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Pay-per-use business models as a driver for sustainable consumption: evidence from the case of HOMIE

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Highlights

- Pay-per-use has the potential to mitigate product life cycle environmental impact
- We present a pay per use case study of HOMIE focused on washing machines
- Pay-per-use significantly reduces the number of washes over time
- Pay-per-use model significantly reduces laundry temperature over time
- Pay-per-use model influences people washing at higher temperatures most

Abstract

Pay-per-use business models where consumers pay for the unit of service (e.g. a wash) without gaining product ownership are often linked to increased environmental performance. Consumers would become more conscious about consumption patterns and companies would take responsibility for product life cycle issues. Such benefits can only be achieved when the business model is intentionally designed to deliver those impacts. Few studies focus on the environmental impacts of pay-per-use business models based on direct measurement of impacts. This paper investigates the following question: What positive environmental impact in terms of improving consumption patterns can be observed in a pay-per-use business model? Through an in-depth case of the start-up HOMIE, we investigate how its pay-per-use business model contributes to sustainable consumption. We use two samples of 56 and 21 customers in a longitudinal study to assess whether their consumption patterns of using a washing machine significantly changed after implementing a pay-per-use business model. It was found that pay-per-use business models have the potential to stimulate sustainable consumption. When customers started paying after the first free month, the total number of washes and washing temperature decreased significantly. Temperature reductions were mostly realized by customers who used to wash at higher temperatures. Future research could focus on mapping ideal sequences of experiments to achieve the greatest levels of sustainability impacts, and investigating other sustainable business models, such as renting and sharing.

Key words: *Circular business model; business model innovation; sustainable consumption; business model experimentation; pay per use; sufficiency.*

1. Introduction

Despite rising popularity in sustainable business models, few publications measure the direct environmental benefits of such new business models. This research focuses on the underexplored area of pay-per-use business models, and how they can drive sustainable consumption, by using an in-depth case.

Sustainable business models, and in particular Product Service Systems (PSS), have been positioned as a way to achieve greater levels of sustainability (Tukker, 2004). PSS can potentially break the link between profit and production volumes, reduce resource consumption and material use, motivate inclusion of through-life and end-of-life issues, and lead to enhanced efficiency in use and product longevity (Bocken et al., 2014). However, to achieve desirable sustainability results, these elements will need to be built into the PSS (Mont and Tukker, 2006). Reviews by Tukker (2004; 2015) and Tukker and Tischner (2006) show mixed results for each of the product service business models, but use- and result-driven business models could have the greatest environmental potential (Tukker, 2015). For instance, when paying per use, consumers would get more conscious about their usage patterns. Manufacturers are incentivised to provide a result in the most efficient way, which often goes hand in hand with environmental impact reductions (Tukker, 2015).

There is little evidence about the actual impact of new business models in literature (see e.g. the reflection by Frenken, 2017 on sharing economy models). Many studies build on secondary data or scenarios or are outdated. Heiskanen and Jalas (2003, p. 191), for instance, reviewed various business models and found that car sharing could reduce various environmental impacts by 30-50%, and tool sharing could lead to a factor ten reduction in material intensity 'per hole drilled'. While comprehensive, the review mainly consists of studies from the 1990s. However, one of the studies (Goedkoop, 1999 quoted in Heiskanen and Jalas, 2003) identified promising results for various business models. For instance, a vegetable subscription service was found to use four times less transport and product packaging than vegetables bought in a supermarket. In later work, Lindahl et al. (2014) through cases of various service and reuse models identified up to factor ten improvements in environmental impact. Nevertheless, more direct evidence is needed to understand the impact of new sustainable and service-driven business models. There is a lack of studies on the environmental impact of new business models and in particular, potentially highly promising ones, such as pay-per-use business models. This paper explores the pay-per-use model by company HOMIE to provide evidence on the potential impact of such business models.

This research connects the fields of sustainable business models, design for sustainable behaviour and sustainable consumption by investigating the potential for pay-per-use business models to drive sustainable consumption. First, literature on sustainable business models, pay-per-use models, and sustainable consumption are discussed to formulate the research gap. Second, in the methodology section, the HOMIE case will be explained, as well as the samples that were used to assess the impact of HOMIE's pay-per-use business model. Third, the results of the pay-per-use case will be presented, followed by the discussion and conclusions. The following research question is explored: *What positive environmental impact in terms of improving consumption patterns can be observed in a pay-per-use business model?*

2. Background

The literature review carves out the research gap by investigating relevant streams of literature on sustainable business models and pay-per-use and (design and strategies for) sustainable consumption.

2.1 Sustainable business models and pay-per-use

New business models are often viewed as a key driver for sustainability. They help gain a competitive advantage while reducing environmental impact and contributing positively to society (Boons and Lüdeke-Freund, 2013). In brief, business models describe the way business is done (Magretta, 2002) and are often depicted as comprising of a value proposition (product/service offering), value creation & delivery (how value is created and delivered to the customer) and value captured (how customer value and other forms of value are captured) (Teece, 2010; Bocken and Short, 2016). Whereas the popularity of sustainable and circular business models is on the rise with an increasing number of publications (Geissdoerfer et al., 2017), a lot of this work remains conceptual (Boons and Lüdeke-Freund, 2013; Bocken et al., 2014) and there is insufficient evidence on the potential positive impact of such new business models. There is a lot of work in 'grey' (non-peer reviewed) literature on different business models, such as pay-per-use business models providing examples of different cases (e.g. Accenture, 2014; ING, 2018 on circular business models and Clinton and Whisnant, 2014 on sustainable business models). Accenture (2014) discuss the example of Michelin selling "tires as a service", where customers pay per miles driven. In a report on 'circular living', ING (2018) discuss lease-type of contracts for appliances in the home, to support accessibility to energy-efficient appliances and facilitate take back with building corporations. Clinton and Whisnant (2014) include various potential sustainable models such as subscription models (e.g. monthly fees) and 'pay for success models', such as the case of Johnson and Johnson who only got paid for a cancer drug if it was effective in over 90% of patients. However, the link to actual positive impacts achieved through such business models is often missing.

Sustainable business models may only achieve greater sustainability impacts when designed in the right way (Tukker, 2004; Mont and Tukker, 2006). Hence, more research is needed to 'design' sustainable business models to achieve the desired intentions. Different business models have varying potential positive and adverse effects (Lüdeke-Freund et al., 2016).

Business models may be more or less service oriented, and Tukker (2004) classifies the main models as product-oriented services, use-oriented services, and result-oriented services. In product-oriented services, the business model is mainly geared towards sales of products, but some extra services are added (e.g. additional warrantees or maintenance or take-back agreements). In use-oriented services, the traditional product still plays a central role, but the business model is not geared towards selling products and the providers retain ownership, which is the case for renting, sharing and leasing models. In result-oriented services, the client and provider agree on a 'result', and in principle, there is no pre-determined product involved; the consumer may pay for a 'pleasant climate' or pay-per-use (e.g. in the case of printer/copy services) (Tukker, 2004). Result-oriented PSS models may have the

highest environmental potential, but to achieve desirable sustainability performance over the total PSS lifecycle, the solution needs to be carefully designed for this purpose (Tukker, 2004). Examples of result-oriented PSS include paying per service unit and paying per functional unit. In the paying per service unit example, people pay for a certain unit of service, like a laundry cycle or mileage driven, whereas in the functional-unit example, a provider and its customer agree on a specific result or outcome (e.g. clean laundry) regardless of the products or services, which is said to have the highest potential (up to a factor of ten) of the different types of PSS (Lindahl et al., 2014). Sometimes the term "access-based consumption" is used to emphasise the move from selling product *ownership* to selling product use or its *functions* (Mont, 2008 in Edbring et al., 2016). Because the profit centre is not the product, but rather the functional units it delivers, the incentive is created among producers to design durable products (Edbring et al., 2016).

Due to the varying nature of PSS solutions, the suitability of different design strategies is highly context dependent. Goedkoop (1999) argues that PSS should be assessed on a case-by-case basis if improvement in environmental performance from a life-cycle perspective is to be achieved. As an example, implementing a PSS (e.g. car sharing) without an efficiency focus (e.g. fuel efficiency) or motivation to drive less (e.g. pay per kilometre) is unlikely to substantially enhance sustainability, since the vast majority of its environmental impact is in the use phase and not in the manufacturing of the car (Bocken et al., 2014). As such, to achieve more significant system-level impact (a key feature of sustainable business models; e.g., Stubbs and Cocklin, 2008), total usage volume would need to be reduced.

Slow consumption or sufficiency would need to become an integrated part of the business model and could potentially be achieved through increased consciousness when paying per use (Tukker, 2004). Moreover, literature suggests that user behaviour can even become less responsible when a product is not owned, leading to reduced efficiencies and increased wear of the product (see e.g. Cohen and Kietzman, 2014; Benjaafar et al., 2015). Because people do not own the products in an access-based service, it is unlikely that they forge strong attachments to these products (Mugge et al., 2005), and consequently, they may take less care of these products (Bardhi and Eckhardt, 2012). Generally, products and buildings may suffer from increased wear and tear, higher maintenance cost and more rapid depreciation due to intensified and different usage in new sharing and service models (Fraiberger and Sundararajan, 2015) and should be redesigned to support intensified usage (e.g. Bakker et al., 2014; Bocken et al., 2016).

