went wrong, especially if all the PSS risk landed with the property developer. Under these conditions firms in the present supply chain may be willing to provide PSS. However, as was explained above, the perception was that when this risk was priced in, provision of PSS would not be viable since the price would be too high for the households.

Participants in the external supplier group doubted that the demand for PSS would be sufficient to generate the volume and geographical density of business[25] to make supply profitable. One participant in particular stressed the need for market research and customer profiling before being able to assess whether or not to get involved. However, the dominant sentiment was to not get involved, as the current b2b markets offered ample opportunity for business as usual.

To sum up, customer relationship issues arising from potential provision of PSS, were barriers rather than drivers for adoption in the context under study.

4.2.2.4 Regulatory framework

The literature review reported in chapter 2 suggested that producer responsibility legislation for WEEE would be a driver for PSS adoption, as it would allow manufacturing firms to meet and benefit from requirements to collect and recycle electrical and electronic equipment.

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[25] Relatively large number of households adopting PSS in a limited geographic area, to reduce the transport distances and the time staff spend travelling rather than performing the PSS,

Producer responsibility legislation did not emerge as a concern in the present research, neither as a driver nor barrier for PSS. Neither the property development firm, nor their FM supply chain partners are producing, importing or selling electrical and electronic equipment, and therefore are not directly affected by the producer responsibility for WEEE.

A policy area of particular importance to the housing development division was planning policy and obtaining planning permission. Previous experience suggested that environmental and community components of housing developments helped ensuring planning permission was awarded. An example of this was excluding infrastructure for private cars and introducing a car-sharing scheme.

Supply chain representatives saw abiding by legislation as a prerequisite for business operations, rather than a particular driver for certain business. However, compliance entails costs and there was concern competitiveness might be thwarted in local service markets with service providers potentially competing with undeclared services, not abiding by the relevant health, safety and tax legislation.

4.2.2.5 Corporate competence

The literature review reported in chapter 2 suggested that corporate competencies comprise the skills set of personnel as well as competencies and business systems to manage service transactions. It was suggested that the presence of these may act as a driver for adoption of PSS.

Competence for provision of services was already in place both in the housing development division and the FM division of the property development firm, through their existing portfolios of offerings. Customer Services had staff with skills for carrying out remedial services in households, and the FM division had staff skills and business systems in place to perform a variety of facilities management services in b2b markets. However, additional skills would be required on the housing development division to market PSS to households, in contrast with the remedial services. The participants felt PSS necessitated a mind-set different to that of remedial services. Also, participants suggested new ways of marketing PSS would be required, compared with selling aftersales material artefacts such as curtains and pictures through show home displays, to show the customers what they would get if they signed up for PSS.

However, the selection of skills among frontline staff would need to be further considered along with cost calculations. Each person in the frontline staff could be experts in one household activity and only provide that service. Depending on the geographical density of demand, this could potentially mean more travelling for each member of frontline staff. This would entail costs both in unproductive time during travel and in fuel costs. Another option would be to use multi-skilled staff who could perform the services PSS of several of the household tasks (garden maintenance, home improvement, house cleaning, laundry). This would, however, mean that they performed some tasks for which they were overqualified, but would need to be paid in accordance with the area of their top expertise. This might potentially mean that some of the services might be overpriced.

Another skill that the participants suggested was important was the ability of supply chain managers to identify best external service providers in a location and appoint them to provide PSS. Participants argued that this skill was present in the FM division of the property development firm. This was a potential driver for adoption of PSS.

Participants stated that in both the housing development division and FM division of the property development firm, IT systems were in place that to some extent, would be able to handle bookings, resource allocation and financial transactions of PSS. However, the IT systems would require further development to fulfil these tasks completely. The FM division had well developed IT systems for service provision in business to business markets, such as for: service bookings; service scheduling; service work allocations; invoicing. However, the system would need to be adapted to enable a large number of households which involve a large number of financial transactions involving small sums of money compared with supplying facilities management services to firms.. Also, direct bookings in the IT systems, placed by households through the Internet, would be likely to require monitoring, since the service quality would be highly dependent on correct entries by the customer. The frequency of erroneous entries was thought to be greater for a large number of individual household customers compared with the contract managers of b2b clients for FM services. Furthermore, existing call-centres would need to be expanded with staff dealing only with household customers for PSS.

The housing development division of the property development firm had a customer database that was currently under-utilised and would need to be adapted for PSS. Furthermore, the systems would need to be adapted to allow invoicing for value added services. This would require the involvement of a number of business functions such as financial and IT functions. In order for this to happen, Finance and IT would need to be convinced of the financial benefit of PSS. This would be a challenge and potential barrier to the adoption of PSS, since it is difficult to assess future costs and benefits even for much more conventional investments.

According to participants, the financial viability of PSS depends on the volume and geographical density of demand, and the way that PSS is delivered. In an area of geographically dense demand, specialised staff may perform each household task. If demand is not very geographically dense, then a mobile team may need to perform a variety of tasks requiring different skills. This also means that staff fulfilling the highest skills requirements has to perform tasks only needing lower skills. Since staff with higher skills are likely to command higher salaries than lower skilled staff, using higher skilled staff for all tasks may lead to the cost of labour being prohibitive. The use of mobile multi-skilled frontline staff would mean down-skilling of some and up-skilling of some, according to one supply-chain participant.

One of the participants in the group of external service providers suggested that even if the property developer were to provide PSS on the housing developments via an on-site model with material artefacts and a couple of permanent multi-skilled staff based on the housing developments, they would still need support from the supplier market to cater for fluctuations in demand for PSS.

The firms which the focus group participants represented had tended to obtain skills in new areas through acquisitions of firms that held the requisite competencies rather than

developing the competencies in-house. A participant stated that the acquisition of local service firms providing PSS to households would be 'too much hassle' unless one firm had geographically dense large business volumes in many geographical areas. Consequently, although the competence to undertake such acquisitions was present, acquisitions were not viewed to be a viable option. This was a barrier to PSS.

4.2.2.6 Strategic orientation

The literature review reported in chapter 2 suggested that the firms' approach to meeting changing market conditions would affect their receptivity to adoption of PSS. These approaches might encompass for instance differentiation or cost reduction, technological improvement of material artefacts or additional service provision (Cook *et al.* 2006).

Most of the participants in the external supplier group represented firms that undertook both planned and reactive services in the business to business market. The provision of similar services to household would mean diversification entailing changes that the participants stated were not their core business. One firm concentrated on reactive services and for them, providing planned services would be a digression from business as usual. There appeared to be little inclination to change this strategic orientation in the absence of strong evidence of guaranteed profit. A representative from the property development firm suggested that the division would need strong evidence in order to change their core business of designing and selling houses. This is perhaps not surprising as the firms had not experienced the type of changing market conditions proposed in the literature, and saw ample opportunities in the b2b markets they currently operate within for FM services.

4.2.2.7 Organisational structure

The literature review reported in chapter 2 suggested that the organisational structure which governs decision making in a firm affects its receptivity to PSS adoption and that matrix organisations with blurred disciplinary boundaries facilitate PSS adoption.

The present research suggested that organisational structure mattered in several ways. The house building and FM divisions of the property development firm, operated in different sectors with different stock market expectations of profit margins. PSS provision was thought to command a much lower profit margin than house-building does. If PSS provision was to affect the overall profit margins this might have an adverse effect on stock prices and would be a barrier to PSS adoption. Thus, most likely, the PSS provision would need to be a part of the FM division.

The performance measurement structure within the firm was a barrier to adoption of PSS. As with many firms, there might be a risk of sub-optimisation in order to achieve the best result for each accounting unit rather than the best outcome for the firm as a whole. An example of this would be if the Supply Chain function procured material artefacts to a lower price but that would incur extra costs at another stage of the life cycle that would be borne by another accounting unit, such as for instance Customer Services. This said, there was willingness among the participants for more

communication and collaboration across business functions, which would be required in case of provision of PSS.

The participants in the external supplier group considered any potential provision of household services as separate business units, ring-fenced or bolted on, and something to be managed outside of their 'day-jobs' providing services to other firm. This might be an attempt to avoid reputational and financial risk before the new business has been established.

4.2.2.8 Portfolio of offerings

The literature review reported in chapter 2 suggested that the presence of services in the portfolios of offerings might potentially facilitate adoption of PSS since competencies for providing services would already be in place.

Both the housing development division and the FM division of the property development firm included a range of services in their portfolio of offerings. The housing development division offered remedial services under warranty, which could potentially be extended to value added services, including PSS. The FM division provided a variety of FM services to other firms and had also been piloting concierge services to private individuals through their employers, who were customers of FM services. Overall, the participants from the property development firm were ambivalent towards offering PSS, due to other factors affecting adoption of PSS, such as customer demand and customer relations, and market conditions. The presence of services in existing portfolios of offerings of the supply chain firms, did not appear to increase the supply chain participants' inclination to provide PSS.

4.2.2.9 Cost, revenue and profits

The literature review reported in chapter 2 suggested that a number of financial issues related to costs, revenue and profits affected firms' willingness to adopt PSS. Examples of such issues include labour costs, cash flow, cost of resources and geographic density of customers.

The costs for changing from business as usual to provision of PSS would among other things entail costs for setting up project management teams, booking systems, contracting service providers. A representative from the Facilities Management division with experience of value-added service in the commercial sector, suggested that customers would need to commit to twelve months' worth of service to increase the possibility for the company to get return on investment if it decided to start offering PSS. This would be a way of managing financial risk in view of uncertain demand for PSS.

Participants aired ideas such as including the charge for services for the first year or two in the house price and then introduce a service charge subsequently, since households might be more willing to pay once they were used to having the service. The service charge for one or two years would only be a small portion of the house price.

Operating costs would include for instance personnel wages (labour costs) and fuel costs. Participants suggested that the time frontline staff spend on the way to and from customers is unproductive time and potentially very costly. Therefore, there needs to be sufficient geographical density of demand in order to reduce travel costs. Otherwise, the prices of PSS may be prohibitive or the firm's costs not sufficiently covered and the supply of PSS would not be financially viable.

For the housing development division of the property development firm, their remedial services provided under warranty to mend faults with residential houses only entailed extra costs and no further revenue. However, the customer services staff had experienced demand for further services by households who would be willing to pay to have other issues tended by customer services. However, there was as yet no system in place whereby customer services could invoice for such value added services although they would like to generate this revenue. This would be a driver for adoption of PSS.

One participant drew attention to the difference in profit margins between the construction and facilities management sectors and suggested that service delivery would not provide similar profit margins to those of house construction and sales. He suggested that if the housing development division was to deliver PSS the profit margin of the division might decrease and undermine share prices. Therefore, he suggested, PSS might be more viable to operate from the Facilities Management division normally operating to those profit margins. For this reason, the experimental PSS were designed for the Facilities Management division to be responsible for their delivery, rather than the house building division.

A representative from the Facilities Management division suggested that the risk of detrimental effects on finances as a consequence of failing to meet SLAs was seen to in the household market compared with business to business markets. In the case of business-to-business markets, the supply chain representatives would deal with a smaller number of contract managers and negotiate an understanding of the SLAs and performance against those. Any compensation for failure to meet SLAs in the business as usual business-to-business market was likely to be a substantially smaller share of the total value of the contract than would be the case in the business-to-consumer markets. For the service provider, the revenue from each household would be relatively small. However, for a household to be satisfied with the compensation, the compensation might need to be at a level which for the PSS provider amounts to a substantial share of the revenue from a service delivery instance, such as one weekly cleaning. In addition, customer relations and negotiation management with a large number of household customers may be considerably more costly than contract management in the business-to-business market and undermine the viability of adding PSS to the portfolio of offerings.

The external supply chain representatives suggested that they would be willing to enter into any business where the revenues and costs were well known and there would be certain profit. Some participants stated that they thought that the idea of household service provision had staying power. However, they doubted that profitability could be guaranteed with the current state of knowledge about customer demand and cost structures. They did not seem inclined to participate in the development of the required knowledge to any great extent, but wanted to be presented with detailed service

specifications, guaranteed business volumes in limited geographical areas in order to cost and price the contracts and decide whether or not to go in. The feasibility was deemed greatest on particular developments where services were an integral part of buying the property and thus would ensure 100% on the same development. Such developments were believed to accommodate mainly well-off households.

The cost of resources, as in the cost of the material artefacts used to perform the PSS was not mentioned by the participants as an issue of consideration for the potential adoption of PSS.

Early conceptual literature seemed to suggest that cost-savings and profits for firms arising from selling the use of material artefacts rather than selling the material artefacts themselves would be a business case for adoption of PSS (use value as highlighted by Meijkamp (2000) and Mont (2002). This might be applicable to manufacturing firms. However, firms already providing services to different markets have to contend with a different set of changes to business-as-usual. Later PSS research and the present research suggests that the issues of supply-side adoption of PSS are complex phenomena and involve a whole set of issues as set out above. Not only does this have implications for adoption of PSS, but also for firms' choice and management of material artefacts. If the incentives for increasing use-value of material artefacts is of limited importance for adoption of PSS, then it may also be of limited importance for increasing resource productivity of material artefacts though the choice and management of material artefacts.

4.2.2.10 Network and supply chain

The literature review reported in chapter 2 highlighted the potential role of business networks and academia to facilitate the adoption of PSS. Such networks did not feature in the primary research in the present study. Instead, supply chain relations emerged as an issue.

If the property development firm were to provide PSS, it would, in the first instance seek to contract the front-line staff and skills through the supply-chain rather than acquiring it in-house. According to a participant form the property development firm, this would allow the firm to learn about the market and PSS delivery. This knowledge was thought be useful if eventually brining the entire PSS provision in-house. However, even if the property development firm were to eventually provide the PSS with in-house capacity, it probably still need to contract external service providers to meet temporary fluctuations in demand.

In the first instance, the property development firm would turn to their existing supply chain partners. However, the project revealed that these were very sceptical to supplying PSS to households. Only under certain conditions would they consider supplying PSS to households. For example, where a property development firm could guarantee the external supplier sufficient geographical densities of demand, in locations where their firms were already very strong, and where the service level agreements were considered viable, would they consider supplying PSS.

Therefore, the property development firm would be likely to need to contract new supply chain partners to provide PSS to the new housing developments. Furthermore, these would be likely to be local or regional ones. Participants perceived a risk that such local service providers might use the PSS delivery on contract with the property development firm to establish contacts with households and then terminate the contract with the property development firm and provide services from their own firms, under-cutting the property development firm. Establishing new supply chain relations with local or regional service providers would also entail costs and therefore present a potential barrier to the adoption of PSS.

4.2.2.11 Natural environment

The literature review reported in chapter 2 suggested that the ease with which environmental concerns could be balanced with other factors might affect adoption of PSS.

Participants recognised that societal interest in environmental issues had increased in recent years and some functions of the property development firm had for instance, attended a sustainability conference. The participants from the property development firm seemed to be positive towards corporate environmental management. On the other hand, environmental issues did not seem to be a strong driver.

Due to land prices, the property development firm would be unwilling to give up a plot of land for an on-site service centre on housing developments. The pay-back time for the PSS to cover the investment and foregone income from the house sales, would be substantial and the financial risk great in view of uncertain demand for the PSS.

Table 16 Summary of findings on the factors influencing supply-side adoption (willingness to supply) PSS

Factor	Summary of findings
Information in the external environment	Different ideas in the firm's external environment converged and acted as a driver for PSS. Confusion about the acronym and concept was a barrier.
Market conditions	Barrier to adoption of PSS. The house building sector was risk averse and preferred tried and tested ideas. There was not competitive pressure for PSS. External suppliers saw ample opportunities in business as usual and were concerned over competition from undeclared local service providers if they adopted PSS.
Customer demand and customer relationships	Both driver and barrier to adoption of PSS. Supply-side participants experienced demand from households for services beyond the remedial services included in the warrantee of the house. Due to the experience of providing remedial services, prolonged relationships were perceived to entail costs undermining profits. Managing relationships with a large number of small customers was viewed as more costly than relationships with contract managers from large client firms in the business as usual. There were concerns over bad publicity potentially arising from disagreements with households over the fulfilment of service level agreements, and this spilling over on customer relationships with other firms. The external supply chain doubted there would be sufficient demand.

Regulatory framework	Neither driver nor barrier to adoption of PSS. Policies that the PSS proposed were drivers for adoption, were not drivers in this context.
Corporate competence	Driver and partly barrier to adoption of PSS. Skills existed for provision of services to firms, would need to be adapted to the household market. Competence to assign supply chain partners existed. IT systems were in place but would require adaptation.
Strategic orientation	Barrier to adoption of PSS. There were no market conditions were perceived to favour the strategic orientation of business as usual.
Organisational structure	Neither driver nor barrier to adoption of PSS. The organisational structure affected where in the organisation responsibility for PSS would reside. Division into different functions is a challenge but the participants representing different functions were willing to collaborate and communicate.
Portfolio of offerings	Both driver and barrier for PSS adoption. The portfolio of offerings of the property development firm and its supply chain included provision of services (driver), although not revenue generating services to households (barrier)
Cost, revenue and profits	Both driver and barrier to adoption of PSS. Uncertain demand from households was a barrier, in particular sufficient volume of demand in a limited geographic area to maximise the productive time of service providers and avoid unproductive travel time. Demand from households and willingness to pay for services in addition to remedial services under warrantee was a driver. Financial risk of compensation to households was a barrier. (Contrary to the proposition in the PSS literature, the cost of the material artefacts was not mentioned as financial concerns).
Network and supply chain	Barrier to adoption of PSS. The property development firm would provide PSS through their supply chain rather than building in-house capacity. The present supply chain partners were not willing to provide PSS. The property development firm would have to appoint new supply chain partners from local service markets.
Environmental potential	Neither driver nor barrier. The business importance of environmental issues was recognised, but absent evidence on environmental benefits of PSS, the environmental potential was not a driver.

4.3 CHOICE AND MANAGEMENT OF MATERIAL ARTEFACTS

The literature review identified a number of propositions on behaviours on choice and management of material artefacts along the PSS life cycle (section 2.4.2.4) on which the waste prevention potential and environmental performance are premised. These behaviours were however, to great extent based on assumptions rather than empirical research. This section reports on the results from primary research exploring the choice and management of material artefacts among the participating self-servicing householders and supply side representatives.

4.3.1 Choice of material artefacts

4.3.1.1 Households' choice of material artefacts

The literature on PSS reviewed in section 2.4.2.1 suggested that households tend to choose material artefacts that are over or underspecified for the household and that have limited durability. The literature also seemed to assume, implicitly, that households purchase new material artefacts rather than used ones. The related literature (section 2.4.2.1) suggested that households sometimes buy used material artefacts. When this is the case, the uselives of the households' material artefacts are likely to be longer. This means that the potential gain in resource productivity by changing from self-servicing to PSS may be smaller.

The majority of participants in the primary research had acquired new rather than used material artefacts. However, a younger participant had obtained used material artefacts from friends. Another participant who had not bought used material artefacts said he would consider doing so if it was a case of an expensive high-specification item.

Cost and price were important criteria in the choice of material artefacts. Some participants considered energy ratings of white goods in order to reduce running costs, whereas another participant found that there was a trade-off between energy rating and purchase price and that the purchase price for the best energy rating may not be affordable. Thus to some extent participants based their choice of material artefacts on rational criteria. When prompted to think about brands, participants appeared to equate certain brands with superior or inferior performance. This may suggest that brand is a criterion for the choice of material artefacts. Tests of material artefacts by consumer organisations often show that brand and price do not equate best performance. Therefore, basing choice of material artefact on criteria such as brand might indicate that householders do not always make calculated rational choices but rather follow intuition or symbolic values. Alternatively, brand may be deemed to be a proxy for performance in the absence of full information on the actual performance of material artefacts. These findings may correspond with the proposition that households do not choose material artefact of the appropriate performance for the household task. While participants stated that some specifications of the different material artefacts used for self-servicing, it was not possible in this study to establish whether the specifications and performances were appropriate for the actual needs of the households.

The reviewed literature largely seemed to assume that PSS users would not themselves own the material artefact required to perform the household task. As is evident from the next section, many households were reluctant to give up ownership of material artefacts even if using PSS. Then the question of the choice of material artefact is extended to the choice of material artefact retained or purchased to perform interim self-servicing while using PSS. Householders participating in the study were of differing opinions as to their requirements of material artefacts retained or purchased to perform interim self-servicing as a complement to PSS. One view was that a cheaper model would be chosen since it would be used less. Another view was that the material artefacts would still need to be able to do the job, which would require the same specifications, even if it was used less often. Another view alluded to the transitory stage of trialling PSS. The view with regard to choice of specification of material artefact was that it would need to

have the same specifications as for self-servicing only in case PSS was abandoned and self-servicing only resumed.

It was not possible to establish how appropriate the material artefacts were that self-servicing households chose. Furthermore, opinions were divided as to the specifications required of material artefacts kept in households' possession to perform complementary self-servicing even while using PSS.

4.3.1.2 Service providers' choice of material artefacts

PSS literature proposed that service providers may use industrial grade material artefacts that would achieve the desired result more efficiently than domestic grade. This was true for laundry, but not for garden maintenance. The participant for laundry said that laundrette type washing machines were used for laundry from the domestic markets, although not industrial batch washing machines used for commercial customers. The participant for home improvement suggested that trade-quality drills would be used. This might pertain to the steel grade in the drill bits as well as the motor power. The participant for garden maintenance suggested that domestic grade lawnmowers would need to be used, since the greater cutting width and larger size of industrial lawnmowers would be inappropriate for the layouts and smaller size of domestic gardens. In addition, petrol lawnmowers were likely to be used since did not rely on access to the houses for power supply. Roughly half of the self-servicing households used electric lawnmowers which are considerably smaller and lighter than petrol lawnmowers. Therefore, PSS would lead to larger and heavier material artefacts in total.

The size and layout of domestic homes may also mean that industrial grade vacuum cleaners are inappropriate. Nevertheless, industrial vacuum cleaners are relatively small and light and could also be used in domestic houses. However, the participant for the house cleaning firm which also provided cleaning services to firms, considered changing to wet and dry vacuum cleaners that could accommodate the requirements of both household and commercial customers. The wet and dry cleaner would be heavier than the dry vacuum cleaners used at the time. This means that industrial grade material artefacts are not necessarily more efficient at achieving the desired results in households.

The literature on PSS proposed that service providers choose more appropriate material artefacts[26] than self-servicing households, to achieve the result, and also that the appropriate material artefact may be of industrial grade. There was no practicable means of establishing the most efficient artefact for the tasks at hand in this study. However, present research yielded some useful insights contributing the understanding of the propositions and thereby the PSS concept.

[26] Aspects of appropriateness or efficiency could for instance be a combination of measures of the material artefact's ability to produce the results, such as the percentage cleanness for different models of vacuum cleaners, manouverability in households, energy efficiency, durability.

Consequently, there is both some support and some rejection for the tentative proposition from the literature review on the supply side. More than anything, this uncertainty points to a need for further empirical research on service firms' choice of material artefacts. It is not sufficient to rely on assumptions on rational behaviour, especially without consideration of other factors that may come into what is considered overall beneficial by the firm. It may also be the case that the households differ in a variety of respects and that there is not single set of most efficient specifications of material artefacts, but that the material artefacts of service providers need to have a set of specifications that can produce good results across that variety of household conditions.

Design of material artefacts

Some of the PSS literature proposed that the manufacturer is also the service provider. The fact that the PSS concept partly arose from the observation that many manufacturing firms are increasingly offering service components in their offerings, might be a reason for this notion. In instances where the manufacturer of the material artefact is also the service provider, this was thought to offer an incentive for the manufacturer to design more durable and efficient material artefacts, which would allow them to gain more use value from the material artefact at lower running costs. Furthermore, since the material artefacts would still be in their ownership, they would have the responsibility for appropriate recycling and remanufacture at the end of a use cycle. Some of the literature on PSS, however, also recognised that often PSS is offered by a third party firm from the service sector. This might weaken the incentive for altered design of material artefacts. The latter was the case in the present research.

This shows that the incentives to design more durable and efficient material artefacts are not an inherent mechanism in PSS for resource productivity. A switch from self-servicing to PSS may occur without manufacturing firms being directly affected by the change. Whether manufacturers or third party service firms provide PSS is likely to be a matter of business strategies based on a wide range of considerations, with a range of potential benefits or disbenefits for both the firms and the wider economy. This thesis has not researched these issues and therefore normative conclusions regarding what types of firms should provide PSS are not warranted. Furthermore, *if* manufacturers provided PSS *and* retained ownership of the requisite material artefact, this might lead to changes in the design of material artefacts and recycling and manufacturing. However, a range of additional business considerations may affect those decisions, and again as manufacturing firms were not the providers of PSS in the present research the findings are not able to advise on this matter.

The literature also suggested that service providers choose durable and efficient material artefacts. If this were the case, one might suggest that only durable and efficient material artefacts would be demanded of manufacturers of material artefacts for the business market. However, such an assumption probably neglects the variety in demands from different segments of the business market and the variety of manufacturers serving different segments.

4.3.2 Ownership of material artefacts

4.3.2.1 Households' ownership of material artefacts

The literature review revealed a mostly implicit assumption that households using PSS[27] would not be in possession of the material artefacts used to perform the job (although some authors did recognise the fact that not all PSS substitute ownership, for instance car-sharing Meijkamp, 2000). Related literatures however, suggested that consumers are less willing to give up ownership of a material artefact that they have had in their possession, than abstaining from buying a new type of material artefact (section 2.4.2.1). The results from the primary research suggest that willingness to give up ownership in the case of starting to use a service is limited. Householders were not willing to do without a washing machine and vacuum cleaner even whilst using PSS for laundry and house cleaning, since urgent needs might arise between the scheduled service delivery instances. Householders were more open to not being in possession of lawnmowers, since the need for garden maintenance was not felt to be in as urgent need of being performed within a short time span.

Some of the participants testified to not owning a lawnmower and drills when using household services in the past. One householder previously used a garden maintenance service during a period of much work-related travel, so as to not add a burden to his wife's other household and family commitments. After that period he started cutting the grass himself and purchased a lawnmower for the purpose.

Opinions were divided as to whether a smaller material artefact would suffice as a complement to using a household service. One stance was that you could get a smaller and possibly cheaper vacuum cleaner as the needs for self-servicing would be of a different nature when the bulk of the task was performed by the household service. A contrary viewpoint was that the material artefact still needed to be up to the job, and therefore be of the same specification.

Availability of storage space was also an issue. Householders in the focus group living in apartments were older middle-age and had down-scaled. This also meant that they had dispensed with a number of material artefacts. For another householder, limited space in the new house meant that she had to replace her separate washing machine and tumble driers with a washer-drier.

Ownership of multiple units of a material artefact

The PSS literature was largely silent on the possibility that households might own more than one unit of a material artefact for self-service, and the effect of this on non-ownership. In other words, in the case of ownership of multiple units, would households give up ownership of any, one or all of the units? The theoretical literature on the other hand, suggested that ownership of multiple units is becoming increasingly common. The number and specification of units of material artefacts, and whether households

[27] And similar service concepts, termed for instance eco-services.

give up any or all of those when using PSS would affect the resource productivity of PSS and therefore needs research attention.

The householders in the primary research in this study only owned one lawnmower and one washer and tumble drier (or washer drier). There were however householders who owned two vacuum cleaners and several drills. The main reason stated for ownership of multiple drills was that drills were felt to do different jobs, for instance different drills were used on different materials. While according to the literature, similar developments may be emerging or perceived for other categories of household appliances, the participants did not see this as being the case for vacuum cleaners, lawnmowers and washing machines. On the contrary, vacuum cleaners were seen as including many different parts that added functions for different needs and could therefore serve all purposes in a household. Instead, the reason for owning more than one vacuum cleaner was to have one on the ground floor and one on the top floor and not having to carry the vacuum cleaners extensively through the house. Presumably, the price of vacuum cleaner is seen as relatively low and thus rendering this practice financially viable and cost-efficient. Another participant could see a similar thing applying to lawnmowers: having one small lawnmower for the front garden and a bigger one for the back garden and not having to drag the lawnmower through the house. However, he did not have two lawnmowers himself. Again, storage space had a constraining effect on the ownership of multiple units. Householders also mentioned inertia as a reason for keeping obsolete material artefacts. One householder had two fridge freezers for that reason.

It could be envisaged that households owning multiple units of a material artefact might reduce the number of units owned when using household services, even if not giving ownership entirely. It is also conceivable that a period of experience of using household services will make the householders more confident in giving up ownership of material artefacts, or alternatively more certain about the need to own the material artefacts.

To sum up, the findings also suggested that ownership of multiple units of a material artefact was more common for certain artefacts than others, typically vacuum cleaners. The study offered little advice as to whether households would give up all units or some if using PSS, and what the effects would be of this, as use patterns and longevity might differ between units depending on the role of each unit in the household. The results indicate a need for PSS research to move outside assumed behaviours and further explore actual behaviours.

4.3.2.2 Service providers' ownership of material artefacts

An underlying assumption in the literature was that the service provider owns the material artefact required to perform the task at hand. The service provider was implicitly assumed to be an economically rational agent seeking to maximise the use value of its material artefacts, by choosing durable and efficient artefacts for the purpose, to maintain and repair them properly, and recycle or remanufacture them at the end of a use cycle.

Findings from the present study, however, suggested that this is the case in some but not all instances. In some instances, like house cleaning, the supply-side participant used the

vacuum cleaners owned by the households. Consequently, the service provider had little influence over how soon the household chooses to replace the material artefact or over the specifications of these. This datum is neither of sufficient scale nor depth to suggest in what contexts this behaviour may apply. It came from a single provider of house cleaning services with no relation to the property development firm in the present study. In the experimental case of household PSS offered through the supply chain of the property development firm, the property development firm may of course place certain demands on its subcontractors regarding material artefacts such as stipulating that they own the material artefact. This may on the other hand counteract the idea of result-oriented PSS allowing for the service provider to choose the most efficient and innovative means to achieve the result.

Importantly, however, these finding provide a disconfirming case compared with the PSS proposition. This indicates a need for further research to study empirically the extent to which service firms own the material artefacts that are used, and if so in what contexts. It also indicates the possibility that material artefact ownership on the part of the service provider is not an inherent mechanism in PSS for resource productivity.

Any potential benefits in resource productivity and waste prevention from PSS is undermined if service providers do not own the material artefacts. The prevalence of service providers using material artefacts in the ownership of households could not be inferred from the present research. While it could be argued that in order to be defined as PSS, ownership of material artefacts would need to reside with the service provider. However, the author considers this might merely lead to fruitless debate on what is and is not PSS, rather than progressing environmental benefits of services.

In addition to the above discussion regarding whether or not service providers actually own material artefacts at all, the central question on material artefact ownership and PSS concerns whether material artefact ownership on the part of the service provider leads to extended uselife and recycling/remanufacturing.

Other strategic business issues may (or may not) be of equal or greater importance for the business overall, as extending the uselife of the material artefacts, especially in cases where the material artefacts are relatively inexpensive. Furthermore, it is not clear whether the propensity to produce the results (e.g. neat lawn, clean linen) in resource productive innovative ways mainly depends on ownership of material artefacts, or on other factors, for example organisational characteristics and strategic intent. In an example from the literature on another type of result-oriented PSS (although in the business-to-business market), namely Energy Performance Contracting, the service provider may be innovative in its analysis of potential energy improvement measures, but still has to specify the measures to the customer, and what equipment it intends to use. The measures and equipment selected depend on for instance the customer's requirements on payback times and financial result over the contract period. On the other hand, the calculations of environmental benefits of this type of PSS do not consider the effects of the material artefacts at all, but only the energy use. It is also common that the customers own the material artefacts as they may often be able to get loans that lead to a lower overall cost than if the customers paid a premium to the service providers for leasing the material artefacts (Axelsson, *et al*. 2010).

4.3.3 Use and maintenance of material artefacts

4.3.3.1 Households' use and maintenance of material artefacts

The PSS literature reported in chapter 2 suggested that householders are less skilled in the appropriate and efficient use of material artefacts than service providers and thereby use more resources during the use-phase. Furthermore, the literature suggested that householders are less inclined to repair and less skilful at repairing their material artefacts than service providers.

It was not possible to establish the efficiency of householders' use of material artefacts to perform self-servicing for the different household tasks, through the exploratory research. This was beyond the scope and resources of the present project. Only the self-reported time use for various household tasks could be identified. However, this says little about the demands on for instance cleanness, and the size and layout of the dwelling, household structure and other factors affecting this time-use. There was a great variety in the time the different spent using material artefacts to perform self-servicing.

Repairs of material artefacts before replacement varied among households and ranged between zero to five times. Households that did not have their material artefacts repaired tended to think that their material artefacts were beyond repair when they broke down, although they had not tried to have them repaired. There was also a sense that having material artefacts repaired would be too expensive to be worthwhile, perhaps especially for the less expensive material artefacts. This seems to at least partly confirm the proposition in the literature, although some householders had their material artefacts repaired several times.

The literature (implicitly) proposed that households are driven by other motives than economic incentives to extending the uselives of their material artefacts by repairing them. The literature also suggested that households have limited skills to repair their material artefacts. The results are ambiguous since many households assume that material artefacts are broken beyond repair without trying to repair them, but some households have material artefacts repaired several times. Some household also stated that replacement was cheaper than repair. It was not possible to establish the quality of repairs carried out by the households themselves, neither by repairs carried out by firms. Thus, households and service providers may behave similarly with regard to repair of material artefacts.

4.3.3.2 Service providers' use and maintenance of material artefacts

The PSS literature assumes that service providers are more skilled in the efficient delivery of a result than self-servicing households. Therefore, PSS was thought to save resources in the use phase, compared with self-servicing. In the present research, the supply side participants were not able to say for how long of the total service delivery time the material artefacts were in use. The households were better able to provide an estimate for this. Consequently, the findings from the present study could neither confirm nor refute the tentative proposition.

The PSS literature also implied that energy savings during the use-phase accrue to the service provider, and acts as an incentive for service providers to reduce energy use during the use-phase. The findings of the present study indicate that for household PSS this depends on the location where the main task is carried out, and the power source used by the service provider. For house cleaning, using electricity, sockets in the house are used, and any savings accrue to the households. For garden maintenance, the service providers would possibly use petrol lawnmowers in order to ensure independence of power supply, and any savings would accrue to the service providers. For laundry which is carried out in separate facilities, any energy use shows up on the service provider's energy bills. For some PSS in the literature, such as 'least cost planning' (*e.g.* Energy Performance Contracting) the energy use shows up on the customer's bill rather than the service provider's bill. The savings are then estimated based on a baseline defined using adjusted historic data for energy use. It is likely to be very challenging to establish robust baselines and savings calculations for household PSS to act as an incentive for households to use PSS in order to reduce energy bills. Therefore, a tentative conclusion is that the ability of PSS to offer incentives to service providers to reduce energy use is limited, more so for certain household tasks than others. The participants did not mention any efforts to reduce resource use during the use-phase.

The PSS literature also suggested that PSS leads to greater intensity of use of the material artefacts, since the service providers use their material artefacts for a larger share of their available time, whereas material artefacts in the possession of self-servicing households are idle for much of the time. However, when this assumption is coupled with the assumption that service providers use their material artefacts until they have reached absolute obsolescence, and that households are thought to replace their material artefacts prior to absolute obsolescence, interesting insights are gained. The present research found that if this assumption about different types of obsolescence for service providers and households holds true, then intensity of use does not matter for the total resource productivity of the materials in the artefact. If absolute obsolescence arises through wear and tear, and wear and tear is a function of the number of hours, or cycles of use or similar, then the total number of hours of uselife is the same regardless of whether the material artefact is used a lot or a little of its available time.

This conclusion on the limited importance for resource productivity of intensity of use, ignores the potential benefit of material artefacts reaching absolute obsolescence sooner rather than later. This issue will be dealt with in the next section on obsolescence, replacement and disposal. It relies on service providers using their material artefacts for more of their operational life than households do with their material artefacts in the case of self-servicing.

The literature suggested that service providers have economic incentives to service and repair their material artefacts in order to extend the uselives of the material artefacts. Service providers tended to repair their material artefacts to some extent but they did not keep records of repairs. Therefore, it was not possible to establish the frequency of repairs. Neither was it possible to establish the standard of the repairs. According to the literature, repairs may rejuvenate material artefacts. However, repairs might also render material artefacts 'as bad as old', rather than 'as good as new'. That is, if repairs are well performs they rejuvenate the material artefacts. If repairs are done badly, they may not restore the material artefact to the functionality of an earlier stage in its uselife.

Nevertheless, self-reports by the participants suggested that larger and more expensive material artefacts were repaired and used until they had reached absolute obsolescence, while it was not considered to make economic sense to have the smaller and cheaper types of material artefacts repaired. The laundry firm had an engineer who repaired the washing machines when needed. The participant for garden maintenance suggested that service providers would typically service lawn-mowers once every season, and points in-between if needed. The participant for home improvement suggested that it was rare to repair the actual drill since it was cheaper to replace it. However, he sharpened the drill bits, and replaced the drill bits more often than the drill itself.

Consequently, the results partly support and partly disagree with the proposition from the literature. The behaviours expressed by the participants might be similar to behaviours of households. This would mean that the proposed mechanisms for increased resource productivity of PSS are weakened. Due to the small sample of external supply side participants, and difference in types of firm they represented, caution should be observed in transferring these results to other contexts. More than anything, more research is needed into the actual behaviours of service providers.

The PSS literature was silent on the question of whether the total service level remained the same when starting to use PSS, compared with self-servicing. The above proposition appears to be based on the assumption that the total service level remains the same and that the service providers deliver the result faster than self-servicing households. The waste prevention assessment (chapter 5), applied this assumption. It is however also conceivable that PSS delivered as a menu of services, would apply standard ranges of service levels. This might mean that the PSS service level might be more or less than the self-servicing level of different households. If the above assumption holds true, this might for instance mean that a household switching to PSS receives a higher service level with the same use of the material artefact due to the speed and efficiency of the service provider. However, the overall resource productivity might not decrease as a result of PSS replacing self-servicing. Conversely, if households are willing to adopt PSS with a lower service level than their self-servicing level without using interim self-servicing to make up for the difference, and in addition, service providers were quicker and more efficient, this would lead to greater savings in the use-phase.

4.3.4 Obsolescence, replacement and disposal

4.3.4.1 Overall

The PSS literature proposed that newer models of a material artefact are more efficient and use fewer resources, such as energy, during the use phase. As a consequence of this, the argument went, it is beneficial to replace material artefacts sooner rather than later, especially when at the time of replacement the material artefact had reached absolute obsolescence. This was suggested to be the case for PSS, since service providers use their material artefacts more intensely than self-servicing households do, and as a consequence wear out their artefacts sooner. For many types of material artefacts this may be true, and therefore the assumption may largely hold true. For some types of material artefacts, however, increased power and consequently increased energy use, is a sales argument. Therefore, newer models of those types of material artefacts have tended to be overall more resource intensive. This has been the case for instance

vacuum cleaners ((AEA Energy & Environment, 2009) (although there are of course a great range of models of different power ranges).

4.3.4.2 Households' replacement and disposal of material artefacts

The PSS literature implied that customers (households) replace their material artefacts before they have reached absolute obsolescence (see section 2.4.2.3). Theoretical literature also supported the prevalence of economic, technological and psychological obsolescence for material artefacts in the possession of households. The findings of the study more or less supported this assumption. Main reasons for material artefacts becoming obsolete or being replaced or both, was that malfunctioning artefacts were thought to be beyond repair, or deemed too expensive to be repaired. If the artefacts were really beyond repair, then they had reached absolute obsolescence. However, in many instances, households assumed they were beyond repair without trying to have them repaired, or felt that another repair would not be cost effective. The latter would be a case of economic obsolescence rather than absolute obsolescence. Another reason for replacing artefacts, or buying additional ones, was the wish for additional features. This technological obsolescence was especially true for drills. None of the participant mentioned dated look of an old appliance as a reason for replacement.

Data on obsolescence was collected in terms of years of ownership of a unit of a material artefact before obsolescence/disposal. In addition, the hours of use before disposal were calculated from the collected use and disposal data. The former may be termed chronological age and the latter operational age of the material artefact. The results showed that some households that replaced their artefact at a relatively younger chronological age, had actually used their artefact for a substantially larger number of hours or cycles than some households that had replaced their artefacts after a longer chronological life. In addition, the operational age of some of the artefacts in the study well exceeded the standard operational age suggested by secondary data on artefact specifications (such as test data on vacuum cleaners). To sum up, chronological age alone is insufficient in determining how much of an artefact's uselife has been spent when a household replaces it; and while many households replace material artefacts due to relative obsolescence (economic, technological or psychological), they have used them for potentially a large share of their operational lives.

While in theory, obsolescence and disposal does not necessitate the procurement of a replacement artefact, certain material artefacts, in particular vacuum cleaners and washing machines were felt to be essential and therefore to necessitate replacement. In some instances, the move to new dwellings (for the households in the North West and the South), had led to new circumstances either requiring replacement of material artefacts or making it redundant. The former was the case for washing machines, since in some instances white goods were included in the new house, or the new house had limited space which necessitates the replacement of separate washing machines and tumble drier for a combined washer-drier. The latter was particularly the case for lawnmowers in the group in South England that had down-scaled from houses to apartments without gardens, but also to some extent in the North West where the new house had a smaller or larger grassed garden felt to require lawnmowers of different specification to the present one.

