Designing a Value Proposition for the Home Energy Management System: Aiming to Enhance Residential Consumer Adoption

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Abstract

The ongoing process of sustainable advancements within electricity grids heralds a new phase of the global energy transition. Moreover, a phase defined by uncontrolled electricity generation from renewable energy sources (RES), the incorporation of energy storage and demand side management (DSM) techniques. Given the potential of the Home Energy Management System (HEMS) to assist utilities, grid operators and governments in DSM and national grid support, these stakeholders are advocating for large-scale HEMS adoption by residential consumers worldwide. However, despite the fact that available HEMSs align with the technological industry standards and are capable of providing individual benefits to its end-users, adoption among these residential consumers is falling short of the global expectations. Therefore, the objective of this research was to design a value proposition for the HEMS aimed to enhance residential consumer adoption. An initial Value Proposition Canvas was designed through the lens of Dutch utility Pure Energie, by aligning their envisioned Value (Proposition) Map with the identified Residential Consumer Profile of this study. This profile was constructed on the basis of data acquired from four qualitative focus group interview sessions with Dutch residential consumers. Subsequently, four validation interviews with HEMS experts from Huawei, Pure Energie and Dutch grid operator Liander were conducted, to assess the alignment within the initial HEMS Value Proposition Canvas and gather additional expert insights regarding the enhancement of residential consumer HEMS adoption. The key findings of this study identified four underlying adoption domains, namely: Knowledge & Vision, Trust & Transparency, Autonomy & Control and Security & Certainty. In addition, financial savings, increased sustainability, the optimal management of electricity, increased convenience and the provision of an innovative edge were identified as the five core HEMS values for residential consumers. Incorporating these findings alongside principles from the Innovation-Decision Process model and Technology Acceptance Model, a final Value Proposition Canvas design was presented for the HEMS. Based on this proposition, it was concluded that accentuating transparently on primarily the core HEMS values of financial savings as well as increased sustainability, is the most effective way for overarching stakeholders in their efforts to enhance residential consumer adoption of the HEMS. Therefore, this research provides an academic contribution by underscoring the manner in which residential consumer adoption of the HEMS can potentially be enhanced. Moreover, it offers a guideline for stakeholders that desire to implement sustainable energy solutions and it marks a significant stride within the discourse on global energy transition.

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In conclusion, I am immensely proud to have finally completed my master thesis and the fact that I am still able to state that there has never been an occasion during my life where I gave up, regardless of how challenging the circumstances sometimes became. However, each individual mentioned above has played a crucial role within my journey for the past months, and for that, I would like to express my deepest gratitude once more through this message!

- Wouter

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1. Introduction

Despite today's global familiarity with the energy transition, the matter remains a dominant topic with ongoing advancements. Furthermore, awareness regarding the consequences caused by fossil fuel implications spurred rapid integration of renewable energy sources (RES) within energy grids all over the world. According to Hossein Motlagh et al. (2020), the Internet of Things (IoT) has become critical related to the optimalization of modern energy systems, since IoT-based technologies can be applied within these systems to improve their efficiency, increase the share of RES, and thus reduce environmental impacts. Nowadays, according to Lin et al. (2017), the IoT is especially utilised effectively within the smart grid domain. While originally introduced to replace traditional energy grids, through the provision of reliable and efficient energy services towards integrated residential consumers, smart grids have since evolved to become the global standard within the energy sector. This emergence was primarily caused by the rise of smart meters, together with underlying and bidirectional communication networks, fostering interactions between residential consumers and utilities. Moreover, since these smart meters allow utilities to monitor various aspects of residential energy utilisation, such as consumption (patterns) and electricity generation from private solar panels, residential consumers are digitally provided with valuable insights related to their costs. In addition, home area networks (HAN) parallelly transformed the electricity utilisation patterns during this period, labelled as the smart grid era by Zhou et al. (2016). Lastly, the upcoming trends of vehicle-to-grid (V2G) technologies as well as energy storage systems (ESS), combined with the extensive generated electricity loads of private RES, have reshaped the manner in which electricity is managed today. Namely, steering away from the centralized (national) energy grid infrastructures and shifting further towards decentralized cyber-physical energy systems. Elaborating further, RES- and ESS-integrated smart grids which incorporate demand side management (DSM), by utilising techniques such as short-term demand response (DR), to modify the residential electricity demand. This demand response enables residential consumers within smart grids to actively participate in the system's management of electricity, by modifying their consumption during peak periods, in exchange for beneficial time-based tariffs and additional personalized incentives. Therefore, according to Hui et al. (2020), IoT-based demand response techniques are widely considered as an effective approach for utilities in realizing long-term demand side management objectives within smart grids.