Finally, few studies quantitatively assess the environmental impact of PSS (Lindahl et al., 2014) and this is even more rare for pay-per-use business models as a specific type of PSS. Few studies using primary data exist in the underexplored Business to Consumer (B2C) space. Tukker (2004) provides a comprehensive qualitative overview of the potential of different types of PSS and broadly describes the potential benefits of different types of PSS. Manzini and Vezzoli (2003) describe a utility company case involving renewable energy and quote an expected reduction of 100 tons of CO_2 emissions per annum but without providing data (Lindahl et al., 2014). Lelah et al. (2011) quantified the environmental benefits of a case of a functional result-driven PSS. The study focuses on a waste collection system, supported with a 'connected infrastructure' to optimise collection of glass waste. It was found that a PSS could have

environmental benefits in waste collection, but careful design of the connected infrastructure is needed: if the 'connected infrastructure' (e.g. sensors, mobile connection) is over-specified, this could negatively outweigh any environmental benefits of optimisation (Lelah et al., 2011). Goedkoop et al. (1999) investigated the economic and environmental impact associated with ten different business models ranging from subscription to car sharing and did four quantitative assessments of those. Such business models look promising, but a life-cycle perspective is necessary, particularly including the consumer use phase (i.e., behavioural change dimension of new business models) to avoid rebound effects and decrease the environmental load of new business models (Goedkoop et al., 1999). Lindahl et al. (2014) assess the environmental and economic impact of PSS business models using Life Cycle Assessment and Life Cycle Costing respectively. Lindahl et al. (2014) investigated three cases including reuse and remanufacturing; cleaning and buildings; and soil compactors. The cases investigate PSS in business-to-business contexts and find overall positive environmental as well as economic results for the service driven offerings. However, uncertainty in data reliability was observed, because of assumptions and lack of data (Lindahl et al., 2014). Finally, Manninen et al. (2018) created an approach and evaluation of a range of PSS case studies. However, the approach is qualitative and focused on exploration and sustainable business model design simultaneously.

Hence, we found a few studies on the environmental impact of PSS, but these often focus on PSS in a B2B context, largely use secondary data, or are outdated. No peer-reviewed studies quantifying the environmental impact of pay-per-use business models directly have been identified at the time of writing. Despite the existence of relevant studies, much more quantitative analysis about the topic of sustainable business models (Lüdeke-Freund and Dembek, 2017) is needed. The business-to-consumer and pay-per-use business model space remains underexplored (Tukker, 2015). This study specifically focuses on pay-per-use business models, where consumers pay for the unit of service (e.g. a wash, an hour of car usage) without gaining ownership of a product, which are often linked to increased environmental performance. An empirical study is conducted based on the case of HOMIE to explore the environmental impact of pay-per-use models related to changing consumption patterns.

2.2 Sustainable consumption

Sustainable consumption is defined as 'the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations' (International Institute on Sustainable Development,1994). To stimulate more sustainable consumption, it is important to change the behavior of consumers with respect to how they buy, use or dispose of products. However, consumer behaviour is not easy to analyse or influence. To help companies and designers to change behaviour, scholars have developed different theories and methods (Boon et al., 2014; Pettersen et al., 2013). First of all, in the field of Design for Sustainable Behavior (DfSB), the focus has been on using theories from psychology for the field of design. Specifically, this field considers the behaviour of individuals in relation to single artefacts (e.g., Bhamra et al., 2008). This stream of research proposes that

behaviour is formed by attitudes, intentions, social norm, and other influencing factors (Ajzen, 1991). A second approach is a practice-oriented design approach, which builds on the notion of social practice theory - a research area in itself (e.g., Shove et al., 2007). For example, Kuijer and De Jong (2012) use such an approach to design a wide variety of opportunities to offer people thermal comfort that go beyond merely turning on the thermostat. The central unit of analysis in social practice theory is not the user and the artefact, but his/her practices. By looking at integrated routines, meanings, functions, and abilities that make up everyday practices, a broader approach is taken (Scott et al., 2012). For example, the focus is on commuting, rather than on cars. A third approach to study sustainable consumption is from the field of Philosophy of Technology (Verbeek, 2005), in which the impact of technology on human beings is the main focus.

In this paper, we build on the theory of DfSB because we aim to investigate how a pay-per-use business model can change the behaviour of individuals while interacting with a specific artefact (i.e., the washing machine), which corresponds to the specific focus of the field of DfSB. In the field of Sustainable Design or Design for Sustainability, several authors have built on these notions to develop sustainable design strategies that influence the consumer at different levels (e.g., Bhamra et al., 2008; 2010; Tang, 2010; Wever et al., 2008). Strategies range from more informative strategies, where the consumer is informed by the service provider about the most sustainable behaviour; to product-oriented approaches (e.g. eco-steer or clever eco-design) where the product steers the most sustainable behaviour, for instance when the heating is automatically turned down when inhabitants leave the home (Tang et al., 2010). Approaches may be ‘forceful’, so that the user cannot change settings (Wever et al., 2008), or subtle and of the nudging type (Thaler and Sunstein, 2008), so that the directed behaviour seems more intuitive (e.g. making the staircase more prominent so that people take the stairs rather than the elevator). Figure 1 shows a framework for Design for Sustainable Behaviour, including strategies which are more guiding (informing feedback), steering, (spur, steer) or embedded (technology, design). Table 1 includes the definitions of the seven observed design interventions.

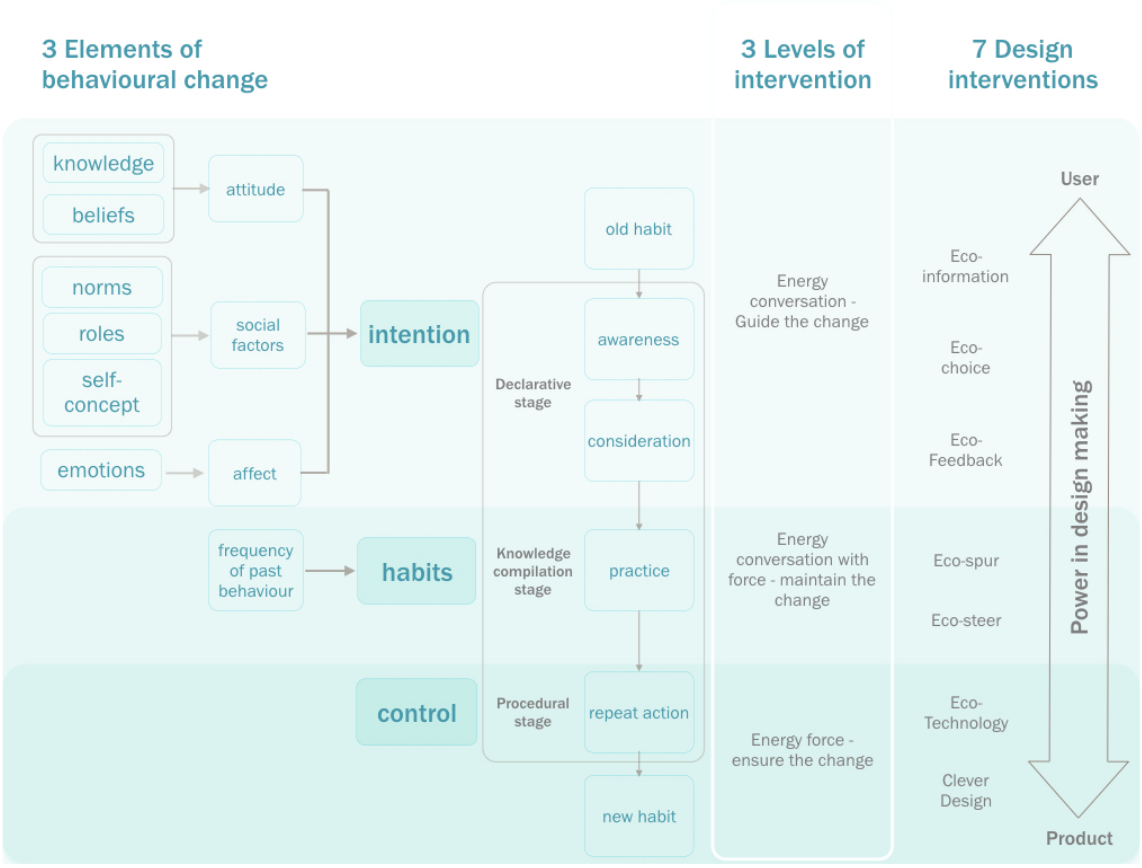

Figure 1: Design Behaviour Intervention Model (DBIM). Source: Tang (2010)

Table 1. Sustainable Design Strategies. Source: Bhamra et al (2008)

Design intervention	Description / summary
Eco-information	To make consumables visible, understandable and accessible to inspire consumers to reflect upon their use of resources
Eco-choice	To encourage consumers to think about their use behaviour and to take responsibility of theirs actions through providing consumers with options.
Eco-feedback	To inform users clearly about what they are doing and to facilitate consumers to make environmentally and socially responsible decisions through offering real-time feedback.
Eco-spur	To inspire users to explore more sustainable usage through providing rewards to 'prompt' good behaviour or penalties to 'punish' unsustainable usage.
Eco-steer	To facilitate users to adopt more environmentally or socially desirable use habits through the prescriptions and/or constraints of use embedded in the product design.
Eco-technology	To restrain existing use habits and to persuade or control user behaviour automatically by design combined with advanced technology.
Clever design	To automatically act environmentally or socially without raising awareness or changing user behaviour purely through innovative product design

According to Bhamra et al (2011) the more coercive approaches, such as Eco-Steer or Eco-Technical may prove more successful in altering behaviour, but consumer acceptance of devices employing these strategies may be low, which may discourage manufacturers to adopt such strategies. Moreover, prior research argues that intelligent products which circumvent the user's decision-making process, adapting automatically to changing circumstances, or designing-in strong obstacles to prevent unsustainable behaviour, would have to be designed very carefully from a usability perspective (Kobus et al., 2013; Wever et al., 2008). "If features would annoy people, because they act when it is not wanted, the feature will be switched off" (Wever et al., 2008, p. 4). Or, they might stop using the product altogether. This suggests a balanced, approach to changing behaviour. Finally, social norms are constantly evolving and designers need to envision potential use contexts and ethical scenarios (Bhamra et al., 2011). Hence, such new products need to be prototyped and user-tested carefully to evaluate their effectiveness and the social and ethical considerations.