If households were to keep their material artefacts while using PSS, in order to perform interim self-servicing, since less frequent use would mean that it would take a greater number of years for the material artefact to age in terms of operational uselife. It is difficult to surmise whether households would keep their material artefacts for longer then, or whether they would still replace them after a few years due to psychological obsolescence.

The PSS literature appeared to assume that obsolescence/replacement leads to disposal of material artefacts through the waste stream. The findings from this research indicated that a fair share of households gave obsolete artefacts to friends and kin, and in some instances sold the artefacts, gave them to charity or even kept them. This finding is in line with the theoretical literature. This means that material artefacts may go through additional use cycles outside the focal households, and therefore have longer uselives than indicated by the use-life in a single household. When this is the basis for assessments of the resource productivity of self-servicing, resource productivity of self-servicing may be underestimated.

A fair share of households took their obsolete material artefacts to civic amenity sites. No data were available on the actual waste management routes from the civic amenity sites, such as the proportion of artefacts actually recycled. Consequently, it was not possible to establish whether service providers recycled and remanufactured their obsolete artefacts to greater extent than households, as was suggested in the literature.

Data on the uselives of material artefacts for the different household tasks were collected in the survey and will be used as input in the waste prevention assessment reported in chapter 5.

4.3.4.3 Service providers' replacement and disposal of material artefacts

The PSS literature suggested that service providers keep their material artefacts for as long as possible in order to maximise the use value of them. This could be understood as service providers using their material artefacts until they have reached absolute obsolescence. The findings of this research offered some support for this. For instance, washing machines were used and repaired until they reached absolute obsolescence, in line with the proposition in the literature. The participant for one household activity (garden maintenance) suggested that service providers to try to get more operational life out of their material artefacts beyond the financial depreciation. The findings did not reveal however, whether this equates absolute obsolescence, or relative obsolescence, such as economic obsolescence.

However, there were also indications to the contrary. For home improvement, it seemed that drills were discarded due to relative rather than absolute obsolescence, since the participant deemed it too expensive to repair broken drills. The participant for home improvement did not leave tools to recycling, but binned the drills which would mean disposal to landfill. Further, a participant for the existing supply chain of the property development firm, suggested that replacement of artefacts after a small number of years may be a requirement to have their contract renewed with their customer, in spite of the contract largely being performance based. Consequently, other factors than economic rationality in relation to the use value of the material artefact may come into play. PSS

literature also suggested that the monetary value of the material artefact plays a role. In the case of PSS for household tasks, the material artefacts are relatively inexpensive compared with equipment used in some industrial sectors. Therefore, the importance of use value to the overall profitability of the firm may differ for different sectors.

The PSS literature also proposed that service providers would have incentives and be in a good position to have material artefacts remanufactured and recycled. This proposition derived from the notion of manufacturing firms extending their business to provision of services using their material artefacts rather than selling them. Manufacturers may fall under regulatory producer responsibility. However, the service providers in the present research were not manufacturing firms and therefore did not fall under producer responsibility. Data in the present study did not specify disposal routes for lawnmowers and washing machines. However, data from home improvement and vacuum cleaning did not indicate any further recycling or remanufacturing.

The study did not reveal the proportions of waste management routes for obsolete material artefacts. There was, however, little evidence for remanufacturing occurring.

4.3.4.4 Underlying assumptions on rationality of agents

The literature review identified an implicit assumption underlying the PSS concept: that households' choices and management of material artefacts are driven mainly by motives other than economic ones. The economic incentives would largely be the same for firms and households, but the literature assumes that households do not respond to those economic incentives. The literature seemed to assume that service providers respond to the economic incentives to try to increase the uselives of their material artefacts – and that this is the main economic incentive for firms.

The findings of this research, however, showed that both households and service providers displayed a degree of economic rationality. This may or may not lead to extended uselives of material artefacts. Economic incentives are not always aligned with environmental sustainability. Furthermore, a range of other considerations made up the decision context. These may contribute to overall economic gain, or other maximisation of utility. As regards the service providers, however, the findings of this research suggested that a wider range of issues than merely the uselife of the material artefact formed the decision context for the service provider. Therefore, it may be concluded that the concept requires revision on this point. This is an important contribution of the research to this topic area. More research is needed to shed on the behaviours of service providers, and a more comprehensive view of their incentives and decision context.

4.3.4.5 Innovativeness of service providers

The literature suggested that result-oriented PSS held the greatest potential for resource productivity as it was said to allow service providers to deliver the results in innovative ways without constraints on the means. There was nothing in the results from this research suggesting that the service providers of result-oriented household PSS delivered the results in innovative ways, so as to increase resource productivity. The examples of services in the conceptual literature on PSS come from both business-to-business markets and business-to-consumer markets and a wide range of sectors and

applications. Many of the propositions for how services might benefit the agents and environment have been taken out of their context and translated into eco-services without consideration for conditions in those markets and sectors.

4.4 CONCLUSIONS ON ADOPTION AND CHOICE AND MANAGEMENT OF MATERIAL ARTEFACTS

The qualitative research reported and discussed in this chapter led to the following conclusions on the research questions.

Research question 1 was concerned with households' and service providers' attitudes towards adopting PSS. Overall, households were ambivalent towards adopting PSS. Households were relatively more positive towards PSS for garden maintenance and home improvement than house cleaning and laundry. There was limited willingness among supply-side participants to adopt PSS, although the property development firm was more open to the possibility than its external supply chain partners were. These findings inform the waste prevention assessment, in particular the scenarios on the potential for waste prevention at a community scale 5.5. The policy implications of the findings are also discussed in chapter 7.

Research question 2 was concerned with households' and service providers' conceptions of the factors influencing PSS adoption. The purpose of the research question was to inform decision-makers of factors for adoption requiring intervention, if they wish to promote PSS adoption. Table 17 summarises the findings on households' conceptions of the factors.

Table 17 Summary of findings on the factors influencing households' willingness to adopt PSS

Factors	Summary of findings
Cost and price	Barrier to adoption of PSS. The cost was seen to be unfavourable or even prohibitive.
Professionalism and skills	Both driver and barrier to households' adoption of PSS, depending on how they perceive their own skills and those of the service provider.
Attitudes and behaviours	Neither driver nor barrier to adoption of PSS *ex ante.*
Accessibility and flexibility	Mainly barrier to adoption of PSS as self-servicing was viewed to offer greater flexibility. Could be driver for PSS if it frees up time to be spent on other things than laborious household tasks
Reliability and trustworthiness	Barrier to adoption of PSS. Trust comprised several issues such as trust in (sustained) results, trust in letting service provider into the home, trust in the service provider turning up at the agreed time.
Service recovery	Barrier to adoption. Households thought it would be difficult to get compensation if results of the PSS failed to meet service level agreements.
Reputation and credibility	Both driver and barrier to households' adoption of PSS provided by large firms. Some households thought large firms were more credible,

	and others emphasised the local reputation of small local firms.
Enjoyment	Both driver and barrier to adoption of PSS. Households enjoyed self-servicing for garden maintenance and home improvement more than for house cleaning and laundry.
Environmental potential	Neither driver nor barrier to adoption of PSS.

Table 18 summarises the findings on the supply-side participants' view of the factors influencing adoption of PSS.

Table 18 Summary of findings on the factors influencing supply-side participants' willingness to adopt PSS

Factor	Summary of findings
Information in the external environment	Different ideas in the firm's external environment converged and acted as a driver for PSS. Confusion about the acronym and concept was a barrier.
Market conditions	Barrier to adoption of PSS. The house building sector was risk averse and preferred tried and tested ideas. There was not competitive pressure for PSS. External suppliers saw ample opportunities in business as usual and were concerned over competition from undeclared local service providers if they adopted PSS.
Customer demand and customer relationships	Both driver and barrier to adoption of PSS. Supply-side participants experienced demand from households for services beyond the remedial services included in the warrantee of the house. Due to the experience of providing remedial services, prolonged relationships were perceived to entail costs undermining profits. Managing relationships with a large number of small customers was viewed as more costly than relationships with contract managers from large client firms in the business as usual. There were concerns over bad publicity potentially arising from disagreements with households over the fulfilment of service level agreements, and this spilling over on customer relationships with other firms. The external supply chain doubted there would be sufficient demand.
Regulatory framework	Neither driver nor barrier to adoption of PSS. Policies that the PSS proposed were drivers for adoption, were not drivers in this context.
Corporate competence	Driver and partly barrier to adoption of PSS. Skills existed for provision of services to firms, would need to be adapted to the household market. Competence to assign supply chain partners existed. IT systems were in place but would require adaptation.
Strategic orientation	Barrier to adoption of PSS. There were no market conditions were perceived to favour the strategic orientation of business as usual.
Organisational structure	Neither driver nor barrier to adoption of PSS. The organisational structure affected where in the organisation responsibility for PSS would reside. Division into different functions is a challenge but the participants representing different functions were willing to collaborate and communicate.
Portfolio of offerings	Both driver and barrier for PSS adoption. The portfolio of offerings of the property development firm and its supply chain included provision of services

	(driver), although not revenue generating services to households (barrier)
Cost, revenue and profits	Both driver and barrier to adoption of PSS. Uncertain demand from households was a barrier, in particular sufficient volume of demand in a limited geographic area to maximise the productive time of service providers and avoid unproductive travel time. Demand from households and willingness to pay for services in addition to remedial services under warrantee was a driver. Financial risk of compensation to households was a barrier. (Contrary to the proposition in the PSS literature, the cost of the material artefacts was not mentioned as financial concerns).
Network and supply chain	Barrier to adoption of PSS. The property development firm would provide PSS through their supply chain rather than building in-house capacity. The present supply chain partners were not willing to provide PSS. The property development firm would have to appoint new supply chain partners from local service markets.
Environmental potential	Neither driver nor barrier. The business importance of environmental issues was recognised, but absent evidence on environmental benefits of PSS, the environmental potential was not a driver.

In chapter 7 discussing the implications of the findings of the thesis, it is argued that it is not appropriate to promote adoption of PSS given the uncertain waste prevention potential and risks of increased waste and emissions. Therefore, the findings for research question 2 are not discussed further. The exception is the cost factor for household adoption, which is discussed in chapter 7 in relation to other potential policy measures which may stimulate adoption regardless of waste prevention and environmental potentials.

Research questions 3 and 4 were concerned with households' and service providers' reasoning and behaviours regarding their choice, management and ownership of material artefacts, and how these compared with the propositions in the PSS literature. The purpose of the research questions was to facilitate a critique of the PSS concept, and also to achieve a rich description of behaviours to further the understanding of those behaviours, in addition to the numeric assessments in chapter 5 and 6. These research questions are answered by Table 19 below drawn from the summary table in chapter 2.4.2.4 completed with summarised findings from this chapter.

Table 19 Comparison of propositions in the PSS literature and findings from this research, regarding the choice, ownership and management of material artefacts

Life cycle stage	Propositions in the literature	Findings from this research
Adoption	The manufacturing firm also provides the services. Recognised in the literature that services are sometimes provided by third-party service providers.	See below.
Ownership; eco-design	Ownership of material artefacts by the service providers makes manufacturers act on the incentive to design more durable products. Recognised in the literature that this incentive is weakened when services are provided by third-party service	Disconfirmed – service providers are not manufacturers in this research

	providers.	
Choice	Service providers choose the most efficient material artefact to perform the job (perhaps professional grade).	Partly disconfirmed. Service providers deemed domestic grade material artefacts for PSS to most appropriate for PSS delivery in domestic homes and gardens. It was not possible to establish what would be the most efficient material artefact.
Choice	Households choose material artefacts that are over or underspecified for the job, have limited durability	Not possible to establish appropriate specifications.
Ownership	Households own only one unit of each type of material artefact (underlying assumption)	Partly disconfirmed. Several households owned more than one unit of some types of material artefacts.
Ownership	Households who use services do not own the corresponding material artefact (assumption: give up ownership when starting to use a service).	Disconfirmed. Households wanted to keep material artefacts and maintain interim self-servicing
Ownership	Service providers own the requisite material artefacts, rather than using material artefacts provided by the households.	Partly disconfirmed. A local service provider used material artefacts owned by households.
Use and maintenance	Service providers have greater skills than self-servicing customers, and thereby use material artefacts more efficiently	Not possible to establish the skills and efficiency of service providers
Use and maintenance	The manufacturer-service provider has the incentives to reduce resource use during the use-phase since reduced energy use during the use-phase will benefit the service-provider financially.	Partly disconfirmed. There was little evidence that service providers sought to reduce energy use. Energy savings will accrue to the households rather than service providers
Use and maintenance	Service provider maximise the use-life of their material artefact	Partly disconfirmed. Some used material artefacts until they had reached absolute obsolescence while some replaced them for other reasons, such as breakdowns.
Use and maintenance		
Replacement and disposal	Households replace well-functioning material artefacts due to changing fashion.	Partly disconfirmed. Households replaced material artefacts due to economic and technical obsolescence. Some households used material artefacts beyond the operational lives specified in material artefact specifications
Replacement and disposal	Increased intensity of use leads to material artefacts reaching absolute obsolescence sooner, allowing sooner replacement (with newer more efficient models).	Partly disconfirmed. *If* service providers use material artefacts until absolute obsolescence. Then the operation may be spread out over a long period of time.
Replacement and disposal	Service providers (often being the manufacturers) remanufacture or recycle the material artefacts at their end-of-life	Disconfirmed. The service providers were not manufacturers and there was no evidence of remanufacturing.

This summary shows that there were findings disconfirming most of the propositions. This will be further discussed in a critique of the PSS concept in chapter 7. Specific findings will be used in chapter 5 and 6 to aid the understanding of the various scenarios in the assessment of waste prevention and environmental potential of PSS.

5 WASTE PREVENTION POTENTIAL – SCENARIOS, RESULTS AND DISCUSSION

5.1 INTRODUCTION

The chapter addresses objective 2 to identify the waste prevention potential of the experimental PSS and the following research questions:

1. Do PSS for the household tasks hold the same potential for household waste prevention?
2. How do the behaviours of households and service providers with regard to adoption of PSS and choice and management of material artefacts affect the potential of waste prevention?
3. What is the scale of the potential for waste prevention of the result-oriented PSS?
4. Do result-oriented PSS hold as great potential as has been suggested by previous research?

In this chapter, the model developed in chapter 3 is used to assess the potential for waste prevention of the PSS and a variety of scenarios for those. Basic cases are presented that use primary and secondary data and assumptions from the PSS literature. Scenarios for alternative behaviours of householders and service providers are presented, as well as different adoption rates of PSS. The scenarios address the assumptions used in the basic cases (see section 3.7.4). The assessment identifies and reflects on the scale of the potential for waste prevention in absolute and relative terms. Assessing the potential for waste prevention of PSS in relation to household waste arisings is novel. The scale of the potential for waste prevention may inform decision-makers' on whether to promote adoption of PSS (or adopt PSS); whether to seek to stimulate certain behaviours among households and service providers, initial comparisons with other tools for ways prevention, issues of design of PSS, and issues for further research. The assessment also identifies differences in the potential for the household tasks, and underlying principles behind these. The chapter also reflects on the PSS concept and needs for further research.

The key messages of the chapter are listed below.

- The potential for waste prevention ranged between 0.01% and 0.68% of total annual household waste arisings for the different household tasks in the basic case of one household changing from self-servicing to PSS. The improvement factor compared with the self-servicing ranged between about factor two and factor seven, which was in line with suggestions in the PSS literature. However, for house cleaning waste generation increased by 0.03%. Input values for the basic cases were derived from primary and secondary data and assumptions from the PSS literature.
- The potential for waste prevention differed between the household tasks, due to differing use patterns and operational age of material artefacts at the time of replacement, the number of households served per unit of transport distance, and the relative mass per unit of material artefact.

- Scenarios for alternative behaviours of households and service providers that would lead to higher and lower waste prevention respectively were assessed. Waste prevention potential remained when values for single variables were altered within the ranges evident in primary and secondary data. For garden maintenance, the higher scenario turned the increased waste generation of the basic case into waste prevention potential. When all scenarios were combined, the lower scenarios led to increased waste generation.
- Scenarios involving communities of households with different rates of adoption of PSS suggested that an adoption rate of 25% lead to potentials for waste prevention between 0.02% to 0.16% for different household tasks, when scale up linearly). Increased adoption could lead to economies of scale enabling greater waste prevention than linearly scaled potential. The exact waste prevention potential is not likely to be constant over time.
- The majority of basic cases and scenarios held potential for waste prevention. Compared with the waste generated from the material artefact used in self-servicing, the potential was in line with the suggestions in the PSS literature, factor 2 to factor 7. However, compared with total household waste arisings, which is the more relevant comparison for waste prevention, the potential was modest. There was little comparable quantitative evidence of the potential of other measures for waste prevention. Since many small activities contribute to waste prevention, each measure is likely to be a small share of total waste arisings.

5.2 BASIC CASES

This section presents the basic cases of self-servicing and PSS with the values of the variables and the potential for waste prevention resulting from the use of the model presented in section 3.7.2. After that the resulting waste prevention is shown and discussed.

The variables for the waste prevention assessment were set out in section 3.7.2 and the data collection method and assumptions were set out in section 3.7.3 and section 3.7.4 respectively. Primary data referred to in the descriptions of basic cases are survey responses from participating households and interview data from service providers. The basic cases refer to a single household changing from self-servicing to PSS and giving up ownership of material artefacts.

5.2.1 Basic case garden maintenance

Self-servicing

Input values are presented in Table 20. The weight of the material artefacts used for self-servicing was one of the variables in the assessment of waste prevention potential. The input value for material artefact weight was selected using the specifications of material artefacts used by households as stated in the primary data, and weights of those material artefacts as presented in secondary data from manufacturer and retailer websites. A weight in the middle of the range of the type of material artefacts used by the householders was selected.

According to primary data, a third of the households participating in the study used petrol-powered lawnmowers and two thirds used electric ones. Of the households using electric lawnmowers half used hover mowers and half wheeled rotary mowers. The power of the electric hover mowers were between 1200W and 1500W. The power of the electric wheeled rotary mowers was between 850 and 1400W. The cutting widths of the electric lawnmowers were 32-35 centimetres. The power of the petrol powered wheeled rotary mowers were 3.5 to 3.75 horse powers and the cutting widths were 35 to 46 centimetres. The weights of the electric models identified ranged from 4.5 kg to 14 kg. The mean[28] weight was 8.5 kg. For the petrol powered lawnmowers, weights were identified from manufacturer and retailer websites for lawnmowers of similar power and cutting widths as the ones specified in the primary data. However, it was not possible to identify the specific models of lawnmowers that primary data referred to. Petrol powered lawnmowers of the power and cutting widths typically weighed 29 to 31 kg although there were examples of lawnmowers weighing as little as 26 kg and as much as 40 kg. 30 kg was selected as the variable value for the basic case for the waste prevention assessment of garden maintenance.

On average, the participating households cut the lawn for a period of 30 weeks per year, 0.6 times per week (almost twice every three weeks), and just over 40 minutes per instance although individual households spent as little as 15 minutes or as much as 60 minutes per instance. The growing period is longer in south England than in North England. This means that on average, households in the south of England are likely to mow their lawns for a longer period of the year than households in North England.

The mean chronological uselife of lawnmowers before disposal was 8.7 years although individual uselives ranged from 2 to 22 years. Given the mean annual use of the lawnmower, this means that the lawnmowers would have been used for on average 102 hours at the time of disposal. However, primary data suggests that a household that uses its lawnmower only a few times per year and for a short time each instance but keeps it lawnmower for a large number of year may have used up less of the lawnmowers operational life than a household that uses its lawnmower more frequently and for longer each instance but discards the lawnmower sooner.

PSS

Input values for PSS for the basic case of garden maintenance are listed in Table 20. Primary data suggested that service providers would only use petrol lawnmowers and not electric ones, in order to have power supply that did not require access to the house, rather than relying on power sockets being available. Furthermore, primary data suggested that industrial lawnmowers used for park maintenance would be unsuitable for domestic gardens on housing developments. These domestic gardens tend to be considerable smaller than public or commercial parks, with layouts of shrubs and flowerbeds that require domestic-size lawnmowers. However, primary data suggested

[28] The reader is reminded that the participants are a relatively small number of purposively sampled households, why statistical methods cannot be used. However, numeric values are needed to complete the assessment and therefore, the mean was calculated to select a reasonable value.

that the lawn-mowers used by service providers would be towards the 'higher end' of domestic-size lawnmowers (for instance in terms of power output). Primary data did not specify a mass of the lawnmower used by service providers. Types of lawnmowers were identified from secondary sources such as manufacturer and retailer websites. It was assumed that such lawnmowers would be somewhat heavier than those used by households and a mass was selected within the range available in secondary data sources. Therefore 35 kg was used as the input variable for the lawnmower used by the service provider (see previous section on self-servicing). Subsequent scenarios account for the possibility that service providers use lighter or even heavier lawnmowers.

It was assumed that the service provider would cut the lawn the same number of times per year as the householder, but would complete the task somewhat (about 15%) faster than the self-servicing householder. The PSS literature suggested that service providers would complete task more efficiently due to their skills gained from specialisation.

For lack of current data from England, the operational life of lawnmowers referred to commercial use of lawnmowers in the US before 1990 (Environmental Protection Agency US 1997, p.9–3) It was assumed that the service provider would use the material artefact for its full operational life before discarding it. Primary data also suggested this was likely to be the case.

Table 20 Input values of variables used in the basic case of the assessment of waste prevention potential for garden maintenance when self-servicing households use a petrol powered lawnmower

	Variable name	Self-servicing	Variable name	PSS
Types of lawnmower		Petrol		Petrol
Mass per material artefact	m_s	30 kg	m_p	35 kg
Uselife per material artefact before replacement	l_s	8.7 years	l_p	858 h
Use number of times per year		17		17
Duration per use instance		0.68 hr		0.58 hr
Total use per year per households		11.8 hr	r_p	10 hr

Table 21 Input values of variables used in the basic case of the assessment of waste prevention potential for garden maintenance when self-servicing households use an electric lawnmower

	Variable name	Self-servicing	Variable name	PSS
Type of lawnmower		Electric		Petrol
Mass per material artefact	m_s	8.5 kg	m_p	35 kg
Uselife per material artefact before replacement	l_s	8.7 years	l_p	858 h
Number of times per year		17		17
Duration per use instance		0.68 hr		0.58 hr
Total use per year per household		11.8 hr	r_p	10 hr

5.2.2 Basic case home improvement

Self-servicing

The values for the variables in the basic case of self-servicing for home improvement are listed in Table 22. The weight of the material artefact was selected considering the types of drills used by the householders as reported in the primary data, and the weights of those types of drills as specified in secondary data. Over half of the participants owned more than one drill and about a third of participating households owned one drill. Two households did not own any drill at all. Of the total number of drills owned by the participating households, half were corded and half were cordless. Half of the households owning cordless drills specified the voltage of their drills and half did not. Of the specified voltages, there was an even spread ranging from 10V to 21,5V. According to secondary data, weights for cordless drills of 12V ranged from about 1 kg to 2.5 kg. Most of the cordless drills of 18V were in the weight range of 1.5 kg to 3 kg although there were examples of drills weighing as little as 1 kg and as much as 6.5 kg.

Of the corded drills one had a power of less than 500W, a third (that is 6 drills) were in the power range of 500-700W. Of the remaining drills, three each were within the power ranges 701-900W, 901-1100W and over 1100 W respectively. The weights of drills in the power range of 500-700 W ranged from 1.2 kg to 3.3 kg. The weights of most of the drills in the power range between 700W and 1100W ranged from 1.8 kg to 4.2 kg, however, with one drill weighing as much as 9.7 kg. While the weight of the drills is not strictly related to the power of the drill, the heaviest drills are high-power drills, which according to Which? (2007a) are suitable for hard surfaces such as granite or hard concrete, whereas cordless drills and lower power drills are more suitable for home improvement tasks requiring drilling interior walls or doors.

2 kg was selected as the weight of drills used by self-servicing households in the basic case of the assessment of waste prevention potential of PSS. This was in the middle of the weight range of the cordless drills. Data required for the subsequent environmental assessment were available for a cordless drill but not for corded drills. Therefore, it was also appropriate to base the assessment of waste prevention potential of cordless drills, since the results feed into the environmental assessment. 2 kg was a weight in the middle of the weight range of the drills of lower power, suitable for drilling in interior walls and doors.

According to primary data, the households estimated that they used drills on average 7.6 times per year, for an average of 20 minutes each time. The households replaced their drills after an average of 10.2 years, although the uselives of drills for individual households ranged from 3 to 20 years.

PSS

The values for the variables in the basic case of PSS for home improvement are listed in Table 22.

Primary data reported in section 4.3.1 suggested that the participating service provider would use ‘trade grade’ drills. Since the PSS for home improvement concerned home

improvement tasks indoors rather than more structural tasks on hard stone materials, it was assumed that drills of the highest power range and weight were not appropriate for the basic case of the assessment. Furthermore, Which? (2007a) suggested that smaller drills were easier to use in smaller spaces. Domestic homes were thought to be smaller spaces than commercial and industrial properties, although there are small spaces in the latter as well. Nevertheless, service providers were assumed to use material artefacts of somewhat greater power than households and this was assumed to be reflected in a higher weight of the material artefact. Secondary data suggested that drills of low power tended be lighter and drills of high power tended to be heavier. However, there is not a strict relationship between power and weight, and especially in the middle range it was evident that more powerful drills in some instances were lighter than less powerful ones.

Given the focus on cordless drills stated above, the weight of the drill used in the assessment of the basic case of PSS for home improvement, was set to 2.8 kg. Subsequent scenarios account for the possibility that service providers used lighter or even heavier drills.

Project resources did not allow a measurement of the time that service providers for home improvement actually use drills to complete different home improvement tasks. It was assumed that the service provider would perform home improvement tasks the same number of times per year as the householder, but would complete the task somewhat faster (15% faster) than the self-servicing householder.

Service providers were assumed to use the material artefacts for its full operational life. Results in chapter four suggested that this may be the case in some instances, but it may not be the case if the material artefact is relatively inexpensive or there are other factors incentivising earlier disposal, such as contractual arrangements with clients. In an assessment by Mont (2004d) the design life[29] of one model of cordless drill was 50 hours and another model 150 hours. 150 hours was selected as the uselife of service providers' drills in the basic case of PSS for home improvement, in line with the assumption in the literature (see chapter 2) that service providers choose more durable material artefacts.

Table 22 Input values of variables used in the basic case of the assessment of waste prevention potential for garden maintenance when self-servicing households use a petrol-powered lawnmower

	Variable name	Self-servicing	Variable name	PSS
Types of drill		Cordless		Cordless
Mass per material artefact	m_s	2 kg	m_p	2.8 kg
Uselife per material artefact before replacement	l_s	10.2 years	l_p	150 h
Number of times per year		7.6		7.6
Duration per use instance		0.3 h		0.26 h
Total use per year per household		2.3 h	r_p	2.0 h

[29] Here, design life is assumed to equate to operational life.

5.2.3 Basic case house cleaning

Self-servicing

The values for the variables in the basic case of self-servicing for housecleaning are listed in Table 23. The weight of the material artefact was selected considering the types of vacuum cleaners used by the householders as reported in the primary data, and the weights of those types of vacuum cleaners as specified in secondary data. Most of the participating households owned only one vacuum cleaner, but 3 out of the 22 households had two vacuum cleaners. Two thirds of all the vacuum cleaners were upright models and one third was cylinder models. For each type of model, the participants were asked to estimate which out of two weight ranges their vacuum cleaner belonged to[30]. For upright vacuum cleaners, the weight ranges were below 7 kg and between 7 and 9 kg respectively. For cylinder vacuum cleaners, the weight ranges were below 5 kg and between 5 and 9 kg respectively. Within each weight range one weight was chosen to calculate the mean weight of all the vacuum cleaners. For upright vacuum cleaners, 6 kg was used to represent the weight range below 7 kg. 8 kg was used to represent the weight range between 7 and 9 kg. For cylinder vacuum cleaners, 4 kg was used to represent the weight range below 5 kg and 7 kg was used to represent the weight range between 5 and 9 kg. Using these weights, the mean weight of all vacuum cleaners was 7 kg.

On average the households vacuum cleaned for 1.8 hours per week, which means that they spent 94 hours per year, not taking into account any extra cleaning that may be done such as 'spring cleaning'.

On average the participants used their vacuum cleaners for 7.9 years before discarding them although the uselife for individual households ranged from 2 to 15 years. The average chronological use life of vacuum cleaners and the average use per year would mean that at the time of disposal, the vacuum cleaners have reached an operational age of 743 hours. That is considerably longer than the minimum requirement for the lifespan of the motor of vacuum cleaners for the EU Eco-label for vacuum cleaners (Official Journal of the European Union 2003a).

PSS

Primary data from a single service provider suggested that a light industrial-type vacuum cleaner weighing 6.5 kg that is, less the ones used by the households.

It was assumed that the service provider would clean the house the same number of times per year as the householder, but would complete the task somewhat faster (about

[30] They were also asked to specify the power range, make and model of their vacuum cleaner. However, some of the models had been discontinued and data on the weights were therefore not available.

15% faster) than the self-servicing householder. Thus it was assumed that service providers would be able to perform the task in 1.5 hours.

No data were available on the uselives of light industrial vacuum cleaners. It was assumed that service providers would choose more durable material artefacts than self-servicing households. Therefore, the uselife of service providers' vacuum cleaners was assumed to be 1000 hours.

Table 23 Input values for variables used in the basic case of the assessment of waste prevention potential for house cleaning

	Variable name	Self-servicing	Variable name	PSS
Types of vacuum cleaner		Upright		Light industrial
Mass per material artefact	m_s	7 kg	m_p	6,5 kg
Uselife per material artefact before replacement	l_s	7.9 years	*ls*	1000 hr
Duration of use per week		1,8 hr		1,5 hr
Total use per year		94 hr	r_p	80 hr

5.2.4 Basic case laundry

Self-servicing

Values for the variables in the basic case of self-servicing for laundry are listed in Table 24. Data on washing machines for the subsequent environmental assessment were derived from Rüdenauer *et al.* (2004). According to their study, washing machines of a medium price segment weighed 76 kg. This was selected as the weight of washing machines used by self-servicing households for the basic case of the assessment of waste prevention potential of PSS.

In their questionnaire responses households stated the capacity of washing in terms of kg of washing of their washing machines. The mean capacity was 6.6 kg. This was well in line with Which? (2007b) who suggested that a washing machine with a capacity of 6 kg would be adequate for most households whereas washing machines with a capacity of 7.5 kg would be able to accommodate a few extra garments. Households washed on average 4.2 cycles per week. Given the mean capacity of the washing machines and the number of cycles washed per week, the total amount of washing washed per year would be 1,418 kg.

The participating households used their washing machines on average 8.5 years before discarding them.

PSS

Primary data suggested that service providers would use laundrette type washing machines. The weight of a medium-capacity laundrette type washing machine was selected for this assessment (Electrolux professional, 2004).

For the other household tasks, r_s was specified as the time self-servicing households spent performing the household task, and r_p was the time required by the service provider to achieve the equivalent result. For laundry, the result is quantified in terms of the amount of laundry required by households in terms of kg per annum. This amount is the same for self-servicing and PSS. However, the washing machines used by service providers have much greater capacities than those of self-servicing households. That washing machine had a drum capacity of 20 kg of laundry per washing cycle. The uselife of service providers' washing machines in terms of use cycles as specified below are then converted to amount of laundry it is able to wash in its operational life.

The laundry of a household would need to be co-washed with that of other households in order to use the full drum capacity. On average each household generated 27 kg of laundry per week which would not be two full loads of the laundrette type washing machine. In addition, the laundry might need to be divided into different temperature fractions.

Stahel, (1992) suggested that a semi-commercial washing machine has a uselife of 8,000 to 15,000 washing cycles. 12,000 washing cycle was selected as the uselife of service providers' washing machine in this assessment. Given the drum capacity and uselife of the washing machine, the total life span of the washing machine in terms of maximum amount of washing would be 240,000 kg of washing.

Table 24 Input values for variables used in the basic case of the assessment of waste prevention potential for laundry

	Variable name	Self-servicing	Variable name	PSS
Types of washing machine		Household		Laundrette type
Mass per material artefact	m_s	76 kg	m_p	205 kg
Uselife per material artefact before replacement	l_s	8.5 years	l_p	12,000 cycles
Uselife per material artefact before replacement (mass of washing before replacement)		N/A		240,000 kg
Capacity per material artefact per cycle		6.6 kg		20 kg
Number of cycles per year		218 cycles		N/A
Total use per year (mass of washing)	r_s	1418 kg	r_p	1418 kg

5.3 WASTE PREVENTION POTENTIAL OF THE BASIC CASES FOR THE DIFFERENT HOUSEHOLD TASKS

The previous section described the basic cases of PSS for the four different household tasks. Table 25 below shows the relative waste prevention potential per household per annum of the basic cases.

Table 25 Absolute and relative waste prevention for one household changing from self-servicing to PSS

Household tasks	Waste prevention		
	Absolute kg Per annum	Relative % by weight of waste from the material artefact in self-servicing	Relative % by weight of total annual household waste
Garden maintenance (petrol lawnmower)	-2.9	-84	-0.24
Garden maintenance (electric lawnmower)	-0.4	-43	-0.03
Home improvement	-0.11	-54	-0.01
House cleaning	0.37	37	0.03
Laundry	-8	-85	-0.68

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

The relative waste prevention pertains to the percentage reduction for the particular material artefact compared with self-servicing, for a household and not for a community of households comprising both adopters and non-adopters. This is the type of measure typically used in the PSS literature, referred to as improvements by a factor (section 2.4.3) or a percentage reduction in the use of various resources. The basic cases of laundry and garden maintenance using a petrol lawnmower showed potentials around factor 7. There was little quantitative evidence for result-oriented PSS in households in the literature, although reported improvements for PSS in other sectors or other types of PSS were in the range of factor 1.7 to factor 10 (Heiskanen & Jalas, 2003)[31]. The basic cases adhered to many of the assumptions in the PSS literature, which primary research reported in chapter 4 suggested may be questioned. Subsequent sections explore alternative scenarios.

Compared with the total amount of waste generated by a household annually, the waste prevention of PSS is a considerably smaller share. According to national statistics , each person in England generates about 500 kg of waste per person and year (Department of Environment, Food and Rural Affairs, 2012). The average number of persons per household in Great Britain in 2008 was 2.36 (Department of Enterprise, Trade and Investment, 2008). On average the total annual household waste arising per household would then be 1185 kg. According to (Emery *et al*. 2003) relatively more affluent households, such as households living in semi-detached houses, generate more waste than less prosperous households. The waste prevention potential in relation to the total annual household waste arisings for a household, PSS for each household task ranges from 0.01% to 0.68%. If a household were to use PSS for all four household tasks, the waste prevention compared with total household waste arisings would be about 1%,

[31] The review of literature reported in chapter 2, noted that descriptions of the systems and contexts assessed and the method for assessment were underreported,and also that actual case studies based on primary research was relatively scarce. This limits the ability for comparison.

which is about half of the WEEE fraction in the household waste stream according to the waste statistics by (Burnley, 2007).

Both the scale of the waste prevention potential, and the usefulness and importance of the absolute and relative measures of waste prevention are further discussed in section 5.6.

The waste prevention potential of the experimental PSS differed across the household tasks. Whether the waste prevention was expressed in absolute terms or relative terms influenced which household task showed the greatest waste prevention potential. The discussion below reveals the reasons behind these differences.

PSS for garden maintenance and home improvement showed greater potential for waste prevention in relative terms, than laundry and house cleaning. This is due to the use-patterns and replacement rates of the material artefacts in the context understudy, that were reported by the participants in the survey questionnaires. Lawn-mowers and drills respectively, were used relatively infrequently and for relatively short durations in each use instance. Even if households kept the material artefact (drills and lawnmowers) for a number of years, at the time of replacement, their operational age was a relative small share of their functional life. For instance, consider the basic case of home improvement (see Table 22). If self-servicing households only used a drill for a total of 2.5 hours per year, and replaced the drill after ten years, then the operational age of the drill at the time of replacement was 25 hours. The operational life, however, might be 100-150 hours. Therefore, only 16-25 % of the functional life had been expended at the time of replacement. Service providers on the other hand were assumed to use their material artefacts until they had reached absolute obsolescence. Due to the small share of operational life utilised in drills and in the case of self-servicing, potential waste prevention is relative large when PSS replaces self-servicing.. For house cleaning, on the other hand, self-servicing households may use their vacuum cleaners 95 hours per year, for 8 years before they replace their vacuum cleaners. This means that the vacuum cleaners are used for 760 hours before replacement, which exceeds the estimated[32] functional life of a vacuum cleaner, and is 76% of the assumed[33] uselife of vacuum cleaners used by PSS providers. These results, however, rely on the assumption that service providers will use their material artefact until they reach absolute obsolescence.

In spite of the waste prevention potential of home improvement in relative terms, drills had too low mass per unit to lead to much waste prevention in terms of mass of waste prevented. Laundry and garden maintenance were the household tasks for which the experimental PSS held the greatest waste prevention potential in terms of mass. These household tasks required the heaviest material artefacts, namely washing machines and lawn-mowers. Washing machines weighed over 75 kg per piece and petrol lawnmowers

[32] Official Journal of the European Union (2003a)

[33] Vacuum cleaner manufacturers were not willing to offer an estimate of the functional life of professional grade vacuum cleaners. Therefore, a functional life in theory three times that of domestic grade vacuum cleaners, and in practice twice that of domestic grade vacuum cleaners, was assumed.

weighed 25 kg per piece, while drills only weighed 2 kg. As a consequence, improved resource productivity for laundry resulted in a greater reduction in the stock of washing machines in terms of mass, than for home improvement. On the one hand, this suggests that PSS to achieve household waste prevention should concentrate on large material artefacts. However, finding large material artefacts used in household tasks for result-oriented PSS may be difficult. The development of the experimental PSS (see appendix A) considered household waste statistics, material artefacts corresponding to the household waste fractions and household tasks for which the material artefacts are used, together with interview and focus group data suggesting for which household tasks there might be potential demand for PSS. Other types of PSS, such as use-oriented PSS may involve large white goods. Use-oriented PSS such as renting white goods and furniture, or sharing lawnmowers or laundry facilities were not pursued in this research, since the initial primary research suggested less willingness to adopt such PSS than result-oriented PSS. Decision-makers need to address both potential gains arising from the characteristics of the material artefacts, the characteristics of the waste fraction, willingness to adopt PSS for different household tasks, and use-regimes when considering for which household tasks PSS is worthwhile, if any.

Of the household tasks under study, garden maintenance (where self-servicing households used petrol powered lawnmowers) held the second largest potential for waste prevention when considering both relative and absolute waste prevention (Table 25). Furthermore, it was a household task which the householders expressed relatively greater willingness to adopt PSS (section 4.2.1.10). For laundry on the contrary, the householders indicated a limited willingness to give up self-servicing and adopt PSS. Therefore, the waste prevention potential of laundry seems unlikely to be realised in the near to medium term future.

For one household task, namely house cleaning, the experimental PSS did not lead to waste prevention at all. Instead, more waste was generated when PSS was used than self-servicing (Table 25). The scope for waste prevention potential depends on the PSS providers using a smaller stock of material artefacts than self-servicing households. However, the delivery of the result-oriented experimental PSS also includes the use of vehicles (and other infrastructure that were not included in this assessment). The service providers drive to the housing development to perform the garden maintenance housecleaning, home improvement, or collect and return the laundry. Therefore, the stock of the material artefacts used by the service providers (lawn-mowers, vacuum cleaners, drills), must be so much smaller that it compensates for the material in the transport vehicle. In addition, greater service yield of transport improves the chances of the reduction in the stock of material artefacts being sufficient to offset the mass of the transport vehicles. Service yield refers to the amount of service delivered per unit of transport, such as number of houses cleaned to the desired service level per journey of a certain distance. Vacuum cleaners had a relatively low mass per unit and therefore PSS did not result in sufficient reduction of the mass of vacuum cleaners used and discarded to offset the mass of the vehicles. The material artefacts used for home improvement, namely drills, were also small with low mass per unit compared with the material artefacts used for the other household tasks. However, while drills are lighter than vacuum cleaners, the service yield by the transport was higher for home improvement, and therefore home improvement still had a positive waste prevention potential.

The service yield by the transport depends on the geographical density of demand, and on the design and logistics of the PSS. The basic cases assumed a distance of 3 km between the service depots and households, and no distance between households that were served the same day. Scenarios in section 5.4.2. explore the effects of distances of 1.5 km and 5 km respectively. For the experimental PSS for laundry, the service yield of transport depends on the load capacity the vehicle and the distance between the households and the laundry. For the other three household tasks, the vehicle is used to transport personnel and material artefacts used by the personnel. Therefore, the service yield of transport depends on whether one person travels alone in a car and services households alone, or whether two persons travel together and perform the service in a household together and thereby manage to service more households in the same amount of time with the same amount of transport. Further research resourced to optimise PSS design and logistics could address this issue. Consequently, PSS involving small material artefacts could still hold waste prevention potential.