A theoretical concept that complements this decentralized smart grid approach exceptionally well and is therefore becoming increasingly indispensable on global scale, is the Home Energy Management System (HEMS). According to Shareef et al. (2018), the HEMS qualifies for demand side management within smart grids since it integrates an automated demand response tool, to efficiently manage the residential electricity demand within smart homes. Moreover, the HEMS optimizes consumption schedules by considering multiple factors, including costs, load profiles and end-user comfort. Since the HEMS receives tariff-related information form utilities upfront, the system is capable of purchasing lower-priced electricity for residential consumers during daily off-peak hours. Optionally, private RES (e.g., solar panels) and home batteries are utilised to support the optimal management of a residential consumer's smart home components during the remaining peak hours. Consequently, Shakeri et al. (2017) underlined

the significance of residential consumer adoption of the HEMS within future smart grid electricity management, as the HEMS characteristics enable improved electricity management, finances, and reliability for both residential consumers as well as utilities. Therefore, the current value proposition for the HEMS offers residential consumers integration of the system within their (smart) homes, in exchange for individual benefits and the opportunity to contribute to the smart grid demand side management exerted by utilities. Given the potential of this mutual trade-off, various utilities around the world seek residential consumer adoption of the HEMS, in an attempt to achieve their demand side management objectives.

1.1 Problem identification and research motivation

As outlined above, HEMS utilisation within smart grids thus has the potential to yield multiple advantages for various stakeholders involved. Furthermore, according to Nizami et al. (2019), the HEMS can offer benefits to residential consumers while still maintaining their end-user comfort. Simultaneously, the integrated demand response tool is able to contribute to local voltage-violation-support, as well as direct load control of national electricity grids. However, in order to realise these mutual benefits, the active involvement and participation of residential consumers within smart grids is of pivotal importance for utilities and grid operators. Therefore, achieving widescale residential consumer adoption of the HEMS could arguably form the gateway to the establishment of an optimal incentive structure, in which benefits for (residential) consumers, utilities, grid operators, and governments are optimised. However, after an assessment of the HEMS market and the identification of several adoption barriers, Sanguinetti et al. (2018) concluded that precisely the residential consumer adoption of the HEMS is falling short of expectations within practical implementations of the system. Therefore, no established or documented optimal incentive structure is currently presented within the HEMS, demand side management and/ or smart grid literature, resulting in unrealised potential for stakeholders within the energy sector, as well as suboptimal functioning smart grids around the world.

Based on this, a significant knowledge gap was identified for this study, related to the residential consumer adoption of the HEMS. Specifically, this gap pertained to the lack of understanding regarding the integration and role of residential consumers within smart grids, through their utilisation of the HEMS. This knowledge gap did not solely obstruct the realization of demand side management and smart grid objectives for utilities but hindered the progress of additional important stakeholders within the energy sector as well, thereby impeded the next phase of the global energy transition. Motivated by these observations and recognizing the awaiting potential that widescale residential consumer adoption of the HEMS within modern energy systems may unlock, this research aimed to further explore this gap.

1.2 Central research question and treatment contribution

Reinforcing the above, the critical role of residential consumers regarding the adoption of smart home technologies (e.g., the HEMS) was strongly highlighted as Ringel et al. (2019) claim that governmental policymakers harbour aspirations to incentivize microeconomic actors towards

harmonising their decisions with broader macroeconomic strategies. Through emphasis on the economic, environmental, and social end-user benefits at the microeconomic level, residential consumers might become advocates for energy efficiency out of enlightened self-interest. As such, this presents an appealing path for utilities to realise demand side management objectives through the HEMS. In addition, Kim et al. (2021) argued that the majority of previous HEMS-related research skewed towards the analysis of technical smart home characteristics, focused on inherent technologies, rather than the prioritisation of residential consumers for whom these technologies are ultimately designed. Therefore, these explorations proposed HEMS design trajectories for future smart homes. Yet, this overemphasis on the current technical advancements triggered a dissonance. Moreover, Kim et al. (2021) underlined the importance of reflection on residential consumer behaviour concerning the HEMS and therefore advocated for a bottom-up approach, to realise smart grid objectives for stakeholders such as utilities, grid operators, and governments. This suggests a design initiation from the residential consumer-level, gradually advancing towards strategic goals within the higher levels. Therefore, this study oriented around residential consumers, the ultimate end-users for whom the HEMS is designed. Therefore, the central research question of this study stated:

"How to design a value proposition for a Home Energy Management System aimed to enhance residential consumer adoption?"

According to Wieringa (2014), in order to answer design questions as the one phrased above, a *treatment* for the identified problem (context) must be designed. Therefore, this paper followed a design science research approach and adopted the term *treatment* to denote the proposed *solution* for its identified design problem as explained within the previous sections above. Therefore, acknowledging no assurance could be given that the lack of residential consumer HEMS adoption would be entirely *solved* by answering the central research question of this paper. Hence, the terminology *to enhance* was preferred over for instance *to optimize* or *to maximize* within the research question of this paper. Nonetheless, since according to Osterwalder et al. (2014), a value proposition represents the unique combination of a business's products, services and characteristics that are designed to meet the specific needs of a targeted consumer segment, designing a value proposition that aims to enhance residential consumer adoption could possibly contribute to saturating the HEMS adoption gap as was described above. Hence, the HEMS value proposition that will be presented at the end of this paper is put forth as a *treatment* for the lacking residential consumer adoption problem context.