Research has started to uncover consumers' attitudes, motivations, and barriers towards access-based services such as pay-per-use (Catulli, 2012; Edbring et al., 2016). These studies have demonstrated that consumers are generally interested in access-based services, because these services can help consumers to avoid the "burdens of ownership" (Schaefers et al., 2015). In comparison to ownership of a product, an access-based service can reduce the financial and performance risks because consumers only pay a fee per usage and are not responsible for maintenance and repair. Consequently, an important motivational factor for engaging in access-based consumption are the economic benefits it provides, especially with short-term access. Other motivations to turn to access-based services are the environmental benefits that it offers and the ability to experience something outside the norm (Armstrong et al., 2015; Lawson et al., 2016). However, consumers also report factors that may impede their involvement in access-based consumption. First, some consumers may have a strong preference for ownership as they may perceive this as an ideal consumption mode (Bardhi and Eckhardt, 2012). Other barriers that impede consumers' acceptance of access-based services are complexity, reliability, contamination, responsibility, lack of trust in the service provider, economic obstacles, and an unfamiliarity with the concept (e.g., Edbring et al., 2016; Hazée et al., 2017).

While knowledge is there about the range of options and consumers' general attitude and motivations as well as barriers to adopt access-based services, Bhamra et al. (2010) argue that: *"Behaviour-changing' devices need to be prototyped and user-tested to evaluate their effectiveness and the ethical considerations related to the selection and use of Design for Sustainable Behaviour strategies explored in greater depth"* (p. 442). This call for action shows the need to test the effect of such options on consumers' actual behaviour in addition to the current attitudinal studies and thus the realisation of sustainable consumption behaviour in practice.

2.3 Research gap: understanding environmental improvement of pay-per-use business models

This research brings together the areas of sustainable business models, sustainable consumption and design for sustainability. It presents a unique case of a pay-per-use

business model, as to the authors' knowledge no other case studies have quantitatively investigated the environmental effectiveness and promise of such business models. A lot of research on the relatively new field of environmental assessment of new business models remains highly qualitative and based on consumers' self-reports rather than their actual behaviour (e.g. Armstrong et al., 2015; Manninen et al., 2018). Moreover, several studies have focused on energy use and sustainability, taking washing machines as an example (e.g., Kobus et al., 2013; Gnoni et al., 2016). However, these either use simulation rather than direct primary data as a starting point and focus on reuse and remanufacturing strategies rather than sustainable consumption (e.g., Bressanelli et al., 2017; Lieder et al., 2017), or they focus on user behaviour rather than simulating or testing the effectiveness of new business models to stimulate sustainable consumption (Kobus et al., 2013).

First, despite rising popularity (Lüdeke-Freund and Dembek, 2017) there is insufficient work on 'designing' and experimenting with sustainable business models (Tukker, 2015; Weissbrod and Bocken, 2017). There are few if any publications on the environmental benefits of pay-per-use business models based on the use of primary data. Second, there is an opportunity for learning between the fields of Design for Sustainability and sustainable business models. The developed sustainable design strategies that influence the consumer at different levels (e.g. Bhamra et al., 2008; 2010; Tang, 2010; Wever et al., 2008) are highly applicable to the design of sustainable business models. In fact, Ceschin and Gaziulusoy (2016) in their description of the historical evolution of Design for Sustainability go as far as arguing that sustainable business models, such as PSS, are an important subset or level of innovation within Design for Sustainability. Third, there is an opportunity to explore how sustainable consumption can become part of viable business models (Bocken, 2017). In line with the idea of experimentation, we need to understand whether new business models work in practice by putting new value propositions to the test (Weissbrod and Bocken, 2017). We also need to understand how new sustainable business models influence consumers' behaviour patterns in order to better understand their environmental impact (Mont, 2004; Tukker, 2004).

Specifically, this paper focuses on the case of HOMIE to investigate the effects of a pay-per-use business model for washing machines on consumers' washing behaviour. In a pay-per-use business model, consumers are encouraged to change their consumption behaviour in multiple ways. First of all, a pay-per-use business model will stimulate consumers to use their devices less often because each additional use directly results in higher costs for the consumer. Second, the specific pricing scheme can also stimulate consumers to change *how* they use the device. Depending on the specific use settings, such as temperature, ECO, or time settings, the environmental impact of using products can be different. The price scheme of the pay-per-use business model provides opportunities to relate the costs to this environmental impact. For example, lowering the laundry temperature will reduce the environmental impact of using the washing machine. By reducing the price per wash for the lower temperature settings, more sustainable washing behaviours are encouraged, and the environmental impact of using the washing machine is reduced. Accordingly, with respect to consumers' washing behaviour in a pay-per-use business model, we hypothesize the following:

H1: Consumers in a pay-per-use business model will reduce the average laundry temperature
H2: Consumers in a pay-per-use business model will reduce the number of laundry cycles

Furthermore, the case study allows us to test more generic behavioural aspects that could be of benefit to the development of new business models. It is expected that people have difficulty predicting their own usage behaviour and they might know what the best behaviour is, but not act accordingly (Bocken and Allwood, 2012). As a result, they would underestimate how much, and at which temperatures they wash. This insight could be useful as a pay-per-use business model could improve such consciousness and stimulate more sustainable consumption patterns. Accordingly, we test the following hypotheses related to the discrepancy between consumer's own estimates and actual behaviour:

H3: Consumers underestimate how much they wash
H4: Consumers underestimate the temperatures at which they wash

3. Method

3.1 Case: HOMIE

This paper presents and in-depth case study based on the work by the start-up HOMIE. Founded in 2016, this TU Delft spin-off company aims to significantly reduce the environmental impact associated with domestic appliances, by offering appliances on a pay-per-use basis. The company was founded by Nancy Bocken and Hidde-Jan Lemstra in the pursuit to demonstrate that new sustainable business models could contribute to sustainable consumption and circular economy, thus testing notions from academic literature in practice (Tukker, 2004; 2015; Bocken et al., 2014). Inspired by shared appliances, such as laundrettes, but realising that most people want the convenience of their own appliance at home, the founders wanted to minimise the environmental impact of home appliances. By introducing paying per use, high quality appliances can be offered on an affordable basis, and sustainable behaviour can be stimulated as paying per use may help reduce product usage.

Starting with washing machines, HOMIE offers free installation and maintenance of quality appliances. Customers pay per wash and there is differential pricing to encourage the use of lower temperature settings with a lower energy-consumption per cycle. For example, a cold wash costs €1.13 compared to €1.69 for a 90°C wash (www.homiepayperuse.com), and uses nearly 90% less electricity[1]. The pricing range is based on HOMIE's own consumer surveys indicating reasonable pricing per wash; in combination with calculations of a viable business case and aiming to stimulate sustainable consumption. The company does not manufacture its own washing machines but rather acquires existing washing machines (which have received good reviews in expert consumer surveys, such as those by "Which?" in the UK) and adapts them for the pay-per-use model (e.g. adding a tracker to enable pay-per-use).

[1] Based on HOMIE energy measurements for several cold and 90ºC cotton washes with Zanussi A+++ washing machine. Cold wash used 0.19kWh, 90ºC wash 1.71kWh. 2016-2017 price levels.

The company invests in the acquisition of the appliances and has its capital expenditure returned over the course of time by charging a 'pay-per-use fee'. This pay-per-use fee includes maintenance, repair and replacement of the machine if the machine were to fail. Also, when customers move house, the washing machine will be (re)moved. While initially a full-service fee was considered also including laundry detergent and energy and water cost, the eventual model focuses on the service of having access to washing machines. HOMIE also provides its customers advice on how to wash better (i.e., in a more sustainable way) and offers them the occasional free 90°C wash to 'clean' the machine.

Our hypothesis was that through the various interventions HOMIE could help customers reduce the total number of washes. Although this may be counter-intuitive as a business model, leading to lower revenues, the focus of HOMIE is on maximising the lifetime of the hardware and sustainable usage patterns, so as to generate a longer term sustainable income. It is assumed that all customers will always have a minimum number of washes each week, so a steady revenue stream could be based on this number. However, the focus is not on maximising the number of washes per customer but rather on stimulating sustainable consumption patterns in a circular business model.