The main material artefact used to performing the household task (for instance vacuum cleaner) and the vehicle required for delivering the PSS were the only material artefacts in the assessment of PSS. PSS are likely to involve a number of additional material artefacts such as buildings and office equipment. If these elements of the PSS were included in the assessment, the question is whether the improved resource productivity in the material artefact is sufficient to still generate an overall waste prevention for PSS compared with the self-servicing system.

These results offer a view of a particular context and time. Material artefacts and behavioural patterns co-evolve over time (McMeekin & Southerton, 2012). However, some of the characteristics of the different household tasks are likely to persist, at least in the short to medium term. For instance, it seems plausible that households will perform house cleaning and laundry more frequently than home improvement, due to the needs for and social norms for hygiene, compared with the needs and norms related to home improvement, particularly in the context of new houses. Likewise, while the size of each type of material artefact might differ considerably, the relative sizes of the material artefacts used for the different household tasks would seem to remain. Having said this, it may be that a number of additional complementary material artefacts are used for each household task. For instance, several different drills may be owned and used, alongside air compressors and other auxiliary tools. This may be the case for both self-servicing and PSS. Further research is needed into each household activity, both concerning households' and service providers' choice and management of material artefacts and the prevalence of multiple artefacts, be it multiple units of the same or complementary material artefacts.

5.4 SCENARIOS FOR CHOICE AND MANAGEMENT AND OWNERSHIP OF MATERIAL ARTEFACT, TRANSPORT DISTANCE

The basic case of the assessment of waste prevention was premised on a number of assumptions set out in section 3.7.4. This section presents scenarios for alternative behaviours of households and service providers and the resulting waste prevention potential. The scenarios address different assumptions set out in the basic cases and show the range of potential waste prevention. It indicates where alternative behaviours

on individual variables are able to change the outcome from waste prevention to increased waste generation or vice versa. It also facilitates the transfer of the results to different contexts and informs judgement of the worth of pursuing PSS to achieve waste prevention.

5.4.1 Choice and management: mass and uselife of material artefacts

Table 26 shows the mass of waste prevented when households and service providers respectively choose material artefacts lighter or heavier than in the basic case. Higher waste prevention arises when households choose heavier material artefacts at the same time as service providers choose lighter ones. The inverse leads to lower waste prevention. Thus, higher waste prevention of PSS may be the consequence if households choose heavier material artefacts. However, overall waste generation in terms of mass would decrease if both households and service providers use lighter material artefacts.

In the basic cases, the mass of material artefacts was selected on the basis of participants' statements on specifications of material artefacts, and a mass in the middle of the range of those specifications, based on secondary data. Mass in the lower and higher end respectively of the specifications were used as values for the scenarios. The percentage increase or decrease in mass compared with the basic case is not the same for all household tasks, as the ranges of mass differ between the types of material artefacts.

Table 26 suggests that different choices of material artefacts may substantially improve or reduce the waste prevention potential when the relative waste prevention is considered in relation to the waste generation from the material artefact in the case of self-servicing. When considering the relative waste prevention potential in relation to total annual household waste arising from one household, the relative difference between the higher and lower scenarios is still substantial. However, this potential is still very small and it is an open question whether this difference is significant for decision-makers. The worth of the scale of the potential waste prevention is further discussed in section 5.6.1.

On its own, the choice of material artefacts of a mass different than in the basic case, does not endanger the potential waste prevention. For house cleaning for which the basic case resulted in increased waste generation, the higher scenario leads to a potential for waste prevention. For the other household tasks, potential for waste prevention remained even in the lower scenarios.

Table 26 Input values of the mass of material artefacts into the assessment in alternative cases, and the resulting absolute and relative waste prevention for one household for the higher scenario, basic case and lower of choice of material artefacts artefacts (mass per unit of material artefacts

	Self-Servicing	**PSS**	**Waste prevention**		
	Kg per unit of material artefact	Kg per unit of material artefact	Absolute Kg per annum	Relative % by weight of waste from the material artefact in self-servicing	Relative % by weight of total annual household waste
Garden maintenance					
Petrol lawnmower					
Higher waste prevention	35	30	-3.5	-88	-0.32
Basic case	30	35	-2.9	-84	-0.24
Lower waste prevention	26	40	-2.4	-79	-0.19
Electric lawnmower					
Higher waste prevention	11	30	-0.8	-60	-0.07
Basic case	8.5	35	-0.4	-43	-0.03
Lower waste prevention	6	40	-0.1	-10	-0.01
Home improvement					
Power drill					
Higher waste prevention	2.8	1.8	-0.21	-77	-0.018
Basic case	2	2.8	-0.12	-61	-0.010
Lower waste prevention	1.2	3.8	-0.03	-23	-0.003
House cleaning					
Vacuum cleaner					
Higher waste prevention	9	5	-0.05	-4	-0.004
Basic case	7	6.5	0.37	37	0.031
Lower waste prevention	5	8.5	0.74	117	0.062
Laundry					
Washing machine					
Higher waste prevention	97	183	-10	-89	-0.84
Basic case	76	205	-8	-85	-0.68
Lower waste prevention	72	282	-7	-78	-0.59

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

Table 27 shows the amount of waste prevented when households and service providers respectively use their material artefacts for shorter or longer before replacing them. It suggests that different behaviours in terms of use before replacement of material artefacts may substantially change the waste prevention potential. The higher scenario for house cleaning turned the increased waste generation in the basic case into a potential for waste prevention. For the other household tasks potential for waste prevention remained in the lower scenarios.

Table 27 Input values of the uselives of material artefacts into the assessment in alternative cases, and the resulting waste prevention, for the better, standard and worse cases of uselives of material artefacts

	Self-servicing	**PSS**	**Waste prevention**		
	Uselife of material artefact before replacement		Absolute	Relative	Relative
	Years	Hour	kg	%	%
Garden maintenance	Chronological uselife	Operational uselife	per annum	By weight of waste from material artefact used in self-servicing	By weight of total annual household waste arising s for one household
Petrol lawn mower					
Higher waste prevention	7.0	1030	-3.8	-89	-0.32
Basic case	8.7	858	-2.9	-84	-0.24
Lower waste prevention	10.4	686	-2.2	-77	-0.19
Electric lawnmower					
Higher waste prevention	7.0	1030	-0.7	-59	-0.06
Basic case	8.7	858	-0.4	-43	-0.03
Lower waste prevention	10.4	686	-0.2	-19	-0.02
Home improvement					
Power drill					
Higher waste prevention	8.2	180	-0.17	-71	-0.014
Basic case	10	150	-0.12	-61	-0.010
Lower waste prevention	12.2	120	-0.08	-47	-0.007
House cleaning					
Vacuum cleaner					
Higher waste prevention	6.3	1200	0.02	1	0.002
Basic case	7.9	1000	0.37	37	-0.031
Lower waste prevention	9.5	800	0.61	82	-0.051
Laundry		Wash cycles			
Washing machine					
Higher waste prevention	6.8	14400	-10	-89	-0.84
Basic case	8.5	12 000	-8	-85	-0.68
Lower waste prevention	10.2	9600	-6	-77	-0.51

The PSS literature suggested that result-oriented PSS might motivate the service providers to innovate so as to achieve the desired results (for instance neat lawn, clean floors, clean clothes and linen) in a much more resource productive way. Such innovation might for instance involve new methods and equipment (Tukker, 2004). In the present research, however, there was little indication of such innovation taking place (see section 4.3.4.5). Hypothetically at least, the question arises of the extent and speed with which such new practices might spread to self-servicing households. It could be that the potential new practice that was developed in service firm remains in the commercial domain. On the other hand, if the new practices diffuse to self-servicing households after some time, the improvement in resource productivity of the PSS may only be temporary. Nevertheless, the hypothetical improvement in resource productivity of the self-servicing and the commercial service respectively compared with previous practices may be improved and this is likely to be beneficial for society as a whole.

As was indicated in section 4.3.1.2 service providers might seek material artefacts that are able to perform several different types of jobs for different types of customers. This might lead to heavier material artefacts being used in households and limited the potential for household waste prevention. On the other hand, such choice of material artefact, might potentially lead to greater resource productivity for the service firm on the whole, it means that it can provide its services with an overall smaller stock of material artefacts than if it has a range of different specification material artefacts.

5.4.2 Transport distance

To deliver the PSS, a vehicle is used to take the staff and material artefacts to the household, or to collect and deliver laundry. This was an additional material component in the PSS compared with self-servicing. The amount of material attributable to PSS for each household task depends on how much PSS may be delivered within the uselife of the vehicle. If the uselife of the vehicle is defined as a distance, then the amount of material in the vehicle attributable to PSS depends in part on the distance between the service depot and the households. Consequently, this distance may affect the potential for waste prevention of the PSS. Table 28 below sets out the distances in the different scenarios, and the resulting potential for waste prevention.

Table 28 Input values of the scenarios for transport distances and the resulting absolute and relative waste prevention for one household for the higher scenario, basic case and lower scenarios for transport distances

	Self-servicing	PSS	Waste prevention		
	Transport distance (km)		Absolute Kg	Relative %	Relative %
			Per annum	By weight of waste from material artefact used in self-servicing	By weight of total annual household waste arising s for one household
Gardening					
Petrol lawnmower					
Higher waste prevention	0	1.5	-3	-86	-0.25
Basic case	0	3	-2.9	-84	-0.24
Lower waste prevention	0	5	-2.8	-81	-0.24
Electric lawnmower					
Higher waste prevention	0	1.5	-0.5	-50	-0.04
Basic case	0	3	-0.4	-43	-0.03
Lower waste prevention	0	5	- 0.3	-32	-0.03
Home improvement					
Higher waste prevention	0	1.5	-0.14	-71	-0.012
Basic case	0	3	-0.12	-61	-0.010
Lowest waste prevention	0	5	-0.09	-47	-0.008
House cleaning					
Higher waste prevention	0	1.5	-0.02	-2	-0.002
Basic case	0	3	0.37	37	0.031
Lower waste prevention	0	5	0.79	89	0.067
Laundry					
Higher waste prevention	0	1.5	-8	-86	-0.68
Basic case	0	3	-8	-85	-0.68
Lower waste prevention	0	5	-7	-83	-0.59

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

Like the scenarios on the mass and uselives of the material artefacts, the lower scenarios for transport distances do not negate the waste prevention potential whereas the higher scenario for house cleaning is able to tip the balance and achieve waste prevention. The scale of the potential is similar to the scenarios on the mass and uselives of material artefacts.

5.4.3 Service volume per annum – time taken to complete the task

One of the assumptions in the PSS literature was that service providers would generate the same results more efficiently than the customers, due to their supposedly superior skills (see section 3.7.4). The basic case of the assessment of waste prevention potential was premised on the assumption that the results for self-servicing and PSS are equal and that service providers achieve the results about 15% faster than the households (section 3.7.1). The scenarios in this section assess the waste prevention potential if service

providers take as long as or longer than the households to perform the task. These scenarios cover the possibility that the results are the same but that the service providers are not faster than the households. It also covers the possibility that service providers generate a better result but produce more of the service than self-servicing households do. For instance more cleaning is done and to a better standard than self-servicing. Results from interviews and focus groups suggested that some householders would demand better results of service providers than they do of their own self-servicing (section 4.2.1.2).

Any actual productivity gains in the use of PSS would need to be established by further research. The scenarios here are based on broadly the same changes in productivity for all four household tasks. However, productivity gains of PSS may differ between different household tasks (Skatteverket, 2011).

Table 29 shows the input values used in the scenarios. The other variable values are the same as in the basic cases. Unlike the scenarios for the other variables, the basic case includes the highest waste prevention potential, since the service providers were assumed to achieve the result faster than households. In the lower scenario, service providers were assumed to take as long as households. In the lowest scenario, service providers were assumed to take about 15% longer than the self-servicing households.

Laundry is not included in the scenarios since the service volume does not depend on the time taken to complete the task, but on the mass of washing to be washed[34].

[34] Certainly, the duration of a washcycle for the laundrette type washing machines used by the service provider might affect the amount of laundry that the service provider is able to wash in any given period of time. This in turn might affect the resource productivity of the PSS. However, this has not been modelled in the present study.

Table 29 Input values of the scenarios for the service volume per annum (time taken to complete task) and the resulting absolute and relative waste prevention for one household for the higher scenario, basic case and lower scenarios.

	Self-servicing	**PSS**	**Waste prevention**		
	Time taken to complete the task				
	Hours	Hours	Absolute Kg	Relative %	Relative %
			Per annum	By weight of waste from material artefact used in self-servicing	By weight of total annual household waste arising s for one household
Garden maintenance					
Petrol lawnmower					
Basic case			-2.9	-84	-0.25
Lower waste prevention			-2.8	-82	-0.24
Lowest waste prevention			-2.8	-80	-0.24
Electric lawnmower					
Basic case	11.8	10	-0.4	-43	-0.034
Lower waste prevention	11.8	11.8	-0.3	-35	-0.025
Lowest waste prevention	11.8	13	-0.3	-30	-0.025
Home improvement					
Basic case	2.3	2	-0.12	-61	-0.010
Lower waste prevention	2.3	2.3	-0.11	-58	-0.009
Lowest waste prevention	2.3	2.6	-0.11	-55	-0.009
House cleaning					
Basic case	94	80	0.37	37	0.031
Lower waste prevention	94	94	0.42	47	0.035
Lowest waste prevention	94	110	0.52	59	0.044

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

The lower and lowest scenario did not negate the potential for waste prevention. However, since there was no higher scenario, PSS for house cleaning led to increased waste generation in all scenarios. The scale of the potentials was similar to those in the scenarios on mass and uselives of material artefacts and transport distances.

5.4.4 Ownership of material artefacts

The scenarios in this section consider the possibility that households keep ownership of material artefacts and use them to perform interim self-servicing while using PSS. Much of the PSS literature assumed that households who use PSS do not own the material artefact when using PSS (see 2.4.2.1). Many of the case studies on PSS in the literature concerned use-oriented PSS such as renting, leasing or sharing material artefacts. Related literatures however suggested that consumers experience greater pain at giving up ownership of something that has been in their possession than enjoyment of acquiring a material artefact (see section 2.5.2.1). This research concerned result-oriented PSS and the results from the focus groups and interviews (section 4.3.2.1) suggested that many households would keep the material artefacts even if they adopted

result-oriented PSS for the household tasks in this study. For instance, if a household used PSS for housecleaning, they would still like to have a vacuum cleaner in their possession to perform interim self-servicing.

The input variables for the self-servicing before adoption of PSS, and PSS respectively are the same as those in the basic cases (see section 5.2). Households' opinions differed concerning requirements of material artefacts retained for intermittent self-servicing. Some householders thought that material artefacts of lower capacity, for instance in terms of size or power, would suffice for intermittent self-servicing. Others felt that the same capacity would be needed as for self-servicing without PSS, since the material artefacts would need to 'be up for the job' even if the task was only performed rarely (section 4.3.2.1). The scenarios assume the former and that this is manifest in a smaller mass of the material artefacts. The following examples present the logic behind this assumption: intermittent vacuum cleaning or lawn-mowing may be performed to tidy up the home before having guests. Since the main share of the dust and dirt, and length of grass respectively, is handled by the PSS, this intermittent self-servicing is not thought be as demanding on the material artefact as if the household task would be performed entirely by self-servicing. While lower power is not always synonymous with lower weight, this is the assumption made in the scenarios on ownership of material artefacts while using PSS. As input values for the weight of these material artefact, weights in the lower ranges of those identified in secondary data in the basic cases were used. Laundry is the exception, where the weight of a compact washing machine was used in the scenario, which was not considered in the basic case.

As input values for the uselives of these material artefacts, chronological uselives twice as long as those identified from primary data were used. This assumes that the households would be less prone to replace their material artefacts to conform to fashion trends or to get additional functionality offered by a newer model. However, the material artefacts would be less likely to break down due to wear and tear. Given the limited time the material artefacts would be in operation, the full operational lives would not have been spent at the end of their chronological lives.

Table 30 Values used for the mass and uselives of the material artefacts in the scenario where households retain ownership of material artefacts to perform intermittent self-servicing while using PSS, and the resulting waste prevention.

	Material artefacts owned and used for interim self-servicing while using PSS		**Waste prevention**		
	Mass kg	**Uselife** years	Absolute Kg Per annum	Relative % of waste from the material artefact in self-servicing	Relative % of total annual household waste
Garden maintenance *petrol lawnmower*	26	17	-2.9	-88	-0.2
Garden maintenance *electric lawnmower*	6	17	-0.4	-44	-0.03
Home improvement	1.5	20	-0.04	-22	-0.003
House cleaning	5	16	0.6	72	0.05
Laundry	50	17	-4.6	-52	-0.39

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

Households retaining ownership and use of material artefacts while using PSS did not negate the potential for waste prevention that occurred in the basic cases of garden maintenance, home improvement and laundry. PSS for house cleaning led to increased waste generation both in the basic case and the scenario where households keep ownership and use of their vacuum cleaners.

5.4.5 Combination of scenarios

The above scenarios assessing changes in one variable at a time, showed that the changes to an individual variable did not eradicate the waste prevention potential, whereas the higher scenarios for house cleaning was able to turn the increased waste generation in the basic case, into waste prevention. This section considers a combination of all lower scenarios and all higher scenarios respectively presented in the previous sections. Table 31 shows the potential for waste prevention of the combination of scenarios.

Table 31 Absolute and relative waste prevention potentials for a combination of all higher and lower scenarios respectively.

	Waste prevention		
	Absolute kg per year	Relative % of waste from the material artefact in self-servicing	Relative % of total annual household waste
Garden maintenance			
Petrol lawnmower			
Higher waste prevention	-4.6	-93	-0.39
Basic case	-2.9	-84	-0.24
Lower waste prevention	0.04	2	0.03
Electric lawnmower			
Higher waste prevention	-1.2	-77	-0.10
Basic case	-0.4	-43	-0.03
Lower waste prevention	0.79	137	0.07
Home improvement			
Higher waste prevention	-0.3	-88	-0.03
Basic case	-0,1	-61	-0.01
Lowest waste prevention	0.1	128	0.01
House cleaning			
Higher waste prevention	-1	-52	-0.08
Basic case	0.37	37	0.03
Lower waste prevention	2	401	0.17
Laundry			
Higher waste prevention	-13	-93	-1.10
Basic case	-8	-85	-0.68
Lower waste prevention	-1.8	-25	-0.15

Note: Negative numbers means reduction in waste, that is waste prevention. Positive numbers mean increased waste generation

For two of the household tasks, namely garden maintenance and home improvement the combination of the lower scenarios negated the potential for waste prevention and led to increased waste generation. Since even the basic case of house cleaning lead to increased waste generation, the lower scenarios of PSS lead to increased waste generation for three out of the four household tasks. The combination of higher scenarios led to waste prevention potential for all four household tasks. Thus, while for many scenarios there is potential for waste prevention, this depends on a combination of behaviours concurring, and the avoidance of a combination of behaviours.

5.5 SCENARIO: DIFFERENT ADOPTION RATES FOR PSS

In the previous sections, the potential for waste prevention for a single household was presented and discussed. This section shows the potential waste prevention for a community of households when different shares of households adopt PSS.

The results reported in chapter 4 suggested that households' willingness to adopt PSS was limited at the present time, or that there were other constraints on adoption in spite

of willingness. Overall, the willingness to adopt PSS was greater for garden maintenance and home improvement than for house cleaning and laundry. Supply chain representatives would like to see all households contractually committed to the use of PSS for a period of time in order to ensure geographical density of demand required to guarantee profitability. A scenario may therefore be a housing development for households who all commit to the use of PSS when living on that housing development. However, such adoption rates would seem likely to be restricted to relatively few housing developments in the short to medium term, whereas it would be possible to conceive of lower adoption rates in contexts outside the housing developments under study.

Table 32 shows the potential for waste prevention when the basic cases for a single household are scaled up linearly to a housing development comprising 200 households.

Table 32 Absolute and relative waste prevented when different shares of households on a housing development comprising 200 households adopt PSS

Share of house-holds adopting PSS	Garden maintenance			Home improvement			House cleaning			Laundry			Total for all four household tasks
	Absolute	Relative	Relative	Absolute	Relative	Relative	Absolute	Relative	Relative	Absolute	Relative	Relative	Absolute
%	kg	% by mass	% by mass	kg	% by mass	% by mass	Kg	% by mass	% by mass	kg	% by mass	% by mass	kg
	Per annum	of waste from the material artefact in self-servicing	of total annual household waste	Per annum	of waste from the material artefact in self-servicing	of total annual household waste	Per annum	of waste from the material artefact in self-servicing	of total annual household waste	Per annum	of waste from the material artefact in self-servicing	of total annual household waste	Per annum
25	-83	-19	-0.04	-5.9	-15	-0.002	16	9	0.007	-378	-21	-0.19	-451
50	-165	-37	-0.07	-11.9	-30	-0.005	33	18	0.008	-756	-42	-0.42	-909
75	-248	-56	-0.10	-17.8	-45	-0.008	49	28	0.012	-1134	-63	-0.57	-1351
100	-330	-75	-0.14	-23.7	-61	-0.010	65	37	0.016	-1512	-85	-1.31	-1801

Note: Negative numbers means reduction in waste, that is, waste prevention. Positive numbers mean increased waste generation

As can be expected the relative waste prevention in a community of households where only a proportion adopt PSS is considerably less than in the basic case which corresponds with 100% adoption. The scale of the waste prevention potential is further discussed in section 5.6.1 below. First, however, potential sources of non-linear effects are discussed. Table 32 presents the marginal rate of waste prevention as if this potential

is linear with increased adoption. However, the rate of waste prevention may increase in a non-linear manner as adoption increases, for reasons set out in the next section.

5.5.1 Potential sources of non-linear effects on waste prevention of increasing adoption

Economies of scale is likely to arise from increased PSS adoption. Economies of scale may influence the design of material artefacts through service providers bulk-buying. It may also lead to greater specialisation both at the managerial level and among frontline staff which may affect the waste prevention potential. It may lead to increased geographical density of demand, and also threshold effects may arise in the utilisation of material artefacts. Adoption rates may not be constant over time and across social groups. Likewise different effects of economies of scale occur at different levels of adoption rather than linearly with adoption. Therefore, the waste prevention potential may not be constant over time with increased adoption. Below, different sources of non-linear effects, which occur both on the demand side and the supply side, are discussed.

Economies of scale is said to enable firms to reduce purchasing prices through bulk-buying and secure long-term contracts with suppliers. An effect of this on waste prevention potential may be if the service providers are better able to influence the design of material artefacts towards more durable ones, or the range of material artefacts that suppliers offer. This may depend on whether the property development firm managing the provision of PSS in this research, were to contract local or regional service providers in each region where PSS were to be offered, or if it provided the frontline service itself, or contracted national service firms. These types of firms are of different sizes and may therefore differ in their power to influence suppliers.

The focus groups and interviews carried out to develop the PSS suggested that the property development firm would not provide the frontline service itself, but would engage other service firms for this. The large service firms in the present supply chain of the property development firm were not willing to provide PSS (section 4.2.2). It was suggested that local or regional service providers would be better suited for this type of service market. Even if the property development firm were to deliver the frontline service it is unlikely that it would be able to influence the design of material artefacts directly. England is only a small share of the global market for the large international manufacturer supplying white goods to the property development firm, and also the property development firm was one out of several such firms, according to a representative from the white goods manufacturer.

Economies of scale can allow greater managerial specialization, which would lead to greater skills. That might for instance involve knowledge on the service operations that enable an optimized flow increasing the amount of PSS delivered per unit of transport distance and the most efficient utilization of material artefacts. The property development firm managing the PSS delivery has experience of delivery of facilities management services in the business to business market, but not in delivering PSS to households. Therefore, independent of adoption rates, initial managerial learning is likely to take place. Given increased managerial specialization with increased PSS adoption, this could lead to PSS performing better on all variables than in the basic case. However, this might depend on whether the main business focus is on the weights and

uselives of material artefacts, or whether the managerial skills are concerned with other business issues.

Increased adoption of PSS may also lead to an increase in the specialization of service providers which, may be thought to lead to greater skills in the PSS delivery. The question is then whether this new level corresponds with the basic case of this assessment, or whether it corresponds with the higher scenario.

Geographical density of demand means shorter transport distances between service depots and housing developments. This would increase waste prevention. Thus effects of increased adoption do not just involve the number of adopters, but also their location relative to each other. More service depots may increase the potential for waste prevention. However, in this assessment service depots are already assumed to exist and the scenario for the shortest distance between a housing development and service depot is 1.5 kilometres. It is difficult to conceive of an even shorter distance that would not affect the service providers' distance to other clients and that would not involve service depots on the housing development. The property developer's unwillingness to give up land on housing developments for depots was a barrier for used-oriented PSS such as sharing.

There may be threshold effects in the utilisation of material artefacts due to increased adoption. In the waste prevention assessment, material artefacts were assumed to be utilized for their entire operational life regardless of whether it was used constantly for a shorter period of chronological time, or whether the use was drawn out over a longer period of time. In reality however, there may be spare capacity to accommodate downtime for maintenance or fluctuations in demand. Over a shorter period of time there may also be spare capacity if a material artefact is not fully utilized all its available time due to limited demand. However, over a longer period of time, this will not affect the waste prevention potential if the material artefact is used for its entire operational life. However, if material artefacts are replaced after a certain period of time regardless of how much of its operational life has been used, then intensity of utilisation will matter to the potential for waste prevention. Since relatively few additional households adopting PSS are needed to fill up the available time of each material artefact, large threshold effects due to increasing adoption are unlikely.

These types of material artefacts are easy to acquire without delay if necessary and they are relatively inexpensive, in contrast with large more expensive industrial equipment for which there may be some time between placing the order and delivery. This would seem to limit the need for substantial spare capacity. The need for spare capacity for maintenance and repair of material artefacts also depends on the extent to which maintenance of repair is performed and to what extent material artefacts are replaced upon failure. Since most of the material artefacts were relatively inexpensive, the economic utility of repairs may be limited compared with replacement.

5.5.2 Reflections on households' adoption of PSS

Results in section 4.2 suggested that the willingness to adopt PSS was limited, although the scale of the willingness to adopt was not quantified. The cost of PSS and budget constraints was one of the limiting factors. News reports suggest that the British

government is considering tax deductions for domestic services of a similar kind to those introduced in Sweden in 2007 (Brant, 2012; Ross, 2012). Between 2007 and 2011 households' use of this tax deduction increased substantially. In 2008 92,470 persons applied for tax deduction and in 2011 the number was 325 734. In 2011 5% of Swedish households[35] used home improvement services including decoration, joining, electrical and plumbing work, masonry, and installation of wet room floors (Skatteverket, 2011). This is a wider range of home improvement services than the one assessed in this research. 4.7% of households used other domestic services in 2011. Of these services, nearly 90% was house cleaning, and just under 10% was garden maintenance. 1% was childcare and 1% other services (Skatteverket, 2011). Since some of the adopters of home improvement services also adopted other domestic services, the total percentage of adoption of domestic service somewhat lower than 12.5% (the sum of the two adoption rates).

Some of this use of declared domestic services is deemed to have substituted undeclared domestic services. Indeed, that was one of the policy rationales (Skatteverket, 2011). PSS competes with undeclared services. Also, the choice and management and ownership of material artefacts among providers of undeclared services is unknown. Consequently, the effects on the waste prevention potential if PSS partly replaces undeclared domestic services rather than self-servicing is unknown.

Skatteverket (2011) did not project the rate of further increased adoption, but noted a slow and steady increase in the use of the tax deduction for domestic services other than home improvement, and a continued growth in the demand for home improvement services, that was however evening out somewhat. Demand for domestic services had increased in spite of a long-standing public debate on economic and gender equality, known as the 'maid debate' (Pålsson, 2004).

The comparison may offer some insights on overall potentials, although Sweden and England make up differing geographic and institutional contexts. If the relative demand for the different household tasks were the same in England as in Sweden, the waste prevention potential for PSS would be very limited. Home improvement offered limited potential due to the relative low mass per unit of material artefact. House cleaning led to increased waste generation due to the relatively low mass per unit of material artefact in combination with low service yield of transport in the design of the PSS in this research. Consequently, if adoption of PSS increases due to policy stimulation, the logistical planning of the PSS need to carefully considered in order to avoid negative impacts on waste generation.

5.5.3 Reflections on supply-side adoption of PSS

The assessment of potential for waste prevention presupposed supply-side adoption of PSS, that is, the property development firm providing PSS. This research was based on a context in which a property development firm would manage the supply while

[35] Based on number of households in 2010 using the 'kosthushåll' ('housekeeping') definition and calculation of number of households.

contracting out the frontline provision through its existing or new supply chain partners. However, it was shown that it was unlikely that PSS would be adopted. While some supply-side participants found the idea interesting, drivers were lacking in their context. In addition, the firms existing supply chain of large facilities management firms were unwilling to deliver PSS. Instead, they suggested the property development firm should engage local or regional service firms.

If these large national and international firms would not provide PSS, might there be other firms willing to supply to PSS-like domestic services? What might the characteristics be of such firms and how would that affect the potential for waste prevention? While constituting a different geographical and institutional context, the tax deduction for domestic services in Sweden, and some characteristics of the firms providing those services may present one possibility. Tax deduction for domestic services was introduced in Sweden in 2007 (Skatteverket, 2011). The firms rather than the households apply for the tax deduction. In 2010 61,137 firms applied for the tax deduction for home improvement services, and 12,451 firms applied for tax deduction for other domestic services. Of the former group of firms, 51% and of the latter 58% operated on a sole proprietorship basis. Of the former type of firms, 31% were new firms and of the latter 47% were new firms. This suggests that in Sweden, declared domestic services are provided in fragmented local service markets at the present time.

There is little literature on local low-tech service markets, with the exception of for instance (Cleeren, *et al.* 2006; Den Hertog, *et al.* 2011). Therefore, little is known about local service providers' choice and management of material artefacts, their productivity and logistics planning. The interviews that formed the basis for the selection of input values for the assessments, involved local service providers rather than the large national firms. However, the service providers were able to give little specific data on those issues. Whether or not local service providers have great skills at the tasks, depends on their previous experience before starting firms. While small local service firms are likely to develop experience and skills at the tasks they perform, the question remains open as to how this skill compares with that of a more large scale service provider which may have more managerial time. As the market matures, the structure of the firms may change, for instance in terms of the number of firms, their market shares, number of employees and geographical coverage.

Seeking to promote PSS in the context under study does not seem like a promising prospect. Given the uncertainty of the potential for waste prevention, especially in fragmented local service markets, more research is needed on the behaviours of firms on those markets. However, according to news reports, (Brant 2012; Ross 2012) the British government is considering tax deductions for domestic services similar to those in Sweden. If such tax deductions were introduced, then policy makers may consider measures to stimulate the combination of behaviours conducive to waste prevention, and to guard against the combination of behaviours leading to increased waste generation.

5.5.4 Reflections on relative waste prevention and adoption of PSS

The PSS literature tended to focus on the improvement of PSS compared with self-servicing[36] for those that adopt PSS. Using this measure, the scale of potential waste prevention of the basic cases of PSS were in line with propositions in the PSS literature (factor 2 to 7).

However, this relative measure does not show the overall waste prevention potential for the particular household task in a community of households where some adopt PSS and some do not. Table 33 illustrates this difference. The left and middle columns in the Table 33 only refer to the amount of waste generated by the household task. The column to the left relates the amount of waste prevented to the amount of waste generated by adopters of PSS compared with their previous self-servicing, that is, 100% adoption. The middle column in Table 33 relates the amount of waste prevented to the total amount of waste generated by the household task by a community of adopters in which some adopt PSS and some do not. The column to the right in Table 33 shows the relative waste prevention compared with total household waste arisings per annum for 200 households on a housing development. There is a great difference in the scale of the potential between the different columns. When discussing PSS for the purpose of waste prevention, it is important for decision-makers to keep this distinction on mind. The scale of waste prevention potential of PSS will be further discussed in section 5.6.1.

Table 33 Absolute and relative waste prevention potential when 25% of households in a community of 200 households on a housing development adopt PSS. Relative waste prevention in relation to self-servicing practice and in relation to total annual household waste arisings from the housing development

Household task	Waste prevention - Comparison with previous practice self-servicing only % by mass	Waste prevention - Percentage reduction when 25% of a population adopts PSS % by mass	Waste prevention – percentage of total household waste arising when 25% of the housing development adopt PSS % by mass
Garden maintenance	-75	-19	-0.035
Home improvement	-61	-15	-0.002
House cleaning	37	9	-0.007
Laundry	-85	-21	-0.159

This also raises the issue of which measures are the most important with regard to PSS for waste prevention, absolute waste prevention or any of the measures of relative waste prevention? If decision-makers are concerned with physical capacities, for instance how much waste may be diverted from a treatment facility for WEEE for instance, through PSS in a geographical area, then absolute waste prevention may be the most relevant measure, or absolute waste prevention as a share of the capacity of the treatment facility.

[36] Although terms such as 'tradtional sales' or 'status qou' were used rather than self-servicing.

If the policy concern is the efficiency of PSS compared with other ways of achieving waste prevention, then relative waste prevention as a share of the total household waste stream, or alternatively a particular household waste fraction, is likely to be useful.

If a type of material artefacts with a low mass per unit (for instance hand-held power drills[37]) were to make up a large share of a waste fraction (WEEE) due to a large number of drills disposed, then a high waste prevention potential in relative terms might be of interest, even if the mass of waste prevented per individual drill is small. Thus, under some circumstances PSS involving small material artefacts may be as policy-relevant as large material artefacts which each achieve a higher absolute waste prevention.

The relative waste prevention potential for an adopter compared with previous self-servicing practice only may be a measure more useful to overall sustainable consumption and production than to waste prevention. It shows which consumption categories or activities have the greatest potential for reduced material use. However, if the total effects in society are of concern, then this measure needs to be considered alongside the relative measure that considers a community of households where some adopt PSS and some do not.

To sum up, all of the measures may be of utility to decision-makers, and the choice of measure depends on the decision at hand. The above are a few examples of potential policy concerns but there is likely to be additional issues relating to waste prevention and its performance measures.

5.6 DISCUSSION OF WASTE PREVENTION POTENTIAL

This chapter assessed the amount of material artefacts and thereby waste that would potentially be prevented through PSS. Whereas previous research on PSS has largely concentrated on the savings from PSS as factor improvements of consumption compared with self-servicing[38] this research also assessed the saving in terms of household waste prevention in relation to household waste arisings.

The assessment was based on claims in the PSS literature of how resource productivity was thought to arise. A model was developed with those claims as variables. Primary data from participating households, combined with secondary data on material artefacts, made up input values for the variables. Due to limited existing knowledge and data availability on the behaviours of PSS providers, input values for PSS were based on assumptions. Scenarios were developed to assess alternative behaviours and to account for the fact that primary research had suggested that the assumptions may hold true in some context but not in others.

[37] The example of handheld power drills is purely hypothetical example to illustrate the point with material artefacts that were included in the assessment.

[38] Or 'traditional sales' or 'status quo' as authors have tended to call it.

The assessment of the potential for waste prevention identified the scale of the potential within a range of higher and lower estimates. It also contributed to the understanding of the concept by exploring the component variables and their effects on the potential for waste prevention, and some underlying principles for the outcomes. This section reflects on and discusses the worth of the scale of the potential for waste prevention, and the PSS concept.

5.6.1 Reflections on the scale of the potential for waste prevention

The majority of basic cases and scenarios resulted in potential waste prevention. However, in relation to the total household waste arisings this prevention is a small share. For a single household adopting PSS, the potential waste prevention as a percentage of total household waste arisings for one household, ranged from 1.1% in the higher scenario for laundry, to increased waste generation by 0.17% in the lower case for house cleaning. If one household adopted PSS for all for household tasks, and the higher scenario held true for all four household tasks, this would lead to 1.49 % prevention of total household waste from that household. If instead the lower scenarios held true, this would lead to an increase in the total waste generation by 0.03%. In a community of households where 25% of households adopt PSS, the potential waste prevention for individual household tasks range from 0.002 % to 0.16% of total household waste arising from that community, based on the basic case. In comparison adoption rates of declared domestic services in Sweden after a tax deduction had been in place for three years, were under 10% although increasing. However, the majority of those services were home improvement services and house cleaning services. These were household task with the least waste prevention potential or even increased waste generation. If the same adoption were to arise for PSS in England, this might result in very limited waste prevention or increased waste generation.

The total scale of the potential waste prevention of the PSS in this research is partly due to the scale of potential for each household task, and limited willingness to adopt PSS and partly it is due to the fact that the research only considered four examples of household tasks and material artefacts. Might there be other material artefacts and household tasks conducive to result-oriented PSS that would increase the total waste prevention potential of PSS? The selection of household tasks for assessment in this research considered both household waste fractions, different material artefacts in those fractions and the household tasks in which those material artefacts may be used. It also considered primary data concerning participating households' and the property development firms' willingness to buy and supply PSS, both use-oriented and result-oriented PSS that had the potential to substitute households' ownership of material artefacts (see appendix A). While there may be potential for result-oriented PSS for other household tasks, the potential for substitution of ownership was deemed to be limited. The willingness to adopt use-oriented PSS, such as leasing white goods or sharing laundry facilities on the housing development was also limited.

Evidence on the potential for waste prevention is scarce, especially in terms of robust quantitative evidence that may be used for comparison of different measures (Cox, *et al*. 2010). Examples of quantitative measures are percentages of households in a community committed to different waste prevention activities such as rejecting junk mail and using own shopping bag and buying second hand. There are examples of mass

of waste reduced following local doorstep campaigns, but according to Cox *et al.* (2010) not necessarily suited for comparison. Case study examples from Vienna in Austria, (Salhofer, *et al*. 2008) suggest that the waste prevention potential for waste fractions such as rejecting unsolicited mail, nappies, mail from events is about 10% of each waste fraction or 1-3% of total municipal solid waste. However, they also state that a lack of basic data limits the accuracy of the estimates.

The potential for waste prevention of individual waste prevention measures may however be limited. Cox *et al.* (2010) suggest that waste prevention is not a uniform action, but comprised of a number of small activities, such as rejecting junk mail, using own shopping bag, avoiding packaging, buying second hand. Then the worth of scale of the waste prevention potential of PSS would be a matter of the cost of achieving this compared with other waste prevention measures. In such comparison, the importance of waste prevention for the particular waste fraction due to the environmental harm of the fraction should also be taken into consideration. In this respect, WEEE, which is the waste fraction in focus for this assessment, has been identified as a waste fraction of concern due to its contents of chemicals, heavy metals and also variety of plastic polymers which makes it difficult to recycle the plastics (Townsend, 2011).

5.6.2 Reflections on the PSS concept

The results of the interviews and focus groups reported in chapter 4 suggested that for practically all propositions in the PSS literature concerning behaviours of PSS customers and providers, there were behaviours diverging from the propositions (although there were also findings partly supporting many of the propositions).When assumptions in the assessment adhered to the propositions in the PSS literature, there was potential for waste prevention for three out of four household tasks. The same was true for scenarios when only one assumption at a time was changed. However, when all assumptions were changed at the same time to reflect lower waste prevention, this lead to increased waste generation for three out of four household tasks. This confirms statements in the PSS literature that the potential of PSS needs to be established on a case-by-case basis. While the outcome of most environmental systems analyses depend on the specific circumstances and the system boundaries, this fact supports the impression that the PSS concept is insufficient for understanding and achieving waste prevention. Instead, a variety of frameworks accounting for specific services management issues for different types of services, and norms and culture associated with domestic services may be required to better understand the behaviours of service providers and households.

5.7 CONCLUSIONS ON THE WASTE PREVENTION POTENTIAL OF THE EXPERIMENTAL PSS

The assessment of the waste prevention potential reported and discussed in this chapter, in pursuit of objective 2, led to the following conclusions on the research questions

Research question 1 was concerned with whether or not all household tasks held the same potential for waste prevention. The waste prevention potential was found to differ between the household tasks. The household tasks for which heavier material artefacts

(laundry and garden maintenance) were used were found to hold the greatest potential in terms of mass. The household tasks for which the material artefacts were used relatively infrequently, and relatively short period of time each use instance, saw the greatest relative potential for waste prevention. The household task for which the PSS had particularly low service yield of transport (house cleaning) resulted in increased waste generation rather than waste prevention. The difference between household tasks in waste prevention potential is important because willingness to adopt also differs between household tasks. In particular, results from chapter four suggested there was limited willingness to adopt PSS for laundry and give up ownership of washing machines. Secondary data from national statistics in Sweden showed that the vast majority of households using tax deductions for domestic services (8-9% of households) used these services for house cleaning and home improvement, which held the least potential for waste prevention in this study, or even led to increased waste generation.