This study theoretically contributes to design science literature, through the development and application of its design science research methodology. This approach will be further explained within the Methodology chapter of this paper. Additionally, this study contributes to the theoretical concepts: HEMS, residential consumer adoption, smart grid (electricity management), demand side management, demand response, smart homes, IoT, RES, energy storage system(s), home area networks, smart cities, and the residential consumer inclusion within several of these concepts. Practically, this design science study holds strategic impact potential, since it can serve as global guidance for HEMS-designing actors, seeking to enhance residential consumer adoption of their system(s). During this research, the scope was confined

to the Netherlands. Specifically, to the case of Dutch utility *"Pure Energie"*. This allowed the researcher to uniquely illuminate the perspectives of two crucial stakeholders within the energy sector. Further elaboration regarding this collaboration will be provided within the Methodology chapter as well. Therefore, this paper aids to bridge the knowledge gap identified as obstructing the progression towards the subsequent stage of the global energy transition - an envisioned, as well as desired phase, in which HEMS end-users stand central to optimal functioning smart grids. Moreover, a stage in which utilities, grid operators and policymakers can potentially realise mutual benefits within the parameters of residential consumers. Since the generation of Dutch electricity from RES continues to increase, efficient demand side management within smart grids through residential HEMS end-users is an extremely topical matter within the Netherlands. Moreover, especially relevant given that TenneT, the overarching grid operator of the Netherlands, recently underscored the urgency on this matter, by expressing their concerns regarding the availability of sufficient electricity and controllable power within the Netherlands by the year 2030 (TenneT, 2023).

The remainder of this paper will first continue by presenting the Theoretical Framework of this study. Subsequently, the Methodology chapter will describe the design science approach that was followed during this research. After that, the fourth chapter will explain the manner in which the stakeholder perspectives of both residential consumers and Pure Energie were analysed. Then, the design process of the initial HEMS value proposition will be described from Chapter 5. After that, Chapter 6 will describe the validation of this design and evaluate it through the Discussion section. Finally, Chapter 7 will present the final design of the value proposition for the HEMS, after which the conclusions, the limitation of this study and directions for future research are provided.

2. Theoretical Framework

Below, this chapter will provide the lens through which the main elements out of the central research question of this paper were analysed. Therefore, marking the scope of this study. The central research question will be dissected, after which all its elements will be clarified comprehensively and coherently. The elements will be linked to relevant theories, frameworks and models as well. First, several HEMS definitions that were extracted from related literature will be provided, serving as the foundation for this paper's formulated HEMS definition, which was thereafter set. Secondly, four core HEMS benefits for residential consumers that were identified through a literature review will be revealed. The third subchapter will subsequently be specifically dedicated to enhancing residential consumer adoption within the HEMS context. Then, the fourth section will introduce the Value Proposition Canvas of Osterwalder et al. (2014) and explain the manner in which this tool can be utilised for the design of a HEMS value proposition that aims to enhance residential consumer adoption. Lastly, the added value which derived from this Theoretical Framework chapter will be summarized, as will explanation be provided related to the specific roles each research question element served within this study.

2.1 HEMS definition

Due to the rapid technological advancements, as well as the emergence of innovative smart home components, the definition of the HEMS has been evolving over the past years. According to Zhou et al. (2016), the HEMS is defined as an optimized system that offers energy management services to effectively monitor and control the generation, storage, and consumption of electricity within smart homes. In addition, Shareef et al. (2018) emphasize that the HEMS has the ability to reduce electricity usage for residential consumers by incorporating a demand response tool. This tool enables the system to shift and minimize household electricity demand, thereby improving the efficient utilisation of electricity. Furthermore, the HEMS generates optimal consumption schedules by considering various factors such as electricity costs, environmental concerns, load profiles, and end-user comfort. The system is able to interact with smart home appliances and is also capable of communicating with utilities to exchange of data, including electricity tariff prices. Consequently, Al-Ali et al. (2017) argue that the installation of the HEMS therefore supports end-users in comprehending the contribution of each smart home device towards their overall electricity bill. The IoT has increasingly emerged as a pivotal technology for communication and control across various devices confined within home area networks and/ or local area networks. Therefore, utilisation of IoT-based technologies especially in conjunction with Big Data analytics is particularly relevant, since it enables residential consumers to digitally access the usage patterns of their appliances via mobile phones, tablets, PCs, and other devices. Hence, Sharda et al. (2021) define the HEMS as an IoT-based cluster of smart home appliances with inherent communication capability that fosters an environment for efficient electricity management.

Based on the definitions gathered above, the HEMS will within this paper be defined as: a sophisticated IoT-based system, capable of minimizing electricity expenses for residential consumers, by generating optimal consumption schedules through an integrated DR tool that

considers a multitude of factors. Due to the interaction-facilitating capability of the HEMS, as well as data exchanges between smart home components and utilities, its end-users gain digital insights into their appliance usage patterns. This empowers residential consumers with the ability to raise electricity efficiency and conduct informed decisions regarding consumption. Crucial smart home components under the purview of the HEMS encompass, yet are not limited to, private photovoltaic (PV) solar panels, home batteries, heat pumps, electric vehicles (EVs) and EV-associated charging stations.

2.2 HEMS benefits for residential consumers

While analysing the body of literature, related to the HEMS end-users (i.e., residential consumers) experiences and perspectives, the individual benefits that the system offers significantly emerged as the factors which shape residential consumer attitudes related to adoption. Therefore, a thorough literature review was conducted to elucidate the HEMS benefits for residential consumers. The depth of this review was driven by 53 initially gathered papers for the first stage. Subsequently, this number was reduced to 20 relevant papers which will serve below as the foundation for the framework upon which this study has determined the HEMS benefits for residential consumers. Within the following chapter, a procedural outline regarding the selection process for these papers will be described in further detail. Figure 1 illustrates several of the specific search terms that were utilised to acquire relevant literature for the HEMS benefit framework. A complete list regarding these terminologies is included within Appendix B of this paper.