This paper uses an in-depth case study method (Yin, 2013) focusing on the sustainable consumption activities of one company by gathering different types of data (e.g. interview, direct measurement of laundry behaviour). It also takes an action-research approach as the authors are involved in the development and implementation of deliberate interventions over time (Van de Ven, 2007). A single case study was chosen because of unusual research access to a unique case (Eisenhardt and Graebner, 2007).

The unit of analysis is the business activity to achieve sustainable consumption. Hence, the production system and other life cycle stages (e.g. reuse and recycling of the washing machine) are out of scope and the study purely focuses on consumption patterns. As such, this study aims to develop insight for companies aiming to contribute to sustainable consumption and wanting to improve the environmental impact associated with novel business models. The interventions are plotted in Figure 2 and explained in Table 2. Each of the interventions is aimed at stimulating more sustainable laundry behaviour (e.g., lower temperature; fewer but fuller washes). The HOMIE experimentation approach can be found in Appendix A. The present research does not test the effects of the individual interventions. We aim to investigate in a real-life, longitudinal setting the effect of implementing a pay-per-use model (including different interventions) on consumers' actual consumption behaviour over time.

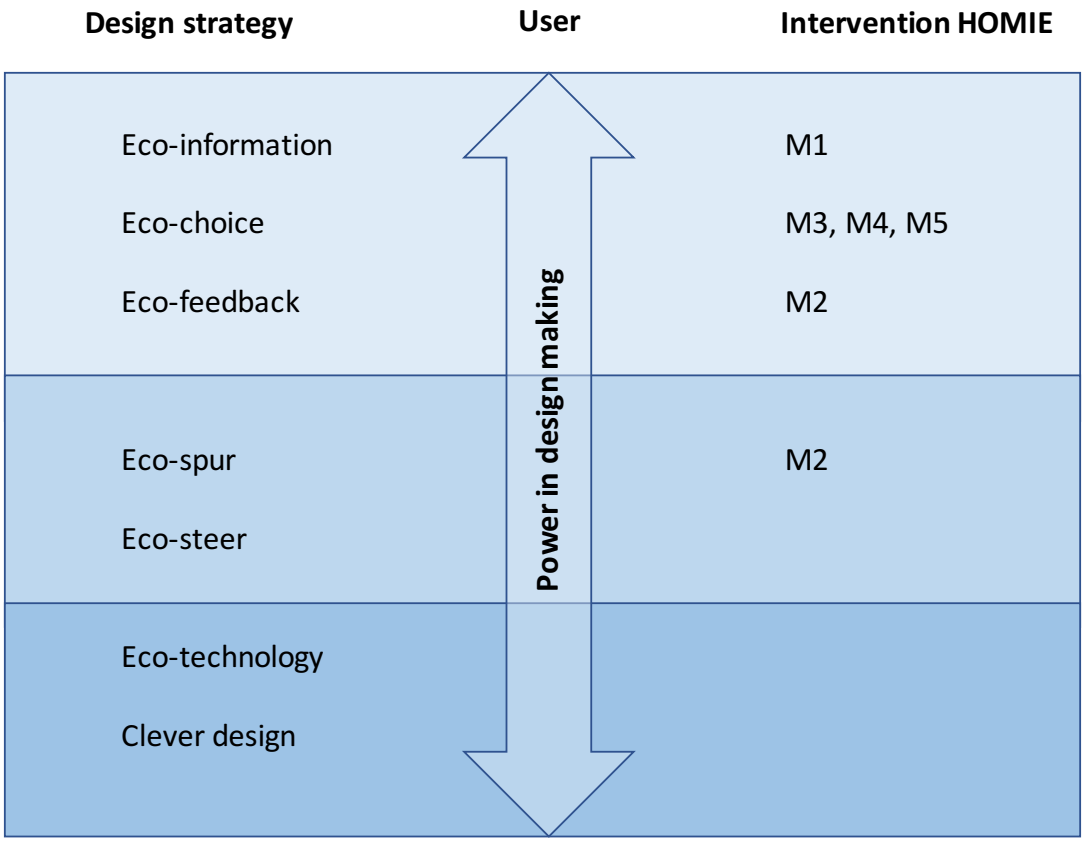

Figure 2: Seven design strategies linked to the three stages of behavioural change, supplemented by intervention levels that HOMIE engages in. Source: building on Bhamra et al. (2008) and Tang (2010)

Table 2. HOMIE Design interventions

Timing	Design intervention	Description summary
Pre-wash	Interview	Before washing machine installation, customers are interviewed to gain insight on their washing behaviour. E.g. "How many times do you wash? What kind of washes do you usually run?
Month 1 (M1)	Free month	The first month is considered a test month, in which users get a full month of washing for free.
Feedback M1		No specific feedback. Customers can access their usage information on the website but this information is not proactively shared.
Month 2 (M2)	Introduce pay-per-use	The first paid month of washing.
Feedback M2	Introduce informative mailing	The feedback users receive in the monthly mailing list after the first full month of washing. Feedback received: Washing behaviour basics (Insight into washing behaviour: Amount of washes, Temperature, Types of washes
Month 3 (M3)		The second paid month of washing.
Feedback M3	Comparison current vs previous month	The feedback users receive in the monthly mailing list after the second month of washing.

		Feedback received: Washing behaviour basics + Comparison washing behaviour (Individual compared washing behaviour between M1 and M2)
Month 4 (M4)		The third paid month of washing.
Feedback M4	Introduce social comparison	The feedback users receive in the monthly mailing list after the third month of washing. Feedback received: Washing behaviour basics + Comparison Washing Behaviour + Social Comparison (Individual washing behaviour compared to average of your user type)
Month 5 (M5)		The fourth paid month of washing.
Feedback M5	Introduce goal setting	Each user receives specific & personalised washing goal, aiming to lower the number of washes and total energy consumption.

3.2 Sample

HOMIE collects the same data for all its customers through its pre-wash interviews and the trackers that are integrated in all its customers' washing machines. All customers contractually agree that their data can be collected and used for research once anonymised but are not informed what type of analyses could or have been made. HOMIE customers are informed in HOMIE's marketing materials and on its website that one of HOMIE's goals is to lower their individual energy usage, and that their laundry data will also be monitored for this purpose besides invoicing per wash.

To test both the short-term (2 months) and the long-term (5 months) effects of a pay-per-use business model, we selected the HOMIE customers that fit these time spans to create two samples. To test both the short-term (2 months) and the long-term (5 months) effects of a pay-per-use business model, we used two samples. Sample characteristics for both samples can be found in Table 3. The first sample included 56 Dutch HOMIE customers who have had a contract with HOMIE for over two months. The first free month was introduced as a 'marketing tool' to attract new customers as well as a means to track how often and at which temperatures people would wash in a 'normal' situation when not paying per use (month 1). By comparing this free month to the new washing behaviour that is triggered by the pay-per-use model (month 2), we could investigate the effects of pay-per-use on sustainable consumption behaviours.

To investigate whether the new washing behaviour has resulted in a new habit, we also analysed a smaller sample. This subset of 21 HOMIE customers have had a contract with HOMIE for over five months. As a result, these customers had experienced the following interventions (see Table 2): Interview; Free Month; Introduce pay-per-use; Informative mailing; Comparison current vs previous month; Introduce social comparison, Introduce goal setting. By analysing their washing behaviour over a period of five months we are able to test the long-term effect of a pay-per-use business model.

Finally, we hypothesised that the pay-per-use model would influence washing temperatures most for customers who are used to washing at relatively high temperatures (> 40°C). The pricing model is developed in such a way that washing at temperature above 40°C is discouraged as the environmental impact of these washes is more severe (A.I.S.E., 2015): a cold wash costs €1.13, a 40°C wash costs €1,31

and a 90°C costs €1,69 for instance [2]. Accordingly, we split customers into two groups (initial washing temperature: high (>40°C) vs. low (≤40°C) based on the temperature they used in the first, free month.

Table 3. Sample Characteristics. *Note. In Europe (2016), the most common household type was a single person living alone (33.1 %) (Eurostat, 2017)*

	Short-term effect of pay-per-use (2 months period)	**Long-term effect of pay-per-use (5 months period)**
Sample size	N = 56	N= 21
Gender	66% female	67% female
Ages	19-81; mean = 37	21-59; mean = 37
Household size	1-5-person households; 64% 1-person household	1-4-person households; 52% 1-person household

3.2 Procedure and measures

A tracking system in the washing machine recorded the washing temperature and programme for each laundry cycle, as well as when this laundry cycle was performed. Based on this data, we calculated the average temperature and number of laundry cycles per month for each customer. For the analysis, the programmes drain and spin were not counted as a laundry cycle because these programmes were usually part of another laundry cycle. A cold wash and the rinse programme were calculated as a laundry cycle at 20°C.

In order to put the findings of the Dutch HOMIE sample in a wider European context, the outcomes are compared to average European data from the International Association for Soaps, Detergents and Maintenance Products (A.I.S.E) who have been advocating sustainable laundry behaviour. In Europe, households wash on average 3.1 times a week, with an average wash temperature of 43°C (A.I.S.E, 2015 based on 2014 data). In countries where the "I prefer 30" campaign (focused on lowering the average laundry cycle temperature) was introduced, being the UK, France, Italy, Belgium, and Denmark, the laundry temperature dropped to 40.9°C (A.I.S.E, 2015).