Research question 2 concerned the effects on waste prevention potential of alternative behaviours of households and service providers for the different variable in the model, that is, the different scenarios. The change in a single variable at the time while the other variables remaining the same as in the basic case, did not negate the waste prevention potential for any household task whereas the higher scenario for house cleaning turned increased waste generation into waste prevention. When all higher and lower scenarios respectively were combined, however, the lower cases led to increased waste generation for three out of four household tasks, laundry being the task where waste prevention potential remained. The relative difference between the higher and lower scenarios was large. For instance, the potential of the higher case may be more than twice that of the basic case, and the potential of the lower case may be less than half that of the basic case. However, the overall potential for waste prevention compared with the household waste stream was very small (for example 0.01% of total household waste arisings for one household adopting PSS for home improvement or 0.68% for laundry). Therefore, the importance of the difference between the higher and lower cases remains uncertain. Adoption rates would influence the overall potential for waste prevention in a community of households. In addition, the relative adoption of PSS for different household tasks would influence the potential substantially, in particular if adoption was the highest for a household task leading to increased waste generation.

Research question 3 concerned the scale of the potential for waste prevention. For a single household adopting the PSS, the potential ranged between an increase in waste generation by 0.03% and waste prevention by 1.5% of total annual household waste arisings from one household. With an adoption rate of 25% in a community of 200 households, for a single household task the potential waste prevention compared with the household waste arisings from all households, would range from increased waste generation by 0.007% and waste prevention by 0.19% (both based on a linear scaling of basic cases). If 25% of households on a housing development comprising 200 households, the potential waste prevention would be 0.23% of total household waste arisings for the housing development. Given the findings in chapter 4 that willingness to adopt PSS was limited, and a comparison with Sweden where under 10% of the households use declared domestic services four years after a tax deduction was

introduced, 25% seems like a fairly large adoption rate at the present time. Thus, at the present time, the waste prevention potential seems likely to be smaller.

There was little quantitative evidence with which to compare the potentials for waste prevention shown in this study. A case study from Austria on four different waste prevention activities suggested these might lead to 1-3% reduction in municipal solid waste, but also stated that lack of data caused uncertainty (Salhofer *et al.* 2008). There was little robust quantitative results on result-oriented PSS for households in the PSS literature readily comparable with the findings in this study (see chapter 2.4.3). Descriptions of the methods used and systems that were assessed were very scant. PSS literature expressed potentials for environmental improvement from various PSS in various markets, either as factor improvements or reduction in the use of various resources or emissions. Examples are a factor 10 improvement for sharing of drills (use-oriented PSS), factor 1.7 improvement for renting of skis, to 30% reduction in the use of detergents for a use-oriented PSS for laundry (Heiskanen & Jalas 2003). The basis for comparison seemed to be a comparison with the self-servicing practice and not with the potentials in a wider population. The results of this research are within those broad ranges, when PSS is compared with the self-servicing practice only and not a wider community, or waste arisings.

To sum up, the research questions were answered and the research objective was met, although as anticipated, uncertainty remains due to the novelty of the research area, exploratory nature of the research and the assumptions and limitations set out in chapter 3.7.4. Further research proposed in section 8.6 could usefully address these uncertainties.

The research contributed a structured model for the assessment of potential waste prevention through PSS. The model may be further developed as further research elaborates knowledge on the self-servicing and PSS systems. It identified a scale of potential waste prevention given a range of potential behaviours based around central estimates derived from primary and secondary data and the review of literature. These scenarios also addressed alternative behaviours to those proposed by the PSS literature, to accommodate findings from the qualitative research which was in some instances contrary to the assumptions in the PSS literature.

Due to the uncertainty of the waste prevention potential and the possibility of increased waste generation, it would be premature for policy-makers to seek to promote adoption of PSS. More research on local service markets and also self-servicing behaviours is needed. However, policy-makers may consider promoting behaviours among households and service providers that reduce the amounts of waste generated from both self-servicing and commercial services. Such behaviours may include choosing material artefacts with a low mass per unit and encouraging longer operational uselives.

In the next chapter, the waste prevention potential identified in the present chapter are used as input to an environmental assessment exploring the impacts of PSS on a wider range of environmental impact categories across the life cycle.

6 ASSESSMENT OF ENVIRONMENTAL PERFORMANCE – SCENARIOS, RESULTS AND DISCUSSION

6.1 INTRODUCTION

While chapter 5 focused on the part of the definition of waste prevention concerned with the quantity of waste generated, this chapter concentrates on the part of the definition concerned with the impacts[39] of waste on the environment and human health. It addresses the following research questions:

1. Are there any trade-offs between household waste prevention and other emissions over the life cycle?
2. Are there any trade-offs between different types of emissions over the life cycle?
3. What is the scale of the changes in emissions?
4. Do PSS for different household tasks have the same environmental potential?

The results of the environmental assessment of a change from self-servicing to the PSS are reported. This informs decision-makers whether direct waste prevention may be achieved without any increases in other types of emissions over the life cycle; whether there are any trade-offs between different emissions; whether household tasks differ with regard to those potential trade-offs, and the broad scale of reductions or increases in emissions. This may inform decision-makers of whether to pursue PSS. It also contributes to filling the research gap on waste prevention.

The key messages of the chapter are listed below:

- PSS for two of the three household tasks that held potential for prevention of direct waste led to increases in some types of emissions over the life cycle both in the basic lower and most of the higher scenarios (scenarios for different behaviours concerning choice, ownership and management of material artefacts, that lead to higher or lower waste prevention). Thus, there are trade-offs between prevention of direct waste and emissions over the life cycle. Increased emissions mainly arose from the transport in the delivery of the PSS.

- The magnitude and direction of change in emissions when PSS replaced self-servicing varied amongst the household tasks. The variations depend on the material compositions of material artefacts used by households and service providers, and additional material artefacts, such as vehicles, used in PSS and the relative service yield of transport.

[39] The term 'impacts' is used in the definition of waste prevention. The environmental assessment reports emissions rather than impacts, and in some instances, mid-point environmental impacts.

- The changes in for instance global warming potential in absolute terms are very small compared to total annual CO_2 emissions from one household. There is a lack of recent data on the other types of emissions arising from a UK household with which to compare the results of the assessment of PSS.

- The legal definition of waste prevention included reduction of both the quantity of waste and adverse impacts on the environment and human health. Even where PSS leads to reduced quantities of waste, there is often an increase in some types of emissions. Therefore, reduction of quantities of waste through PSS may not be waste prevention in strict terms.

6.2 INPUT DATA ON MATERIAL COMPOSITIONS, ENERGY USE AND WASTE MANAGEMENT

The environmental assessment compares the resource use and emissions of self-servicing with the PSS. The scenarios in the environmental assessment are the same as the scenarios used in the assessment of waste prevention potential (sections 5.2; 5.4; 5.5). The basic cases used the central assumptions from primary data, and the higher and lower scenarios consider alternative behaviours of households and service providers leading to higher or lower potentials for waste preventions. The choices are the choice of material artefacts (expressed as the mass of the material artefacts), the uselife of material artefacts (the behavioural aspect being the choice of time of ownership/use before replacement). The scenarios also included transport distances and alternative service volumes.

The environmental assessment requires data upstream and downstream to that of the waste prevention assessment, using the results of the latter as input. Below, material composition of material artefacts, energy use and waste management are presented for the different household tasks. The environmental indicators are presented in appendix D.

6.2.1 Garden maintenance

6.2.1.1 Material composition

About a third of the participating households used electric lawnmowers and about two thirds used petrol lawnmowers (see section 5.2.1). Since petrol powered and electric lawnmowers have different power sources, differ in mass per unit of material artefact, and in material composition both types are included in the assessment. Table 34 below shows the material compositions of electric and petrol powered lawnmowers used in the assessment. The same material composition of petrol powered lawnmowers is used for self-servicing and PSS since service providers would also use domestic grade lawnmowers. The material composition derived from a lawnmower manufacturer in 2003 (Mont 2004d).

The material composition from Mont (2004d) required some interpretation to be applicable to the environmental indicators. The steel was assumed to be a cast iron motor and the aluminium was assumed to be cast aluminium chassis. No material composition for electric lawnmowers was available. The motor was assumed to have the

same material composition and weight as the motor in the vacuum cleaner, that is, a ferrite motor with copper wire and aluminium housing. Freegard *et al.*(2005) identified the plastics in electric lawnmowers to be 90 % ABS and the rest being plastics such as PP and PS.

Table 34 Material compositions of lawnmowers used for self-servicing and PSS respectively

Material	Petrol % by weight	Electric % by weight
Steel sheet galv.	-	9
Cast iron	40.0	-
Ferrite	-	21
Aluminium	43,5	7
Brass	2.0	-
Coppar wire	-	5
Coppar winding wire	-	7
ABS	2.0	46
PP	2.0	3
PS	-	3
LDPE	1.0	1
EPS	1.3	1
Paper	3.4	2
~~POM~~	~~2.0~~	-
~~Rubber~~	~~3.0~~	-

Source: (Mont 2004d)

The petrol lawnmower comprised two materials for which there were no environmental indicators: POM and rubber. These materials made up 5 % of the material composition and were excluded from the assessment.

The packaged volume of the petrol powered lawnmower was 0.27 m^3 and the packaged volume of the electric lawnmower was 0.09 $m^{3.}$

6.2.1.2 Energy use

The power of the petrol powered lawnmower was 4 horse powers which corresponded to 0.003 MW. According to (Mont 2004d) the operating power was 40% of this. The operating power was multiplied by the time the lawnmower was in use annually to calculate the energy use. The petrol consumption was 460 kg/MWh. The power of the electic lawnmower was 0.00115 MW.

6.2.1.3 Waste management

Total recovery includes total energy recovery and total recycling. Since there were no indicators for two of the materials in the material composition of the petrol lawnmower, they were excluded from the assessment. Therefore, the sum of total landfill and total recovery for the petrol powered lawnmower is less than 100%.

Table 35 shows the percentages of different types of material going to different waste management routes: materials recycling, energy recovery and landfill. Participating households were asked what they did with obsolete material artefacts (giving to kin or charity, selling, keeping, taking to civic amenity site or put out for waste collection). However, there were no data on how much of the waste taken to civic amenity sites goes through the different waste management routes[40]. Also, even if a material artefact is sent for recycling, the entire material artefact may not be recycled. Indeed, WEEE plastics have been difficult to recycle due to the contamination of for instance flame retardants (Bio Intelligence Service, 2007) and also other contaminants and mixture of polymers in the plastics delivered to WEEE plastic reprocessors from the primary WEEE treatment plant (Freegard, *et al*. 2007). However, the WEEE directive (Official Journal of the European Union, 2003b) requires recycling rates from 50 % to 75% and recovery rates from 70 % to 80%.

Recycling rates for the metals were already included in the indicators for the materials extraction and production. Therefore, these could not be influenced in this assessment. The share of metals that were not recycled (as specified in the notes to the indicators for materials extraction and production), were assumed to be landfilled rather than thermally treated, since metals have no calorific value.

The rates of recycling of different WEEE plastics were not known. The recycling rates for plastics in this assessment were set so that for each type of material artefact the total recycling and recovery rates would approximate the requirements of the WEEE directive. The recycling rates of the plastics (percentage by weight of the total weight of the plastic in the material artefact) ranged from about 50% to 100% for different material artefacts, depending on what recycling and recovery rates were achieved by metals recycling already accounted for in indicators for the materials. The assumption of 100% is likely to be an overestimation.

The percentages in Table 35 below are percentages recycling and recovery by the total weight of the material artefact. So for instance, the percentage for plastics recycling does not refer to the percentage of the total plastic in the material artefact, but the percentage of the recycled plastics as a share of the weight of the whole material artefact. Total recovery includes total energy recovery and total recycling. Since there were no indicators for two of the materials in the material composition of the petrol lawnmower, they were excluded from the assessment. Therefore, the sum of total landfill and total recovery for the petrol powered lawnmower is less than 100%.

[40] According to an interview with an officer at the Environment Agency, after literature search.

Table 35 Distribution of waste management routes in the assessment - garden maintenance

Waste management	Petrol powered lawnmower % by weight	Electric lawnmower % by weight
Metals landfill	13	42
Plastics landfill	0	0
Metals energy recovery	0	0
Plastics energy recovery	2	0
Other energy recovery	3	0
Metals recycling	73	7
Plastics recycling	4	51
Total landfill % by weight	13	42
Total recovery, of which	83	58
Total energy recovery	5	0
Total recycling	77	58

6.2.2 Home improvement

6.2.2.1 Material composition

A material composition for a handheld power drill was obtained from Mont (2004d) (Table 36). Mont (2004d) included two different qualities of drills but found that there was little difference in the material composition between the two. However, only type of material was stated rather than specific materials. Thus, the two drills may differ in the grades of the types of materials in a way that is not revealed by the data and therefore not taken into account in this assessment. Due to the similarity of the material compositions of the two drills of different quality, the same material composition was used for self-servicing and PSS in this environmental assessment.

Table 36 Material composition of handheld power drill

Part of the drill	Material	% by weight
Engine & pole shoe	Steel	35-38
Gear & drill chuck	Steel	24-25
Screws	Steel	3
Casing PA66 F35	Plastic	15-16
Hand grip PA 66 GF 35	Plastic	5
Mixed plastics	Plastic	3
Electronics	Electronics	3
Cable	Mixed material	10-11

Source: Mont (2004d)

The types of materials in the material composition by Mont needed further specification to enable the application of environmental indicators used in the environmental assessment. The cable was assumed to be composed of PVC and copper wire. By taking a cable apart and weighing the copper and plastic respectively, it was established that that copper made up about 20 % and the plastic 80 % of the cable by weight. The steel in the motor was assumed to be ferrite. The mixed plastics were assumed to be ABS because the different types of emissions from the extraction and production stage were in the middle of range for the different plastics.

Table 37 Material composition of drills used in the environmental assessment

Material	% by weight
PVC	7.9
ABS	2.5
PA	19.9
Steel	27.3
Ferrite	37.2
Copper wire	2.0
Electronic Components	2.5

The packaged volume was 0.009 m^3.

Packaging materials were LDPE (1kg per m3), PS (0.5 kg/m3); paper (1 kg/m3).

6.2.2.2 Power

The power of the drill was 700 W.

6.2.2.3 Waste management

The rationale described for the distribution of waste management options for garden maintenance applies to all household tasks, although the specific values differ. The values for home improvement are shown in Table 38 below. Total recovery includes total energy recovery and total recycling

Table 38 Distribution of waste management routes used in the assessment – home improvement

Waste management routes	% by weight
Metals landfilled	65%
Plastics landfilled	0%
Other landfilled	2.5
Metals energy recovery	0%
Plastics energy recovery	0.4%
Other energy recovery	0%
Metals recycled % of product by weight	1.4%
Plastics recycled	30.3%
Total landfill	67.7%
Total recovery, of which	32.1%
Total energy recovery	0.4%
Total recycling	31.7%

6.2.3 House cleaning

6.2.3.1 Material composition

A material composition for vacuum cleaners was obtained from the product cases of the methodology study for energy-using products (Kemna, *et al.* 2005). Since only one material composition for vacuum cleaners was found, the same material composition

was used for both self-servicing households and service providers Table 39, although slightly different types of vacuum cleaners were used by the participating households and service provider.

Table 39 Material composition of vacuum cleaner

Material	% by weight
ABS	7 %
PP	40 %
PS	2 %
PC	2 %
cast Al motor housing	7 %
Cu power wire	4 %
Cu winding wire motor	7 %
Steel sheet	8 %
Ferro motor	18 %
Cardboard box	6 %

Source: (Kemna, *et al.* 2005)

The packaged volume of the vacuum cleaner was 0.05 m^3.

6.2.3.2 Power

The actual power is not the same as the maximum power stated on the vacuum cleaner. Thus 1200 W is the median actual power of the material artefact used by self-servicing households.

6.2.3.3 Waste management

The rationale described for the distribution of waste management options for garden maintenance applies to all household tasks, although the specific values differ. The values for house cleaning are shown in Table 40 below. Total recovery includes total energy recovery and total recycling.

Table 40 Distribution of waste management used in the assessment – house cleaning

Disposal	Self-servicing	PSS
	% by weight	% by weight
Metals landfilled	38%	38%
Plastics landfilled	0%	0%
Other landfilled	0%	0%
Metals energy recovery	0%	0%
Plastics energy recovery	9%	9%
Other energy recovery	6%	6%
Metals recycled	6%	6%
Plastics recycled	41%	41%
Total landfill	38%	38%
Total recovery, of which	62%	62%
Total energy recovery	15%	15%
Total recycling	47%	47%

6.2.4 Laundry

6.2.4.1 Material composition

The material composition of washing machines was derived from a study commissioned by AEG, Bosch, Electrolux, and Siemens (Rüdenauer, *et al.* 2004). Their assessment comprised six different machines representing different market segments: low price, medium price simple design, medium price average design, medium price elaborate design, high price, and large rated capacity. The medium price average design model was used for the self-servicing and the large rated capacity for PSS in this assessment (Table 41).

The material composition in Table 41 differs somewhat from the material composition in (Rüdenauer *et al.* 2004). The washing machine used for the self-servicing, contained 14% carboran but no polypropylene with mineral filler[41]. The large rated capacity washing machine did not contain carboran, but instead it contained 13% polypropylene with mineral filler. Therefore, the indicator for polypropylene with talcum filler was used instead of carboran. Furthermore, cable was specified in (Rüdenauer, *et al.* 2004) rather the materials in the cable. The material composition below assumes that the cable is made of PVC and copper wire.

There were no environmental indicators for some of the materials in the material composition. These materials are marked with a stroke across the text and numbers in Table 41. For self-servicing, 10 % of materials were excluded and for PSS 11 %.

[41] Polypropylene may be toughened by mineral fillers such as calcium carbonate (Goldman & Copsey 2000), or as in the environmental indicators used in this assessmend, talcum.

Table 41 Material composition of washing machines used in the environmental assessment

Material	Self-servicing % by weight	PSS % by weight
PE (polyethylene)	0.00	0.01
PP (polypropylene)	1.33	1.22
PP (with mineral filler)	8.30	7.4
Talcum filler for PP	6.2	5.6
PVC (polyvinyl chloride)	0.30	0.28
ABS (Acrylonitrilebutadienestyrene)	2.35	2.12
PA (polyamide)	0.07	0.07
PMMA (polymethyl methacrylate)	0.07	0.05
Steel	33.39	32.06
Cast iron	2.42	9.02
Aluminium	5.20	5.76
Copper	0.94	0.88
Copper wire	0.08	0.07
Brass	0.03	0.02
Electronic Components	0.68	1.11
Concrete	23.56	19.61
Glass	2.13	1.94
~~POM~~	~~0.06~~	~~0.06~~
~~EPDM~~	~~3.71~~	~~3.42~~
~~Chipboard~~	~~2.96~~	~~2.70~~
~~Cotton with phenolic binder~~	~~0.48~~	~~1.15~~
~~Other materials not considered~~	~~1.50~~	~~1.65~~
Packaging		
~~Wood~~	~~1.4~~	~~1.3~~
Corrugated cardboard	1.6	1.5
PE	0.3	0.2
PS	0.6	0.6
PA	0.1	0.1
Paper	0.2	0.2

Source: Rüdenauer et al. (2004)

Table 42 shows the measures and volume of the packaged washing machines.

Table 42 Packaged measures and volume of washing machines

	Self-servicing	PSS
packaged measures (m)	0.86	0.83
packaged measures (m)	0.59	0.955
packaged measures (m)	0.6	1.141
packaged volume (m3)	0.30	0.90

6.2.4.2 Energy and water use

The energy use depends on the temperature at which the laundry is washed (Table 43)

Table 43 Energy use per kg of laundry at different temperatures

	Self-servicing	PSS
Temperatures	**MWh/kg**	**MWh/kg**
30°	0.00007	0.00006
40°	0.00011	0.00010
60°	0.00020	0.00018
90°	0.00032	0.00029

Source: (Rüdenauer et al. 2004)

In order to establish the amount of energy used in the use-phase, the amount of laundry washed at different temperatures needed to be established (Table 44). Participating householders filled in the number of loads at different temperature in the survey questionnaire 3.7.3. The service provider provided the distribution between different temperatures in an interview.

Table 44 Percentage of laundry at different temperature

Temperatures	Self-servicing % by weight	PSS % by weight
30°	23	13
40°	61	50
60°	16	35
90°	0	2

The water use per kg of washing is shown in Table 45.

Table 45 Volume of water used per kg of laundry

Self-servicing m3/kg	PSS m3/kg
0.0097	0.0089

Source: Rüdenauer *et al.* (2004)

6.2.4.3 Waste management

The rationale described for the distribution of waste management options for garden maintenance applies to all household tasks, although the specific values differ. The values for house cleaning are shown in table Table 46 below. Total recovery includes total energy recovery and total recycling. A number of the materials in the material composition were excluded from the assessment since there were no indicators for them. Therefore, the materials included did not add up to 100% of the total mass of the material artefacts. Therefore, the sum of total landfill and total recovery is less than 100%

Table 46 Distribution of waste management options used in the assessment - laundry

Waste management	Self-servicing % of material artefact by weight	PSS % of material artefact by weight
Metals landfilled	33	33
Plastics landfilled	0.0	0.0
Other landfilled	23.6	19.6
Metals energy recovery	0	0
Plastics energy recovery	17.0	10.6
Other energy recovery	0.0	0.0
Metals recycled	8.7	14.7
Plastics recycled	2.6	2.4
Total landfill	56.9	52.6
Total recovery, of which	28.3	27.7
Total energy recovery	17.0	10.6
Total recycling	11.3	17.1

6.2.5 Vehicle used in PSS

A vehicle required to deliver PSS was included in the assessment. The material composition is shown in Table 47 below.

Table 47 Material composition of vehicle

Materials in vehicle	% by weight
ABS	0.6
PP	5.5
PA	0.2
HDPE	1.1
PUR (flexible)	1.7
Steel sheet galvanised	58.7
Cast iron	9.6
Aluminium die-cast	6.3
Cu wire	1.0
CuZN38 cast	0.5
Glass	2.9
Fluids	2.1
Electronics (PWB)	0.7
~~rubber~~	~~1.6~~
~~carpet~~	~~0.4~~
~~battery~~	~~1.1~~
~~process polymers~~	~~1.1~~
~~tyres~~	~~3.5~~
~~other~~	~~1.4~~

The excluded materials add up to 9 % by weight of the total materials.

As explained in section 6.2.1.3, the indicators for materials extraction of metals already accounted for recycling rates for metals (in energy-using products rather than cars). This would mean that the rest of the metals are landfilled. However, this rate would add up to some 60% which far exceeds the limits in the End-of-Life Vehicle Directive. Instead a considerably lower landfilling rate was used for the metals, namely 20%, more in line with the ELV directive. This however means that recycling credits are not awarded to all the metals that are thought to be recycled. On the other hand, the disproportionate environmental burden of landfilling metals is avoided. This also means that waste management is only included for less than half of the vehicle. Thus the emissions arising from the vehicle may be somewhat underestimated.

Table 48 Waste management options used in the assessment – vehicle. Percentage by weight of the materials in the material composition.

Waste management	Vehicle % of material artefact by weight
Metals landfilled	20
Plastics landfilled	0.0
Other landfilled	0.4
Metals energy recovery	0.0
Plastics energy recovery	0.0
Other energy recovery	0.4
Metals recycled	16.8
Plastics recycled	9.1
Total landfill	20.4
Total recovery	26.3
Total energy recovery	0.4
Total recycling	25.9

6.3 RESULTS FOR BASIC CASES

The results of the environmental assessment of the basic cases[42] of PSS compared with self-servicing show that there are trade-offs between different types of emissions. A comparison of these results with the results of the assessment of waste prevention potential (section 5.3) shows that there are also trade-offs between prevention of direct waste and other types of emissions.

[42] Basic cases of self-servicing and PSS are those with input values for mass and uselife of material artefacts etc. drawn from primary data (questionnaire and interview responses). Scenarios are those alternative input values identified from ranges of behaviours emerging from interviews and secondary data on material artefacts, and in some instances assumptions.

Table 49 shows the changes in emissions in absolute terms, and Table 50 shows the percentage emissions of PSS compared with self-servicing.

Table 49 Changes in resource use and emissions per functional unit (total time of performing each household task during one year, and for laundry, total mass of laundry for one household for one year) - PSS basic case for one household

	Primary energy	Waste, hazardous	Waste ,non-hazardous	Global warming potential	Acidification potential	Volatile organic compounds	Polycyclic aromatic hydrocarbons	Eutrophication potential
	(MJ)	(g)	(kg)	(kg)	(g)	(g)	(mg)	(g)
Garden maintenance - petrol lawnmower	-199	0.9	-0.6	12.5	-47	-76.9	-24.6	-0.7
Garden maintenance - electric lawnmower	56	-5.0	-0.7	34.2	-49	423.4	-0.2	-0.3
Home improvement	-16	-2.3	-0.2	-0.9	-6	0.2	5.7	-0.1
House cleaning	-698	-1.8	0.0	-29.2	-281	3.9	102.6	0.2
Laundry	-360	-18.6	-5.6	-30.2	-57	-1.9	-1.3	-2.5

Table 50 Percentages changes in resource use and emissions when PSS replaces self-servicing - basic case for one household

Basic cases	Primary energy	Waste, hazardous	Waste non non-hazardous	Global warming potential	Acidification potential	Volatile organic compounds	Polycyclic aromatic hydrocarbons	Eutrophication potential
Garden maintenance petrol lawnmower	-38%	60%	-65%	35%	-49%	-15%	-78%	-84%
Garden maintenance electric lawnmower	21%	-68%	-70%	251%	-50%	92,586%	-3%	-69%
Home improvement	-31%	-64%	-63%	-28%	-46%	139%	1244%	-74%
House cleaning	-74%	-6%	-1%	-49%	-79%	489%	1615%	52%
Laundry	-14%	-25%	-62%	-24%	-10%	-52%	-6%	-84%

Garden maintenance (when self-servicing households used petrol powered lawnmowers) was the household task for which PSS held the second greatest household waste prevention, both in terms of mass of waste prevented, and as a percentage improvement over self-servicing (see section 5.3). This also resulted in reductions of most types of emissions. However, global warming potential increased (Table 49) due to the service providers PSS using exclusively petrol lawnmowers, whereas a third of self-servicing households used petrol powered lawnmowers and two thirds used electric ones (section 5.2.1). Thus there was a trade-off between waste prevention and global warming potential. Households were more willing to adopt PSS for garden maintenance than for the other household tasks (section 4.2.1.10). Consequently, there might be potential to realise prevention of direct waste through PSS for garden maintenance, but a danger of causing increased global warming potential.

House cleaning, which was the only household task for which PSS led to *increased* waste generation (section 5.3), was the also the household task for which PSS led to the

greatest *reduction* in primary energy use (Table 50). This was due to the energy savings during the use-phase. This saving was also large enough to off-set the additional primary energy for the fuel use by the transport vehicle and increased primary energy use in all other life cycle stages. Reduced global warming and acidification potential during the usephase was also sufficient to offset increased acidification potential arising from other life cycle stages. Eutrophication potential and emissions of VOC and PAH increased (Table 50).

For home improvement which had the third largest relative waste prevention potential although the second smallest absolute waste prevention potential (section 5.3), the experimental PSS led to reduced resource use and emissions for most types of emissions. However, emissions of VOC and PAH increased greatly when the experimental PSS replaced self-servicing (Table 50). These additional emissions from PSS arose from the additional transport in the use-phase. Households' willingness to adopt PSS for home improvement depended on their perceived skills and enjoyment of self-servicing (section 4.2.1.10).

Laundry held a great waste prevention potential both in absolute and relative terms (section 5.3). It led to reduced environmental burdens for all types of emissions (Table 49). However, households had particularly negative attitudes towards adoption of PSS for laundry (section 4.2.1.10).

To sum up, increased emissions were caused by the transport in PSS, mostly the fuel use during the use-phase, but also from extraction and production of the materials in the vehicle. The mass of the material artefact used to perform the household task influenced its ability to offset increased emissions from transport. The reduction in material use for washing machines through PSS, was large enough to offset more of the emissions arising from transport, than the smaller material artefacts in home improvement and house cleaning. For garden maintenance, service providers' use of petrol lawnmowers led to increased emissions of some types. In this assessment, the same material compositions were used for the material artefacts used by both self-servicing households and service providers, for garden maintenance with petrol lawnmowers, home improvement and house cleaning. If there were greater differences between material compositions for material artefacts used by households and service providers respectively, this may lead to greater reductions of some types of emissions and greater increases in other types of emissions, that is, further trade-offs. If the assessed systems were expanded to include more of the infrastructure required for PSS, for instance service depot buildings and IT systems, more material artefacts with a variety of emissions profiles would be introduced. Then trade-offs are likely to increase further. The magnitude and direction of change in emissions will vary depending on the specific system under the study, the characteristics of the material artefacts and the organization of PSS with regard to for instance transport efficiency. Therefore, the environmental potential of PSS needs to be established on a case-by-case basis. This finding is consistent with statements in the PSS literature. More research on variation of a specific system could lead to the development of rules of thumb.

If decision-makers consider whether or not to promote PSS to achieve household waste prevention, they then need to decide what, if any, increases in other emissions over the life cycle are acceptable. For instance, PAH are persistent, highly mobile emissions

potentially causing cancer (Wenborn, *et al.* 1999). Some volatile organic compounds (VOC) may cause sensory irritation, nervous system impairment and cancer (Delgado-Saborit, *et al*. 2011). VOC also contributes to the formation of low level ozone under some circumstances. Low level ozone can cause respitory problems in humans and damage to vegetation and ecosystems (Environmental Protection Agency US, 2012). Therefore, great increases in those emissions may be cause for concern. However, climate change may have profound effects on ecosystems across the globe. Thus, global warming potential is likely to be the overriding concern. The precise impact of some types of emissions may depend on the absolute amount of emissions, the specific compound and the sensitivity of the receiving environment and other sources of exposure where the impact occurs. However, life cycle type environmental assessments do not typically address where an impact occurs, or consider the sensitivity of the particular recipient (Ekvall, *et al*. 2007). The judgement of which emissions and impacts are acceptable and which are not is a political decision balancing the interests of and impacts on different stakeholders. This could judgement could be supported by further research using developments of LCA method which seeks to address regional or site specific impacts.

It is well known that production and consumption gives rise to a variety of environmental impacts over the life cycle and that changes in those may differ across environmental impact categories. Yet, these differences and potential trade-offs have been obscured in much of the previous PSS literature. Some of the PSS literature concentrated on a single indicator for environmental performance, such as primary energy use (*e.g*. Jalas, 2002; Hirschl, *et al.* 2003), or aggregations of environmental impacts into a single indicator (Goedkoop, *et al*. 1999). Other authors have merely discussed potential environmental performance of PSS at a conceptual level (Stahel 1997; White, *et al*. 1999; Roy, 2000). or expert ratings on an ordinal scale (Goedkoop *et al.* 1999; Halme, *et al*. 2006). Meijkamp (2000) included a variety of emissions and impact categories and to some extent referred to changes in individual impact categories. However, to great extent he referred to environmental savings in terms of an aggregated single environmental indicator. Behrendt *et al.* (2003) referred to different environmental impacts although not in a structured manner, depending on the availability from cited studies, such as Meijkamp (2000). Mont (2004c) included emissions of CO_2, nickel and cadmium for drill rental and sharing, and emissions of CO_2, hydrocarbons and nitrogen oxides for lawnmower rental and sharing. This has not sufficiently brought to light trade-offs between different environmental impact categories, such as trade-offs between direct waste prevention and primary energy use, or between direct waste prevention and global warming potential.

Quantitative environmental assessments of PSS are scarce. Comparisons of the findings of this study with other quantitative assessments is impeded by differences in the indicators and impact categories used and differences in functional units and system boundaries. For instance, Mont (2004c) used a functional unit of lawn mowing function for 10 to 15 years for 100 households and excluded the disposal stage from her assessment. Opaque reporting of methods and system boundaries also hinder comparisons. Thus, this research contributes to filling the research gap on quantitative assessments offering a structured report of the model, data and assumptions used.

Literature on quantitative environmental assessments of waste prevention is also very scarce (see section 2.2.3) with a couple of exceptions (Gentil *et al*. 2011; Olofsson 2004). The focus and system boundaries in these studies are different to the assessment reported in this thesis. Therefore a comparison of the results is not relevant. Instead, this research contributes to an incipient body of research on the emissions of PSS and waste prevention.

Nevertheless, to put the result into some context for a global type of environmental impact, the mean annual emission of CO_2 per household is 21.5 tonnes (Druckman & Jackson, 2009). By comparison, both the increases and reductions in global warming potential resulting from PSS are very small. However, since waste prevention measures are diverse and often 'small' activities (see section 5.6.1), it may be that the reductions in emissions of each measure are small.

6.4 RESULTS FOR SCENARIOS AT HOUSEHOLD SCALE

In the environmental assessment of the basic cases, PSS led to increased emissions for two to three out of seven types of emissions for all household tasks except laundry. The limited scale of the potential for prevention of direct waste (section 5.6.1), increase in emissions over the life cycle (section 6.3), and the limited willingness of both households and service providers to adopt PSS (section 4.2) cast doubts over the utility of PSS to achieve household waste prevention. The assessments of scenarios in this section explores whether different behaviours by households and service providers is able to negate the increased emissions.

The scenario names are the same as in the assessment of waste prevention potential reported in chapter 5.4 (Table 26,Table 27, Table 28, Table 29, Table 30). Thus, 'higher' scenarios refer to higher waste prevention potential and 'lower' refers to lower waste prevention potential[43]. The shaded cells with positive values show increases in resource use and emissions (henceforth, emissions). The unshaded cells with negative values show reductions in emissions.

For garden maintenance, the increases in hazardous waste generation and global warming potential in the basic case remained, although at a lower scale, in the higher scenarios for mass and uselife of material artefacts, when the self-servicing households used petrol-powered lawnmowers PSS (Table 51)Table 51 Changes in resource use and emissions through PSS for garden maintenance (self-servicing household using petrol powered lawnmower prior to adoption of PSS). The higher scenario for transport and the combined higher scenarios were the only ones in which no emissions increased when households adopted PSS and gave up ownership and use of lawnmowers.

[43] The higher scenario for mass means that households choose material artefacts of higher mass per unit, and service providers lower mass per unit; the higher scenario for uselife means that households use their material artefacts for a shorter period of time and service providers for a longer period of time than in the basic case; the higher scenario for transport means that the distance between the PSS depot is shorter than in the basic case; the combined higher scenarios means that all the higher scenarios occur at the same time. The lower scenarios are the opposite to the higher scenarios.

Conversely, in the combined lower scenario all types of emissions increase. For PSS to achieve waste prevention without any environmental trade-offs over the lifecycle, several behaviours need to occur that are different to the behaviours reported by participants or assumptions.

Table 51 Changes in resource use and emissions through PSS for garden maintenance (self-servicing household using petrol powered lawnmower prior to adoption of PSS)

Garden maintenance (petrol ss)	Primary energy	Waste haz	Waste non-haz	GWP	AP	VOC	PAH	EP
Combined higher	-49 %	-33 %	-85 %	-16 %	-61 %	-15 %	-90 %	-93 %
Transport higher	-39 %	-6 %	-76 %	-2 %	-50 %	-15 %	-82 %	-86 %
Uselife higher	-45 %	27 %	-73 %	23 %	-56 %	-15 %	-84 %	-89 %
Mass higher	-41 %	49 %	-71 %	30 %	-52 %	-15 %	-81 %	-88 %
Basic case	***-38 %***	*60 %*	***-65 %***	*35 %*	***-49 %***	***-15 %***	***-78 %***	***-84 %***
Mass lower	-36 %	74 %	-59 %	41 %	-45 %	-15 %	-75 %	-81 %
Uselife lower	-33 %	95 %	-54 %	45 %	-42 %	-15 %	-70 %	-77 %
Service volume lower	-28 %	62 %	-63 %	46 %	-41 %	0 %	-76 %	-82 %
Service volume lowest	-22 %	63 %	-61 %	53 %	-35 %	10 %	-74 %	-80 %
Transport lower	-37 %	148 %	-50 %	85 %	-46 %	-15 %	-72 %	-81 %
Ownership	-13 %	90 %	-12 %	60 %	-14 %	-7 %	3 %	-40 %
Combined lower	**20 %**	272 %	**55 %**	153 %	**22 %**	**19 %**	**62 %**	**1 %**

In the basic case of garden maintenance when the household used an electric lawnmower for self-servicing before adopting PSS, primary energy use increased as did global warming potential and emissions of VOC (Table 52). Increase in the latter two remained even in the combined higher scenario. In the lower scenarios for changes in single variables, PAH emissions also increased. In the combined lower scenarios, all emissions except hazardous waste increased. Since garden maintenance was the households task for which households were the most willing to adopt PSS, prevention of direct waste might be realized. However, this is likely to lead to increased global warming potential.

Table 52 Changes in resource use and emissions through PSS for garden maintenance (self-servicing household using electric lawnmower prior to adoption of PSS

Scenarios	Primary energy	Waste haz	Waste non-haz	GWP	AP	VOC	PAH	EP
Combined higher	-6 %	-86 %	-88 %	96 %	-65%	68,341 %	-58 %	-87 %
Transport higher	20 %	-81 %	-79 %	155 %	-51%	92,581 %	-21 %	-73 %
Uselife higher	8 %	-72 %	-76 %	208 %	-57%	76,219 %	-28 %	-78 %
Mass higher	9 %	-72 %	-77 %	212 %	-57%	83,219 %	-28 %	-78 %
Basic case	*21 %*	*-68 %*	*-70 %*	*251 %*	*-50%*	*92,586 %*	*-3 %*	*-69 %*
Mass lower	37 %	-63 %	-58 %	301 %	-38%	104,324 %	39 %	-51 %
Uselife lower	34 %	-64 %	-62 %	289 %	-42%	108,223 %	31 %	-56 %
Service volume lower	41 %	-68 %	-68 %	278 %	-42%	109,258 %	7 %	-65 %
Service volume lowest	55 %	-68 %	-67 %	296 %	-37%	120,374 %	13 %	-62 %
Transport lower	24 %	-51 %	-57 %	379 %	-47%	92,592 %	22 %	-63 %
Ownership	39 %	-47 %	-37 %	270 %	-26%	92,580 %	31 %	-29 %
Combined lower	114 %	-9 %	27 %	578 %	22%	158,085%	214 %	61 %

The basic case of PSS for home improvement led to reductions in all types of emissions except VOC and PAH. When households keep ownership and use of material artefacts while using PSS, global warming potential increases (Table 53). In the combined lower scenario emissions of all types increased. In most scenarios PSS leads to both prevention of direct waste, reduced global warming potential and reductions in other types of emissions. Therefore, policy-makers need to determine whether the increases in emissions of VOC and PAH are acceptable considering the reductions in waste and the other types of emissions. Households were unwilling to give up ownership and use of material artefacts while using PSS. Since the scenario where households keep ownership and use of material artefacts leads to increased global warming potential and increased use of primary energy, PSS may nevertheless cause more environmental problems than it solves. On the other hand, some households that adopt PSS may feel that they lack the skills to perform home improvement tasks, in which case they are unlikely to own and use power drills.

Table 53 Change in primary energy use and emissions as PSS for home improvement replaces self-servicing – higher and lower scenarios

Home improvement	Primary energy	Waste haz	Waste non-haz	GWP	AP	VOC	PAH	EP
Combined higher	*-63 %*	*-80 %*	*-87 %*	*-67 %*	*-70 %*	*-21 %*	*415 %*	*-92 %*
Transport higher	-45 %	-71 %	-70 %	-47 %	-53 %	31 %	582 %	-77 %
Uselife higher	-42 %	-72 %	-72 %	-41 %	-55 %	92 %	994 %	-82 %
Mass higher	-44 %	-68 %	-77 %	-43 %	-57 %	84 %	1,149 %	-86 %
Basic case	*-31 %*	*-64 %*	*-63 %*	*-28 %*	*-46 %*	*139 %*	*1,244 %*	*-74 %*
Mass lower	-12 %	-59 %	-32 %	-5 %	-29 %	236 %	1,353 %	-47 %
Uselife lower	-19 %	-54 %	-51 %	-13 %	-36 %	188 %	1,488 %	-63 %
Service volume lower	-25 %	-60 %	-60 %	-23 %	-40 %	142 %	1,247 %	-71 %
Service volume lowest	-18 %	-57 %	-56 %	-18 %	-34 %	146 %	1,250 %	-68 %
Transport lower	-12 %	-54 %	-54 %	-2 %	-37 %	284 %	2,126 %	-69 %
Ownership	3 %	-19 %	-25 %	9 %	-13 %	180 %	1,289 %	-35 %
Combined lower	*92 %*	*32 %*	*98 %*	*121 %*	*62 %*	*621 %*	*2,807 %*	*78 %*

The waste prevention assessment showed that house cleaning would lead to increased generation of direct waste. Over the life cycle, however, waste generation is reduced in the basic case. In the basic case, as well as the higher and lower scenarios, eutrophication potential and emissions of VOC and PAH increase. In the scenario where households keep ownership of vacuum cleaners and vacuum clean between the PSS deliveries, six out of eight types of emissions increase. House cleaning was the household task for which households were particularly inclined to keep ownership of material artefacts. PSS for house cleaning is likely to generate both more direct waste and emissions. Households were however, unwilling to adopt PSS for house cleaning and laundry in particular, therefore this increase in direct waste and emissions is unlikely to be realized.