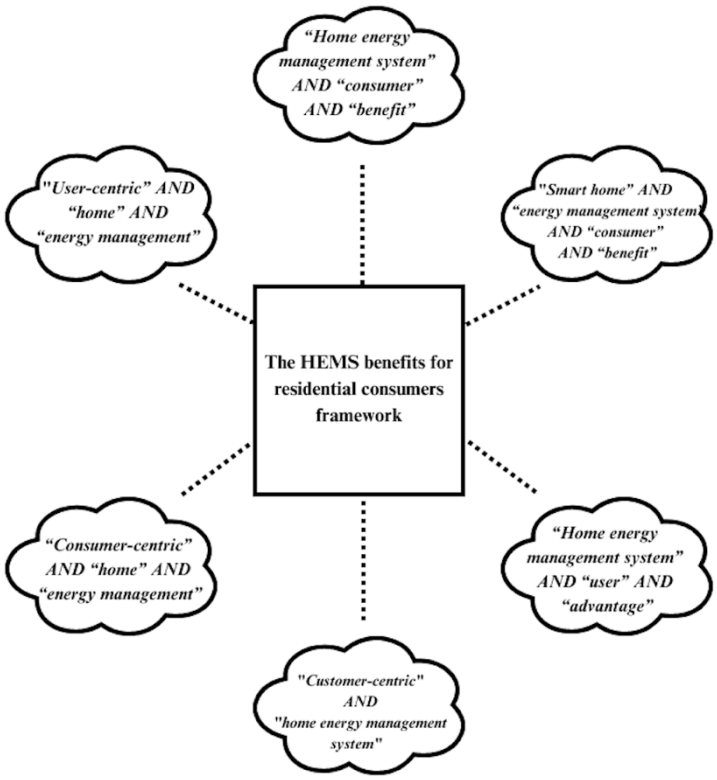

Figure 1. Examples of utilised search terminologies regarding the HEMS benefits for residential consumers framework

Within the scope of the framework's literature review, eleven distinct HEMS benefits for residential consumers were identified by all the 20 reference papers combined, as depicted in Table 1 below. This table highlights the frequency of which a specific benefit was determined as a HEMS benefit by the authors. Therefore, providing insights into the relative significance of all eleven benefits. Ultimately, several benefits were categorized under four overarching benefits, representing the core HEMS benefits for residential consumers specifically identified within this study. Figure 2 provides an illustration of these core benefits. Specific benefits that were scaled under one of the four core benefits are included as well.

Among the main themes emerging from the literature review, *the preservation of residential consumer comfort* surfaced as a critical prerequisite related to the HEMS. This theme echoed in nine out of the 20 papers that were analysed. Importantly, the preservation of residential consumer comfort was therefore not determined as a standalone HEMS benefit. Rather, it was identified as an essential condition that must be fulfilled, after which additional benefits can be realised, since the HEMS should not diminish the smart home conditions of residential consumers. Below, each of the four core HEMS benefits for residential consumers, as displayed in Figure 2 will be further explained.

Table 1. The HEMS benefits for residential consumers framework (N = 20)

			FRAMEWORK REFERENCE																			
		Total number of determinations:	Aurangzeb et al. (2022)	Chen et al. (2019)	Di Giorgio & Pimpinella (2012)	Etedadi Aliabadi et al. (2021)	Fotouhi Ghazvini et al. (2017)	Hou et al. (2019)	Hu et al. (2018)	Javaid et al. (2017)	Jin et al. (2017)	Khezri et al. (2020)	Lobaccaro et al. (2016)	Mahmood et al. (2016)	Merdanoğlu et al. (2020)	Paetz et al. (2012)	Siano et al. (2013)	Wang et al. (2015)	Wang et al. (2021)	Yao et al. (2015)	Yoon et al. (2014)	Zhao et al. (2021)
HEMS BENEFIT	Financial savings	**20**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Optimal management of electricity	**14**			X	X		X	X	X	X		X	X	X	X	X	X	X		X	
	Increased convenience	**5**						X			X			X	X	X						
	Increased self-consumption	**5**				X								X	X			X	X			
	Reduction of electricity load	**4**				X				X			X								X	
	Reduced ecological footprint	**3**		X							X					X						
	Higher transparency	**2**											X			X						
	Facilitating energy trading	**1**				X																
	Prolonging (home and EV) battery life	**1**						X														
	Provide ancillary services	**1**																	X			
	Technological orientation	**1**														X						