Before installation, all HOMIE customers were interviewed to better understand their washing behaviour and explore their needs. The interviews were done in a semi-structured manner and were conducted by one of the authors, and usually lasted up to half an hour. This happened before the washing machine installation and included questions such as: "Who typically does the laundry? How many times do typically you wash a week? What kind of washes do you usually run? (temperature, cycle etc.)" So, besides qualitative information on who typically does the laundry, how sorting takes place and the like, customers were asked to estimate how often they think they would wash on a weekly basis and what the average temperature of their executed laundry cycles is. Answers were either recorded in an online survey programme or taken as notes during the interview and processed afterwards. For this study, we only used the

[2] HOMIE prices (https://homiepayperuse.com - 4 Dec 2017)

- A **cold** wash costs **€1,13** (incl. VAT)
- A **30°C** wash costs **€1,18** (incl. VAT)
- A **40°C** wash costs **€1,31** (incl. VAT)
- A **60°C** wash costs **€1,47** (incl. VAT)
- A **90°C** wash costs **€1,69** (incl. VAT)

quantitative data about how often and at which temperatures and cycles people estimate to do the laundry to compare estimates against actual numbers of washes and temperatures.

4. Results

4.1 Average temperature

Our first hypothesis was that through the pay-per-use model, we would encourage customers to reduce their average laundry temperature, in line with recommendations by the A.I.S.E. (2015).

A mixed analysis of variance (ANOVA) was performed with the introduction of the pay-per-use model (first free month vs. second paid month) as a within-factor, the customer groups based on their initial washing temperature (high vs. low) as a between-factor and washing temperature as the dependent variable. A main effect was found for the introduction of the pay-per-use model ($F(1, 57) = 9.18$, $p < .01$), supporting H1 that the average washing temperature across the full sample dropped between the free first month and the second paid month ($M_{month\ 1} = 40.2°C$ vs. $M_{month\ 2} = 38.1°C$).

Furthermore, a significant interaction effect was found between the introduction of the pay-per-use model and the customer groups ($F(1, 57) = 5.88$, $p < .05$). When analysing the two customer groups separately, it is found that customers who were used to washing at relatively high temperatures significantly lowered their washing temperatures after introduction of the pay-per-use model ($M_{month\ 1} = 45.6°C$ vs. $M_{month\ 2} = 42.1°C$, $t(29) = 3.21$, $p < .01$). However, customers who were used to washing at relatively low temperatures did not significantly lower their washing temperatures after introduction of the pay-per-use model ($M_{month\ 1} = 34.8°C$ vs. $M_{month\ 2} = 34.4°C$, $t(28) = 0.59$, $p > .20$). Figure 3 illustrates these findings.

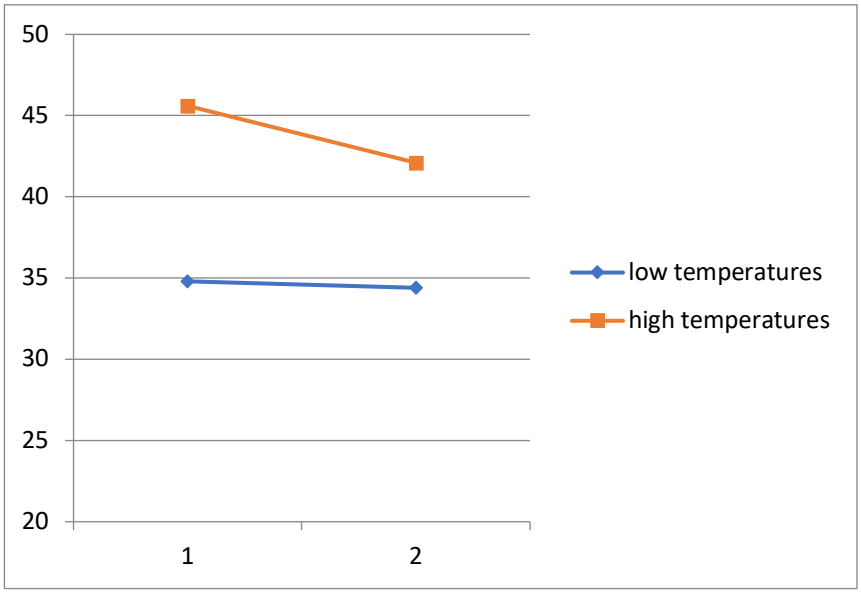

Figure 3. Average washing temperature per month (n = 56) for customer groups who were used to washing with either low (blue) or high (red) temperatures.

Furthermore, one-sample t-tests were conducted in which the average temperatures of our full sample during the second month were compared with the average temperature of 43°C ($t(55) = -5.42$, $p < .001$) in Europe as quoted by the A.I.S.E. (2015), and 40.9°C ($t(55) = -3.09$, $p < .01$) in "I prefer 30" campaign countries. Both one-sample t-tests revealed significant differences, providing additional support for H1 and indicating that the pay-per-use model combined with interventions could be a promising way to help reduce the average washing temperature further. Table 4 summarizes these effects.

Table 4. Average temperature and number of laundry cycles for Sample 1 (n=56) in the free month (month 1) compared to the pay-per-use month (month 2) and to the European averages.

	No pay-per-use (month 1)	**Pay-per-use (month 2)**	
Average temperature			
Sample 1 (n=56)	40.2°C	38.1°C	$F(1, 57) = 9.18$, $p < .01$
A.I.S.E. (2015)	43°C		$t(55) = -5.42$, $p < .001$
I prefer 30" countries	40.9°C		$t(55) = -3.09$, $p < .001$
Number of laundry cycles			
Sample 1 (n=56)	12.9	10.3	$t(55) = 3.46$, $p < .01$
A.I.S.E. (2015)	13.5		$t(55) = -2.60$, $p < .05$

To test whether the new washing behaviour resulted into a new habit, another mixed ANOVA was performed for the smaller sample (n = 21) who had used the pay-per-use model for over 5 months. Time (month 1 vs. month 2 vs. month 3 vs. month 4 vs. month 5) was included as a within-factor, the customer groups based on their initial washing temperature (high vs. low) as a between-factor and washing temperature as the dependent variable. As there was a violation of sphericity ($p < .05$, $\varepsilon > .75$), Huynh-Feldt correction was applied.

A marginally significant main effect was found for time ($F(3.16, 60.10) = 2.17$, $p < .10$). Post hoc analyses demonstrate that the average washing temperature dropped after introducing the pay-per-use model ($M_{month\ 1} = 39.8$°C vs. $M_{month\ 2} = 37.2$°C, $p < .05$), after which it remained relatively stable ($M_{month\ 3} = 39.4$°C, $M_{month\ 4} = 37.4$°C, $M_{month\ 5} = 37.8$°C).

Furthermore, a significant interaction effect was found between the introduction of the pay-per-use model and the customer groups ($F(3.16, 60.10) = 2.92$, $p < .05$). When analysing the two customer groups separately, similar results were found as those presented above. Again, customers who were used to washing at relatively high temperatures significantly lowered their washing temperatures after introduction of the pay-per-use model ($M_{month\ 1} = 46.2$°C vs. $M_{month\ 2} = 41.7$°C, $M_{month\ 3} = 43.2$°C, $M_{month\ 4} = 41.2$°C, $M_{month\ 5} = 40.4$°C, $F(3.21, 35.32 = 5.38$, $p < .01$). However, customers who were already used to washing at relatively low temperatures did not significantly lower their washing temperatures after introduction of the pay-per-use model ($M_{month\ 1} = 33.4$°C vs. $M_{month\ 2} = 32.7$°C, $M_{month\ 3} = 35.7$°C, $M_{month\ 4} = 33.7$°C, $M_{month\ 5} = 35.2$°C, $F(1.84, 14.74) < 1$). Even though no significant differences were found over the five months, the mean values for the monthly temperatures for this group are not

completely constant (see Figure 4), suggesting that also the 'low temperature wash group' occasionally washes at relatively higher temperatures. The findings are visualised in Figure 4.

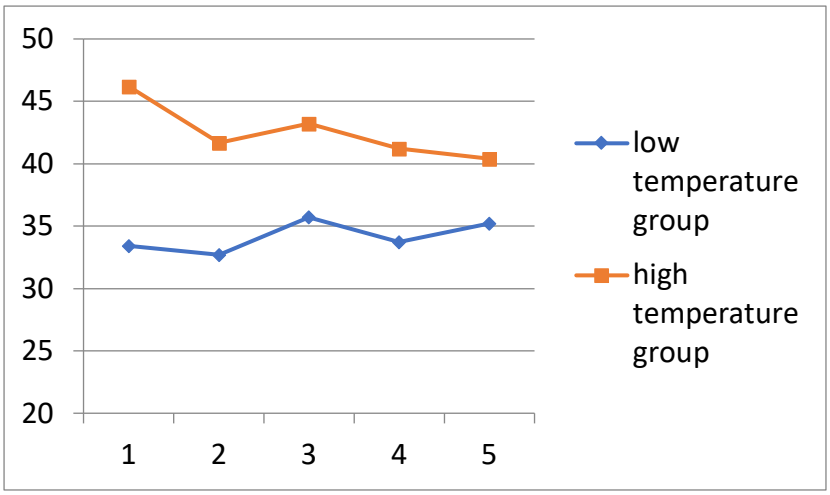

Figure 4. Average washing temperature per month (n = 21) for customer groups who were used to washing with either low (blue) or high (red) temperatures.