Table 54 Changes in primary energy use and emissions as PSS for house cleaning replaces self-servicing - higher and lower scenarios

House cleaning	Primary energy	Waste haz	Waste non-haz	GWP	AP	VOC	PAH	EP
Combined higher	*-86 %*	*-54 %*	*-57 %*	*-74 %*	*-89 %*	*152 %*	*543 %*	*-46 %*
Transport higher	-84 %	-51 %	-40 %	-70 %	-85 %	212 %	779 %	2 %
Uselife higher	-76 %	-8 %	-12 %	-52 %	-81 %	425 %	1,374 %	17 %
Mass higher	-76 %	-8 %	-14 %	-52 %	-82 %	444 %	1,386 %	12 %
Basic case	*-74 %*	*-6 %*	*-1 %*	*-49 %*	*-79 %*	*489 %*	*1,615 %*	*52 %*
Mass lower	-72 %	-4 %	16 %	-46 %	-76 %	542 %	1,927 %	125 %
Uselife lower	-72 %	-4 %	10 %	-46 %	-77 %	544 %	1,828 %	94 %
Service volume lower	-73 %	-6 %	2 %	-48 %	-78 %	494 %	1,621 %	61 %
Service volume lowest	-72 %	-5 %	7 %	-47 %	-76 %	499 %	1,629 %	72 %
Transport lower	-61 %	54 %	51 %	-22 %	-71 %	858 %	2,729 %	119 %
Ownership	0 %	69 %	62 %	23 %	-7 %	542 %	1,662 %	93 %
Combined lower	*48 %*	*164 %*	*198 %*	*91 %*	*41 %*	*1,121 %*	*1,895 %*	*410 %*

Laundry was the household task with the greatest potential for prevention of direct waste in both absolute and relative terms, and also the only household task with reductions in all types of emissions in the basic case. In all the lower scenarios for changes in single variables, only emissions of PAH increase. In the combined lower scenario, emissions of all types except non-hazardous waste increase. Since households were particularly unwilling to adopt PSS for laundry (and house cleaning), the prevention of direct waste and reduced emissions is unlikely to be realized.

Table 55 Changes in primary energy use and emissions as PSS for laundry replaces self-servicing - higher and lower scenarios

Laundry	Primary energy	Waste haz	Waste Non-haz	GWP	AP	VOC	PAH	EP
Combined higher	*-29 %*	*-37 %*	*-76 %*	*-40 %*	*-22 %*	*-74 %*	*-60 %*	*-93 %*
Transport higher	-15 %	-26 %	-63 %	-25 %	-10 %	-60 %	-38 %	-85 %
Uselife higher	-21 %	-34 %	-69 %	-32 %	-16 %	-62 %	-24 %	-89 %
Mass higher	-21 %	-26 %	-69 %	-31 %	-15 %	-59 %	-23 %	-89 %
Basic case	*-14 %*	*-25 %*	*-62 %*	*-24 %*	*-10 %*	*-52 %*	*-6 %*	*-84 %*
Mass lower	-12 %	-24 %	-56 %	-20 %	-7 %	-47 %	2 %	-79 %
Uselife lower	-9 %	-15 %	-53 %	-16 %	-4 %	-41 %	13 %	-78 %
Transport lower	-13 %	-23 %	-60 %	-22 %	-9 %	-41 %	37 %	-83 %
Ownership	-4 %	-2 %	-36 %	-9 %	0 %	-21 %	24 %	-52 %
Combined lower	*7 %*	*12 %*	*-12 %*	*5 %*	*8 %*	*16 %*	*111 %*	*-27 %*

The above results show that the higher scenarios do not cancel out the increases in emissions that occur that occur in the basic case. The scenario where households keep ownership of material artefacts led to increased emissions for additional types of emissions for most households tasks. Since households were unwilling to give up ownership and use of material artefacts while using PSS this scenario is particularly plausible. The results in chapter 4.2 suggested that households as well as the property development firm and its supply chain were unwilling to adopt (buy and provide) PSS.

Reductions or increases in emissions in the basic cases, remain in many of the scenarios although at relatively higher or lower levels. For garden maintenance (electric lawn-mower for prior self-servicing), house cleaning and laundry, an additional type of emissions increases through all scenarios. For garden maintenance (electric lawnmower), home improvement and house cleaning, the combined higher scenarios led to reductions in one type of emissions that increased in the basic case and the other higher scenarios, whereas the other types of emissions that increased in this scenario increased in the combined higher scenario as well. The lowest service volume and ownership are the only lower scenarios with changes in single variables that led to increased emissions for types of emissions that were reduced in the basic case and the other lower scenarios. When households keep ownership and use of material artefacts for home improvement and house cleaning, global warming potential increases. In the case of house cleaning, ownership and lower transport scenario led to increased hazardous waste.

To sum up, the combined higher scenarios are not enough to negate increased emissions of all types for all household tasks. For two household tasks, the combined lower scenarios led to increased emissions of all types except one. For the other household tasks, the combined led to increased emissions of all types. Reductions or increases for a type of emission is relatively stable through the changes in single variables, and sometimes also through the combined higher scenarios. A small number of types of emissions are sensitive to changes in single variables for a couple of single-variable scenarios. The relative changes in the levels of reductions or increases are relatively large even if a type of emission increases in all scenarios.

The results of environmental assessments of systems depend on the modelled systems and on methodological decisions on for instance input data, assumptions, choice of time perspective and modelling of environmental impacts (Ekvall *et al*. 2007). Therefore, those methods do not generate complete or absolutely accurate information (*ibid).* Further research may generate more knowledge on behaviours that enables modelling of more complex systems and reduces the number of assumptions.

The definition of waste prevention includes a clause on reducing "the adverse impacts of the generated waste on the environment and human health" (Official Journal of the European Union 2008). Given the occurrence of increased environmental emissions for some types of emissions for the majority of scenarios in the environmental assessment, it is questionable whether the PSS that reduce direct waste can be called waste prevention if other emissions increase. However, the intention behind the legal definition may not be to exclude any increase in any emissions but to emphasise the importance of consider environmental and health impact to seek to avoid shifting burdens.

6.5 CONCLUSIONS FROM THE ENVIRONMENTAL ASSESSMENT

This chapter reported on the results from the environmental assessment undertaken to meet objective 3. It led to the following conclusions.

Research question 1 is concerned with whether there are any trade-offs between prevention of direct waste and emissions over the life cycle. Three of the four household tasks (garden maintenance, home improvement and laundry) have potential for prevention of direct waste in the basic case (see chapter 5). House cleaning was the exception. PSS for house cleaning also led to increased eutrophication potential and increased emissions of VOC and PAH for most scenarios. Of the three household tasks with waste prevention potential, PSS led to increased emissions of two to three types of emissions, such as VOC, PAH and global warming potential in the basic case and most of the lower and higher scenarios for garden maintenance and house cleaning. Transport by petrol powered vehicles typically led to increased emissions of VOC and PAH. However, savings in electricity during the usephase was sufficient to offset increases in global warming potential from the transport. However, since the service providers' lawnmowers were petrol powered, PSS for garden maintenance led to increased global warming potential. The size of the material artefact influences its ability to offset increased emissions from transport.

Research question 2 is concerned with whether there were any trade-offs between different types of emissions over the life cycle. PSS led to reductions in some types of emissions and increases in some types of emissions for all household tasks. What types of emissions decreased and increased differed across the household tasks and scenarios. Transport by petrol powered vehicles typically led to increased emissions of VOC and PAH. However, savings in electricity during the use phase was sufficient to offset increases in global warming potential from the transport. However, since the service providers' lawnmowers were petrol powered, PSS for garden maintenance led to increased global warming potential. Differences in material compositions between material artefacts used for self-servicing and PSS respectively may also contribute to such trade-offs. For instance, for house cleaning, the increased eutrophication potential arose from the extraction and production of PUR and steel sheet used in the vehicle. The former did not occur at all in the vacuum cleaner, and the latter as a much larger share in the vehicle than in the vacuum cleaner.

Research question 3 is concerned with the scale of the changes in emissions. The total reductions in global warming potential in the basic cases if a household adopted PSS for all four household task would be about 40 *kg*. This is a very small part of the annual CO_2 emissions from households which are 21.5 *tonnes*. In relative terms the savings in global warming potential are between 24% and 49% (when looking at the adopting household before and after adoption, for individual household tasks). It is very difficult to compare these results with results from other PSS research because of the scarcity of quantitative research, and the use of different indicators and bases for comparison and types of services. PSS research sometimes expresses the potential environmental improvements as factor improvements. These reductions in CO_2 are then between factor 1.3 and factor 2. However, *increases* in emissions such as VOC and PAH in relative terms are of orders of magnitudes of two to three, compared with relative reductions in

other types of emissions of one order of magnitude. The importance of these increases in local and regional emissions depends on other sources of exposure and the sensitivity of the receiving environment, which life cycle data typically do not address. It also depends on whether the cause is easy to isolate and abate. There were no comparable quantitative assessments of waste prevention.

Research question 4 was concerned with whether there were any differences between household tasks. Differences between the household tasks were revealed in the answers to the previous research questions. Laundry held the greatest potential for prevention of direct waste in absolute terms and was also the household task with reductions in all types of emissions in the basic case, and only increases in one type of emissions (PAH) which in the scenarios for single variables. However, households expressed limited willingness to adopt PSS for laundry. Thus the likelihood is limited that this waste prevention and environmental potential be realised. PSS for garden maintenance held potential for waste prevention in both relative and absolute terms, and households expressed a relative willingness to adopt it. However, it led to increased global warming potential in all scenarios except the combined higher scenario and the higher scenario for transport. Home improvement which also held potential for prevention of direct waste led to increased emissions of PAH in all scenarios, increased VOC emissions in all scenarios except the combined high scenarios, and increased global warming potential if households kept ownership and use of a material artefact. Households were unwilling to give up ownership and interim self-servicing when using PSS. Thus the overall waste prevention and environmental potential of PSS seems limited.

Thus, the research questions were answered and objective 3 met, although as anticipated, uncertainty remains due to the novelty of the research area, exploratory nature of the research and assumptions and limitations set out in chapter 3.8.3. The environmental assessment added to the uncertainty about the potential of PSS to achieve waste prevention and reduced emissions, due to the trade-offs between the two and limited willingness to adopt PSS with the greatest waste prevention and environmental potentials. Thus it would be premature for policy-makers to seek to promote adoption of PSS.

With regard to data uncertainties in the environmental assessment, further research could identify material compositions including material grades of different models of the same type of material artefact to see whether there are any signifant differences in models used by households and service providers. Policy-makers may also wish to support further research that compares the environmental performance of waste prevention through PSS with other waste management options such as reuse and recycling.

7 REFLECTIONS ON THE POLICY IMPLICATIONS OF THE RESEARCH

7.1 INTRODUCTION

This chapter reflects on the implications of the results of this research for policy-makers. First, the behaviours of households and service providers explored in chapter 4, in relation to the propositions in the PSS literature and in pursuit of objective 1, are used to critique the PSS concept. This critique also concerns the definition of PSS. The critique has theoretical as well as practical relevance. Policy-makers need to understand whether they should think of PSS as some particular kind of value offering[44], or whether they should just think of services. After that, results concerning households' and service providers' willingness to adopt the PSS are discussed, as well as potentials for adoption of household services provided by local service providers. This may have implications both for the waste prevention and environmental potential and for policy approaches required. The waste prevention potential and environmental potential are discussed both with regard to the scale of the potential, and uncertainties. The discussion points to a policy agenda of sustainable consumption and production to address both household behaviours and service providers' behaviours. Finally, policy areas and initiatives are proposed. The key messages are as follows:

- The PSS concept is critiqued, concluding that the term and concept is superfluous and that policy-makers and other actors should simply think of services and their environmental potential.
- The willingness to adopt PSS in this study was limited both among households and the property development firm and its supply chain. Nevertheless, literature suggests there may be potential for adoption of household services in local service markets, provided by many small local service providers. This may reduce chances of economies of scale, and increase the likelihood of the lower scenarios occurring. This also means that policies seeking to improve the environmental potential of household services should be directed at small local service firms.
- Household services have some potential for waste prevention although of a limited scale. Since household waste prevention activities tend to be many small diverse activities, household services could have a role as one in a suite of waste prevention measures. The potential is however uncertain and possibilities of increased waste generation arising need to be avoided.
- Due to the possibility that PSS could lead to increased waste generation and increased emissions, policy-makers should not seek to stimulate adoption of PSS at the present time.
- The direction and magnitude of changes in emissions when households use PSS instead of self-servicing depends on the difference in behaviours between self-servicing and service provider. A greater difference, and thereby better result for

[44] Value offering is the value that firms create for customers in terms of material artefacts and/or service, their attribute performance, pricing, ,relationship and interaction with customers (Ngo & O'Cass 2009)

PSS, could be the result of self-servicing households behaving in less environmentally sustainable ways. Therefore, policy-makers should not seek to stimulate the environmental potential of such a change, but should consider stimulating the potential of both self-servicing and household services.

- Policy-measures are proposed, in the areas of sustainable production and consumption directed both at households and service providers. On the supply side, policies seeking to improve skills and innovation in small service firms may increase the environmental sustainability of their choice, use, maintenance and disposal of material artefacts, and their design and transport planning of household services.

7.2 REFLECTIONS ON BEHAVIOURS AND THE PSS CONCEPT

The PSS literature suggested that PSS has potential for improved resource productivity and reduced environmental burdens. This potential was premised on a number of behaviours of service providers and self-servicing actors respectively (section 2.4.2.4). However, the proposed behaviours were often based on assumptions rather than empirical research. This research explored a number of proposed behaviours (Table 3, section 2.4.2.4). In this chapter, the PSS concept is critiqued in light of the findings in Chapter 4 and the critique of the definition of PSS in the literature review (section 2.3.3.1). PSS is found not to be a useful distinction. The critique below results in a rejection of the PSS concept and claim that PSS are simply services.

Some of the PSS literature sought to distinguish PSS from other value offerings[45]. For instance, Tukker & Tischner (2004) suggested ways in which PSS differ from 'normal business systems', seemingly viewing all other business activities as homogenous. One of the differences they suggest is that in PSS firms need to offer the product-service combination in a 'professional way', and taking into account the core competences of partners and ensure that all the partners in the system profit from the PSS. This statement suggests that no other business offerings than PSS does this, in spite of extant research on for instance strategic alliances and strategic sourcing. Other similarly sweeping claims on for instance organisation, customer relation and user interface are made. No convincing argument was presented by authors in the PSS literature as to whether and how PSS differed from other value offerings. If there is no difference, then the term PSS is redundant and confusing for decision-makers.

Some definitions also suggested that PSS were only those systems of products and services that had a lower environmental impact than 'traditional sales' (or other terms referring to the often unspecified reference case with which PSS was compared). The findings of this research suggest that it is difficult to guarantee environmental potential of a change from self-servicing to commercial services. The relative environmental burdens of self-servicing and a commercial service depend on for instance the choice and management of material artefacts, material compositions of material artefacts and

[45] Value offering is the value that firms create for customers in terms of material artefacts and/or service, their attribute performance, pricing, ,relationship and interaction with customers (Ngo & O'Cass 2009)

transport distances. These may differ across contexts. Service providers could voluntarily abide by eco-labelling standards that require certain standards of equipment and practices. However, household behaviours cannot be guaranteed and therefore it is very difficult to define certain services as having lower environmental impacts. Furthermore, the behaviours of households and service providers may change over time. Therefore it is difficult to identify PSS (services) that consistently over time perform better in environmental terms than other services. The definition of PSS by Mont (2004c) also neglects the trade-offs between emissions or environmental impacts that occur in many instances.

Many studies shared a number of propositions on how those concepts might generate environmental benefits over self-servicing[46]. This research explored those propositions and found that self-reported behaviours among participants in some instances confirmed the proposition in the literature. However, for all propositions there were diverging behaviours, as summarised in Table 19, section 4.4. For instance, the PSS literature largely suggested that households give up ownership and use of material artefacts when using PSS. Households in this research however were unwilling to give up ownership and wanted to be able to perform some household tasks between the PSS deliveries, for instance cleaning in case of spills. Service providers were thought to have incentives to reduce energy use during the use-phase. However, in many of the result-oriented PSS in this study, the service providers used power supply in the homes, and any energy savings would have accrued to the households. There was no evidence of service providers seeking to reduce energy use during the use-phase. Service providers were thought to maximise the use of their material artefacts to increase the revenue flows from them generated by the service provision. Households on the other hand were thought to replace material artefacts due to changing fashion. There were examples of households using their material artefacts for much longer than the typical operational age, and also examples of service providers replacing material artefacts after a relatively short uselife. Thus, there seems to be no consistent basis for an all-embracing concept such as PSS for household tasks.

There are many overarching terms that are imprecise and whose meaning differ depending on the discipline or context in which they are used to suit the typical problem of each discipline. Examples are 'service' (Gadrey, 2000; Heiskanen & Jalas, 2003) and 'technology' (Fleck & Howells, 2001). Thus, closure on a particular and exclusive definition may not be a fair or necessary requirement on PSS. However, the key components in definitions of PSS (Table 1, section 2.3.3.1) are covered by the term 'service' as defined by for instance (Gadrey, 2000; 1999). Therefore the term PSS seems redundant. The term 'service' does however not refer to environmental potentials, which some definitions of PSS do. The environmental performance was found to be difficult to guarantee. Therefore, the term PSS is not warranted. To be of analytical use, overarching terms may need further sub-characterisations. The services marketing literature offers a variety of ways to classify services which facilitate different service design and operations challenges to be addressed (Lovelock, *et al.*

[46] Or 'traditional business models' as some authors referred to.

1999). Life cycle approaches are used to understand the environmental potential of different types of services in certain contexts. The sub-categories that the PSS literature used (product-oriented, use-oriented, result-oriented) proved to be a blunt types for understanding design, management, waste prevention and environmental issues. Therefore, it is better to simply refer to household services, some of which may achieve waste prevention and reduced emissions compared with self-servicing, under some circumstances.

The propositions on the behaviours of the service providers were based on the idea that service providers own the requisite material artefact. Gadreys (2000, pp.382–383) definition of services also suggests that the service provider 'controls' the technical capacity to which the human capacity is applied to produce a useful effect. This research identified an instance of a household service provider for cleaning services who did not own the requisite material artefact but used the one provided by the households.

PSS concept is of limited utility for waste prevention in conceptual terms. Instead, the term 'service' suffices. Policy-makers should consider the environmental potential of services in different contexts, rather than conceiving of PSS as a particular kind of service.

7.3 REFLECTIONS ON ADOPTION OF HOUSEHOLD SERVICES

PSS literature pointed to the increased share of service sectors in western economies as a means of harnessing potentials for increased resource productivity (White et al. 1999; Roy 2000; Manzini & Vezzoli 2002; Cook et al. 2006). If PSS are simply services in accordance with definitions by for instance Gadrey (2000) (see section 2.3.1), then the limited willingness to adopt PSS noted by the PSS literature seems contradictory. However, PSS is a very broad term and adoption may depend on the particular offering in the particular context. Many of the PSS studies comprised a large number of services in several European countries (*e.g*. Bartolomeo *et al.* 2003; Behrendt *et al.* 2003; Halme *et al*. 2005; Tukker & Tischner 2006). Therefore, it is difficult to identify particular contexts or PSS designs that lead to limited willingness to adopt.

The present research on attitudes towards adoption of PSS suggested limited willingness among households, the property development firm and its current supply chain to buy and provide the experimental PSS (household services). This conflicts with developments in literature pointing to an increased use of domestic services (Delap, 2011). However, this expressed reluctance may be due to the context in this study. In this study, potential providers of PSS were a large national property development firm and its supply chain comprised of large facilities management firms, for reasons set out in section 3.3. Their concerns related to a variety of consequences of adding services to households to their current portfolio of offerings to other firms (see section 4.2.2). This is consistent with the statement by Leather & Rolfe (1997) that large firms do not enter the market for household repair and maintenance in the UK due to the absence of major contracts. Instead the market is dominated by small firms and self-employed. This is also consistent with experiences from Sweden which show that an increased demand for

household services has been met by a large number of small local service providers (Skatteverket, 2011).

This means that there is likely to be supply for household services although it seems unlikely to be from large property development and facilities management firms. This in turn means that the potential for infrastructure on new housing developments to facilitate service provision (section 3.3) is unlikely to be realized. On the other hand, the property development firm expressed an unwillingness to set aside land for infrastructure for household services. They also expressed that it was difficult to gain acceptance for other infrastructure in the buildings with uncertain financial return. Therefore, they deemed it difficult to get management consent for developing infrastructure for household services on the housing development.

The behaviours of service provider proposed by the PSS literature (section 2.4.2) draw partly on ideas of economies of scale, in that service providers have greater skills to use and maintain material artefacts than self-servicing or firms, and that they are able to influence the design of material artefacts[47]. If household services are provided by small local service firms, or individuals employed by households, then the extent to which economies of scale arise. According to Leather & Rolfe (1997), the small firms in the domestic repair and maintenance sector often have low skills, limited exposure to innovations in terms of new technologies and materials, and face competition of rogue traders. The finding by Leather & Rolfe (1997) may or may not reflect the present time with regard to for instance training opportunities for trades people. However, in order to realize the waste prevention and environmental potential of household services, and avoid increased waste generation and emissions, skills and innovation in small local firms is an important policy area.

Householders in the research also expressed limited willingness to adopt PSS (section 4.2.1), although some of the participants had used household services such as garden maintenance, ironing, window cleaning and laundry. As will be further discussed in the next section, policy-makers are not recommended to promote adoption of household services with a view to achieving household waste prevention at the present time. However, other policy measures could lead to increased adoption of household services. In some European countries such as Denmark, Finland and Sweden, tax credits on household services have been introduced, and in France, Belgium, Austria and Germany domestic service vouchers have been introduced (Kvist, 2012). News reports suggest that the British government is considering tax credits for domestic services of a similar kind to those introduced in Sweden[48] in 2007 (Brant, 2012; Ross, 2012). If adoption of

[47] Although the reason for the latter was more do with the idea of PSS being provided by manufacturing firms who retained ownership of their material artefacts to generate income by selling the use of the artefacts instead.

[48] In Sweden, a householder only pays 50% of the labour cost for certain services in or near the home. (up to an annual limit). The tax credit is deducted against municipal and state income tax and property charge. The service provider files the claim to the Tax Agency and only invoices the household 50% of the labour cost.

household services increases either as a continuation of market trends or policy incentives from other policy areas than waste policy, then waste and environmental policy-makers may wish to consider policy measures for improving the environmental sustainability of household services to avoid increased waste generation and emissions. This is further discussed in section 7.5 below.

7.4 REFLECTIONS ON WASTE PREVENTION AND ENVIRONMENTAL POTENTIAL

The assessed PSS had some potential for waste prevention compared with self-servicing (although PSS for one household task led to increased waste generation). The scale of the potential waste prevention was modest (section 5.6.1). However, waste prevention comprises many small diverse activities (Cox et al. 2010), each with a limited potential (although was however a substantial lack of robust and comparable quantitative evidence), the PSS (household services) may play a role as one in a suite of waste prevention activities. The total waste prevention potential in this research was comparable with the potential reported by Salhofer *et al.* (2008) from case studies of rejecting unsolicited mail, reuse of cloth nappies, reusable serving materials during events which was reported to be between 1% and 3% of household waste generation. Therefore, PSS may still be useful as one measure in a suite of measures for waste prevention in spite of the limited scale of the potential. Instead, the usefulness of different measures for waste prevention depends on the relative cost-effectiveness of any policy measures required to realise the potential of different waste prevention activities. The relative costs and potential environmental gains also need to be compared with other waste management options such as reuse and recycling. Further research is required to address these issues.

The waste prevention and environmental potential is however uncertain. PSS for house cleaning led to increased waste generation. In addition, PSS for all household tasks led to increased emissions for most of the assessed combinations of behaviours for households and service providers. The waste prevention and environmental potential depends on for instance the organisation of the PSS, in particular concerning the transport required for the PSS delivery. It also depended on the size of the material artefacts (their ability to offset emissions from the transport) and the difference in behaviours of the reference case of self-servicing and PSS.

Most of the trade-offs between different types of emissions arose from the transport in PSS, and mostly from the fuel use in the use-phase although in some instances also from the extraction and production of materials in the vehicle (section 6.4). On the one hand, these emissions may be averted to some extent if the service delivery is optimised so as to reduce the overall transport distance. The extent to which optimised service delivery is able to reduce transport distances more than the shortest distance used in the assessment is uncertain due to the short transport distances used in those scenarios (1.5 km, 3 km and 5 km) The increased emission in the case of garden maintenance arose from the use of petrol powered lawnmowers by service providers. Some emissions from the combustion of petrol may be reduced by using for instance alkylate petrol.

The potential for prevention of waste and emissions are subject to assumptions and limitations set out in the methodology chapter. Alternative behaviours of commercial service providers and self-servicing households were assessed in a range of scenarios to address the assumptions. Some combinations of behaviours led to reduced waste generation and some led to increased waste generation when PSS replaced self-servicing. There is however insufficient knowledge at present on the contexts in which the different behaviours occur, on which to base policy. It is also uncertain what effects changes in technology (including knowledge, behaviours and material artefacts) will have over time.

Higher waste prevention through a change from self-servicing to a commercial household service is predicated on a greater difference between the behaviours of households and service providers. If households choose heavier material artefacts and replace them more frequently after a shorter operational life, then the waste prevention potential increases. The overall waste generation and emissions in society would be reduced if both households and service providers chose lighter material artefacts and used them for longer. Therefore, higher waste prevention potential of a change from self-servicing to commercial household service is not necessarily the best outcome for the environment.

Determining the importance of the increases in some types of emissions with potential regional or local impacts is another more applied problem. May large increases in transnational although not global, and persistent emissions such as polycyclic aromatic hydrocarbons be acceptable if PSS leads to reduced global warming potential? If so what scale of increases? This is ultimately a political and stakeholder issue. It could be supported by specific developments of the LCA method that seek to address local impacts that depend on overall concentrations and the sensitivity of the receiving environment.

The legal definition of waste prevention comprised the quantity of waste, adverse impacts on the environment and human health, and content of harmful substances. It is uncertain whether waste prevention activities, such as PSS, that lead to increased emissions which could lead to adverse impacts on the environment and human health qualify as waste prevention in strict terms. The emphasis in the definition to avoid shifting of burdens is important but could be difficult for many waste prevention measures to achieve entirely. A more workable interpretation is that modest increases in some types of emissions may be acceptable.

Given the possibility of increased generation of direct waste, increase of some types of emissions in most scenarios, it would be inappropriate for policy-makers at the present time to stimulate adoption of these household services with a view to achieving household waste prevention. Bartolomeo *et al.* (2003) came to the same conclusion although for a variety of services in the business-to-business market. Instead, policy-makers could consider further research into behaviours especially of service providers but also of households. A number of topics for further research are proposed in section 8.6. Such knowledge could lead to better understanding of how the worse scenarios may be avoided and the potential realised.

In conclusion, the waste prevention potential of PSS is limited and uncertain. It is confounded by the variability of the reference case (self-servicing) and trade-offs between waste and emissions. Therefore, policy-makers should seek to promote environmentally sustainable behaviours of both households and service providers. Improved performance of both households and service providers may lead to overall reduced waste and emissions. Policy measures are discussed in the next section.

7.5 REFLECTIONS ON POLICY IMPLICATIONS FOR SUSTAINABLE CONSUMPTION AND PRODUCTION

Given the possibility of increased waste generation of PSS (household services) and the prevalence of increased emissions (not withstanding potentials for waste prevention and reduced emissions) section 7.3 suggested that it would be inappropriate for waste policy-makers to stimulate households to abandon self-servicing and adopt household services. Instead, it was concluded that policy-makers should promote increased resource productivity and reduced emissions over the life-cycle for both self-servicing and household services. This conclusion leads into a sustainable consumption and production (SCP) policy agenda rather than a strict waste prevention agenda. The results of this research are discussed with respect to recent developments in UK policy approaches to SCP below.

The research of PSS here shows that the individual behaviours (individual variables in the model[49] used to assess waste prevention) were rarely critical to the waste prevention and environmental potential of the PSS (household services). Potential for prevention of direct waste remained when one alternative behaviour at a time, such as mass or uselife of material artefacts, was altered such that it resulted in lower waste prevention. When all the behaviours were altered at the same time, so that they resulted in lower waste prevention, waste generation increased for all household tasks except for laundry. Changes in emissions over the life cycle tended to remain when one behaviour was altered at the time. This means that policy-makers need to address behaviours influencing all of those variables for both households and service providers, rather than targeting particular behaviours.

7.5.1 Households

One of the components of Defra's framework for sustainable lifestyles (Defra, 2011) is the 4E's model, which stands for Enable, Engage, Exemplify, Encourage. 'Enable' involves the removal of barriers, provision of facilities and viable alternatives, provision of education and training. 'Engage' refers to getting people involved. It includes working with networks and trusted intermediaries, and using insights to mobilise particular population groups (segments). 'Exemplify' means that policy-makers should lead by example, demonstrate that others are acting, and ensure consistency in policies. 'Encourage' refers to provision of incentives and disincentives.

[49] Choice of material artefact of a certain mass, uselife of material artefact, transport distance, service volume

In this research, households only accounted for conscious criteria for choice of material artefacts, like price and brand. Enabling policy-measures to influence households' choice of material artefacts may include removing the most polluting material artefacts by legislation, promotion of eco-design so that less polluting options are available, promotion of eco-labels and energy labels to ensure that information is available to households that compare alternatives before making purchasing decisions. Households did not account for more unconscious biases related to emotions, culture and social norms. (Shove & Walker, 2010) though suggests that everyday practices are reproduced and altered by an array of influences from different actors, and that policy can influence ideologies and practices. Therefore, policy measures may not merely target specific behaviours, but also campaign to convey messages such as the value of environmental sustainability. Policy-makers could also engage other organisations to enable and encourage the choice of second hand material artefacts. While there were examples in the research of households using a second-hand material artefact, buying new ones was the common choice. However, more households gave their material artefacts to friends or kin when replacing them.

Results in chapter four and from the literature review suggest that limited willingness to give up *ownership* of material artefacts when using a household service may be due to both concerns with service providers' professionalism and skills, reliability and trustworthiness (4.2.1) and thus the sustained standard of performance of the service. Initiatives for consumer rights targeting household services may help build households' trust in sustained performance of the household service so that willingness to give up ownership of material artefacts is increased. Citizens' advice bureau offers remedial advice to consumers, which includes builders and home improvement, and service providers.

The results in chapter four and input data into the waste prevention assessment in chapter 5 showed that there was a great variety in the frequency and duration of performing the tasks. The extent to which households repaired/had their material artefacts repaired also varied. There was a tendency among participants to think that artefacts could not be repaired when they broke down, or that repair would not be economically beneficial. Increased knowledge on the availability and costs of commercial repair services may encourage some households to have their material artefacts repaired. Increased knowledge on typical faults and remedies may increase the propensity of householders to repair material artefacts themselves at home. The possibility of including this in existing government schemes to increase skills or transform markets could be explored. Again, conveying messages that contribute to ideologies of maintenance and repair should not be neglected.

7.5.2 Service providers

Section 7.3 concluded that while the property development firm and its supply chain of large facilities management firms were unwilling to provide PSS, there may be other drivers for expansion of household services. However, such services were likely to be provided by a large number of small, probably local service providers. Thus it is unlikely that any substantial economies of scale arise. Some of the proposed behaviours thought to result in increased resource productivity through PSS drew on simple notions of economies of scale, notably the skills of service providers to choose the most

appropriate material artefact for the jobs and the skills to perform the tasks efficiently and maintain material artefacts properly. To some extent local service providers are likely to have such skills from some form of training as well as every-day practice. However, Leather & Rolfe (1997) suggested that this type of firm, skills and uptake of new methods are limited. Therefore, training is important as are ways to improve those small firms' exposure to innovative practices and materials, and transport planning and service design. The Department for Business, Innovation and Skills currently pursues Sector Skills Councils to bridge gaps in various sectors and promote improved learning through various routes, for instance apprenticeships and higher education. The National Skills Academy acts as hubs of specialist resource and expertise, leading specialist networks for training providers. The Design Council offers a mentoring service for small and medium-sized firms to help them become more innovative. Business Link offers advice on a number of issues, including the environment and resource efficiency. These initiatives could be reviewed to establish the extent to which they engage with household services or whether additional initiatives are needed.

Additional policy initiatives that could contribute to the knowledge among small and medium sized service firms on how to reduce resource use and emissions are pursued by the Department of the Environment, Food and Rural Affairs (Defra). The Market Transformation Programme provides information on impacts arising from products over their life cycle, to support decision-making. Currently, six product areas are covered which may partly be applicable to households services. The Waste and Resources Action Programme provides advice and support to firms and other actors on how to become more resource efficient.

Voluntary schemes such as eco-labelling cannot guarantee the environmental performance of a change from self-servicing to commercial household services since this depends on the behaviours of both households and service providers. However, third-party certified eco-labels for household services could set criteria for material artefacts and processes used in the delivery of the household services. There are many different ecolabels. The EU Ecolabel is one example.

Since the transport in PSS was the main reason for increased emissions over the life cycle when PSS replaced self-servicing, promoting vehicles and power sources with lower emissions could also contribute to the 'greening' of household services. Current initiatives of the Department for Transport include grants for plug-in cars and vans, match-funding of other actors installing recharging infrastructure for plug-in cars; Business Link offers advice on low emissions vehicles; advice on fuel efficient driving techniques, car-sharing and car clubs, fuel economy labels for cars. These initiatives could be reviewed to identify the extent to which also reduce the environmental burdens from transport in the delivery of household services.

By bringing household services out of the undeclared sector into the declared sector, a professionalization might occur. This may enable policy makers to reach service providers and engage them in policy initiatives. Thus tax deductions for household services may indirectly contribute to increased resource productivity and reduced emissions.

Finally, it is important for policy to also contribute to green ideologies and norms, as well as promoting for instance infrastructure and skills. Shove (2010) notes that government campaigns can influence societal ideologies and norms, although each actor can only contribute to the total outcome.

The above are examples of policy areas that could contribute to the increased environmental sustainability of result-oriented household services by addressing behaviours of households and services providers related to their choice, ownership use, maintenance and disposal of material artefacts. Examples are given of policy initiatives already in place. However, their effectiveness at reaching providers of household services needs to be established. However, more research and in-depth policy impact analyses are needed to establish the effectiveness, efficiency, practicality and acceptability of the discussed policy measures, and their fit with other policies.

7.6 CONCLUSIONS

This chapter considered the policy implications of the research. The PSS concept was critiqued and policy-makers were advised that PSS are just services. The assessed household services had some although modest potential for household waste prevention. Since household waste prevention measures are made up of many small activities (Cox, *et al*. 2010) household services may have a role in a suite of waste prevention measures. However, there are many uncertainties associated with the potential. Some combinations of the assessed behaviours of households and service providers led to increased waste generation, and most behaviours for most household tasks led to increased emissions of some types. The waste prevention and environmental potential of the household services depends on the organisation of the services, in particular regarding the efficiency of the transport required to deliver the result-oriented PSS. It also depends on the size and material composition of the material artefacts used by self-servicing households and service providers respectively. In particular the behaviours of service providers were uncertain as they were based on a small number of interviews with local service providers outside of the context of this research. Alternative behaviours were assessed to show a reasonable scale of the potential. However, the circumstances in which these different behaviours occur are unknown.

Due to these uncertainties, policy-makers should not promote adoption of PSS at the present time. Households, the property development firm and its supply chain expressed reluctance towards using and providing the household services. However, considering literature on household ('domestic') services in the UK, there seemed to be a possibility for increased use of household services provided by small local service providers. Literature suggested that small local service providers have limited skills and exposure to innovation. This reduces the potential for economies of scale which may in turn reduce the scale of the waste prevention potential. To avoid that such an increase in household services leads to increased waste generation, policy-makers should support initiatives for development of skills and innovations in small firms in local service markets.

Greater waste prevention potential of a change from self-servicing to commercial household services (PSS) arises if households perform self-servicing in a less

environmentally sustainable way, such that the difference between self-servicing behaviours and the behaviours of service providers is relatively greater. This does not contribute to overall environmental sustainability in society however. Therefore, policy-makers should seek to influence the behaviours of both households and service providers towards greater environmental sustainability. This leads into a policy agenda of sustainable consumption and production, rather than a pure waste or PSS policy agenda. Policy measures were proposed. On the supply-side, examples were offered of policy measure to stimulate skills and innovations, and resource efficiency for small firms, and reducing environmental impacts of transport. For households, examples of ways to enable, engage, exemplify and encourage more sustainable lifestyles in households were provided in accordance with Defra's '4E' framework (Defra, 2011).

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 INTRODUCTION

This chapter draws together the conclusions from the research. First, the aim and objectives are reviewed and found to be fulfilled. Second, conclusions for each objective are summarised as well as conclusions from the policy implications of the research. After that, the generalizability of the findings and the contributions to knowledge are discussed in turn. Finally, recommendations for further research are made.

8.2 REVIEWING AIM AND OBJECTIVES OF THE RESEARCH

As detailed in chapter 1, the aim of the research was to explore the utility of PSS concept in achieving household waste prevention in urban areas of the UK.

The objectives were:

1. To identify attitudes towards PSS adoption and behaviours concerning choice and management of material artefacts which influence the waste prevention and wider environmental performance of PSS

2. To identify the waste prevention potential of experimental PSS

3. To identify the environmental potential of experimental PSS

The concluding sections of chapters four to six showed how the research questions for each objective were answered. The research questions were formulated so as to lead to the fulfilment of the related objective. In turn, the objectives of the research were designed to lead to the fulfilment of the aim of the research. Thus, by answering the research questions, the aim and objectives were met. Due to the exploratory nature of the research it was anticipated that the findings would offer indicative rather than definitive answers and also raise further questions. This was the case. In the next section, the conclusions pertaining to the different objectives are summarised.

8.3 CONCLUSIONS FROM THE THESIS

Conclusions emerging from the research for each objective are summarised below.

Objective 1 was concerned with the attitudes of households and service providers respectively towards adopting[50] the experimental PSS, since adoption is a prerequisite for realising any potential and the literature suggested PSS adoption was a challenge. This was explored through focus groups and interviews (section 3.6.2) and analysed by

[50] In this research adoption on the supply-side means providing PSS

coding and clustering (section 3.6.3) using frameworks from the literature (section 2.4.4.3).

- Consistent with the concern in the PSS literature, the findings from this research suggested ambivalence and limited willingness to adopt PSS, both among households and supply side participants.

- The attitudes to adoption were relatively more positive for some household activities than other. Households were more positive towards the experimental PSS for garden maintenance and home improvement. Supply side representatives were more positive towards the experimental PSS for garden maintenance, home improvement and house cleaning and less positive towards PSS for laundry.

- Cost and price, accessibility and flexibility, reliability and trustworthiness, service recovery, were barriers to households' adoption of PSS. Professionalism and skills, reputation and credibility and enjoyment could act both as drivers and barriers to adoption. Attitudes and behaviours, and environmental potential were neither drivers nor barriers to households' adoption of PSS.

- Market conditions, strategic orientation, network and supply chain were barriers to supply side adoption for the property development firm and its supply chain to provide PSS. Customer demand and customer relationship, corporate competence, portfolio of offerings, cost, revenue and profits were both drivers and barriers to supply-side adoption of PSS. Regulatory framework, organisational structure and environmental potential were neither drivers nor barriers.

Objective 1 was also concerned with the behaviours of households and service providers pertaining to choice and management of material artefacts. This enabled the qualitative testing and critique of key propositions underpinning the concept of PSS and how it is thought to lead to resource productivity. It also provided qualitative insights to the assessment of waste prevention potential reported in chapter 5, since the variables in the model developed to assess the waste prevention potential drew on those behaviours (section 3.7.2).

- Findings partly confirmed and partly disconfirmed the propositions in the PSS literature (see summary table in section 4.4). The occurrence of findings that contradict almost all propositions suggest that these propositions do not form a coherent and consistent basis for the PSS concept.

Objective 2 was concerned with the potential of PSS to achieve household waste prevention. A model was devised comprising variables pertaining to households' and service providers' choice and management of material artefacts (section 3.7.2). Input data was collected through a survey questionnaire with households and interviews with service providers (section 3.6.2) and assumptions derived from the PSS literature (section 3.7.4)

- The waste prevention potential differed among the assessed household tasks (garden maintenance, home improvements, house cleaning and laundry). When the waste prevention potential was expressed as mass, the household tasks with the heaviest material artefacts (laundry and garden maintenance) had the greatest potential. When the waste prevention potential was expressed as a percentage, the household tasks with the material artefacts with the shortest operational age at the time of replacement in self-servicing had the greatest waste prevention potential of PSS. These were garden maintenance (lawn-mowers) and home improvement (drills).