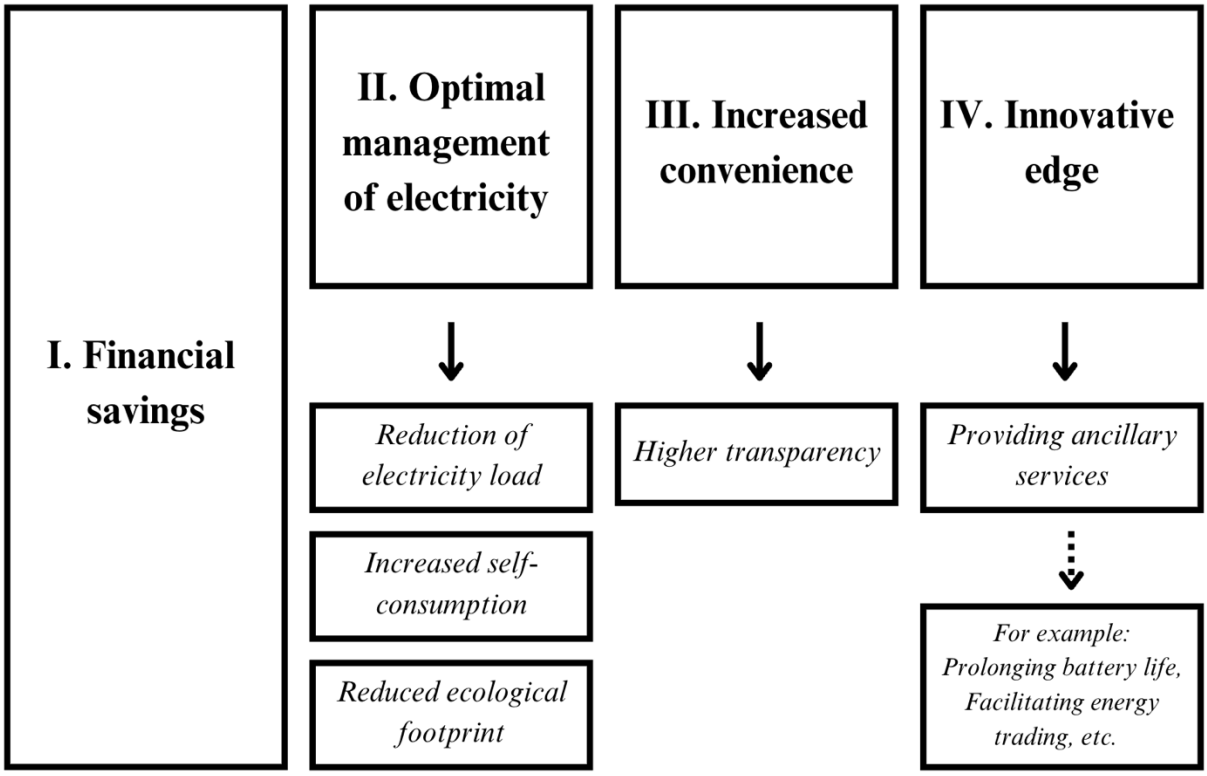

Figure 2. The four core HEMS benefits for residential consumers

I. **Financial savings**: A universally recognized benefit were the financial savings that the HEMS can secure for residential consumers. All authors across the 20 framework papers highlighted this benefit. By minimizing electricity expenditure, smart households can maximize their profit, thus reducing their overall energy bills, as argued by Wang et al. (2015). However, the estimated extent of these potential financial savings varies greatly among the researchers. Etedadi Aliabadi et al. (2021) suggested potential savings might start at 5%, whereas Aurangzeb et al. (2022) argued these savings could mount up to as much as 63.02% annually. Therefore, financial savings was determined as the first core HEMS benefit for residential consumers within this study.

II. **Optimal management of electricity:** Despite its close connection to the financial savings benefit, the optimal management of electricity has been identified as a separate benefit. It pertains to the efficient utilisation of electricity, which, as noted by Hu et al. (2018) and Siano (2013), results in electricity savings and reduced overall costs. However, this benefit is not solely tied to financial savings, as it for instance plays a crucial role related to the prevention of short circuits within smart homes as well. In addition to this *reduction in electricity load*, the optimal management of electricity yields two further sub-benefits, as depicted in Figure 2 above, namely: *increased self-consumption* and a *reduced ecological footprint*. Below, these sub-benefits will be further elaborated:

- *Reduction of electricity load:* As suggested by Mahmood et al. (2016), the effective management of both utility-supplied as well as self-generated electricity optimizes the appliance utilisation within smart homes. Moreover, by directing electricity to the appropriate components at suitable intervals, it is possible to flatten large electricity load peaks within a smart home's profile (Javaid et al., 2017). Furthermore, Lobaccaro et al. (2016) noted that reducing electricity load also results in lower peak-to-average ratios and peak loads within residential households. Therefore, by providing a more reliable and peak-shaved electricity flow, the optimal management of electricity contributes to local grid stability and the prevention of short circuits within residential consumer smart homes.

- *Increased self-consumption:* Furthermore, since the optimal management of electricity reduces the risk of smart home grids becoming overloaded, electricity is also less likely to flow back towards the centralized national grid (Etedadi Aliabadi et al., 2021). Therefore, according to Wang et al. (2015) and Merdanoğlu et al. (2020), optimal electricity management can increase the utilisation of self-generated RES (e.g., private solar panels) within smart homes. Besides financial savings, this increased self-consumption mitigates electricity waste as well.