4.2 Number of laundry cycles

Our second hypothesis was that through the various interventions we could help customers reduce the total number of washes. To test this hypothesis, a paired t-test was performed with the introduction of the pay-per-use model (first free month vs. second paid month) as a within-factor and the monthly number of washes as the dependent variable. A significant effect was found for the introduction of the pay-per-use model ($t(55) = 3.46$, $p < .01$), supporting H2 that the average number of washes across the full sample dropped between the free first month and the second paid month ($M_{month\ 1} = 12.9$ vs. $M_{month\ 2} = 10.3$).

Furthermore, a one-sample t-test was conducted in which the average number of monthly washes of our full sample during the second month were compared with the average number of 13.5 washes monthly (on the basis of 3.1 washes per week and a 30.5-day month in Europe as estimated by the A.I.S.E., 2015, for European households). A significant difference was found ($t(55) = -2.60$, $p < .05$), providing additional support for H2 and indicating that the customers in the pay-per-use model washed less often than the average European customer. Table 4 summarizes these effects.

To test whether the pay-per-use model trigger a new habit of washing less often, a repeated measures ANOVA was performed for the smaller sample (n = 21) who had used the pay-per-use model for over 5 months. Time (month 1 vs. month 2 vs. month 3 vs. month 4 vs. month 5) was included as a within-factor and number of washes as the dependent variable. A significant main effect was found for time ($F(4, 80) = 2.93$, $p < .05$). Post hoc analyses demonstrated that the average number of washes dropped after introducing the pay-per-use model ($M_{month\ 1} = 15.2$ vs. $M_{month\ 2} = 12.0$, $p < .05$), after which it remained relatively stable ($M_{month\ 3} = 12.2$, $M_{month\ 4} = 12.1$, $M_{month\ 5} = 12.9$). These findings are visualised in Figure 5.

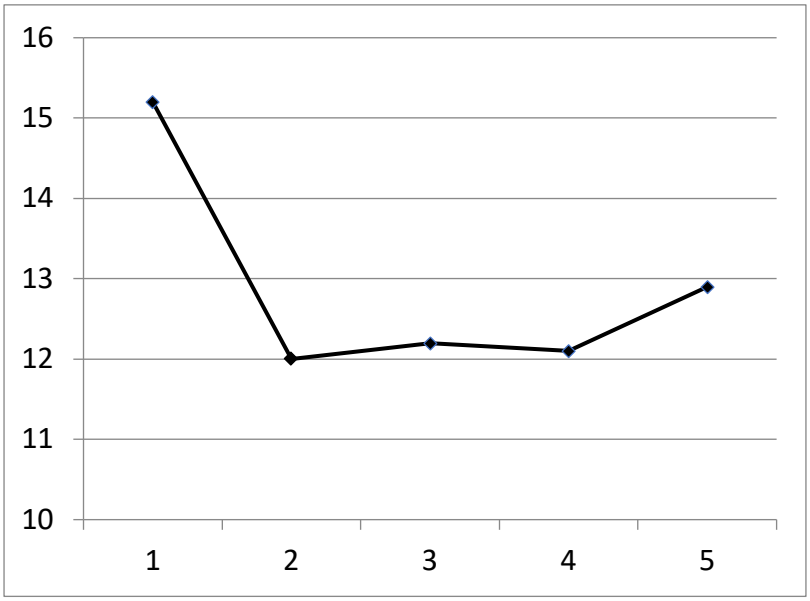

Figure 5. Average number of laundry cycles per month (n = 21)

4.3 Interviews: comparing estimates vs. actuals

Our third and fourth hypotheses related to how much, and at which temperatures people think they wash.

Paired t-tests were performed to compare customers estimated washing behaviour with their actual washing behaviour (based on the first, free month). The estimated weekly number of washes was recalculated to an estimated number of washes per month by multiplying the given score with 52/12. As expected, customers underestimated the amount of washes that they do on a monthly basis ($M_{estimated}$ = 10.5 vs. M_{actual} = 12.9, $t(53) = -2.14$, $p < .05$) supporting H3.

Furthermore, a significant difference was found in washing temperatures between the estimated washing temperature as indicated in the interview and the actual washing temperature based on the first month ($M_{estimated}$ = 43.8°C vs. M_{actual} = 40.6°C, $t(49) = 3.08$, $p < .01$). Customers expected that they would wash on higher temperatures than they actually did in the first month. These findings do not support H4 as it was expected that customers would *under*estimate laundry temperatures.

5. General discussion and conclusions

5.1 Main findings

This study contributes to the emergent literature on sustainable business models (Stubbs and Cocklin, 2008; Boons and Lüdeke-Freund, 2013; Bocken et al., 2014; Lüdeke-Freund and Dembek, 2017) and sustainable consumption through the case study of a pay per wash business model. While prior research demonstrated that consumers seem to be interested in access-based services (e.g., Armstrong et al., 2015; Catulli 2012; Edbring et al., 2016), these studies only explored attitudinal responses. This study contributes to this literature by investigating the impact of a pay-

per-use model on consumers' actual behaviour. Specifically, it provides evidence on sustainable consumption patterns based on customer interviews, measured numbers and types of washes, and measured changes in consumption patterns after interventions. In this way, this study contributes to literature and practice through a unique and rare case of a pay-per-use business model and contributes to the limited number of quantitative cases (Goedkoop et al., 1999; Lindahl et al., 2014). Also, it provides a rare and in-depth case of a company experimenting with a sustainable business model in order to achieve desirable sustainability impacts through business model innovation (Weissbrod and Bocken, 2017).

The results demonstrated that pay-per-use models can be effective at changing consumer behaviour, and thereby have a more positive environmental impact than the conventional product-oriented business model (Tukker, 2004). It was found that the pay-per-use model could be a promising way to help reduce the average washing temperature. In particular, consumers who typically washed at high temperatures significantly lowered their washing temperatures after introduction of the pay-per-use model. This suggests that, if a company pursuing a pay-per-use business model focused on stimulating sustainable consumption could attract a wider, potentially less environmentally conscious, group of customers, it could expand its impact further by stimulating and ingraining more sustainable washing behaviour. Potentially, this could be achieved by emphasising other benefits to the customer of paying per use besides 'sustainability', such as cost savings or flexibility, which is already done by companies with novel business models, such as Zipcar who emphasise multiple other benefits besides environmental gains associated with car sharing (see Bocken, 2017). Although flexibility and cost savings are already part of HOMIE's current value proposition as emphasised on its website (homiepayperuse.com), specific customers could be targeted by focusing marketing messages on specific target groups' preferences (see e.g. Mugge et al., 2017 who create different propositions for refurbishment in different target groups). In this way, the pay-per-use business model could create sustainable consumption patterns with a wider range of consumers, also including less environmentally conscious ones.

Over time, the total number of laundry cycles dropped after introducing the pay-per-use model, although the number stabilized at about 12-13 washes per month. As the lowered temperature and amount of laundry cycles remained stable over time, this suggests that consumers had formed a new washing habit. As both temperature and amount of laundry cycles compromise are often regarded as an imperative share of the overall environmental impact of washing machines (A.I.S.E., 2015; Cullen and Allwood, 2009), this suggests that a pay-per-use business model will have an important environmental impact on the overall life cycle impact associated with the washing machine. Moreover, the A.I.S.E estimates that households wash on average 3.1 times a week (13.5 monthly), with an average wash temperature of 43°C (A.I.S.E, 2015 based on 2014 data). However, if these figures are based on self-reported data like interviews, our study suggests that the averages are generally underestimated and people wash more than they think. Hence, introducing a pay-per-use model could have an even more significant impact reducing the number of washes. At the very least, it would give a reliable measure of actual consumer behaviour.

Our findings also contribute to the research on changing households' energy consumption (e.g., Hargreaves et al., 2010; Kobus et al., 2015). This stream of

literature has concluded that providing households with high quality feedback via energy management systems, is needed for households to reduce their energy consumption. Based on the present research, we conclude that an energy management system is only one way by which such feedback can be offered. A pay-per-use business model and the feedback that is then provided by the monthly payments can also serve as a trigger for people to change their energy consumption of specific energy-demanding appliances, such as washing machines.

5.2 Future research

This study looked at the specific actions of the start-up HOMIE and focused on a limited experimentation space. HOMIE's consumer influencing tactics focused on "Eco-information, eco-choice, eco-feedback and eco-spur" (Figure 2; Bhamra et al., 2008). However, the more "coercive approaches", such as Eco-Steer (facilitate users to adopt more desirable use habits through the prescriptions or constraints of use embedded in the product design) or Eco-Technology (control user behaviour automatically by design combined with advanced technology) may prove more successful in altering behaviour (Bhamra et al., 2011). Nevertheless, adoption may be low if consumers are annoyed by the level of interference of such devices (Kobus et al., 2015; Wever et al., 2008). At the time of writing, HOMIE does not yet manufacture washing machines itself, but there would be scope to redevelop the washing machine and test a wider spectrum of sustainable design strategies. This could also be done in a low cost, experimentation-type of way to test under which circumstances such a new interface would entice customers to adopt sustainable behaviour patterns (Weissbrod and Bocken, 2017; Ries, 2011). For instance, with stickers the existing interface could be adapted to give a new appearance and limit the number of options (e.g. hiding the 90ºC button). As a next step, in collaboration with washing machine manufacturers, different combinations of propositions and designs could be experimented with, also including smart features, which are not yet used to their full potential to stimulate sustainable consumption.