- For house cleaning a change from self-servicing to PSS resulted in more waste being generated, that is negative waste prevention potential. The reduction in the stock of vacuum cleaners in the case of PSS, was not sufficient to off-set the mass of the vehicle used for the PSS delivery. This occurs when the material artefact is relatively light and the service yield of transport[51] is limited. The service yield by the transport is a matter of design and organisation of the PSS. Therefore, PSS involving small material artefacts may still hold waste prevention potential with a different organisation.

- The amount of waste prevented by a change from self-servicing to the experimental PSS is a very small share of the total household waste arisings (some 0.5% of total household waste arisings even if 100% of households adopt PSS for all four household tasks).

- Given the limited interest among households and service providers to adopt PSS, especially for laundry which offers the greatest waste prevention potential both in absolute and relative terms, the overall waste prevention potential is very small. However, waste prevention activities are diverse small activities (Cox *et al.* 2010*)*. Therefore, the limited scale of the potential may not preclude PSS from being one in a suite of measures for household waste prevention.

Objective 3 of the research concerned the environmental potential of PSS, considering primary energy use and seven types of emissions (including waste) in a life cycle perspective to show whether a shift from self-servicing to PSS can be achieved without environmental trade-offs. Equations set out in section 3.8.1.4 relate life cycle indicators for the emissions to the mass of the different materials used in the material artefacts, drawing on the mass of material artefacts from the assessment of waste prevention. Additional secondary data on material compositions and other life cycle processes were used (section3.8.2 and 6.2). The results of this assessment were reported and discussed in chapter 6. From this may be concluded that:

- The magnitude and direction of change of emissions differ across emissions and household tasks. Environmental performance does not improve or deteriorate

[51] The amount of service delivered, for instance expressed as the number of households serviced per day.

uniformly for all types of emissions. Thus PSS leads to trade-offs between different types of emissions.

- Types of emissions for which environmental burdens increase are typically emissions of VOC and PAH due to transport emissions in PSS, whereas global warming potential from transport was offset by the savings in energy use during the usephase for the household tasks. Emissions from the petrol powered lawnmowers used in PSS led to increased global warming potential.

- There are also trade-offs between emissions and prevention of direct waste. Even if the waste assessment showed waste prevention potential, other types of emissions over the life cycle increased.

- In absolute terms, reductions in global warming potential were very small compared with total annual CO_2 emissions from households. Relative reductions in global warming potential for a single household after PSS adoption was between factor 1.3 and factor 2, which is in line with the potential proposed by Heiskanen & Jalas (2003) in their review of evidence. Relative increases in VOC and PAH for some household tasks were in orders of magnitude of two to three. The importance of these increases depends on the exact species and concentrations in the receiving environment, which life cycle type assessments do not typically address.

Key conclusions from the consideration of policy implications of the research are as follows:

- The PSS concept was found to be redundant and of limited utility for waste prevention. Most definitions of PSS were not able to distinguish PSS convincingly from services in general, or indeed any value offerings. The waste prevention and environmental potential depends on relative differences in the behaviours of households and service providers across the life cycle and needs to be determined on a case-by-case basis. In addition, the potential is likely to be dynamic over time. Therefore, defining PSS as services that have superior environmental performance compared with self-servicing is not fruitful. The behaviours reported in this research were partly consistent with and partly contradicting the propositions from the PSS literature. The occurrence of behaviours diverging from practically all of the propositions led to the conclusion that there is no consistent basis for the PSS concept. Instead, policy-makers should think of services and seeking to reduce environmental impacts of services along with other measures for sustainable production and consumption.
- The PSS held some potential for waste prevention. The modest scale of the potential may not preclude PSS from being one in a suite of measures for waste prevention.
- However, given the possibility of increased waste generation, the prevalence of increased emissions of some types, the inability of higher scenarios to negate those increases in emissions, and uncertainties, policy-makers should not seek to stimulate adoption of PSS/household services with a view to achieving household waste prevention at the present time.

- Adoption of commercial household services may arise from other market and policy developments. Such services may be provided by a large number of small local firms rather than the national property development firm and its supply chain of large facilities management firms in this study. Economies of scale are not as likely to arise in fragmented local service markets. Skills and exposure to innovation may be problematic.
- Policy-makers should not seek to promote the environmental potential of a *change* from self-servicing to commercial household services, but to stimulate improved resource productivity and reduced emissions from both. A number of policy measures were proposed, both from policy areas of skills and innovation, and sustainable consumption and production.

The above leads to the following conclusion on the aim of the thesis: The PSS concept (result-oriented PSS for household tasks) is of limited and uncertain utility for achieving household waste prevention.

8.4 GENERALISABILITY OF THE FINDINGS

The findings of this research are generalizable in the sense of theoretical generalisation, in several respects.

- Since the dimensions used to explore willingness to adopt PSS came from well-tried service management research in combination with previous research on PSS, and confirmed in the present research, these dimensions may be theoretically transferred to contexts beyond the present study. However, caution should be observed in the generalisation of perceptions of the relative performance of different services against these criteria in other contexts

- Behaviours concerning the choice and management of material artefacts varied greatly among different respondents. While average values were used for the waste prevention assessment in the present research, the prevalence of these values outside the context is uncertain. Another reason for caution in the generalisation of findings on these behaviours is that some of the findings disconfirmed propositions in the literature. This calls for more research before any firm general conclusions may be drawn on these behaviours.

- Since a wider range of potential behaviours in terms of willingness to adopt PSS; ownership of material artefacts and interim self-servicing while using PSS, choice of material artefacts of different weights, and different uselives were included in the assessment, the scale of the potential covers a wider set of circumstances than the behaviours emerging from the respondents in the context of this research

- Parts of the critique of the PSS concept are likely to extent to other terms as wells, such as eco-services due to the difficulty of verifying consistently better environmental performance of certain services compared with self-servicing. The same ideas on behaviours thought to occur and to generate resource productivity that were partly refuted in this research are present in service

concepts such as eco-services or eco-efficient services. The term PSS may still be appropriate for other phenomena such as 'servicizing' manufacturing firms.

8.5 CONTRIBUTIONS TO KNOWLEDGE

The academic contribution to knowledge have been to apply the PSS concept to household waste prevention, and in so doing has contributed to the conceptual as well as empirical development of the research area. The following points are of particular importance:

- The research made a contribution to knowledge on PSS by developing a model based on the PSS concept, for assessing the waste prevention potential of a change from self-servicing to PSS. It identified an approximate magnitude of the household waste prevention potential, and also some key principles behind differences in waste prevention performance for the different household tasks. Heavier material artefacts offer greater potential for waste prevention in absolute terms. This was exemplified by the PSS for laundry. Infrequent use of material artefacts and short duration per instance of use can offer to greater potential for relative waste prevention. This was exemplified by the PSS for home improvement. Organisation of the service delivery to minimise the burden of transport to service yield increases the potential for waste prevention. This was exemplified by the PSS for house cleaning. If light-weighting of material artefacts occurs equally among material artefacts used by households and service providers, then the waste prevention potential of PSS will remain in relative terms but will be lessened in absolute terms. The effects of light-weighting of material artefacts on harmfulness of the waste or the environmental burdens in a life cycle perspective depends on whether the lighter materials and material artefacts are equally recyclable, and potential presence or emissions of harmful substances in for instance the production or waste management stage.

- There are many research areas and theories related to the propositions made in the the PSS literature that have so far been neglected by the PSS literature. This research has identified a number of such theories or research areas, and suggested whether or not they offer support for the propositions in the PSS literature (see chapter 2). Examples of such research areas are loss aversion (willingness to give up ownership of material artefacts), theories of management of maintenance and replacement, and disposal behaviours. By drawing attention to those research areas and how they might inform the understanding of PSS, this research contributes to the theoretical development PSS research.

- The empirical testing of the qualitative propositions in the PSS literature on behaviours of households and firms concerning their choice and management of material artefacts adds empirical relevance to this research area. This also led to a critique of the PSS concept questioning, whether there is a basis for it at all, at least in the context studied.

- The focus on result-oriented PSS for UK households was novel.

- This research contributed to knowledge in the under researched area of household waste prevention. A model was developed that enabled a structured assessment of an approach to achieving waste prevention that has been advocated as a waste prevention tool, but not thoroughly assessed. The research contributed both to methodological understanding pertaining to this approach to household waste prevention, as well as insights for policy makers.

- Finally, the research contributed to the understanding of the area of services and their potential to improve resource productivity and alleviate environmental harm through a structured approach and transparent reporting.

8.6 RECOMMENDATIONS FOR FURTHER RESEARCH

The exploratory nature of this research gives rise to a number of issues for further research. Below these are grouped into broad ideas on services, waste and the environment, issues related to behaviours concerning choice and management of material artefacts, methodological issues, and alternative theoretical perspectives and issues.

8.6.1 Services, waste and the environment

This thesis identified at least three different strands of ideas on whether and how a shift to service consumption might lead to increased resource productivity and environmental benefits (section 2.3.2). In order to better understand the potential of services to achieve this, an in-depth comparison of these strands of ideas, with their definitions, methods and results, would be useful.

More research is needed to establish the role of result-oriented service contracts for stimulating innovation in general, and innovation that leads to increased resource productivity in particular. The results of this research suggested that that result-orientation is not sufficient to bring about innovation for resource productivity and that a number of other business factors affect the propensity to innovate versus relying on tried and tested methods.

8.6.2 Behaviours related to choice and management of material artefacts

Further research is needed on service providers' choice, use, maintenance and disposal of material artefacts, given the findings of the present research that service providers in many instances do not behave according to the assumptions in the PSS literature. Such research could address questions like:

- The extent to which service providers own the requisite material artefacts and the extent to which they use material artefacts that are in the ownership of their customers
- the extent to which service firms make careful comparisons of alternative material artefacts;

- any differences in specifications of material artefacts compared with those used by households; definition and assessment of efficient use of the material artefacts;
- the skills of service providers to produce the desired result, for instance the time taken to produce the result and some measure of the result
- explore the frequency, type and quality of maintenance and repair of material artefacts and whether or not this differs for different types of material artefacts
- Reasons for and frequency of disposal, and also actual waste management option used for the waste, such as recycling, incineration or landfill
- Such research should take into account the business context and strategies that make up the decision framework for firms
- Further research should also explore the extent to which result-oriented PSS contracts would be entirely free from requirements on material artefacts or have requirements on material artefacts along with other parameters of the result to be produced
- For instance, data on material compositions and energy use of material artefacts typically used by households and service providers respectively could be identified to assess the significance of potential differences. Development trends for different types of material artefacts could be explored and assessed. Material compositions and energy use could be identified for additional material artefacts potentially used for the household tasks, to enable the inclusion of a wider range of sub-tasks. Further research is also needed into the waste management of WEEE, in particular what shares of the material artefacts left at the civic amenity sites are recycled, thermally recovered and landfilled.

Further research is also needed into households':

- ownership of material artefacts and their willingness to give up one or more units of material artefacts if they use services for household tasks
- choice of material artefacts, including the extent to which used ones are being purchased (as this extends the uselives of material artefacts over more than one use cycle. Waste prevention assessments should be extended to take this into account)
- requirements of material artefacts they use for interim self-servicing while using a commercial service provider to perform PSS
- propensity to having material artefacts repaired and skills at repairing material artefacts themselves
- propensity to sell or give away material artefacts that have fallen into disuse (as this extends the uselives of material artefacts over more than one use cycle. Waste prevention assessments should be extended to take this into account) and whether this differs for different types of material artefacts

Alternative designs of service systems might be considered in further research to seek to ensure that additional resource requirements in the PSS (vehicles, buildings and other equipment) do not offset any potential resource productivity gain from the main material artefact used to deliver the result (e.g. lawn-mower, washing machine).

8.6.3 Methodological issues

Further research could consider alternative methodological choices, for example:

- Behaviours and attitudes to adoption of households that have recently adopted household services, to enable identification of actual behaviours rather than expressed attitudes.
- Data collection methods such as observation and diaries to get a closer approximation of actual behaviours than self-reporting at a particular point in time
- Further development of the model assessing the waste prevention potential to account for a number of further circumstances including non-linear effects. For instance, a refined model might account for the possibility that some material artefacts are not new, but have been obtained second hand by the households. New material artefacts may not become waste immediately, but may enter another use cycle as they are given to charity or kin.
- Further development of the waste prevention assessment model and waste prevention should also account for additional material artefacts used in the self-servicing system and commercial service system respectively. Commercial service provision is likely to entail capital burdens that should not be excluded by default. This needs to be balanced carefully in PSS design in order that additional burdens of PSS do not off-set potential resource productivity gains.
- A more comprehensive life cycle assessment
- Applying weighting of different impact categories using some method reflecting concerns of policy-makers and stakeholders, to enable judgement of the importance of the magnitude of changes in emissions/impacts.
- Research into the consequences of changes in consumption, and the environmental effects thereof, should adopt change-oriented, also known as consequential, approaches. That is, they should consider second-order changes including rebound effects (please see section 3.8.1.1 for a discussion of first and second-order changes). Life Cycle Assessments adopting this approach to the study of environmental impacts of commodities often use economic modelling to estimating these second-order effects. Alternative theoretical approaches, for instance from sociology, might be fruitful to estimate these changes.

8.6.4 Alternative issues and theoretical perspectives

This thesis concentrated on a set of propositions from the literature concerning behaviours of self-servicing households and service providers. Other theories could elucidate various aspects of household services, such as:

- the meanings households attach to different household tasks, material artefacts and services. This may offer important insights for understanding households willingness to adopt services and give up ownership of material artefacts.
- More detailed service design and operations management issues
- Co-evolution of technology development and use practices both for self-servicing and commercial household services, from an evolutionary economics perspective
- Innovation in local low-tech service markets

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APPENDIX A DEVELOPING EXPERIMENTAL PSS

1.1 Introduction

New housing developments built by property development firms were considered a promising context for household waste prevention through PSS (see section 3.3). However, property developers did not offer such PSS. Therefore experimental PSS needed to be developed to enable the different assessments included in this research: attitudes to adoption, waste prevention potential and environmental potential. The development of experimental PSS results in descriptions of the PSS. This chapter concentrates on the supply-side processes in the property development firm. The resulting descriptions of the PSS from the households' point of view are presented as user narratives in appendix E. In chapter 5, self-servicing and the PSS are described in terms of the frequency and duration of performing the household tasks, and the material artefacts used. (The latter were established through a questionnaire completed by the participating households and interviews with local service rather than through the methods and descriptions set out in this appendix). The PSS descriptions were presented to focus group participants to facilitate their discussion of adoption of PSS (chapter 4), although their discussions went beyond the specific designs of the PSS.

Section 3.5 gave an overall description of the method used to develop the experimental PSS for subsequent assessment. This appendix elaborates on the choices made in the development.

1.2 Method

The development of the PSS was guided by service development processes identified in the literature. There are various models for new service development, which comprise similar stages although different as to the exact numbers and names of the stages, see for instance (Alam & Perry 2002; Aurich *et al*. 2006; Panesar & Markeset 2008). Similar PSS development models are also presented by (Tukker & Tischner 2006). Regardless of the exact name and number of stages, the models tends to comprise elements of idea generation and screening, demand identification, business feasibility analysis, service concept or more overarching process development to development of detailed operational processes, staff training, piloting and commercialisation. The development of the PSS comprised the stages from idea generation and screening through to an outline level of service process development in line with the exploratory natures of this research. Given the limited knowledge on PSS and waste prevention in this context, this level of detail was deemed sufficient to offer an indication of the scale of the potential for waste prevention and environmental performance.

Section 3.5 in the thesis details the data needs and methods for data collection and analysis for the development of the PSS. The following is a brief recapitulation. The literature recommended that new service development involves multi-functional teams from the focal firm, their suppliers and potential users, and may also involve knowledge gained from the research community (Alam & Perry 2002; Panesar & Markeset 2008). The development of the PSS involved participants from various functions in the property development firm (facilities management, supply chain, customer services,

environmental services and marketing) and its supply chain, and householders who had recently bought new homes on housing developments build by the property development firm (section 1.2.1 below gives the reasons for the choice of this context). Focus groups and interviews were held with the participants to identify household tasks for which there would be at least a potential adoption, and also to elicit criteria for the supply and demand of material artefacts and PSS. In addition, documents were studied, such as waste statistics and information on business processes in the property management firm, such as booking and management processes.

First however, the context for the research was selected.

1.2.1 Choice of context

New housing developments built by property development firms were considered a promising context for household waste prevention through PSS (see section 3.3). However, property developers did not offer such PSS. Therefore, experimental PSS needed to be developed to enable the assessments. The experimental PSS were developed in collaboration with a property development firm building domestic homes as well as providing facilities management services to firms. The UK has an ambitious housing growth strategy aiming to develop 2 million new homes by 2016 and an additional 3 million by 2020 (Department for Communities and Local Government 2011). The best part of these homes is likely to be built by property development firms on new housing developments. Developing new homes and housing developments offers an opportunity to consider resource conservation and infrastructure to support it. New homes on new housing developments may also cater for new life-styles where services are increasingly consumed. Many of those new homes are likely to be purchased by those relatively more affluent socio-economic groups that Emery *et al.* (2003) identified as generating more waste than less affluent households. Moving house may be a key 'moment of change' at which householders reconsider their stock of material artefacts, service consumption and how they perform household tasks. Thus, the presence of PSS in the range of after-sales offerings that may be opted for in the house purchase could offer opportunities for PSS production and consumption.

The context set out above was chosen deliberately to be conducive to PSS. Likewise, the household tasks selected for development were chosen that held potential for demand, as identified in the primary research process. These household tasks were also ones utilising material artefacts that after disposal would fall into waste fractions that were deemed relevant to household waste prevention. The outcome of the development of the experimental PSS are descriptions of those PSS, rather PSS actually piloted by the property development firm[52]. The degree of detail achieved in the PSS design was in line with exploratory nature of research as a whole.

[52] Towards the end of the data collection and analysis, the firm underwent a merger with another large firm. Subsequently, one of the divisions was sold to another large firm. These organisational changes probably contributed to the PSS not being implemented. However, the facilities management division does offer its concierge services.

1.3 Developing experimental PSS

1.3.1 Idea generation and screening

Idea generation was the first of a number of iterative stages of new service development. It was carried out through focus groups and interviews with supply-side representatives from a variety of functions within the property development firm and its supply chain, and householders, together with the researchers, as set out in section 3.5. This constellation made up an approximation of the multifunctional teams, user-involvement and influence from stakeholders noted in the literature to be of relevance to the service development process, such as scientific knowledge from research institutes, recommended in the literature (Alam & Perry 2002; Panesar & Markeset 2008).

New ideas could come both from outside the focal company, such as from consultants, other market actors, development of new technology, government policy, and from inside the company, such as from employees, market analysis and analysis of competence and capabilities (Panear & Markeset, 2008*).* The research team introduced the PSS concept to the participants and it was congruent with related ideas participants had come across (see section 4.2.2.1). Idea generation and screening (and the integral feasibility analysis) also needed to consider the points below.

- The type of PSS to focus on (product-oriented, use-oriented or result-oriented)
- Household tasks for which PSS adoption would be at least potential demand
- Material artefacts used in these household tasks, the waste fractions these products give rise to, and the possibility to prevent household waste through PSS for these tasks
- To identify criteria that households use when choosing material artefacts and services to establish potential adoption for the purpose of choosing household tasks, and also to support the investigation of adoption in chapter 4.
- To identify criteria that the property development firm uses when considering developing products or services to establish potential adoption of PSS for the purpose of choosing household tasks, and also to support the investigation of adoption in chapter 4.

1.3.1.1 TYPE OF PSS

The literature review referred to three main types of PSS: product oriented, use oriented and result oriented. Product-oriented were rejected for further study since the literature suggested this category offers limited opportunities to improve resource productivity (Tukker & Tischer, 2006). Use oriented and result oriented PSS were further explored with the firm and householders on the housing developments. The literature suggested that result-oriented PSS held the greatest potential for resource productivity (see section 2.4.1). Result oriented PSS were selected after this consultation, for reasons described below.

Use-oriented services - sharing

Use-oriented PSS include sharing and leasing household material artefacts. The householders expressed concerns with sharing. They lacked confidence in the availability and state of shared equipment and associated facilities. They also suggested that the need to manage maintenance of shared equipment would increase the cost of sharing schemes. The householders also believed that a relatively large stock of material artefacts would be required to ensure availability at peak times, such as lawnmowers on dry weekends in the summer. Safety and security regarding shared laundry facilities was another reason for apprehension about sharing. The householders said they would not be confident leaving their washing during a washing cycle in communal facilities. Additional concerns were issues of convenience and flexibility. Having to go to a shared laundry facility was felt to be inconvenient and inflexible, especially for certain life stages such as families with young children.

Participants from the supply-side had concerns regarding Health and Safety and liabilities associated with the provision of on-site shared facilities and equipment. In addition, due to the value of land and property in the UK, participants from the supply-side stated that there was little incentive for house builders to reserve land for facilities to enable sharing of material artefacts among the households.

Use-oriented services – leasing/renting

Householders did not outright reject the idea of leasing, 'if the deal was right'. They did however, doubt the cost-effectiveness of leasing. They believed that total price over a period of time for leasing a material artefact would exceed that of buying and owning the material artefact. A white good rental firm confirmed that the prices for renting household appliances over a period of some 2-3 years reached the cost of purchase, and therefore only the most disadvantaged groups who were unable to afford the upfront outlay for the purchase price, rented material artefacts. Householders also tended to associate leasing with financial deprivation and had concerns about the hygiene of leased products that had previously been used by others.

Participants from the supply-side did not see leasing as a viable business option since household material artefacts are relatively inexpensive. It was thought that leasing would require many small transactions to be managed over a long period of time leading to high management costs. In addition, literature suggested that product life extension is not an automatic consequence of leasing. Therefore, it is the product life extension rather than whether the material artefact was leased or sold that determined the resource productivity (Tasaki *et al*. 2006). Mont (2004c) also found that renting power tools led to increased emissions due to the transport to the tool rental shop.

Participants from firms which produce and supply household appliances, also suggested that leasing might not lead to changes in the design of household appliances or stimulate take-back of these and remanufacturing. Participants stated that a range of standard designs are sold in global markets, from which The property development firm can choose, but that the design of household appliances would not be changed for a small player such as The property development firm. Participants stated that remanufacturing is expensive and would not be cost effective for the typical range of appliances supplied for after sales.

Result-oriented services

Households appeared to favour result-oriented services. They felt that such services would increase the accessibility of the service since they can be performed while the householders are out and eliminated many of the concerns associated with use-oriented PSS. In addition, several households already used services for various household tasks such as landscaping and gardening, ironing, window cleaning and home improvement. Due to the support in the literature as well as from primary data, for result-oriented PSS, result-oriented PSS were selected for the development of experimental PSS.

Existing capabilities (both staff skills and business systems) within The property development firm were particularly well aligned with result-based services. The Facilities Management branch within the property development firm provides a range of result based services to commercial firms. Although these were not aligned with aspects of demand that would have any effects on household waste. The property development firm was interested in providing value-added result orientated PSS that would generate additional revenue.

1.3.1.2 WASTE FRACTIONS, MATERIAL ARTEFACTS AND HOUSEHOLD TASKS CONDUCIVE TO RESULT ORIENTED PSS

To address the research and policy problems of household waste prevention, one of the issues for the selection of experimental PSS was what waste fractions were relevant for waste prevention through PSS. Both the quantity of waste, harmful effects on the environment and human health and content of harmful substances are issues of concern for waste prevention according to the legal definition of the term. Waste statistics and waste policy priorities facilitate the selection of waste fractions for experimental PSS in those respects.

Waste fractions are made up of different types of material artefacts, which in turn are used to perform different household tasks (before disposal). Different material artefacts and the corresponding household tasks may lend themselves more or less well to result-oriented PSS. For instance, even if a household had their food purchasing, storage and preparation provided by a result-oriented PSS (e.g. meal delivery service or eating out) rather than through self-servicing, it may not be possible to avoid food packaging materials. Thus, there might be limited opportunity to prevent household waste in fractions relating to food packaging and food waste. Likewise, it is unlikely that many households could manage entirely without a refrigerator and cooking facilities. Certain PSS may be less suitable since they are well outside the core business of the property development firm. For instance, paper newsprint and magazines may be delivered electronically. This still requires households to possess the material artefacts (such as IT equipment) in order to read the contents of the news and magazines. Therefore, the material artefacts corresponding to the waste fractions, and different household activities were considered regarding how suitable they appeared for result-oriented PSS that would be within the remit of the property development firm to deliver.

Table 56 below shows the waste fraction, their percentage of total household waste (Burnley, 2007), examples of corresponding household tasks, and reasoning on the

viability of result-oriented PSS for the different waste fractions and aspects of household demand.

Table 56 Household waste fractions, their relative shares of the household waste stream, corresponding material artefacts and comments on feasibility of result-oriented PSS provided by the property development firm

Waste fractions (and material artefacts)	% of household waste	Household tasks	Comments on PSS and selection
Paper and card (newspaper, magazines, card packaging)	21%	Entertainment; packaging for a variety of aspects of household demand.	Potential PSS: electronic substitution, e.g. electronic newspapers and magazines. Outside TW core business to provide.
Plastic (bags, packaging film, other plastic film, dense bottles, other dense plastic)	7,1%	Food, other consumption	Food excluded for reason of system complexity. (In addition, food services require packaging. Little ownership substitution in this case)
Textiles	1.8%	Clothing and linen ownership and care	
Shoes	0.4%		
Absorbant hygiene products	2.3%	Personal hygiene	Recent thorough study exists conducted with major partners involved from reusable and disposable firms and organisations, and authorities.
Wood (incl. furniture)	4.3%	E.g. furniture	Furniture leasing: Type of PSS excluded (see separate justification)
Combustibles (shoes, carpets, underlays, misc. combustibles)	5.5%		Potential service: carpet leasing. Leasing excluded type of PSS
Non-combustibles (Bricks, plaster, soil, inorganic pet litter)	8%	Construction and home improvement, pets	Non-combustible waste from home improvement likely to arise in the household even if home improvement carried out by service provider.
Glass (drink bottles, jars)	5.8%	Food	Food excluded household tasks due to complexity of food systems. (In addition, food services require packaging. Little ownership substitution in this case).
Organic: (kitchen, garden, other organic waste)	30.5%	Food Gardening	Food excluded household tasks due to complexity of food systems. Much of the waste arises from organic growth and the trimming of that organic growth and may not be possible to prevent by gardening PSS.
Metals (food and drink cans, foil)	5.6%	Food	Food excluded household tasks due to complexity of food systems. (In addition, food services require packaging. Little ownership substitution in this case).
WEEE (large household appliances, small household appliances, tools,	2%	All: Food, clothing and linen care, leisure activities,	Potential for result-oriented PSS for several household tasks, such as house cleaning, garden maintenance, home improvement and laundry.

toys, etc.)		household admin, gardening, etc.
Lead/acid batteries (car batteries)	0.2%	Transport
Oil	0.1%	Vehicle and home maintenance
Identifiable clinical waste	0.2%	Health care
Other potentially hazardous	0.3%	Various
Fines	5.2%	(No material artefact category as such, and no household tasks)

The table showed that organic waste is the largest waste fraction, followed by paper and card. Future scenarios by Brook Lyndhurst (Brook Lyndhurst, 2007) suggest that organic waste fractions will continue to be the greatest in terms of mass. Other fractions like paper, WEEE and clothes are likely to remain relatively smaller fractions. WEEE and clothing are thought to increase while the paper fraction is thought to decrease in all scenarios.

In addition to considering the scale of the different household waste fractions, the potential hazardousness needs to be considered in order to address all dimensions of the definition of waste prevention. WEEE is highlighted as a waste fraction comprising hazardous components. Components like capacitors, circuit boards, cables and batteries may contain hazardous substances (Ogilvie, 2004). In addition, the plastics used in WEEE may contain hazardous substances and other contaminants which makes them difficult to recycle (Freegard, *et al.* 2005). Due to the hazardous substances in WEEE and the projected growth of the waste fraction, WEEE was selected as the focal waste fraction for this research. In addition, as will be shown in the next section, household tasks involving the use of WEEE lent themselves particularly well to result-oriented PSS.

1.3.1.3 SELECTION OF HOUSEHOLD TASKS

'Household tasks' refers to groups of tasks that householders undertake and which involve the use of material artefacts (self-service). Literature on time-use by households (Fernandez & Sevilla Sanz, 2006), as well as primary research (see section 3.2) was used to identify household tasks, material artefacts, to select household tasks amenable to PSS with a view to achieving household waste prevention.

Household tasks identified in this research, comprised: administration and working from home, food shopping, storage, preparation and eating, leisure and entertainment, home improvement, laundry, garden maintenance and house cleaning.

Administration and working from home

Household administration and working from home usually requires IT equipment and furniture. Leasing material artefacts, such as IT equipment was rejected for this

research, as detailed above on use-oriented PSS – leasing. In addition, requisite equipment may also be provided by employers. Therefore, this household activity was not included in the further experimental PSS development.

Food shopping, storage, preparation and eating

Food shopping, storage, preparation and eating was rejected for further development and assessment within the present research. From a waste point of view, food was deemed to be a highly relevant waste fraction to target for waste prevention. Organic kitchen waste made up some 16% by tonnage of all household waste. In addition, packaging, both paper and card, plastic and glass, come with food items. However, unlike some other aspects of household demand, conceivable food services would not directly reduce the amount of food stuffs supplied and wasted. Institutional and commercial kitchens also waste substantial amounts of food (Karlsson, 2002). Food storage and preparation require use of large household appliances such as refrigerators and cookers. Large household appliances make up 43% of WEEE*)* and present a challenge for recycling. Therefore, reducing the number of fridges used if food services substituted food storage and preparation at home, would be useful from a waste prevention point of view. From the point of view of environmental impacts over the life cycle, food and beverage consumption is one of the three consumption categories with the greatest environmental impacts (Tukker, *et al.* 2006). From this point of view, food shopping, storage, preparation and eating would also be a relevant household task.

Householders in the focus groups and interviews did use food services such as going to restaurants, ordering takeaways, ordering food over the Internet and having it delivered by supermarkets, and subscribing to organic food boxes. There did not appear to be any great demand for food services that rendered possession of refrigerators superfluous. Furthermore, householders in the focus groups, especially those with young children, stated that they liked to prepare food themselves in order to have knowledge of the nutritional content of the food. Finally, the systems involved with production and consumption of food were deemed to be too complex to model and assess within the resources of the project.

Leisure and entertainment

Leisure and entertainment may involve the use of a range of material artefacts. The focus in the present research was on material artefacts owned by the households, that by definition would become household waste and therefore be a potentially relevant target for household waste prevention. Hobbies outside the home were therefore excluded. Such material artefacts included for instance PCs, and audio-visual artefacts. Renting and leasing was rejected. Furthermore, the speed of development is very high for this type of material artefacts and it was not deemed to be cost-effective for the property development firm to provide such PSS.

From an environmental point of view, the consumption categories ‘communication’ and ‘recreation and culture’ are not among the consumption categories with the greatest environmental impacts, although housing including ‘equipment’ is (where utilities is also included). From a waste point of view, PCs and audio-visual artefacts become WEEE, which made up 2% of household waste by mass.

Garden maintenance

Garden maintenance was selected for further development and assessment in this research. The demand-side focus groups suggested that local garden maintenance services including lawn-mowing, general maintenance and landscaping were already used by some residents, although the service use tended to be interrupted after the house move, before the residents had identified a new gardener. The service was also viewed positively by the supply side.

Various electrical and hand tools are used for gardening. If residents used services they would potentially not need to own the tools. Organic garden waste is a large and policy relevant waste fraction (some 20% by tonnage), but is unlikely to be avoided by using a garden maintenance service, as it arises mainly through organic growth and subsequent trimming which is more or less required to avoid wilderness. Lawnmowers and other electrical equipment classify as WEEE (tools 3% of WEEE or large household appliance, 43% of WEEE by tonnage).

Home improvement

Home improvement was selected for further development and assessment in this research. The focus groups showed that there was a demand among the householders for 'handy-man' jobs accruing after the move into the new house and felt to require professional skills. House and garden services were also the most popular of the property development firm's concierge services. Supply side representatives found this an attractive service to offer since it requires systems, material artefacts and skills similar to those of existing remedial customer services, with the different that this home improvement service would generate revenue. The facilities management division also had experience in contracting maintenance jobs.

From a waste, resource and environmental point of view, potentially, households do not need to own the tools required for the home improvement jobs. Manual and electric tools are the main material artefacts required to carry out home improvement tasks. Electric tools made up 3% of total waste electronic and electric equipment. The tools may contain circuit boards and cables with potentially hazardous substances. Cord-less tools contain batteries.

House cleaning

The householder focus groups suggested that house cleaning was a service that was already in some demand, and that it was difficult for residents to find reliable house cleaners that would produce a good result. Sourcing cleaners was also one of the Facilities Management's concierge services, and thus supply side capabilities existed.

The main material artefacts used are vacuum cleaners, detergents, cloths and similar. Vacuum cleaners are WEEE (small household appliances, making up 3% of WEEE). While vacuum cleaners do not present a major concern with regard to hazardous substances, the circuit boards and cables may contain some.

Laundry

Doing washing oneself in one's own washing machine was perceived to be convenient and offer flexibility, and be cheap. Householders in the focus groups and interviews used laundry services occasionally, for instance in cases of large loads after over-night guests. Facilities management were already providing a dry cleaning service in its pilot concierge service package.

While demand for subscribed laundry services was limited, large household appliances, such as for instance washing machines, make up 43% of WEEE. It was deemed appropriate to include a size span of material artefacts, from hand tools weighing some 2 kg and making up 3% of WEEE, to washing machines weighing nearer 100 kg, and being a part of a material artefact category making up a substantially larger share of WEEE).

1.3.1.4 CONCLUSIONS FROM IDEA GENERATION AND SCREENING

The joint consideration of types of PSS, material artefacts and waste fractions and waste prevention objectives, and aspects of household demand, in light of literature and primary research via interviews and focus groups with householders and supply-side representatives from a variety of functions, lead to the selection of the following aspects of household for further development and assessment of result-oriented services:

1. Home improvement
2. Laundry
3. Garden maintenance
4. House cleaning

The supply-side representatives suggested that these result-oriented services would form the basis of a menu of services on offer to their house-buyers.

1.3.2 PSS process development

Idea generation and screening resulted in the selection of result-oriented, subscribed PSS for garden maintenance, home improvement, house cleaning and laundry. This section further develops the process and service designs. In accordance with the literature (e.g. Lovelock *et al.* 1999), this stage included decisions such as steps involved in the service delivery, location, timing and sequencing of these steps, whether the main provider should take responsibility for all steps or use an intermediary for some steps, reservation procedures. These issues are further set out below.

1.3.2.1 CHARACTERISTICS OF SELECTED EXPERIMENTAL RESULT-ORIENTED PSS, TO INFORM PROCESS DEVELOPMENT AND DESIGN

To aid decisions on the service design and process development, different service dimensions and different alternative choices were considered. Awareness of those characteristics of the selected result-oriented PSS will inform requirements on design and management of the PSS. In Table 57 below, a number of service dimensions are collated from Lovelock *et al.* (1999) and alternatives for each dimension. The left two columns are collated from this literature. The column to the far right presents reasoned

suggestions what alternative is relevant for the menu of result-oriented experimental PSS in the present study. This is further discussed after the table.

Table 57 Service characteristics, alternatives and characteristics of the result-oriented PSS. Drawn from (Lovelock *et al*. 1999)

Dimension	Alternatives	Characteristics of selected experimental result-oriented PSS
Place of delivery	Service shop/facilities, customers home, electronic transaction, other,	Customers' home
Encounters with service personnel	Personnel or technology the main encounter/delivery interface?	Personnel
	Customer presence at the delivery interface? Low – High	Customer presence low – medium (customer presence not necessary)
	Service staff present at the delivery interface? Low – High	Service staff present - high
	Material artefacts the main encounter/delivery interface?	No
Encounters with other customers during service delivery		No
Direct recipient of service act and effects	Person or possession?	Possession (house, garden, clothes)
Recipient tangible or intangible?	physical possession, intangible asset; persons body, persons mind	Physical possessions
Level of co-production by customer	Low- high	Moderate
Ease of performance evaluation of effects	Search qualities, experience qualities, credence qualities	Experience qualities
Nature of service delivery	Discrete transactions Continuous service delivery	Discrete service delivery
Type of relationship with customer	Individual, communal[53] Membership relationship: formal relationship with identifiable customer (p. 182) No formal relationship: anonymous customer, no records are kept.	Formal relationship with identifiable customer. 'Membership' relationship.
Standardised or	Standardised, modularised,	Relatively standardised

[53] Authors interpretation of text in Lovelock *et al* 1996.

customised	customised?	
Demand/supply balance	Degree and predictability of demand fluctuations	High degree of predictability of demand fluctuations
Tangible service elements	e.g. material artefacts, appearance	Not given by type of PSS.

The place of delivery is tied to the customer's home in most instances (home improvement, house cleaning and garden maintenance). The location of the service delivery for laundry is not tied to the customer's home, although collection and delivery of the clothes and linen might take place at the customer's home, especially if the basis for the PSS is a particular housing development. The PSS delivery would in most instances require service personnel to go to the customers' homes to deliver the PSS (perform the household task). The presence of service personnel at the PSS delivery interface is high. However, this does not necessitate that the householders meet the service personnel, depending on the arrangements for letting the service personnel into the homes and gardens. Thus, customer presence at the delivery interface could range from low to high. While material artefacts are an integral part of the PSS, they do not make up the main service encounter (contrary to for instance the financial service of taking out money from a cash machine, where the cash machine is the main service encounter). Neither are other customers likely to be present at the PSS delivery to each household.

The recipient of the PSS are physical possessions (material artefacts), namely householders' houses, gardens and clothes and linen, rather than intangible assets or the householders bodies or minds. The degree of co-production of the PSS by customers is moderate. The PSS needs to be purchased by the customer in order to be produced (inlike for instance radio broadcasting or public transport). The customers are required to provide some specifications for the purchase, and may need to perform a degree of preparation, such as tidying up prior to the delivery of housecleaning or garden maintenance PSS. However, customers do not have to be present at the delivery and the PSS have a high degree of standardisation.

The households are likely to be able to evaluate the PSS performance after experiencing it (unlike the 'credence qualities' of some services, that are difficult for customers to evaluate confidently even after experiencing them, and unlike material artefacts and services that are high in 'search qualities' and therefore easy to evaluate before purchase) (Lovelock *et al.* 1999). For instance, householders are likely to be able to evaluate the cleanness of the home and laundry or the neatness of the lawn after trying the PSS.

The delivery of the selected PSS is likely to take place as discrete although regularly recurring events, such as weekly house cleaning. It was deemed that most of the PSS would be provided as subscription services and the customers are known to the service provider. Therefore, the nature of the PSS delivery and the relationship between the service provider and customer is that of formal 'membership' relationship.

It was envisaged that the PSS features and the underlying processes would be more or less standardised, although possibly with a number of standard options or limited degree of customisation to meet the needs of individual households. The combination of a

largely subscribed PSS with a great degree of standardisation also means that any fluctuations in demand are highly predictable.

1.3.2.2 SUPPLY-SIDE RESPONSIBILITY FOR PSS DELIVERY

Focus group consultations with the property development firm informed the PSS development choice of where within the property development firm responsibility for PSS would reside.

Within the property development firm, there were different options for where the responsibility of the service provision would reside. Customer services within the development division had human and technical capacity to go out to households and perform various tasks, although an administrative mechanism was not yet in place to invoice for those activities. At the time of the data collection, those tasks were purely remedial, although Customer Services had experienced customer demand for value-added services. The remedial services shared some characteristics with the proposed experimental result-oriented PSS set out in the previous section, and differed in other respects. They were performed in the customers' homes on the customers' property, and although material artefacts were an integral part of the service delivery, personnel were the main service encounter. There was a formal relationship with an identifiable customer (house-buyer) and the service delivery was discrete, but on a one-off basis depending on the faults to be remedied. This might also make the remedial service less standardised than the experimental PSS. Also, demand fluctuations are likely to be less predictable for the remedial services than for the experimental PSS. Customer Services were also in the same division of the firm as the house-sales including the groups selling after-sales material artefacts.

Facilities management within the construction division were also experienced service providers, albeit to business customers. For instance, they offered cleaning and ground care services to commercial facilities. In addition, they had experience of providing concierge services to householders, although to employees of customers of their FM services, rather than householders on housing developments of the Development division. The concierge services meant experience of sourcing other providers of the specific services. The Facilities Management groups had administrative systems for reservation and invoicing in place. It was estimated that the potential profit of the PSS, was more aligned with the customary profit margins in the facilities management division, than the development division with its greater profit margins. Thus, placing PSS within the facilitites management would not jeopardise the valuation of the shares.

Since both Customer Services and Facilities Management had experience of service delivery, but Facilities Management also had administrative systems in place and possible profit margins were more aligned to those in the FM sector rather than the construction sector, it was decided for the experimental PSS that responsibility would reside with Facilities Management.

Provision of services directly to households would mean entering a new type of market for Facilities Management. Under such circumstances, their normal procedure would be to deliver the services through their supply chain, while they would manage this delivery. In the first instance they would seek to use their existing supply chain firms,

which were mostly large, often global FM companies. If those suppliers were not willing to provide those services, Facilities Management would need to extend their supply chain partner base with alternative service providers, likely to be medium size, local or regional firms.