- *Reduced ecological footprint:* This mitigation of electricity waste through increased self-consumption, as described above, contributes to the general sustainability of residential consumer smart homes. Therefore, Jin et al. (2017) and Chen et al. (2019) argue that optimal electricity management, specifically through increased self-consumption, directly results in lower carbon emissions as well. Paetz et al. (2012) further claimed that adoption of the HEMS could therefore reduce a smart home's ecological footprint as result of the system's optimal electricity management. This sub-benefit holds appeal for residential HEMS end-users with environmental considerations, as well as future sustainability-oriented legislation. Overall, it was decided to scale this sub-benefit under the second core HEMS benefit rather than determine it as an independent benefit, due to its direct theoretical link with the optimal management of electricity.

III. **Increased convenience:** While preserving residential consumer comfort was determined as a prerequisite for the HEMS within the scope of this study, five out of the 20 framework papers argued that the HEMS is able to *additionally* increase residential end-user convenience. Moreover, the HEMS is capable of reducing end-user frustration (Mahmood et al., 2016) and in turn increase overall convenience (Merdanoğlu et al., 2020), by providing better flexibility (Hou et al., 2019). Furthermore, this third core HEMS benefit also includes the provision of comprehensive data by the HEMS, facilitating for instance historical comparisons of the electricity consumption within smart homes. Therefore, the provided the sub-benefit of *higher transparency* (Lobaccaro et al., 2016) is scaled under this core HEMS benefit for residential consumers.

IV. **Innovative edge:** For this study, this fourth and final core HEMS benefit was composed out of several aspects which are linked with the state-of-the-art status that smart households can achieve, once its residential consumers decide to adopt the HEMS, namely: *technological orientation* (Paetz et al., 2012), as well as *providing ancillary services* (Wang et al., 2021), such as *prolonging the battery life of both home batteries as well as EVs* (Hou et al., 2019) and *facilitating energy trading* (Etedadi Aliabadi et al., 2021). Elaborating further, through HEMS adoption, residential consumers are believed to be capable of creating an *innovative edge*, opposed to non-adopting residential consumers. This innovative edge is related to the most state-of-the-art, as well as future smart home technologies and especially visible related to sub-benefits such as prolonging battery life, as the HEMS is a direct cause of this effect. While the ancillary service of peer-to-peer energy trading is currently not (yet) dominant within the Netherlands, this benefit coupled with extended battery life, could translate into additional indirect financial savings for residential consumers. Therefore, the incorporation of these sub-benefits under this fourth core benefit is reflective for the HEMS's general potential as a critical tool to create an innovative edge for residential consumers who decide to adopt the system. Moreover, an edge of preparedness for upcoming technological innovations related the rapidly advancing smart home technologies and smart grid developments. Therefore, establishing the foundations for realisation of future HEMS benefits for residential consumers and offering a distinct advantage over less technologically advanced smart homes, given the trajectory of the energy transition.

Given that these individual HEMS core benefits are, in theory, drivers for residential consumer adoption, it was deemed important to ensure that these benefits were integrated into the design of the value proposition for the HEMS of this study. Furthermore, it was expected that residential consumers would primarily be attracted to the financial savings that the HEMS can provide. Additionally, it was anticipated that residential consumers would recognize the HEMS's potential to optimize their electricity management as well as consumption, resulting in a reduction of electricity load, increased RES self-consumption, and a reduced ecological footprint. However, it should be noted that the electricity grid stability within the Netherlands was of high quality at the time of writing, and the reduction of electricity load benefit might therefore have been less noticeable. Residential consumers were also expected to recognize and appreciate the increased convenience core benefit, as well as this benefit's incorporated sub-benefit of higher transparency. Lastly, expectations were doubtful whether residential consumers would completely identify the innovative edge benefit since this benefit primarily relates to concepts which were not (yet) dominant within the Netherlands, such as home batteries and (peer-to-peer) energy trading. Furthermore, this specific core benefit therefore required a certain level of concept-related knowledge, in order to be recognised.

2.3 Enhancing residential consumer adoption

Based on relevant literature, the HEMS definition, as well as the related benefits for residential consumers are now clarified. However, as mentioned within the Introduction chapter of this paper, Sanguinetti et al. (2018) argued that the residential consumer adoption of the HEMS is lacking behind practical expectations. Therefore, it can be argued that the HEMS benefits alone are not satisfactory for residential consumer adoption. Hence, it is vitally important for this study to analyse the manner in which their adoption can potentially be enhanced. Moreover, the integration of relevant literature on this matter, as well as the application of these contributions throughout this research are critical processes for the central research question of this paper to be answered. Therefore, the following subchapters will present and briefly describe two models that could potentially contribute to enhancing residential consumer adoption of the HEMS. Moreover, explanation will be provided on the manner in which these models can be utilised as supporting tools to answer the central research question of this paper.

2.3.1 The Innovation-Decision Process model

The first model that is integrated within this study's Theoretical Framework, is the Innovation-Decision Process (IDP) model, developed by Rogers (2003) and illustrated below in Figure 3.