In relation to this, experimentation with the pricing model could be expanded in the future to identify the optimum pricing levels to stimulate sustainable consumption. Furthermore, messaging including co-benefits such as "low temperature washes makes clothes last longer" (Bocken and Allwood, 2012; p. 126) could be tested to help stimulate sustainable consumption behaviour further. Collaborations with laundry detergent manufacturers could help optimise behaviour and have the potential to improve the credibility about washing behaviour advice (i.e. about the perception of cleanliness at low temperatures).

We acknowledge that more research is needed to determine the overall environmental impact of a pay-per-use model for washing machines. In a pay-per-use model the company (and not the consumer) is responsible for the repair of the washing machine, due to which products are more likely to be repaired than to be replaced, resulting in a longer lifetime of the product (Tukker, 2004). On the other hand, past research has suggested that consumers may care less for products that are used in an access-based service (Bardhi and Eckhardt, 2012), which may reduce the overall lifetime of the washing machine in a pay per use model. The full life cycle impacts of the washing machine could thus be analysed and more fully understood (Cullen and Allwood, 2009) in relation to sustainable business model innovation. For instance, when would be the

best time to upgrade and remanufacture washing machines to optimise overall life cycle impacts (Cooper and Gutowski, 2017)? In addition to understanding the full environmental impacts of pay-per-use, future research could focus on mapping ideal sequences of experiments to achieve the greatest levels of sustainability impacts and investigating the environmental impacts of other sustainable business models, such as renting and sharing.

Our study demonstrated the effects of the pay-per-use model in a real-life setting measuring actual behaviour rather than intentions or behaviours in a lab setting. However, this also resulted in several limitations.

First of all, the study was limited by a sample of 56 customers, who had been using the pay-per-use model for over two months. Because we used a real-life setting, the starting date for this two-month period varied across the sample and depended on the initiation of the customer's contract with HOMIE. Accordingly, we believe that it is unlikely that seasonality and holiday periods have influenced our findings. Nevertheless, the fact that our sample consisted of HOMIE customers can be considered a limitation. Possibly, HOMIE customers are more environmentally conscious than the average customer using washing machines as they have voluntarily opted for a new 'sustainable business model'. However, it was found that behaviour can still be improved through a pay-per-use business model. The product design and end of life issues associated with the washing machine were also out of scope for this study, which was specifically focused on driving sustainable behaviour change through new business models. Future research could look into the longer-term effects, with a larger sample of customers, also allowing for comparisons across types of households (e.g. single household vs. large families), age, gender, and other individual differences, such as environmental consciousness, price sensitivity, and involvement. This would make it possible to study in detail which groups of people are more likely to change their behaviour in a pay-per-use business model. Our sample consisted of a relatively high amount of single person households (52% HOMIE sample vs. 33% European average; Eurostat, 2017), which could have affected the total number of laundry cycles. The effects of new interventions, such as goal setting and defaults (see e.g. Thaler & Sunstein, 2008) could also be explored. Past research has demonstrated the effects of feedback via energy management systems on households' energy consumption (e.g. Abrahamse et al., 2005; Fischer, 2008; Kobus et al., 2015). More research is needed to test how different types of feedback can contribute in further encouraging sustainable consumption in pay-per-use models.

In this study, we did not analyse the separate effects of the different interventions that were sent through mailings (e.g. providing information and social comparison). We decided to focus on the effects of the pay-per-use model in general (including the combination of all interventions), because of the short time span of each of the interventions, the small sample size, and the fact that effects could not effectively be isolated.

A final limitation of our research is that we only tested the effects of a pay-per-use model for washing machines. Prior research has demonstrated that the product category (e.g., utilitarian or hedonic) strongly affects the benefits and risks that consumers perceive in circular products (Mugge et al., 2017). Washing machines are valued for their functional value and generally do not fulfil any self-expressive

purposes. Consequently, the absence of ownership may not be an issue for such utilitarian products. However, it is questionable whether consumers are also willing to accept a pay-per-use model for products that fulfil a more prominent identity function, such as cars or espresso machines (e.g. Belk, 1988). In a similar vein, it is interesting to investigate whether a pay-per-use model would be interesting for cheaper products, such as vacuum cleaners. More research is needed to investigate consumers' acceptance and behaviour in relation to pay-per-use models.

5.3 Conclusions

The study demonstrates the potential of novel sustainable business models and in particular pay-per-use for encouraging sustainable consumer behaviour. Through the in-depth case of start-up HOMIE, we investigated how pay-per-use business models could contribute to sustainable consumption with samples of 56 (2 months period) and 21 customers (5 months period). It was found that pay-per-use business models have the potential to stimulate sustainable consumption as the total number of washes and washing temperature decreased significantly over time. Even though, our findings demonstrate that consumers' habits change due to the pay-per-use model, some important challenges remain. For instance, is a sufficiency-driven business model focused on consuming less (Bocken and Short, 2016) financially viable in the long run? Would such business models need to be combined with further service provisions, such as advice and provision of the most sustainable laundry detergents, to improve the sustainability and business impacts? Through the unique case of HOMIE, combining sustainable business model and consumption strategies, this study includes powerful insight for future research in sustainable consumption and business models, as well as practical insight for sustainable entrepreneurs and intrapreneurs.

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References

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. 2005. A review of intervention studies aimed at household energy conservation. J. Environ. Psych., 25(3), 273-291.

Accenture. 2014. Circular advantage. Innovative business models and technologies to create value in a world without limits to growth. Available at: https://www.accenture.com/ t20150523T053139__w__/us-en/_acnmedia/ Accenture/Conversion-Assets/DotCom/ Documents/Global/PDF/Strategy_6/Accenture- Circular-Advantage-Innovative-Business- Models-Technologies-Value-Growth.pdf. (accessed 3 April 2018).

A.I.S.E. 2015. I PREFER 30° CAMPAIGN CLOSE OUT REPORT OCTOBER 2015. Available at: https://www.aise.eu/documents/document/20151102163916-ip30-report-2015_full_version_no_annexes.pdf (accessed 6 September 2017).

Ajzen, I. 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process, 50, 179–211.

Armstrong, C. M., Niinimäki, K., Kujala, S., Karell, E., & Lang, C. (2015). Sustainable product-service systems for clothing: exploring consumer perceptions of consumption alternatives in Finland. J. Clean. Prod., 97, 30-39.

Bakker, C., Wang, F., Huisman, J., & den Hollander, M. 2014. Products that go round: exploring product life extension through design. J. Clean. Prod., 69, 10-16.

Bardhi, F., & Eckhardt, G. M. (2012). Access-based consumption: The case of car sharing. J. Consum. Res., 39(4), 881-898.

Belk, R. W. 1988. Possessions and the extended self. J. Consum. Res., 15(2), 139-168.

Benjaafar, S., Kong, G., Li, X., & Courcoubetis, C. 2015. Peer-to-peer product sharing: Implications for ownership, usage and social welfare in the sharing economy.

Bhamra, T., Lilley, D., Tang, T. 2008. Sustainable use: changing consumer behaviour through product design. Changing the Change: Design Visions, Proposals and Tools, Turin, 2008, Proceedings.

Bhamra, T., Lilley, D., Tang, T. 2011. Design for Sustainable Behaviour: Using Products to Change Consumer Behaviour, Des. J., 14 (4), 427-445.

Bocken, N.M.P. 2017. Business-led sustainable consumption initiatives – impacts and lessons learned. J. Manag. Dev., 36 (1), 81-96.

Bocken, N., Allwood, J. 2012. Strategies to reduce the carbon footprint of consumer goods by influencing stakeholders. J. Clean. Prod., 35, 118-129.

Bocken, N.M.P., Bom, C.A., Lemstra, H. 2017. Business-led sustainable consumption strategies: the case of HOMIE. 18th ERSCP Conference, Greece, 1-5 October 2017.

Bocken, N. M.P., de Pauw, I., Bakker, C., van der Grinten, B. 2016. Product design and business model strategies for a circular economy. J. Ind. Prod. Engineering., 33(5), 308-320.

Bocken, N. and Short, S. 2016, Towards a sufficiency-driven business model: experiences andopportunities, Env. Innov. Societ. Transit., 18, 41-61.

Bocken, N., Short, S., Rana, P., Evans, S. 2014. A literature and practice review to develop Sustainable Business Model Archetypes. J. Clean. Prod., 65, 42–56.

Boon, B., Wever, R., Quist, J. 2015. Beyond behaviour change: technological artefacts and characterological development. Int. J. Sust. Engin., 8(3), 231-247.

Boons, F., Lüdeke-Freund, F. 2013. Business models for sustainable innovation. State-of-the-art and steps towards a research agenda, J. Clean. Prod., 45, 9–19.

Bressanelli, G., Perona, M., Saccani, N., 2017. Reshaping the Washing Machine Industry through Circular Economy and Product-Service System Business Models. Procedia CIRP 64, 43-48.