1.3.2.3 PSS PROCESSES

The consultation with the supply-side suggested that the experimental result-oriented PSS would take the form of a menu of subscribed services, that is, regular delivery of standardised services at discrete instances. The households would be able to choose from the menu. The menu of services would be presented alongside the reservation of the house, like other after sales material artefacts. It would also, however, be possible to start a subscription or reserve one-off service at any time. In addition, there would be one-off PSS. The following PSS were pursued in this research:

Home improvement

- Man in a van – one off handy man job on hourly basis, e.g. shelving, picture hanging, minor repairs
- Painting & Decorating – one off
- Bathroom renovation/refurbishment – one off

Laundry (Clothes and linen Washing)

- Subscription – weekly/fortnightly small or large load
- On-demand – one-off – assumed large linen load

Garden maintenance

- Subscription – lawn-mowing
- 'Spring clean' annual

House cleaning

- Subscription – weekly/fortnightly, apartment/small house or large house
- 'Spring clean' – one-off/yearly, apartment/small house or large house

Depending on the timing of the reservation, there would be different routes to placing the order. Either the order would be placed directly by the sales manager, or by the householder, via phone or the Internet. In the case of the latter it is likely that the initial booking would be made by the Internet, but that additional service specification might require telephone conversations. The reservation and subsequent contract is managed by a project team comprising commercial management, data management and contracts management. The reservation requires a customer database.

When the contract is in place, a work order is generated and communicated to the service provider actually performing the job, presumably through an agreed IT system. The individual jobs are scheduled so that jobs on the same housing development are performed at the same time, while meeting the customers desired timing of the jobs.

Since transportation is a major cost item, both in terms of unproductive staff time, and running cost of vehicles, and is also impacting negatively on the environment, minimising transportation is a priority.

The service provider travels out from its service depot to the households with the requisite material artefacts, and performs the jobs for the households on the housing development in accordance with the schedule and work orders. He or she then travels back to the service hub and files notifications that the work has been completed, which is a basis for invoices. The supply chain service provider and facilities management manager invoicing between them. The facilities management project team ensures invoices are sent to the households.

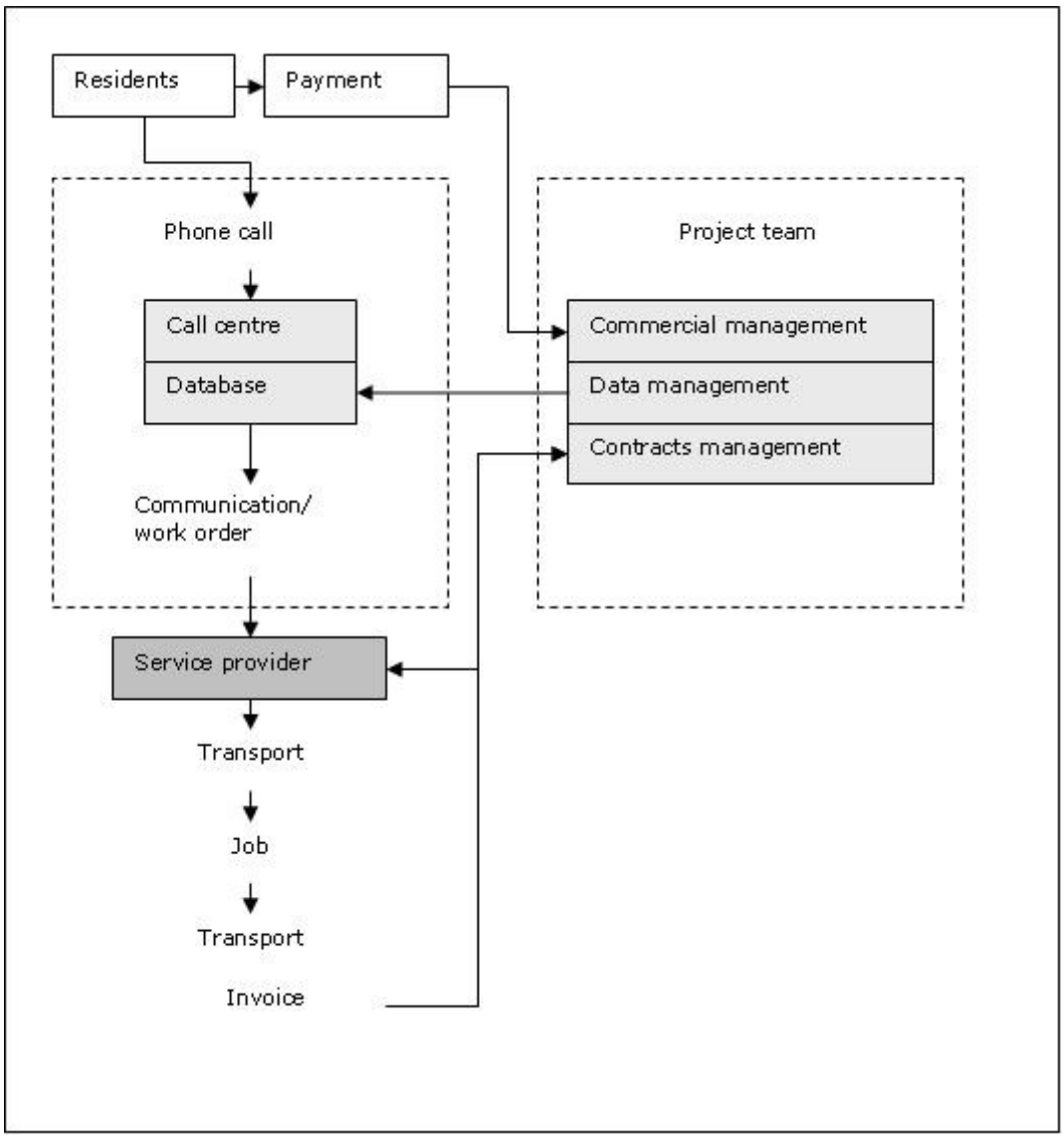


Figure 6 PSS booking and management process

Focus results revealed that existing large supply chain service providers were not interested in providing household services. Instead, the most likely solution would be for the property development firm to extend its existing suppliers by contracting

regional service providers. In order to minimise the costs of transportation, not least unproductive staff time, focus group participants stated that there was a need for sufficient geographic density of demand for the services. Also, service providers needed to have physical presence in each region in order to reduce transport distances.

1.3.3 Costing and pricing of the services

Costing and pricing of services is not a discrete stage in the service development process, but an important part of the development of the service concept and feasibility analysis. The literature suggested that price is one important criterion, among others, when households choose whether or not to adopt PSS. The pseudo prices were presented to householders in the focus groups to inform their discussion on adoption.

1.3.3.1 PRICING STRATEGY

Development of pseudo costing and pricing was carried out in collaboration with the property development firm, using their costing models. The model applied used cost-plus pricing (Drury, 2001), meaning that the selling price is based on the costs that the property development firm would incur in delivering the services, plus a percentage mark-up to cover overheads and profit. All firms are likely to have to cover their costs and make a profit in order to survive. However, in theory, this may be achieved by alternative pricing strategies such as target pricing. Target pricing means that a firm determines the target selling price, then the desired profit margin, and then identifies the costs that enable this selling price and profit margin. Then the costs are adjusted to achieve the target price (Drury, 2001).

1.3.3.2 COST COMPONENTS

The number of service units sold was an important parameter for the pseudo costing and pricing. The reason for this was economies of scale, and cost thresholds for the call centre and project team. The remit of the present research was not quantitative market research, neither was such information at hand. Therefore, the customer base and call volumes used for this exercise, were based on assumptions. Thus the costs were made up of costs for shared infrastructure allocated to each of the types of service items on the menu, and further allocated to service units, plus a unit cost for each service type and unit for the contracted service provision, plus mark-up.

At the design and process development stage of the development of the PSS, it was decided that the services be delivered on a regional basis. As a basis for the estimation of the size of the customer base, the Manchester region was chosen. There was a significant number of housing developments built by the property development firm there, giving offering potential for sufficient geographical density of demand for the PSSs. The region comprises some 1950 households on 13 developments built since 2002. A notional customer base was assumed as a certain percentage of this total number of households. Various percentages of 1950 households was used as a customer base. Percentage uptake was assumed to range form 12,5% to 50%.

1.3.3.3 SHARED INFRASTRUCTURE: CALL-CENTRES AND PROJECT MANAGEMENT

The below are excerpts from technical reports for the Defra project (Gottberg, *et al.* 2008) on which this thesis was based.

In order to establish a service level agreement for PSS delivery, residents would telephone the call centre to book a one-off PSS or to start a subscription for PSS delivery over a given period of time. In the context under study, the firm has experience in running a similar operation but does not have spare call centre team and project management team capacity. However, the rental and running costs for the existing call centre are not included in the assessment and are assumed to fall under a different cost centre within TW.

The costs of setting up and running a call-centre were provided by a costing model from the property development firm. The cost items included staff accommodation (e.g. staff relocation packages), salaries and expenses (e.g. employment costs), IT and related equipment.

Through consultation with senior project managers in the facilities management branch, call centre teams and project teams appropriate to the notion customer base and call volumes were developed. Teams would be developed to achieve a high utilisation of staff capacity to achieve a lower cost per unit of PSS service delivery.

One call centre manager would oversee all call centre activity relating to the four experimental PSS. One customer service representative would be allocated to each of the experimental PSS. As such call centre costs were split evenly across the experimental PSS types.

Table 58 Call centre costs associated with PSS delivery over three years

PSS	Number of calls	% calls per service type	Mobilisation costs £	Annual running costs £	Total costs £
Home Improvement	9750	28.5	13,880	34,400	≈117,000
Laundry	9750	28.5	13,880	34,400	≈117,000
House Cleaning	6826	20	13,880	34,400	≈117,000
Garden Maintenance	7800	23	13,880	34,400	≈117,000

The call centre staff log orders from residents in a service management software database already in use by facilities management branch of the property development firm. Software licence costs for setting up a database are therefore excluded from the costing/pricing.

The call centre staff then communicate the PSS requirement to the nominated service provider in accordance with contracts established between the property development firm and the service providers.

Costs would include:

- Payment mechanisms
- Accounts administration
- Supply chain procurement
- Development of service level agreements
- Auditing of external service providers
- Database maintenance,
- Developing promotional literature

Project team members would include:

- Project manager
- Commercial manager
- Contracts manager
- Data manager
- Customer manager
- Commercial assistant

Project team costs would include:

- Staff accommodation (e.g. staff relocation packages)
- Salaries and expenses (e.g. employment costs)
- IT and related equipment
- Insurances/ bonds

As with the call centre costs, staffing levels were identified in consultation with participants from the property development firm to realistically reflect the capacity required to deliver the experimental PSS. One team was assumed to be able to deliver all four of the experimental PSS, with costs allocated evenly to each.

The total project management costs for the experimental PSS are detailed in the table below:

Table 2: Project management costs associated with experimental PSS delivery over three years

PSS	Number of contracts	% contracts per type service	Mobilisation costs £	Annual running costs	Total costs£
Home Improvement	2439	25 (23)	≈33,250	≈84,000	≈285,250
Laundry	1950	20 (27)	≈33,250	≈84,000	≈285,250
House Cleaning	2438	25 (23)	≈33,250	≈84,000	≈285,250
Garden Maintenance	2926	30 (27)	≈33,250	≈84,000	≈285,250
					≈1,141,000

Since the present supply chain partners in the facilities management sector were unwilling to provide PSS, the property development firm would need to contract regional or local service providers. Such service providers did not participate in the research. Therefore a participant from the property development firm collected quotations of prices from local service providers. However, the exact business processes in the frontline service firms were not detailed.

1.3.4 Description and pseudo prices of PSS

1.3.4.1 GARDEN MAINTENANCE

Two options for PSS delivery in this area were developed to illustrate the performance of the PSS concept:

- Subscription PSS for weekly grass cutting for 20 weeks of the year
- Garden maintenance service on-demand, assumed to be twice per year, once in the spring and once in the autumn. The garden maintenance service would include hedge cutting, pruning of shrubs, general tidy-up, rubbish removal, planting and weed spraying. Typical tools that would be used are pruning saws, hedge trimmers, shears, rakes and small hand-tools.

Each of the PSS options were considered for a small and a large garden respectively.

Upon booking the subscription PSS, a weekly time for lawn mowing is agreed with the household. It is assumed that all households on one development subscribing to the service are served at one time to reduce costs associated with the logistics of PSS delivery. It is further assumed that most households are willing to have the gardeners in while they are out.

It was assumed that 975 households in the pilot regions would use the lawn mowing service, and 488 households would use the garden maintenance service. It was further assumed that 3 calls from the households to the call centres was required during the setup and running of the subscription, and two calls per year for the on demand service, one in the spring and one in the autumn.

Table 59 Costs, pseudo prices and profits of PSS for garden maintenance over three years

	Call centre costs £	Project mgt costs £	Service costs £	Service provide rate £ per service instance per household	Marked up pseudo price per service instance per household (1.25)	Call-out charges £
Mowing small				15	**£19**	9750
Mowing large				£35	**£44**	975
Maintenance small				£100	**£125**	29,250
Maintenance large				£200	**£250**	2950
	117,000	285,250	1,902,150			
	Cost £2,304,400				Revenue £2,77688	Revenue £78000
					Profit 3%, £73, 288	Added profit %3

Table 4 shows that a 25% mark-up from the service provider unit price covers costs and makes some 3% contribution to profit. (Overheads were already covered in the cost calculations). If a subscription/call-out fee of £10 is charged, another 3% is added to the profit. This scenario assumes there is no growth in the uptake over the three years.

1.3.4.2 HOME IMPROVEMENT

Three different options for home maintenance and improvement PSS were developed to illustrate the performance of the PSS concept:

- 'Man in a van' – one off handy man job on hourly basis, e.g. shelving, picture hanging, minor repairs
- Painting & Decorating – one off
- Bathroom renovation/refurbishment – one off

'The man in the van' was selected to illustrate the potential of PSS delivery to satisfy household demand for home improvements and maintenance. A handy-man service involves one or more service staff are being called out to residents, go out in a van equipped with tools and materials required for various jobs like putting up shelving, hanging up pictures, curtain and blind hanging, small repair jobs and adjustments that fall outside the warranty. The particular PSS priced here refers to putting up shelves: 6 shelves in the living-room and 4 shelves in the bedroom. The price is based on the time and materials required.

It was assumed that 75% of households in the pilot region would use the 'Man in a Van' PSS, and 25% use the painting and decorating service and bathroom renovation service respectively, per annum.

Table 60 Cost, pseudo prices and profit of PSS for home improvement over three years

	Call centre costs £	Project mgt costs £	Service Costs £	Service providers rate per service instance per household	Marked up Pseudo price (1.3) per service instance per household	Call-out charges £
Man in van	117,000	285,250	1,536,840	£120	**£156**	43,900
Painting and decorating				£150	**£195**	14,640
Bathroom renovation				£540	**£702**	14,640
	Cost £1,939,090				Revenue £1,997,892	Revenue £73,180
					Profit 3% £58,800	Added profit 3.5%

Table 3. shows that a 30% mark-up from the service provider price covers the costs and makes a 3% contribution to profit. (Overheads are already included in the call centre

and project management costs). If there is a call-out fee of £10 per service unit, a further 3.5% is added to the profit.

1.3.4.3 HOUSE CLEANING

Two main options for PSS delivery were developed to illustrate the performance of the PSS concept:

- subscription of weekly cleaning, including hoovering, dusting, mopping and other standard cleaning activities
- on-demand 'spring clean' service, assumed to be used once a year, comprising inside window clean, all skirting boards, doors & window brassware, dusting to ceilings, fittings, fireplaces, wooden furniture. Kitchen units, oven, other equipment clean. Mirrors. Bathroom - bath, sink, toilets, tiles. Vacuum cleaning all carpets & mopping all laminate floors.

Each of the scenarios was considered for a small and a large house respectively.

Upon booking the subscription, a time from available slots are agreed with the household. It is assumed that all households on one development subscribing to the service are served at a time to reduce travel costs and loss of time. It is further assumed that most households are willing to have the cleaners in while the family is away. The service provider could collect keys from the marketing suite on the development.

It was assumed that 975 households in the regions would use each of the subscription fortnightly cleaning and 244 would use the spring clean service each for a small and large house respectively.

Table 61 Costs, pseudo prices and profit of PSS for house cleaning over three years

	Call centre costs £	Project mgt costs £	Service costs £	Service provider rate per service instance per household £	Marked up Pseudo price per service instance per household (1.15)	Call-out charges £
Fortnightly subscription small house	117,000	285,250	4,445,114	£19	**£22**	9750
Fortnightly subscription large house				£38	**£44**	9750
Spring clean small house				£57	**£66**	2440
Spring clean large house				£95	**£110**	2440
	Cost £4,847,364				Revenue £5111881	Revenue £24, 380
					Profit 5.5% £264517	Added profit 0.05%

Table 5 shows that a 15% mark-up from service provider unit prices covers costs and makes a 5.5% contribution to profit. (Overheads were already covered in the cost models). A subscription/call-out fee of £10 would add marginally to the profit.

1.3.4.4 LAUNDRY (CLOTHING AND LINEN WASHING)

Two main PSS options were developed for washing to illustrate the performance of the PSS concept:

- A subscription service for weekly laundry (collection, washing, drying, return – ironing not included in this scenario)
- An on-demand service (collection, washing, drying, return – ironing not included in this scenario)

The subscription service was developed for a small volume (e.g. single person) and large volume (e.g. family). The small volume option was defined as 9 kg per week and the large volume was 36 kg per week of clothing and linen. When booking the subscription with The property development firm, a time for collection and return every week would be agreed. The collection and return could be undertaken either at the dwelling or at a designated place on the development, such as by the marketing suite, depending on the householder preferences. Upon collection, the loads would be weighed and minor discrepancies from the ordered quantity would not matter. If over time the loads frequently diverged notably from the ordered quantity, the customer would be asked to change the subscribed quantity. It is assumed that the service provider keeps a database of the volumes and based on actual historic data could suggest appropriate loads to the customer and scaling the service capacity. The service provider gives a high degree of reassurance that washing will not get lost or damaged but also has an insurance to cover compensations in the unlikely event that this happens.

The on-demand service was assumed to be used on one occasion every year, for instance after having guests to stay. The load was assumed to be 22.5 kg. Upon booking the on-demand service, the customer would have to estimate the quantity required and agree a convenient time for collection and delivery among available time slots. It is assumed that the availability would be good but not unlimited.

It was assumed that 975 households in the regions would each use the subscription services and 975 households would use the on-demand washing once a year.

Table 62 Costs, pseudo prices and profits of PSS for laundry over three years

	Call centre costs £	Project mgt costs £	Service costs £	Service provider rate £ per service instance per household	Marked up pseudo price per service instance per household	Call-out charges £
Single	117,000	285,250	24,877,125	£32	**£34**	9,750
Family				£130	**£137**	9,750
On-demand washing				£81	**£85**	4,875
	Cost £ 25,279,375				Revenue £26, 120,891	Revenue £23,375

		Profit 3% £841,515	Added profit %0.01

Table 62 shows that a 5% mark-up from the service provider unit price covers the costs and contributes 3,3% profit. A subscription/call-out fee of £10 and £5 respectively, makes a marginal contribution to profit.

1.4 Summary and conclusions

This chapter developed and priced a number of PSSs, to enable the subsequent assessment of their waste prevention potential and their environmental potential, and also the exploration of households' and service providers' attitudes to adoption of the PSS.

New services development frameworks were drawn upon, as was literature on service management and new service development and waste were drawn upon. In addition primary data from interviews and focus groups with participants from multiple functions of the property development firm and households (potential customers) were used, in line with recommendations from the literature.

The joint consideration of relevance for waste prevention, customer demand and supply-side feasibility led to the selection of a menu of services, comprising garden maintenance services, home improvement service, house cleaning service and a laundry service. PSS for these were further developed and priced. The experimental PSS developed were fairly conventional household services and not as innovative as the PSS literature suggests that result-oriented PSS allowed. Yet, these PSS were taking the PSS idea as far as possible given that a premise was that there should be a degree of potential supply and demand acceptance for the experimental PSS. The ideas of the supply side tended to be more closely aligned with business as usual, such as offering the households extra waste collection service, placing skips on the housing development in order to alleviate household frustrations with limited disposal opportunities. Furthermore, the supply side representatives suggested that uncertainty of profitability made it difficult to gain acceptance for untried ideas in the higher management tiers within the firm.

This appendix mainly described supply-side processes, and prices of the PSS. In appendix E, user narratives describing user encounters with the PSS are presented.

APPENDIX B: COMPOSITION OF MUNICIPAL SOLID WASTE

Table 63 Composition of municipal solid waste in Wales (Burnley 2007)

Waste fractions	%
Paper	**21**
Newspapers and magazines	9
Recyclable papers	2,1
Cardboard boxes/containers	5,1
Other paper and card	4,8
Plastic	**7,3**
Refuse sacks and carrier bags	1,3
Packaging film	1,3
Other plastic film	0,2
Dense plastic bottles	1,7
Other packaging	1,5
Other dense plastic	1,3
Glass	**5,8**
Packaging glass	5,3
Non-packaging glass	0,5
Organic waste	**30,5**
Garden waste	12,7
Kitchen waste	15,7
Other organic waste	2,1
Metals	**5,6**
Ferrous metal food/beverage cans	1,7
Other ferrous metals	3,1
Non-ferrous food/beverage cans	0,3
Other non-ferrous metals	0,5
WEEE	**2,0**
White goods	0,8
Large electronic goods	0,2
TVs and monitors	0,3
Other WEEE	0,7
Textile	1,8
Shoes	0,4
Disposable nappies	2,3
Wood	2,8
Carpet and underlay	1,5
Furniture	1,5
Other miscellaneous combustible	3,6
Lead acid batteries	0,2
Oil	0,1
Identifiable clinical waste	0,2
Other potentially hazardous	0,3
Construction and demolition waste	5,2
Other non-combustible material	2,8
Fines	5,2

APPENDIX C: EXAMPLE OF A COMPLETED SURVEY QUESTIONNAIRE

[redacted] Shoreham 2007

Questions on products and product use in self-servicing

Thank you very much for filling in the questionnaires on how you ranked the performance of the different services, during the session in the evening of the 24th January 2007.

Now we would like to know a bit more about the products you use for self-service (you or a member of your household performing a household task yourself using a product that you own) and how you use the products.

[redacted]

Name: [redacted] FERSTEAD

First however, two quick questions:

1. What household task would you most prefer to farm out to a professional service provider? Please fill in number 1-5 in order of preference, 1=prefer the most to farm out, 5=prefer the least to farm out. You can only use each number once.

   ☐ 4 cleaning
   ☐ 5 washing
   ☐ 3 ironing
   ☐ 2 gardening
   ☐ 1 DIY/'handyman' jobs

2. What household task do you enjoy doing yourself the most? Please fill in number 1-5 in order of preference, 1=enjoy the most, 5=enjoy the least. You can only use each number once.

   ☐ 1 cleaning
   ☐ 2 washing
   ☐ 4 ironing
   ☐ 3 gardening
   ☐ 5 DIY/'handyman' jobs

Thank you! And now to the questions on your products and product use. The questionnaire covers the following activities that you may be using products for: handyman jobs, gardening, cleaning and laundry.

N.B. When we say "you", we mean you or another member of your household

1

Handyman

1. How many drills do you own?
   ☐ 0 ☐ 1 ☑ 2 ☐ 3 ☐ 4 If "0", please go to question 20

2. Is your drill cordless or corded?
   ☐ Cordless ☑ Corded

3. For how long does the battery of your cordless drill run on one charge?
   .....(please state units, e.g. minutes, hours) ☑ N/A

4. How long does the battery need to be recharged?
   .....(please state units, e.g. minutes, hours) ☑ N/A

5. What is the Wattage of the battery charger for the cordless drill?
   .....W ☑ N/A

6. What is the input power of your corded drill?
   ☐ <500W ☑ 500-700W ☐ 701-900W ☐ 901-1100W ☐ >1100W
   ☐ N/A

7. Did you get your drill new or second-hand?
   ☑ New ☐ Second hand

8. How did you get your drill?
   ☑ Went into shop ☐ ordered over the Internet
   ☐ Ordered over the phone ☐ Got from a friend

9. If you went into a shop, how did you get there?
   ☑ by car ☐ took the bus/train ☐ walked ☐ cycled
   ☐ Other, please specify.....

10. If you went into a shop, what type of route did you take?
    (you may tick more than one box if you used a combination of routes)
    ☐ motorway ☑ town/city ☐ country road

11. Was the journey only to look at/buy the drill?
    ☐ Yes ☑ No, also for other errands/shopping/work

12. Was the drill delivered to you or did you take it home yourself?
    ☐ delivered by shop ☑ got it myself
    ☐ got friends/kin to take it home for me

13. How many times per year do you use the drill?
☐ 0 ☐1-2 ☐3-4 ☐ 5-6 ☐7-8 ☑ 9 or more

14. For how long do you typically use the drill each time?
.....1 hour.....(please specify unit, e.g. minutes, hours)

15. Why did you *stop using* your old drill?
☐ I haven't had a drill before
☐ It wasn't working properly and it cost too much to have it repaired
☑ It wasn't working properly and it was beyond repair
☐ It cost too much to run (e.g. electricity costs)
☐ I wanted the additional features of another model
☐ It looked dated
☐ Other, please specify.....

16. How long did you have your old drill before *stopped using* it for good?
.....6.....years ☐ N/A

17. How long did you have your old drill before you *replaced* it
.....6..... years ☐ N/A

18. Why did you *replace* your old drill?
☑ The new drill would do a better job
☐ The new model had additional features that I wanted
☐ I liked the style of the new one better than the old one
☐ The new one would be cheaper to use than the old one (e.g. electricity)
☐ The new one would be better for the environment
☐ I could afford to
☐ The prices had come down
☐ There was a special offer
☐ Other, please specify.....

19. What did you do with your old drill after you had stopped using it for good?
☐ Gave it to relations or friends
☐ Gave it to charity
☐ Sold it
☐ Kept it
☐ Took it to the civic amenity site
☑ Put it out for waste collection
☐ Other, please specify.....

20. What other power tools do you have?
Please specify.....Stand Drill.....

Gardening

21. How many lawnmowers do you have?

☑ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4

If your answer was "0", and you have not had a lawnmower before, please go to question 44.

If your answer was "0" but you have had a lawnmower before, please go to question 37.

22. What type of lawnmower(s) do you have?

☐ Hover	What make and model is it?.....
☐ Wheeled rotary	What make and model is it?.....
☐ Wheeled cylinder	What make and model is it?.....
☐ Mulcher	What make and model is it?.....

23. Is your lawnmower powered by petrol or electricity?

☐ Petrol ☐ Electricity

24. What is the motor power of your lawnmower?

.....

25. What is the cutting width (i.e. the total width of the blades)?

.....

26. Did you get your lawnmower new or second-hand?

☐ New ☐ Second hand

27. How did you get your lawnmower?

☐ Went into shop ☐ ordered over the Internet
☐ ordered over the phone ☐ from a friend

28. If you went into a shop, how did you get there?

☐ by car ☐ took the bus/train ☐ walked ☐ cycled
☐ Other, please specify.....

29. If you went into a shop, what distance did you go?

☐ 0-5 miles ☐ 6-10 miles ☐ 11-15 miles ☐ >15 miles

30. If you went into shop, what type of route did you take?
(you may tick more than one box if you took a combination of routes)

☐ motorway ☐ town/city ☐ country road

31. Was the journey only for to look at/buy the lawnmower?

☐ yes ☐ no, for other errands/shopping/working as well

32. Was the lawnmower delivered to you or did you collect it yourself?

☐ delivered by shop
☐ got it myself
☐ got friend/family to transport it home for me

33. How many months per year do you mow your lawn?

☐ N/A ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

34. How often do you mow your lawn?

☐ N/A ☐ once per month ☐ once per fortnight ☐ once per week

35. How long does it typically take you to mow the lawn each time?

☐ N/A ☐ 15 min. ☐ 30 min. ☐ 45 min. ☐ 60 min.

36. If you have a petrol lawnmower, how much petrol do you usually use per season?

.....please state unit, e.g. gallons, litres ☐N/A

37. How many times did have your old and current lawnmower respectively, repaired?

The last lawnmower: ☐ 0 ☐ 1 ☑ 2 ☐ 3 ☐4 ☐5
My current lawnmower: ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐4 ☐5

38. Who repaired the lawnmower?
(you may tick more than one box if appropriate)

☐ a member of the household
☐ friend/kin without professional repair skills
☐ friend/kin with professional repair skills
☑ a professional repairer

39. Why did you stop using your old lawnmower?
(you may tick more than one box if appropriate)

☐ It wasn't working properly and it cost too much to have it repaired
☐ It wasn't working properly and it was beyond repair
☐ It cost too much to run (e.g. petrol or electricity costs)
☐ I wanted the additional features of another model
☐ It looked dated
☐ Other, please specify.....Moved to a flat.....

40. How long had you had your old lawnmower before you *stopped using* it?

.....2.....years ☐ N/A

41. How long had you had your old lawnmower before you *replaced* it?

.....years ☐ I didn't replace it (go to question 43)

42. Why did you replace your old lawnmower?

☐ The new lawnmower would do a better job
☐ The new model had additional features that I wanted
☐ I liked the style of the new machine better than the old one
☐ The new one would be cheaper to use than the old one (e.g. petrol use)
☐ The new one would be better for the environment
☐ I could afford to
☐ The prices had come down
☐ There was a special offer
☐ Other, please specify.....

43. What did you do with your old lawnmower after you had stopped using it for good?

- ☑ Gave it to relations or friends
- ☐ Gave it to charity
- ☐ Sold it
- ☐ Kept it
- ☐ Took it to the civic amenity site
- ☐ Put it out for waste collection
- ☐ Other, please specify .....

44. What garden equipment do you own aside from lawnmowers?

Please specify.....

☑ None

Laundry

45. Which of the following appliances do you own?

☐ Washing machine What make and model is it?.....
☐ Tumble Drier What make and model is it?.....
☑ Washer-drier What make and model is it?....Bosch.....

In the following, please only consider the questions for the appliances that you own and ignore questions for appliances you do not own.

46. What is the capacity of your washing machine

☐ 3-4 kg ☐ 5-6kg ☐ 7-8kg ☐ 9-10kg Don't Know

47. What is the capacity of your tumble drier?

☐ 3-4 kg ☐ 5-6kg ☐ 7-8kg ☐ 9-10kg

48. What is the capacity of your washer/drier?

Washing ☐ 3-4 kg ☐ 5-6kg ☐ 7-8kg
Drying ☐ 2.5-4 kg ☐ 5-6kg

49. What is the energy rating of your washing/drying appliance(s)?

washer	☐ AAA	☑ A	☐ B	☐ C	☐D	☐ E	☐ F	☐ G	
Drier	☐ AAA	☑ A	☐ B	☐ C	☐D	☐ E	☐ F	☐ G	Don't Know
Washer-drier	☐ AAA	☑ A	☐ B	☐ C	☐D	☐ E	☐ F	☐ G	

50. How much water does your washing machine typically use per washing cycle?

Washing machine:
☐ 43-49 l ☐ 50-55 l ☐ 56 -59 l ☐ 60-65 l ☐ more than 65 l Don't Know
Washer drier:
☐ 45-55l ☐ 85-100l ☐ 150 -170 l

51. Did you buy your laundry appliances new or second hand?

Washing machine	☐ new	☐ second-hand
Tumble dryer	☐ new	☐ second-hand
Washer dryer	☑ new	☐ second-hand

52. How did you get your washing machine/tumble drier/washer drier?

Washing machine:

☐ Went into shop ☐ ordered on the Internet

☐ ordered on the phone ☐ From friends/kin

Tumble dryer:

☐ Went into shop ☐ ordered on the Internet already installed

☐ ordered on the phone ☐ From friends/kin

Washer dryer:

☐ Went into shop ☐ ordered on the Internet

☐ ordered on the phone ☐ From friends/kin

53. If you went into a shop, how did you get there? N/A

Washing machine:

☐ by car ☐ took the bus/train ☐ walked ☐ cycled ☐ other.....

Tumble dryer:

☐ by car ☐ took the bus/train ☐ walked ☐ cycled ☐ other.....

Washer-dryer:

☐ by car ☐ took the bus/train ☐ walked ☐ cycled ☐ other.....

54. If you went into a shop, what distance did you go?

☐ 0-5 miles ☐ 6-10 miles ☐ 11-15 miles ☐ more than 15 miles

55. If you went into shop, what type of route did you take?
(you may tick more than one box if you took a combination of routes) N/A

☐ motorway ☐ town/city ☐ country road

56. Was the journey travelled only to look at/buy the washing machine/tumble dryer/washer dryer? N/A

57. Washing machine:

☐ yes ☐ no, for other errands/shopping/work as well

Tumble dryer:

☐ yes ☐ no, for other errands/shopping/work as well

Washer-dryer:

☐ yes ☐ no, for other errands/shopping/work as well

58. Was the washing machine delivered to you or did you take it home yourself?

Washing machine:

☐ delivered by shop ☐ got it myself ☐ got friend/kin to take it home for me

Tumble dryer:

☐ delivered by shop ☐ got it myself ☐ got friend/kin to take it home for me

Washer dryer:

☐ delivered by shop ☐ got it myself ☐ got friend/kin to take it home for me

59. How many loads do you wash and/or dry per week?

Wash:.....6.....(number of loads)

Dry:.....4.....(number of loads)

60. How many of these weekly loads do you wash at each the temperatures below?

30°.....4..... 40°.....2..... 60°..... 90°.....

61. How many of these weekly loads do you dry at each temperature?

High:.....4..... Low..... ☐ I don't use a dryer

62. What number of wash loads at each temperature are full, half, single garment, respectively?

At 30°: Full..4 Half..... Single garment .....

At 40°: Full.2 Half..... Single garment .....

At 60°: Full.... Half..... Single garment .....

At 90°: Full..... half..... Single garment .....

63. How much detergent do you use?

.....Required amount.....

64. How many times did you have your old washing machine repaired?

☐ 0 ☐ 1 ☒ 2 ☐ 3 ☐4

65. If you had it repaired, who repaired it for you?
(You may tick more than one box if appropriate)

- ☐ A member of the household
- ☐ Friend/kin without professional repair skills
- ☐ Friend/with professional repair skills
- ☒ A professional repairer

66. Why did you stop using your old washing machine?
(you may tick more than one box if appropriate)

- ☐ It wasn't working properly and it cost too much to have it repaired
- ☐ It wasn't working properly and it was beyond repair
- ☐ It cost too much to run (e.g. electricity and water costs)
- ☐ I wanted the additional features of another model
- ☐ It looked dated
- ☐ Other, please specify..... I moved .....

67. How long had you had your old washing machine before you *stopped using* it?

.....7.....years ☐ N/A

68. How long had you had your old washing machine before you *replaced* it?

.....years ☒ I didn't replace it

69. Why did you replace your last washing machine?

- ☐ The new washing machine would do a better job
- ☐ The new model had additional features that I wanted
- ☐ I liked the style of the new machine better than the old one
- ☐ The new one would be cheaper to use than the old one (e.g. petrol use)
- ☐ The new one would be better for the environment
- ☐ I could afford to
- ☐ The prices had come down N/A
- ☐ There was a special offer
- ☐ Other, please specify.....

70. What did you do with your old washing machine after you had stopped using it for good?

- ☐ Gave it to relations or friends
- ☐ Gave it to charity
- ☐ Sold it
- ☐ Kept it
- ☐ Took it to the civic amenity site
- ☐ Put it out for waste collection
- ☐ Other, please specify .....

Cleaning

71. How many vacuum cleaners do you have (for indoor use only)?

☐ 0 ☑ 1 ☐ 2 ☐ 3 ☐ 4

72. What type of vacuum cleaner do you have?

(if you have more than one, please fill in number in the appropriate box, e.g. 1 cylinder bagged, small; 1 upright bagless medium)

☐ Upright, bagged – small (less than 7 kg)
☐ Upright, bagged – medium (7-9kg)
☐ Upright, bagless – small (less than 7 kg)
☑ Upright, bagless – medium (7-9 kg)
☐ Cylinder, bagged – small (less than 5 kg)
☐ Cylinder, bagged – medium (5-9 kg)
☐ Cylinder, bagless – small (less than 5 kg)
☐ Cylinder, bagless – medium (5-9 kg)
☐ Handheld

73. What is the power of your vacuum cleaner(s) (i.e. the max. power stated on the vacuum cleaner)

(You may fill in more box than one if appropriate) Don't Know

☐ less than 1000W ☐ 1000-1300W ☐ 1400-1600W
☐ 1700-1900W ☐ 2000-2200W

74. What is the make and model of your vacuum cleaner?

.....Dyson.....

75. Did you buy your vacuum cleaner(s) new or second-hand?

(fill in more than one box if appropriate)

☑ New ☐ Second-hand

76. How did you get your vacuum cleaner(s)?

☑ Went into shop ☐ ordered over the Internet
☐ ordered over the phone ☐ got from friend/kin

77. If you went into a shop, how did you get there?

☑ by car ☐ took the bus/train ☐ walked ☐ cycled ☐ other.....

78. If you went into a shop, what distance did you go?

☑ 0-5 miles ☐ 6-10 miles ☐ 11-15 miles ☐ >15 miles

79. If you went into shop, what type of route did you take?
(you may tick more than one box if you took a combination of routes)

☐ motorway ☑ town/city ☐ country road

80. Was the journey only for to look at/buy the vacuum cleaner?

☑ yes ☐ no, for other errands/shopping/working as well

81. Was the vacuum cleaner delivered to you or did you take it home yourself?

☐ delivered by shop
☑ got it myself
☐ got friend/family to transport it home for me

82. How many hours does someone in your household spend on vacuuming every week?

☐0 ☑0.5 ☐1 ☐1.5 ☐2 ☐2.5 ☐3 ☐3.5 ☐>4

83. If you have more than one vacuum cleaner, how much of the total time do you use each vacuum cleaner?

Description of vacuum cleaner (e.g. cylinder small):
..... Number of hours:.....
Description:.....Number of hours:.....
Description:.....Number of hours:.....

84. Do you usually use the maximum power setting?

☑ yes ☐ No

85. Do you change adjust the power during use/between instances of use?

☐ yes ☑ No

86. Why did you stop using your old vacuum cleaner?
(you can tick more than one option)

- ☐ It wasn't working properly and it cost too much to have it repaired
- ☐ It wasn't working properly and it was beyond repair
- ☐ It cost too much to run (e.g. electricity costs)
- ☑ I wanted the additional features of another model
- ☐ It looked dated
- ☐ Other, please specify.....

87. How long had you had your old vacuum cleaner before you *stopped using* it?

.....12.....years

88. How long had you had your old vacuum cleaner before you *replaced* it?

.....6.....years

89. Why did you replace your last vacuum cleaner?
(you may tick more than one box if appropriate)

- ☑ The new vacuum cleaner would do a better job
- ☐ The new model had other features that I wanted
- ☐ I liked the style of the new one better than the old one
- ☐ The new one would be cheaper to use than the old one (e.g. electricity use)
- ☐ The new one would be better for the environment
- ☐ I could afford to
- ☐ The prices had come down
- ☐ There was a special offer
- ☐ Other, please specify.....

90. What did you do with your old vacuum cleaner after you had stopped using it for good?

- ☑ Gave it to friends/kin
- ☐ Gave it to charity
- ☐ Sold it
- ☐ Kept it
- ☐ Took it to the civic amenity site
- ☐ Put it out for waste collection
- ☐ Other, please specify .....