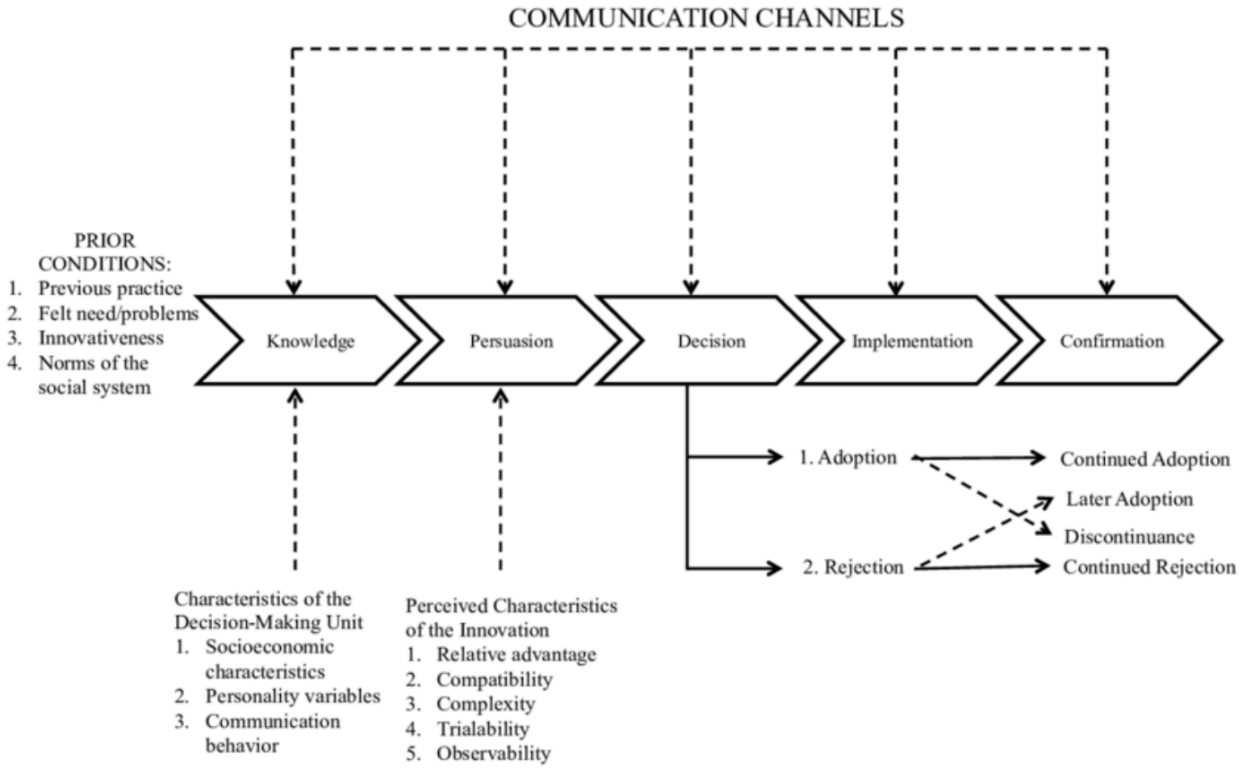

Figure 3. The Innovation-Decision Process (Rogers, 2003)

As can be seen above, the IDP represents a sequence of five stages, namely: Knowledge, Persuasion, Decision, Implementation, and Confirmation. This process elucidates the trajectory of cognitions and behaviours from the initial awareness related to an innovation, up to the final adoption or rejection, as well as the potential reversal of this decision.

Knowledge: The IDP initiates with the "Knowledge" stage, in which an individual becomes aware of the innovation's existence yet lacks a detailed understanding of its functionality and application. During this stage, this knowledge gap is gradually filled, as the individual explores and assimilates information about the innovation.

Persuasion: The second stage involves the forming of an attitude towards the innovation, influenced by subjective judgements and social norms. Therefore, the "Persuasion" stage is critical in steering the individual's tendency towards either adopting or rejecting the innovation.

Decision: During the 'Decision' stage, the individual engages in activities that lead to the actual decision of either adopting or rejecting the innovation. As illustrated above, this decision is influenced by a multitude of factors, such as the perceived benefits, perceived barriers, and the individual's general predisposition towards change.

Implementation: During this stage, the innovation is adopted and implemented. Therefore, this stage may require innovative adjustments within existing systems, to accommodate the innovation. Moreover, problems which require new solutions might surface during this stage.

Confirmation: Finally, the "Confirmation" stage manifests the individual seeking affirmation regarding the adoption decision. Here, the outcomes of the adoption are evaluated, which either leads to sustained utilisation of the innovation, or the possibility of discontinuance, if the results are not beneficial/ desirable.

Since the value proposition design process of this research was aimed specifically at enhancing residential consumer HEMS adoption, particularly the first three IDP stages are highly relevant for this study. Moreover, the five characteristics within the Persuasion stage, related to the HEMS perception of residential consumers require thorough analysis and integration within the final design of the value proposition, in order for the central research question to be answered properly. Notable is that the IDP is not proposed as a linear path through the five stages. Hence, the "Persuasion" stage can for instance initiate once a residential consumer becomes aware of the HEMS and this individuals' knowledge can possibly continue to develop after interest and the decision to adopt the HEMS has been made. Therefore, the stages can be characterised as dimensions as well (Rogers, 2003).