Catulli, M. 2012. What uncertainty? Further insight into why consumers might be distrustful of product service systems. J. Manuf. Technol. Manage., 23(6), 780-793.

CBS. 2017. Households; size, composition, position in the household, 1 January. Available at: http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLEN&PA=82905ENG&LA=EN

Ceschin, F. Gaziulusoy, I. 2017. Evolution of design for sustainability: From product design to design for system innovations and transitions. Des. Stud., 47, 118-163.

Clinton, L., Whisnant, R. 2014. Model behavior: 20 business model innovations for sustainability. London, UK: SustainAbility.

Cohen, B., Kietzmann, J. 2014. Ride on! Mobility business models for the sharing economy. Org. Environ., 27(3), 279-296.

Cooper, D. R., Gutowski, T. G. 2017. The environmental impacts of reuse: a review. J. Ind. Ecol., 21(1), 38-56.

Cullen, J. M., Allwood, J. M. 2009. The role of washing machines in life cycle assessment studies. J. Ind. Ecol., 13(1), 27-37.

Edbring, E. G., Lehner, M., Mont, O. 2016. Exploring consumer attitudes to alternative models of consumption: motivations and barriers. J. Clean. Prod., 123, 5-15.

Eisenhardt, K., Graebner, M. 2007. Theory building from cases: Opportunities and challenges. Acad. Manage. J., 50(1), 25–32. https://doi.org/10.2307/20159839

Eurostat. 2017. Household composition statistics. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_composition_statistics (accessed 2 April 2018).

Fischer, C. 2008. Feedback on household electricity consumption: a tool for saving energy?. Energ. Eff., 1(1), 79-104.

Fraiberger, S.P. and Sundararajan, A. 2015. Peer-to-Peer Rental Markets in the Sharing Economy. NYU Stern School of Business Research Paper (First version March 2015; current version September 2017). Available at SSRN: https://ssrn.com/abstract=2574337 or http://dx.doi.org/10.2139/ssrn.2574337

Frenken, K. 2017. Political economies and environmental futures for the sharing economy. Phil. Trans. R. Soc. A, 375(2095), 20160367.

Geissdoerfer, M., Savaget, P., Bocken, N., Hultink, E. 2017. The Circular Economy – a new sustainability paradigm? J. Clean. Prod., 143, 757–768

Gnoni, M.G., Mossa, G., Mummolo, G., Tornese, F., Verriello, R., 2017. Circular economy strategies for electric and electronic equipment: a fuzzy cognitive map. Environ. Eng. Manag. J. 16, 1807-1817.

Goedkoop, M., van Haler, C., te Riele, H., Rommers, P. 1999. Product Service-Systems, ecological and economic basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ).

Hargreaves, T., Nye, M., Burgess, J. 2010. Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. Energy Policy, 38(10), 6111-6119.

Hazée, S., Delcourt, C., Van Vaerenbergh, Y. 2017. Burdens of Access: Understanding Customer Barriers and Barrier-Attenuating Practices in Access-Based Services. J. Serv. Res., 20(4), 441-456.

Heiskanen, E., Jalas, M. 2003. Can services lead to radical eco-efficiency improvements?–a review of the debate and evidence. Corp. Soc. Resp. Env. Ma., 10(4), 186-198.

ING. 2018. De circulaire corporatie. Naar volledig duurzame huisvesting. ING Economisch Bureau, March 2018. Available at: https://www.ing.nl/media/ING_EBZ_de-circulaire-corporatie_naar-volledig-duurzame-huisvesting_maart-2018_tcm162-143041.pdf (accessed on 3 April 2018).

International Institute on Sustainable Development. 1994. Oslo Round-table on Sustainable Production and Consumption. Defining sustainable consumption. [WWW document] URL http://www.iisd.ca/consume/oslo004.html (accessed on 29 March 2018).

Kobus, C. B., Mugge, R., Schoormans, J. P. 2015. Long-term influence of the design of energy management systems on lowering household energy consumption. Int. J. Sust. Engineer., 8(3), 173-185.

Kobus, C. B., Mugge, R., Schoormans, J. P. 2013. Washing when the sun is shining! How users interact with a household energy management system. Ergonomics, 56(3), 451-462.

Kuijer, L. and De Jong, A, 2012. Identifying design opportunities for reduced household resource consumption: exploring practices of thermal comfort, J. Design Research, 10,1/2.

Lawson, S. J., Gleim, M. R., Perren, R., Hwang, J. 2016. Freedom from ownership: An exploration of access-based consumption. J. Bus. Res. , 69(8), 2615-2623.

Lelah, A., Mathieux, F., Brissaud, D. 2011. Contributions to eco-design of machine-to-machine product service systems: the example of waste glass collection. J. Clean. Prod., 19, 1033-1044.

Lieder, M., Farazee, A., Rashid, A., Mihelič, A., Kotnik, S. 2017. Towards circular economy implementation in manufacturing systems using a multi-method simulation approach to link design and business strategy. Int. J. Adv. Manuf. Tech., 93, 1953-1970

Lindahl, M., Sundin, E., & Sakao, T. 2014. Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. J. Clean. Prod., 64, 288-296.

Lüdeke-Freund, F., Dembek, K. 2017. Research and Practice on Sustainable Business Models: Emerging Field or Passing Fancy?, J. Clean. Prod. (online first 17 August 2017), https://doi.org/10.1016/j.jclepro.2017.08.093.

Lüdeke-Freund, F., Massa, L., Bocken, N., Brent, A., & Musango, J. 2016. Business Models for Shared Value: How Sustainability-Oriented Business Models Contribute to Business Success and Societal Progress. Cape Town: Network for Business Sustainability South Africa.

Magretta, J. 2002. Why business models matter. Harvard Bus. Rev., 80(5), 86-92.

Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., Aminoff, A. 2018. Do circular economy business models capture intended environmental value propositions?. J. Clean. Prod., 171, 413-422.

Manzini, E., Vezzoli, C. 2003. A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize. J. Clean. Prod., 11(8), 851-857.

Mont, O. 2002. Clarifying the concept of product-service system, J. Clean. Prod.,10, 237–245.

Mont, O., Tukker, A., 2006. Product Service Systems: reviewing achievements and refining the research agenda. J. Clean. Prod., 14 (17), 1451-1560.

Mont, O., 2008. Product-service Systems: Panacea or Myth? VDM Verlag Dr. Müller Aktiengesellschaft & Co. KG.

Mugge, R., Jockin, B. Bocken, N. 2017. How to sell refurbished smartphones? An investigation of different customer groups and appropriate incentives. J. Clean. Prod., 147, 284-296.

Mugge, R., Safari, I., Balkenende, R. 2017. Is there a market for refurbished toothbrushes? An exploratory study on consumers' acceptance of refurbishment for different product categories. In: Product Lifetimes and the Environment Conference Proceedings, C. Bakker & R. Mugge (Eds.), 293-297.

Mugge, R., Schoormans, J. P.L., Schifferstein, H. N. 2005. Design strategies to postpone consumers' product replacement: The value of a strong person-product relationship. Des. J., 8(2), 38-48.

Pettersen, I. N., Boks, C., Tukker, A. 2013. Framing the role of design in transformation of consumption practices: beyond the designer-product-user triad. Int. J. Technol. Manag., 63(1-2), 70-103.

Schaefers, T., Lawson, S. J., Kukar-Kinney, M. 2016. How the burdens of ownership promote consumer usage of access-based services. Marketing Letters, 27(3), 569-577.

Scott, K., Bakker, C., Quist, J. 2012. Designing change by living change. Design Studies, 33(3), 279-297.

Shove, E. 2007. The design of everyday life. Berg.

Stubbs, W., Cocklin, C. 2008. Conceptualizing a "sustainability business model". Org. Environ., 21(2), 103-127.

Tang, T. 2010. Towards sustainable use: design behaviour intervention to reduce household environment impact. Loughborough: Loughborough University.

Teece, D. J. 2010. Business models, business strategy and innovation. Long Range Plann. 43(2), 172-194.

Thaler, R.H, Sunstein, C.R. 2008. Nudge: Improving Decisions about Health, Wealth, and Happiness. New Haven, CT: Yale University Press.

Tukker, A. 2004. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Bus. Strateg. Environ., 13(4), 246-260.

Tukker, A. 2015. Product services for a resource-efficient and circular economy – a review. J. Clean. Prod., 97, 76-91.

Tukker, A., Tischner, U. 2006. Product-services as a research field: past, present and future. Reflections from a decade of research. J. Clean. Prod., 14(17), 1552-1556.

Van de Ven, A.H. 2007. Engaged Scholarship: a Guide for Organizational and Social Research: a Guide for Organizational and Social Research. OUP Oxford (2007).

Verbeek, P. P. 2005. What things do: Philosophical reflections on technology, agency, and design. Penn State Press.

Weissbrod, I., Bocken, N. M. P. 2017. Developing sustainable business experimentation capability–A case study. J. Clean. Prod., 142, Part 4, 2663–2676.

Wever, R., Van Kuijk, J., Boks, C. 2008. User-centred design for sustainable behaviour. Int. J. Sust. Eng., 1 (1), 9-20.

Yin, R. 2013. Case Study Research: Design and Methods. (Sage: Thousand Oaks.).

APPENDIX A

HOMIE Experimentation roadmap (source: Bocken et al., 2017)