APPENDIX D: TABLES OF INDICATORS FOR RESOURCE USE AND EMISSIONS

Table 64 Environmental impact indicators from Kemna et al. 2005. used in the environmental assessment of PSS and self-servicing for garden maintenance

Material/process	Primary energy	Haz waste	Non haz waste	(Air) GWP	(Air) AP	(Air) VOC	(Air) PAH	Water (EP)
	MJ	g	g	kg	g	g	mg	mg
Plastics in kg								
ABS	95	10	92	3.32	18	0	2	630
PP	73	4	28	1.97	6	0.02	0	165
PS	87	1	22	2.79	17	0	121	55
LDPE	78	4	44	1.9	7	0.49	0	27
EPS	84	1	38	2.7	18	0	61	125
Metals in kg								
St sheet galvanised	34	*0*	1722	2.83	7	0.14	*0*	65
Cast iron	10	*0*	315	1.06	3	0.12	*0*	26
Aluminium die-cast	55	*0*	150	3.55	16	0.07	18	1
CuZn38 cast	38	*0*	43	1.81	35	0.01	3	15
Cu wire	117	*0*	12	6.2	292	0.01	5	155
Cu winding wire	143	1	40	7.37	304	0.03	6	158
Ferrite	51	*0*	2582	4.24	11	0.2	*0*	79
OEM all plastic parts	41	*0*	128	2.27	10	*0*	*0*	24
OEM aluminium foundries	7	*0*	20	0.36	2	0	*0*	4
OEM Cu/Zn foundries	2	*0*	7	0.12	1	0	*0*	1
OEM sheet metal	15	*0*	47	0.84	4	0	*0*	6
Sheet metal scrap	12	*0*	180	0.8	4	0.09	*0*	*0*
Final assembly								
per m3 appliances	700	6	277	46.67	150	15.73	36	7
per product	52	1	51	4.52	12	0.05	3	1
Office paper	40	*0*	68	0.58	5	0.2	*0*	5288
per m3 retail product	500	6	322	29.31	84	5.03	9	9
per retail product	59	1	55	4.03	13	0.04	*0*	1
Use								
Electricity per MWh	####	242	12174	458.21	2704	3.95	21	323
Lawnmower petrol (per kg of petrol)	48.4	*0*	*0*	3.4	6.6	77.4	0.002	*0*
Mini-van diesel (per km)	2	*0*	*0*	0.19	0.19	0.04	1	*0*

Disposal								
Landfill burdens	68	*0*	226	5.1	10	0.28	*0*	325
Thermal recycling burdens	67	*0*	*0*	5.02	10	0.14	*0*	325
Recycling burdens	7	*0*	3	0.44	2	0.13	*0*	*0*
Recycling credits	####	-2.21	-14.07	-0.99	-2.81	-0.01	-0.19	-82.28
Thermal recycling credits ABS	####	0	0	-3.42	-4.28	-0.06	0	0
Thermal recycling credits PP	-53	0	0	-3.93	-4.93	-0.07	0	0
Thermal recycling credits PS	####	0	0	-3.55	-4.44	-0.06	0	0
Thermal recycling credits LDPE	-52	0	0	-3.85	-4.82	-0.07	0	0
Thermal recycling credits EPS	-48	0	0	-3.57	-4.47	-0.06	0	0
Thermal recycling credits Paper	-27	0	0	-2.01	-2.52	-0.03	0	0

Table 65 Environmental impact indicators from Kemna et al. 2005. used in the environmental assessment of PSS and self-servicing for home improvement

	Primary energy	Haz waste	Non haz waste	(Air) GWP	(Air) AP	(Air) VOC	(Air) PAH	Water (EP)
	MJ	g	g	kg	g	g	mg	mg
Plastics								
LDPE	78	4	44	1.9	7	0.49	0	27
PS	87	1	22	2.79	17	0	121	55
PVC	57	5	67	2.16	15	0	0	314
ABS	95	10	92	3.32	18	0	2	630
PA	120	19	176	8.56	39	0.01	*0*	1872
Steel (sheet)	34	*0*	1722	2.83	7	0.14	*0*	65
Ferrite	51	*0*	2582	4.24	11	0.2	*0*	79
Cupper wire	117	*0*	12	6.2	292	0.01	5	155
Other								
Electronic Components	281	1733	2625	11.22	214	2.33	4	3686
Manufacturing								
OEM plastics	41	*0*	128	2.27	10	*0*	*0*	24
sheet metal	15	*0*	47	0.84	4	0	*0*	6
sheet metal scrap	12	0	180	0.8	4	0.09	*0*	*0*
PWB assembly	128	4	107	8.52	49	2.13	3	709
Final assembly per m3 retail product	700	6	277	46.67	150	15.73	36	7
Final assemby per retail product	52	1	51	4.52	12	0.05	3	1
Corrugated cardboard	28	*0*	52	0.7	1	*0*	*0*	86
Paper	40	*0*	68	0.58	5	0.2	*0*	5288
Distribution per m3 retail product	500	6	322	29.31	84	5.03	9	9
Distirubiton per retail product	59	1	55	4.03	13	0.04	0	1
Use								
Electricity (per MWh)	####	242	12174	458.21	2704	3.95	21	323
Minivan diesel (per km)	2	*0*	*0*	0.19	0.19	0.04	1	*0*
Disposal								
Landfill burden	68	*0*	226	5.1	10	0.28	*0*	325
Incineration burden	67	*0*	*0*	5.02	10	0.14	*0*	325
Recycling burden	7	*0*	3	0.44	2	0.13	*0*	*0*
Recycling credit	####	-2.21	-14.07	-0.99	-2.81	-0.01	-0.19	-82.28
Incineration credits LDPE	-52	*0*	*0*	-3.85	-4.82	-0.07	*0*	*0*
Incineration credit PS	####	*0*	*0*	-3.55	-4.44	-0.06	*0*	*0*
incineration credit PVC	-23	*0*	*0*	-1.7	-2.14	-0.03	*0*	*0*
incineration credit ABS	####	*0*	*0*	-3.42	-4.28	-0.06	*0*	*0*
incineration credit PA	-39	*0*	*0*	-2.9	-3.64	-0.05	*0*	*0*

incineration credit paper	-27	*0*	*0*	-2.01	-2.52	-0.03	*0*	*0*

Table 66 Environmental impact indicators from Kemna et al. 2005. used in the environmental assessment of PSS and self-servicing for house cleaning

Material or process	Primary energy	Haz waste	Non haz waste	(Air) GWP	(Air) AP	(Air) VOC	(Air) PAH	Water (EP)
Plastics per kg	MJ	g	g	kg	g	g	mg	mg
ABS	95	10	92	3.32	18	0	2	630
PP	73	4	28	1.97	6	0.02	0	165
PS	87	1	22	2.79	17	0	121	55
PC	117	10	177	5.39	25	0	0	504
Metals per kg								
Aluminium die-cast	55	*0*	150	3.55	16	0.07	18	1
Cu wire	117	*0*	12	6.2	292	0.01	5	155
Cu winding wire	143	1	40	7.37	304	0.03	6	158
St sheet galvanised	34	*0*	1722	2.83	7	0.14	*0*	65
Ferrite	51	*0*	2582	4.24	11	0.2	*0*	79
Manufacturing								
OEM all plastic parts	41	*0*	128	2.27	10	*0*	*0*	24
OEM aluminium foundries	7	*0*	20	0.36	2	0	*0*	4
OEM sheet metal	15	*0*	47	0.84	4	0	*0*	6
Sheet metal scrap	12	*0*	180	0.8	4	0.09	*0*	*0*
Final assembly								
per m3 appliances	700	6	277	46.67	150	15.73	36	7
per product	52	1	51	4.52	12	0.05	3	1
Cardboard	28	*0*	52	0.7	1	*0*	*0*	86
per m3 retail product	500	6	322	29.31	84	5.03	9	9
per retail product	59	1	55	4.03	13	0.04	*0*	1
Use								
Electricity per MWh	10500	242	12174	458.21	2704	3.95	21	323
Mini-van diesel (per km)	2	*0*	*0*	0.19	0.19	0.04	1	*0*
Disposal								
Landfill - burden	68	*0*	226	5.1	10	0.28	*0*	325
Incineration -burden	67	*0*	*0*	5.02	10	0.14	*0*	325
Recycling burden	7	*0*	3	0.44	2	0.13	*0*	*0*
Energy recovery credits ABS	-45.77	0	0	-3.42	-4.28	-0.06	0	0
Energy recovery credits (PP)	-52.72	0	0	-3.93	-4.93	-0.07	0	0

Energy recovery credits PS	-47.53	0	0	-3.55	-4.44	-0.06	0	0
Energy recovery credits PC	-37.99	0	0	-2.84	-3.55	-0.05	0	0
Energy recovery cretids cardboard	-16	0	0	-1.19	-1.50	-0.02	0	0
Recycling - credits for all plastics	-49.85	-2.21	-14.07	-0.99	-2.81	-0.01	-0.19	-82.28

Table 67 Environmental impact indicators from Kemna *et al.* (2005). used in the environmental assessment of PSS and self-servicing for house cleaning

Material or process	Primary energy MJ	Haz waste g	Non haz waste g	(Air) GWP kg	(Air) AP g	(Air) VOC g	(Air) PAH mg	Water (EP) mg
PE	77	5	38	1.81	6	0.16	0	30
PP	73	4	28	1.97	6	0.02	0	165
Talcum filler for PP	10	*0*	6	0.61	3	*0*	1	*0*
PS	87	1	22	2.79	17	0	121	55
PVC	57	5	67	2.16	15	0	0	314
ABS	95	10	92	3.32	18	0	2	630
PA	120	19	176	8.56	39	0.01	0	1872
PMMA	110	1	105	6	44	0	0	2068
Steel (sheet)	34	*0*	1722	2.83	7	0.14	*0*	65
Cast iron	10	*0*	315	1.06	3	0.12	*0*	26
Aluminium	55	*0*	150	3.55	16	0.07	18	1
Copper	51	*0*	14	2.73	63	*0*	5	62
Cupper wire	117	*0*	12	6.2	292	0.01	5	155
Brass	38	*0*	43	1.81	35	0.01	3	15
Electronic Components	281	1733	2625	11.22	214	2.33	4	3686
Concrete	1	*0*	*0*	0.19	1	*0*	*0*	*0*
OEM plastics	41	0	128	2.27	10	*0*	*0*	24
sheet metal	15	0	47	0.84	4	*0*	*0*	6
sheet metal scrap	12	0	180	0.8	4	0.09	*0*	*0*
foundries Fe	2	0	7	0.12	1	0	*0*	1
foundries Al	7	0	20	0.36	2	0	*0*	4
PWB assembly	128	4	107	8.52	49	2.13	3	709
Per m3 retail product	700	6	277	46.67	150	15.73	36	7
Per retail product	52	1	51	4.52	12	0.05	3	1
Corrugated cardboard	28	*0*	52	0.7	1	*0*	0	86
Paper	40	*0*	68	0.58	5	0.2	0	5288
Distribution per m3 retail product	500	6	322	29.31	84	5.03	9	9
Distirubiton per retail product	59	1	55	4.03	13	0.04	0	1
Use								
Electricity	10500	242	12174	458.21	2704	3.95	21	323
Water per m3	0.008	*0*	*0*	0	0.00	0	0	*0*

Diesel	2	*0*	*0*	0.19	0.19	0.04	1	*0*
Disposal costs								
Landfill	68	*0*	226	5.1	10	0.28	*0*	325
Incineration	67	*0*	*0*	5.02	10	0.14	*0*	325
Plastics recycling	7	*0*	3	0.44	2	0.13	*0*	*0*
Disposal credits								
Energy recovery credits PE	-54.1	*0*	*0*	-4.04	-5.06	-0.07	*0*	*0*
Energy recovery credits PP	-52.72	*0*	*0*	-3.93	-4.93	-0.07	*0*	*0*
Energy recovery credits PS	-47.53	*0*	*0*	-3.5	-4.44	-0.06	*0*	*0*
Energy recovery credits PVC	-22.93	*0*	*0*	-1.7	-2.14	-0.03	*0*	*0*
Energy recovery credits ABS	-45.77	*0*	*0*	-3.4	-4.28	-0.06	*0*	*0*
Energy recovery credits PA	-38.91	*0*	*0*	-2.9	-3.64	-0.05	*0*	*0*
Energy recovery credits PMMA	-41.82	*0*	*0*	-3.1	-3.91	-0.05	*0*	*0*
Energy recovery credits cardboard	-16	*0*	*0*	-1.2	-1.50	-0.02	*0*	*0*
Energy recovery credits paper	-27	*0*	*0*	-2.01	-2.52	-0.03	*0*	*0*
Recycling credits for plastics	-49.85	-2.21	-14.07	-0.99	-2.81	-0.01	-0.19	-82.28

APPENDIX E: USER NARRATIVES FOR THE EXPERIMENTAL PSS

Introduction

Experimental PSS were developed that would be presented to focus groups of household respondents to facilitate exploration of their attitudes to adopting PSS. The development of these experimental PSS was described in appendix A. In order to aid the accessibility of these experimental PSS for the household respondents, Dr Emma Dewberry, Cranfield University and Loughborough University, was engaged to develop narratives for the experimental PSS for each of the four household activities. The narratives presented in this appendix were all produced by Dr Emma Dewberry, whom the author owes thanks.

Experimental PSS: Garden maintenance

Older couple

Roy (74) and Yvonne (67)

1 car

3 bed terrace - Watton, Norfolk.

Roy and Yvonne Hastings have recently moved to be near their daughter and her family who live in Norwich. They moved from a large 4-bed detached house in the Wirral to a smaller 3-bed terrace house on the Blenheim Grange development at the edge of the village of Watton.

Roy, a retired engineer, has always enjoyed gardening – the last house had around 3/4 acre of land, but in recent years the garden was beginning to get on top of him a bit and he felt he was no longer able to manage the up keep of it. The new house is on a corner plot and has a relatively large garden compared to the rest of the terrace – but it is still a more manageable size than the old garden.

Since moving in 6 months ago, Roy has undergone a major knee and hip operation which has left him relatively immobile and with the summer fast approaching, the garden is beginning to look unkept. Yvonne has tried to operate Roy's old lawnmower but hasn't managed to get it working and is loathed to purchase a new lawnmower just for, as she sees it, "that bit of grass at the back". They also don't want to bother their daughter with helping out as she works full-time and has a young family to look after.

They decided to look for a gardener, mainly to cut the lawns as Yvonne likes to potter and plant up the borders. However, being new to the area, they didn't know of any reputable companies and the one gardener they were recommended by the lady in the local PO was already oversubscribed with work.

One day they received a flyer through the post from the housing and development company whom they had bought the house from. The flyer listed a range of services that were being provided to local homeowners. One of these services was a gardening service, everything from hard-landscaping, water features, driving, planting and grass cutting. There were different rates depending on what service you required and different subscriptions depending on whether it was a one-off job or something that need continual update.

Roy phoned the number on the flyer to get more information. A person answered the phone, provided Roy with the details and gave him a ref. no. in case he decided to book the service - she also took his name and address. After discussing it through with Yvonne they decided to opt for a year's subscription of grass-cutting. The service guaranteed professionalism and the housing and development company guaranteed that any problems would be resolved immediately. Roy phoned the call centre again and provided the ref no he'd been given. The details of his previous call regarding the lawn mowing rates and levels of service were quickly reviewed and Roy explained which option he wanted: Roy had the option to book all seven grass cutting appointments in the service diary there and then or he could book them individually, no less than 2 weeks in advance. The company informed him of times in the year when the service was nearest capacity, and said that if he could confirm dates during that time that would ensure he would have his lawn mowed during the peak times. A convenient time was arranged for the first appointment and a direct debit was set up to cover the additional payment, spread across the duration of the service.

On the appointed day both Roy and Yvonne were in, just to check up on the work done. A man in his 30's arrived about 2pm and knocked on the door to explain who he was and to confirm what he'd been asked to do – Roy showed him round the garden – though it was pretty obvious which bits were grass and what needed cutting. After that Joe unloaded his lawnmover – one of the high specification diesel variety – and proceeded to cut the lawns. He also strimmed the edges of the lawn and swept up all the bits which Roy asked if he could put on the compost (otherwise Joe would have taken all waste away with him to a central composting area). Once the job was complete Joe left Roy a signed receipt for his records of the date, the work done and the cost debited from his credit card.

Later that afternoon Roy and Yvonne sat out on their patio, enjoying a glass of wine, the smell of freshly cut grass and a very tidy garden.

Experimental PSS: home improvement

Single professional

Katherine (28) – [IT – web designer]

A motorbike

1 bed apartment - Leeds, Yorkshire

Katherine Forester was one of the first to buy her one bedroom apartment on the Beeches development. She has lived there for 13 months. Katherine moved to the area when she started her current job as a web designer for a large IT consultancy in Leeds. She works long hours in the week, often bringing work home with her. Her weekends are usually spent away, visiting University friends who are now widely dispersed. Katherine was particularly taken with the idea of buying a new property because she knew she wouldn't have time – or interest – in having to do renovation or decoration. Having recently got round to unpacking the last of her boxes – stuff that had been sitting in the attic – she was keen to make her home feel a little less cluttered. She had spent time on the internet looking at storage solutions and visiting local DIY stores. She eventually ordered a couple of sets of shelves, one for her lounge and one for her bedroom. She chose a product that could be delivered as she only has a motorbike and didn't want the hassle of hiring a car or van for the sole purpose of bringing the shelving home. Having unpacked the shelving she realised she required a masonry drill and screwdriver to put the shelves up. She doesn't own these tools and doesn't know anyone locally who is into DIY.

Katherine's neighbour, Anne, had recently used a Handy Man service, managed locally by the housing and development group that had built the apartments. Anne had had both bedrooms painted and new fittings in the shower room installed - she had been very pleased with the quality of the work. Katherine phoned the number Anne had given her and arranged for a quote from the management company to put up her shelves. The call-centre phoned her back promptly with a price and details of what would be included in this cost; this was agreed and Katherine's credit card details were taken – it would be debited after the work had been completed and once she had verified that it had been completed to her satisfaction. A date and approximate time was arranged for the work to be done: Katherine had the option to either be at the house to let the person in, or to drop a key off at the local housing service group and collect it at the end of that day. She decided on the latter.

That morning the handy man picked up her key, along with the others for his work that day in the local area. He arrives at Katherine's house by 10.00 He carries the required tools in from his van to the apartment and goes into the living room. The call centre had asked Katherine to mark where she wants the shelves by putting a cross on the wall at the correct level where the centre of each shelf was to go. She had done this in both rooms. Katherine had put the shelves back in the boxes and so the handyman unpacked them and checked all the necessary fittings were there [he had spare screws and rawlplugs in case some were missing]. He drills the holes in the walls, puts in the rawlplugs, secures the shelves, vacuums up the small amount of masonry dust produced

by drilling the holes, and tidies up. He leaves a card with his REF no. and the invoice receipt for the work. He locks Katherine's house, finishes the rest of the morning's jobs and returns all the keys to the local office by 13.00.

Working late that day, Katherine decides to pick up her spare key the next day. She heads home and is pleased with how the shelves look. She phones the call centre to key in the job ref. no. which confirms that she is satisfied with the work; she files the receipt for payment that the handy man left. She pins the card with all the service details on her kitchen notice board – perhaps she'll get her bedroom painted next.

Experimental PSS: house cleaning

Young family – 2 kids under 5

Chris (34) [Plumber] & Becky (35) [Primary Math / Science Teacher] Tom (3) & Zara (18 months)

1 cat

1 car; 1 van

3 bed town house - Swindon, Wiltshire

Chris and Becky Spencer moved into Burghley Fields 3 weeks ago – they'd been living locally in rented accommodation as a previous house purchase had fallen through. Becky had started her new job at the local primary school a couple of months back and they were relived to be actually now in their own property. Their house is a 3 bed town house on 3 levels. They have two young children, Tom and Zara and both Becky and Chris work full-time … so life is fairly hectic.

Part of the reason for moving to this area was to be nearer the grandparents. Chris's mum and dad help out with childcare, looking after the kids 2 days a week. For the other 3 days both children attend a local nursery which is attached to Becky's Primary School. Chris is self-employed – a plumber by trade – and works long hours keeping on top of his growing list of work … he has been so successful in building up the business that he's recently employed a young apprentice to help him 3 days a week. Both Chris and Becky work long hours – and evenings are spent, once the kids are in bed, preparing course work and keeping up to date with the accounts and responding to enquiries. To add to this, they also purchased a cat when they moved into the house – the kids adore her but she leaves fur everywhere. Becky is increasingly frustrated that her lovely new house is beginning to look like a bomb's hit it – not only untidy, but also cat fur on everything. She has concerns that this is not healthy, particularly for the children And her current vacuum cleaner isn't up to the job of cleaning the house sufficiently well.

One Friday night Chris suggests that rather than buy a new vacuum cleaner they could think about getting a cleaner in once a week. He remembers that the housing and development firm who sold the house to them, also runs a housekeeping service company and rummages through the house bumf until he finds the details: a professional cleaning service where you can specify exactly what jobs you want doing. The price was also really reasonable, especially if it meant Becky wasn't going to be so stressed and that perhaps they'd be able to spend more time with the children at the weekends. Becky thought it sounded a good idea and Chris phoned the number the next morning. The lady at the call centre explained how the service worked: you had a basic cleaning package on top of which you could specify extras like cleaning the oven or upholstery, things that you might not want doing on a regular basis. Alternatively you could book a one-off service like a full 'Spring Clean'. She said she could post him an up-to-date list of services and prices or he could look at their website. Chris and Becky browsed the site and decided to opt for a fortnightly house clean which included kitchens: floors, work-surfaces, hob, sink; bathrooms: all fittings and floors; vacuuming and dusting the house throughout including stairways. Windows were not included in this package but could be additionally booked on a one-off basis or they could subscribe to a deluxe cleaning package where these would be included on a regular basis.

Becky phoned the call centre back later that day and gave them the enquiry REF no. Chris had been given earlier. She specified the service level they required and the lady listed the activities included at this level (the same as had been listed on the website). All cleaning liquids, cloths and tools would be provided by the company. Becky confirmed this is what they were expecting and the lady explained that a service agreement outlining the details of the cleaning service, the costs of the service and insurance details would be posted to them. They would need to sign this and post back before an initial cleaning appointment could be made. The reason for this is that the company hold keys to their clients' houses which the cleaners pick each morning to enable them to clean the houses listed on their schedule for that day. The keys are then returned at the end of that day. It is therefore important that both parties are covered from an insurance perspective. The company aims to have at least one cleaner as the primary cleaner for each house – therefore one of the two cleaners in each house would be the same each week – this helps with building trust between clients and the company but also aids the efficiency of the work through building a familiarity with the space to be cleaned. Becky provided her credit card details: an initial subscription charge would be debited from their account and then a monthly debit to cover the cost of the service. After 6 months they had the option to move to a 6 monthly or yearly direct debit for which they would receive a range of discounts and service offers. The company required 4 weeks cancellation notice.

Becky and Chris signed the agreement, keeping a copy for themselves. They booked the first appointment for the following Thursday and Chris was at home just to talk through the service with the cleaner. The cleaner's arrived in a small van, branded with the company logo. They had security ID and a copy of the service agreement which Chris and Becky had signed. The primary cleaner for Chris's house discussed what they would do each week and also said that if there was anything that they particularly wanted doing or focusing on one week (e.g. cleaning the shower heads), then to leave a note and she would aim to do that if there was time. She seemed very nice and Chris

was relived as he felt confident Becky would like her and also would appreciate her flexibility in doing other small tasks if asked to do so. Thursdays mornings were booked through the call centre as their 'cleaning days'; the company would also aim to accommodate any changes to these times if given at least 2 weeks notice.

Becky was amazed when she walked through the door that evening with Tom and Zara – she hardly recognised the place – it looked and smelt really clean. Once the children were in bed, Chris poured her a glass of wine and they toasted their clean house and his good idea!

Experimental PSS: Laundry

Professional couple, 3 kids
John (47) [Accountant] and Sandra [Doctor] (43)
Alex (15), Amanda (13) and Louie (8)
2 cars
5 bed detached - Cheshire

John and Sandra Holden and their family had recently moved back to Cheshire from Dubai where Sandra had been working in private practice for 2 years. They had rented their house whilst away and were now glad to be back in their home with the kids back in local schools. She had joined the largest General Practice in the town and was quickly beginning to know folk in the local community again. John – a chartered accountant - ran his own accountancy firm; he'd hired local premises in the centre of Lymm and already employed 3 other members of staff. As well as their busy day jobs, both parents seemed to spend inordinate amounts of time running 'taxi services' for their three children: Alex 15, rugby player & swimmer; Amanda 13 – piano, karate and pony club; and Louie 8 – judo & drums!

The amount of washing 3 children and a husband generate never ceases to amaze Sandra, and the addition of sports kit, swimming gear and muddy riding jodhpurs each week was forcing the washing pile to frequently topple over. Although Sandra - and John to some extent – tried to keep on top of the washing load, the children were always complaining that they didn't have the right shirt, or the correct training gear etc.

Complaining about this over coffee one day at the surgery, the receptionist, Jean, who happened to live round the corner from Sandra, mentioned that the housing and development company had recently established a local washing service operating in Lymm and the neighboring villages. She said she'd bring Sandra a leaflet that had been dropped through her door about three months ago – a few weeks before the Holden's had moved back into their house. A couple of days later Jean popped the leaflet in

Sandra's in-tray. It was quite an expensive service but by the time John had arrived home that evening, Sandra had justified the expense to herself - it wasn't so much all the washing --- it was all the drying - clothes everywhere … this would be the perfect solution. The information on the service came just in time as their A* energy efficient washing machine had just broken down and so rather than rush out and buy a new machine, they thought they'd try the laundry service on a trial basis. That evening Sandra phoned the call centre – lines were open until 10opm – she explained what she wanted and asked them to explain how the service worked. Basically they drop off 3 colored bags: white for whites, blue for colored's and green for 'others' (delicates, woolens etc). Each house is also given a security bin which the company lock to the house or garage depending on the house owners preference. This is opened by a security key, unique to each bin. On the appointed collection day, the household drop off their washing bags in the bin and the laundry service collects and weighs them. A receipt detailing the weight and cost of the washing collected is left in a pouch in the bin. In normal circumstances laundered clothes etc are returned to the secure bin within 48 hours of collection. Exceptional requests like dry-cleaning or big pieces like duvets may take an additional 24 hours to return. Payments for regular washing services are made by direct debit. One-off cleaning items are dealt with individually. Sandra was happy with the details and subscribed to a months trial (at an introductory offer price of a single payment). The man at the call centre identified a convenient time for the van to call round to secure the bin and to drop off the key and laundry bags: 2 days time. The following Monday Sandra and the kids sorted out the laundry into the specific bags and placed these in the washing bin by the garage. That night, Sandra checked to see it had been collected – it had, and the receipt was there. The van returned the washed clothes by the Wednesday morning, all neatly folded. Sandra did limited ironing anyway – just John's and the kids shirts - so having folded laundry was almost perfect! The system worked. She felt less stressed and she subscribed for a further 6 months.

APPENDIX F: OVERVIEW OF QUANTITATIVE ENVIRONMENTAL ASSESSMENTS FROM THE LITERATURE

Table 68 Overview of quantitative environmental assessments from the literature

Authors	Participant countries	PSS	Reference case	Aim	Assessment method	Results
Bartolomeo et al 2003	Germany, Italy, the Netherlands, Spain, Sweden the UK	A range of B2b services, unspecified.	Not reported	To identify environmentally superior services, among existing services	'Broad brush environmental assessment'. No further information.	References to information from a firm: a case of chemical management service: 50% reduction in coolant use and 90% reduction in coolant waste;
Behrendt et al 2003	Austria, Germany, the Netherlands, Spain	Commercial forms of shared use, e.g. • Car-sharing • Laundry • DIY • Sports equipment	Traditional household consumption involving product ownership	Unclear	Drew on secondary data on average user behaviour in continental Europe from a range of secondary sources from the mid-late 1990s. Presented secondary data on energy water and detergent consumption for washing at home and in shared facilities in the Netherlands from a study in Dutch language published in 1996. Estimated savings in water use and primary energy use during the use phase of a laundrette compared with washing at home. The scope and boundaries of the comparisons were not specified. Results were normalised to two ideal families, and then scaled up to national level to assess the potential at the macro level.	Various measures of various issues, e.g. Reference to other research on car pooling showing that car pooling reduces energy consumption and CO_2 emissions by 30% and material input by 25%. Reference to research on laundry suggests energy use per kg of washing is 7.1MJ for home washing, 6.8MJ for shared facilities in housing, 8.2 in laundrette and 8.6 for washing service. Home washing and shared facilities use 22 litres of water per kg of washing whereas a laundrette or washing service use only 13.3 litres. Lawnmower rental increases energy use due to transport and frequency of rental.
Goedkopp et al 1999	The Netherlands	Numerous PSS are studied, e.g. • Vegetables by subscription • Laundry	Traditional household consumption involving product ownership	To identify existing or piloted services with potentially superior environmental performance.	LCA for 3 PSS. Described LCA in general but not how it was applied to the scenarios and no data presented. Stated that Ecoindicators 95' method (method for LCIA weighting) was used but without reference to the scope for the LCIs. Expert panel graded the performance of the other PSS on an	Subscription of organic vegetables compared with buying non-organic vegetables from a supermarket: score +3 (PSS beneficial for the environment). Laundrette compared with washing at home: score + 2 Car sharing compared with own car: score +1 (PSS beneficial for the environment)

		Services • Car sharing			ordinal scale fro m-3 to +3 according to their expert judgements.	
Halme et al 2005	Austria, Finland, Germany, the Netherlands, Portugal, Spain	A range of home (household) services	Unspecified	Unclear	The group of researchers scored the perceived environmental performance of a large number of services on an ordinal scale from -2 to +2 along the environmental categories direct emissions, energy use, waste (referring to source separation and recycling), material use and water use. The total score for all services in a service area was divided by the number of services.	Average scaled scores for all environmental indicators ranged from 0.02 to 0.78 for the different service areas. The scaled score for the service area safety and security was negative with regard to material use and space use. All other scores were positive.
Hirschl et al 2003	Germany	Laundry service Sports equipment rental	Traditional household consumption involving product ownership	To assess the environmental impact of existing consumer services.	Streamlined LCA. No further information presented.	Rental skiis compared with privately owned improved resource productivity by factor 1.7 (in terms of number of days the skiis were used). The primary energy use of washing machines in a laundrette in the use-phase is factor 2.4 improvement over washing at home.
Meijkamp 2001	Netherlands	Consumer car sharing (mobility)	Traditional household consumption involving product ownership	To assess the environmental impact of changes in mobility behaviour	Conducted LCA of car sharing following the SETAC guidelines for LCA and using the Simapro software and IDEMAT database and the Eco.-indicator and EPS – indicators for LCIA. The main processes in the use-phase are mapped, and data sources for the different processes are stated, fuel consumption, use-life and material composition are presented, although upstream and downstream processes and associated assumptions were not presented.	Environmental impact of the total mobility behaviour of car sharing adopters after adoption is 21% less in terms of Eco-indicator points than before adoption. It is 40% lower than the average Dutch household, since adopting households' mobility behaviour before adoption was already 23% below Dutch average.
Mont et al 2004	Sweden	Laundry service Gardening service DIY	Traditional household consumption involving product ownership	Not reported	Not reported	Car sharing: refers to the results of Meijkamp (2000). Refers to Behrendt et al 2003) concerning tool sharing, concluding that any environmental benefits are offset by increased transport. Refers to other research on washing in laundrette compared with washing at home, stating that environmental impacts of washing in a laundrette are higher than washing at home due to increased tumble drying when washing in a laundrette. Monts (2004) own scenarios for drill rental suggests drill rental gives rise to much more emissions of CO2 (2.5-3 times as much) as owning a drill. Sharing drills between 2-100 households would reduce CO2 emissions. Ownership and sharing between 2-3 households gives rise to larger emissions of Ni and Cd than rental or sharing between

						50-100 households. Lawnmower rental gives rise to much more CO2 emissions than owning or sharing. The transport off-sets reductions in CO2 emissions achieved by producing fewer lawnmowers.
Tasaki 2006	Japan	Consumer leasing of electronic and electrical equipment	Traditional household consumption involving product ownership	To assess material productivity /waste prevention effects of existing and hypothetical consumer services	Not reported	The amount of material used does not depend on whether products are leased or owned, it depends on the lifespan of the products. Leasing system increases the annual product demand in Japan (number of product units) by 0-20 million. The reuse system reduces the annual product demand (number of units of products) by 30-150 million units per year.
Wong 2004	UK	Numerous, e.g. • Consumer leasing of micro CHP • Car leasing • Carpet leasing • Electronic services such as e-mailing, online computer gaming • Consumer goods rental	'Traditional household consumption' involving product ownership	Not known	Reasoned scores for energy use, pollutants, material usage, hazardous substances, water on a scale from 1 to 5 (irrelevant to critical). Scores reasoned from various secondary sources.	Examples of environmental scores: PSS given overall scores of 2: Peer-to-peer filesharing, carpet leasing, e-mailing, car lift sharing, pay-as-you drive car sharing, cleaning service, Rental of consumer goods and white goods, upgrading modular TVs PSS given overall score of ?: Leasing PC, leasing PET-bottle derived sports clothing; PSS given overall score of 3: online gaming, leasing consumer micro CHP units PSS given overall score of 4: Leasing cars to consumers PSS given overall score of 5: chemical management service

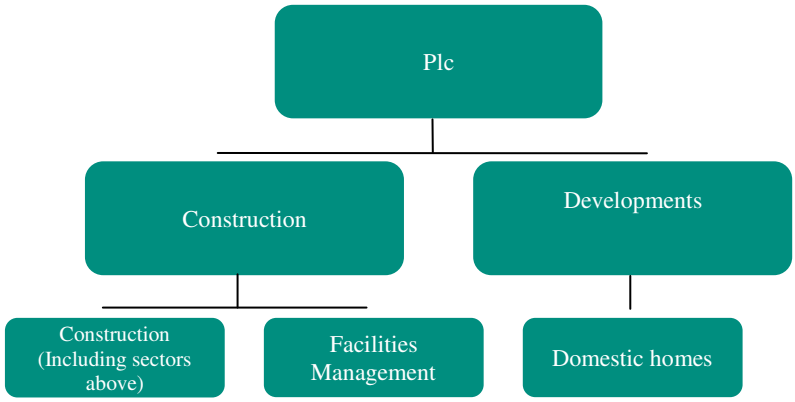
APPENDIX G THE PROPERTY DEVELOPMENT FIRM

The property development firm was founded in the early 1920s.. The company is today a leading provider of construction and facilities management services throughout the UK and in selected markets overseas. The company is active in the following sectors:

- Public
- Retail
- Offices
- Energy
- Airports
- Education
- Housing
- Health
- Rail

The company has built up a reputation for delivering complex projects, and has aimed to vertically integrate its activities providing a range of services covering the lifecycle of the built environment, from feasibility through to handover and facilities management.

The property development firm is a public limited company comprising a branch for development of domestic homes, which is a leading UK housing company. The facilities management business is part of the construction branch.



In 2006 the public limited company achieved group revenues of £3.68bn with housing profit from operations at £469m. In the same year basic earning per share were 50.5 pence with a full year dividend of 14.75 pence. In 2007 the Plc merged with another large house builder. However, the construction branch has retained its existing autonomy and operating structure.

APPENDIX H DESCRIPTIONS OF HOUSING DEVELOPMENTS

Primary data were collected from a number of housing developments by the property development firm. None of the developments had been fully completed at the time of the focus groups and interviews.

North East **Newcastle**

The development includes some 2,500 energy efficient homes set in 442 hectares of parkland plus a further 80 of commercial development space. A number of properties were fitted with photovoltaic technology. A new phase of development was started in 2006. This Greenfield development is four miles away from Newcastle city centre.

North West **Altrincham**

This development is situated on part of the National Trust's Dunham Massey estate. It comprises 650 new dwellings to be built by the property development frim over a period of six years. Both house builders aim to develop high environmental performance standards on this development. The development is based around a sustainable homes scheme, which aims to ensure Stamford Brook is an exemplar sustainable community. The scheme has a predicted Eco-homes rating of excellent. The first properties went on sale in summer 2004.

South East **Shoreham**

This develop comprises some 291 waterfront properties ranging from one and two bedroom apartments to two and three bedroom homes. The development is located approximately two miles from Shoreham town centre and 10 miles from Brighton. The development is due to complete in 2008.

APPENDIX I FOCUS GROUP AND INTERVIEW GUIDES

Property development firm interviews

1 Opening (warm up)

1. Outline of the purpose of the study
2. Confidentiality; informed consent, permission to record
3. Name, company, function within company
4. What did you do before taking up this position?
5. What responsibilities and activities does the job involve?
6.

2 Main questions

1. Are you aware of the PSS concept? (if not, explain)
2. What might PSS mean for you and your role?
3. Give example of household services and what they would mean for you role.
4. Describe household goods and services provided or tried in the past?
5. How successful were they?
6. What criteria were used to establish this performance?
7. To what extent are the past criteria adequate to guide future development of services?
8. Against this background, what features should future service (PSS) development have?
9. What investments would be needed (e.g. technology, staff/capabilities, business relations, admin systems)?

Pursue new lines of inquiry as they emerge

3 Topics for further elaboration if appropriate

- *Cost/benefit of new product development*
- *Household demand*
- *System overview*
- *Staff skills*

4 Close

Property development firm internal focus group 1

Intro presentation - slides

- Welcome, thank you for participating
- Presentation of facilitators (name, etc.)
- Purpose of focus group: *explore product service system concepts*
    - Brief introduction by participants on their role and the setup of their function

- Outline of session:
    - presentation on the concept of product service systems;
    - comments on presented concept;
    - discussions around 4 points :
        1. Describe PSS provision might mean to you in your role?
        2. What might the business case for PSS provision in the property development firm be?
        3. What are the performance criteria for PSS?
        4. What do you perceive household performance criteria to be?
    - Discussion: will PSS work?
    - Wrap up
- The participation and responses will be anonymised
- Audio-recording for memory aid

Presentation

- PSS origins of the idea, examples from Rolls Royce, BT, air conditioning, laundry, mobility; definition of services, environmental benefit of PSS; drivers & barriers for PSS delivery.

Feedback on presentation.

- Discussion of PSS delivery by the property development firm as part of after sales

Discussion of 4 topics.

1. Describe PSS provision might mean to you in your role?
2. What might the business case for PSS provision in the property development firm be?
3. What are the performance criteria for PSS?
4. What do you perceive household performance criteria to be?

Household attitudes
• Presentation of main points from demand side data • Participant discussion of findings
• Discussion: will PSS work? • Repeating back what was said during session: did it reflect what was said; anything we should have discussed that we didn't? • **Close**

Property development firm internal focus group 2

Intro presentation - slides

• Welcome, thank you for participating
• Presentation of participants and facilitators (name, etc.)
• Reminder of discussion in the previous focus group and criteria for adoption of PSS
• Purpose of focus group:
  o Opinion of selected PSS, discussion of process flows, discussion on costing and pricing, to feed into the development of experimental PSS.
• Outline of session:
  o presentation of results from focus groups and interviews with households
  o discussion of results from focus groups and interviews with households
  o Presentation of suggested PSS
  o Discussion of suggested PSS
  o Concluding discussion on PSS to pursue, process flow, ownership of processes within the property development firm, costing/pricing method.

Property development firm and supply chain

- Welcome and presentation
- Outline of focus group session
- Outline of PSS concept
- Outline of research project
- Description of the experimental PSS
- Results from interviews and focus groups with households
- (Analytical hierarchy)
- Qualitative discussion:
    - Customer demand and relationships
    - Logistics
    - Cost, revenue and profits
    - Information in the external environment
    - Market conditions
    - Regulatory framework
    - Corporate competence and portfolio of offerings
    - Organisational structure
    - Strategic orientation
- Wrap-up

Households interviews 1

Intro presentation - slides

- Presentation, thank you for participating
- Responses will be anonymised
- Audio-recording for memory aid
- Purpose of interview *explore product service system concepts* in household consumption
- Go through daily activities from morning until evening, material artefacts used in those activities,
- Categorising activities into household task
- Criteria for choice of material artefacts and services.
- Close

Households focus group 1

Intro presentation - slides

- Welcome, thank you for participating
- Presentation of facilitators (name, etc.)
- Purpose of focus group: *explore product service system concepts* in household consumption
    - Brief introduction by participants

- Outline of session
    - a brief presentation on the concept of product service systems;
    - An exercise where we write down daily activities and products on notes and stick the notes on the flip chart paper on the wall over there
    - After that, I will summarise the activities and products and we will discuss in the group what the products do for you, in terms of technical functions, but also for instance social, economic and convenience benefits or what ever comes up
    - Then we will present briefly a couple of scenarios for PSS and ask you what you like and dislike about those ideas, and why.
- The participation and responses will be anonymised
- Audio-recording for memory aid

Daily activities, goods and services

- Participants list activities undertaken on a typical weekend (last Tuesday) and at the weekend (last Sunday) and products (goods and services) required to support these

Discussion

- Discussion of activities and products and associated performance criteria

Presentation

- PSS origins of the idea, examples from business to consumer markets: laundry, mobility; definition of services, environmental benefit of PSS; potential drivers & barriers for PSS delivery.

Household attitudes to PSS

- Discussion of PSS concepts and performance criteria

- Closing discussion: will PSS work?
- Repeating back what was said during session: did it reflect what was said; anything we should have discussed that we didn't?
- **Close**

Households focus group 2

- Welcome and introduction
- Introduction to project and focus group
- Presentation of experimental PSS: storyboards and user narratives
- (Analytical hierarchy process scoring self-servicing and PSS respectively; qualitative comments while filling in questionnaire)
- Group discussion:
    - Design of the experimental PSS

- Multiple units of material artefacts
- Non-ownership of material artifact when using household service:
  - any experiences and practices in the past?
  - Specifications of material artefacts kept and used occasionally for self-servicing while using PSS;
  - what conditions for not owning material artefacts when using PSS
- Service quality
  - What does it mean to you?
  - How do you establish trust in quality?
  - What is the standard of your self-servicing with which you compare the PSS?
- Rebound effect
  - What would you do with the time you free up if you used PSS?

- Close

Households interview 2

- Introduction, thank you for participating
- Aim of interview: more in-depth and individual understanding of self-servicing behaviours
- Questions: talking through the topics and questions in the survey questionnaire on choice and management of material artefacts for the four household tasks.
- Close