2.3.2 The Technology Acceptance Model

The second integrated model, is the Technology Acceptance Model (TAM), as proposed by Venkatesh & Davis (1996) and illustrated below in Figure 4. This model states that an end-user's *intention to use* a system is influenced by two significant factors, namely: *perceived*

usefulness and *perceived ease of use*. Perceived usefulness is defined as the degree to which an individual believes that utilisation of a particular system would *enhance* this individual's job performance. Perceived ease of use, on the other hand, refers to the degree to which an individual believes that employing a particular system involves a low degree of effort. The foundational premise of the TAM suggests that these two determinants play a pivotal role in shaping an end-user's attitude towards the technology, thereby influencing their intention to use, which ultimately impacts their *actual system use* and thus *acceptance* of the technology.

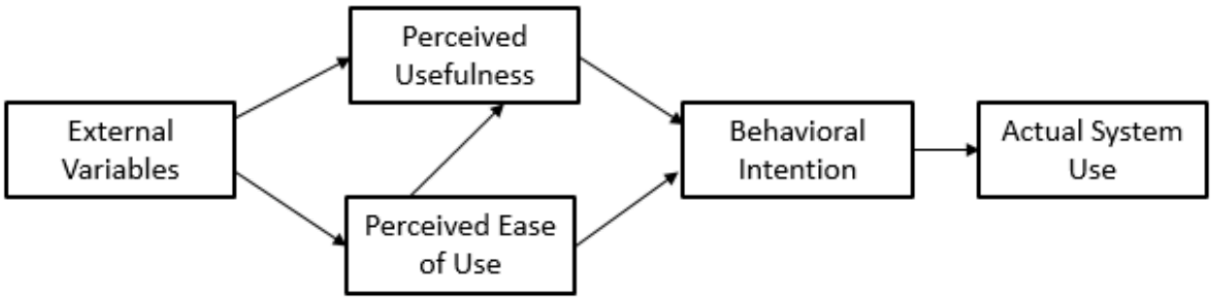

Figure 4. The Technology Acceptance Model (Venkatesh & Davis, 1996)

Therefore, within the context of designing a value proposition for a HEMS that aims to enhance residential consumer adoption, utilisation of the TAM can provide a solid framework to understand, evaluate, and predict residential end-user behaviour. Moreover, the perceived usefulness is a crucial determinant for the HEMS value proposition. If residential consumers perceive the HEMS to be beneficial, the likelihood of their actual system use will be higher, thereby *enhancing* acceptance of the HEMS. In other words, enhancing residential consumer adoption. In addition, the perceived ease of use could directly impact residential consumer adoption of the HEMS. Moreover, if the HEMS is perceived as too complex or difficult to use, potential end-users may be deterred, reducing the likelihood of HEMS residential consumer adoption, regardless of the perceived usefulness. Therefore, by improving both the HEMS perceived usefulness and ease of use within the value proposition design, the behavioural intention to use the HEMS can theoretically be enhanced. Therefore, the TAM can potentially contribute to this study, by providing insights into the key drivers of residential consumer adoption, which can be integrated within the value proposition design for the HEMS.

2.4 Designing a value proposition for the HEMS

In order to support the actual design process of a value proposition for the HEMS, this study integrated a foundational theoretical tool for achieving this, namely the Value Proposition Canvas (VPC) developed by Osterwalder et al. (2014) and displayed in Figure 5 below.

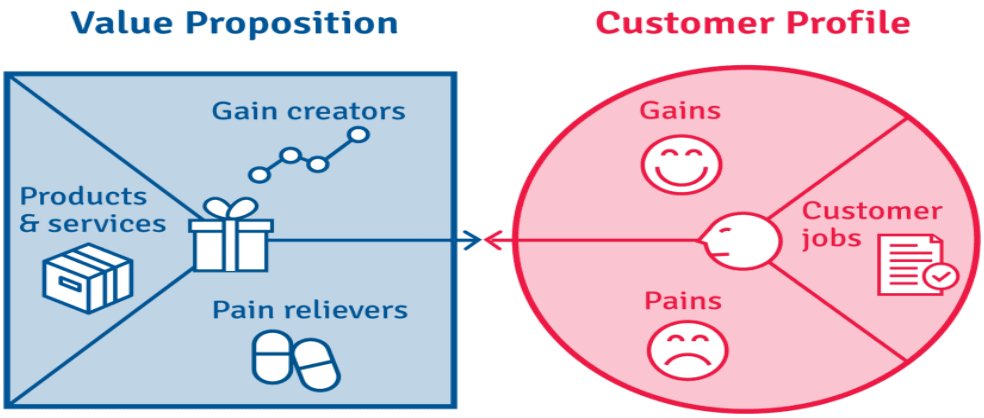

Figure 5. The Value Proposition Canvas (Osterwalder et al., 2014)

The VPC consists of two key sides, namely: the *Value (Proposition) Map* and the *Customer Profile*. The Value (Proposition) Map describes the unique combination of *products & services, pain relievers* and *gain creators*, aimed to create value for customers, whereas the Customer Profile describes the targeted customers, including their *jobs*, *gains,* and *pains*. Therefore, both of the main sides consists of three VPC fragments. Overarching this dual focus, the ultimate goal of the VPC is to achieve *Fit*. This refers to the alignment between the Value (Proposition) Map and the Customer Profile.

Related to this study's scope, the Customer Profile was renamed to the *Consumer Profile*. Furthermore, the utilisation of the VPC within this research enables for the identification and articulation of the specific manners in which the HEMS can create value for residential consumers. Moreover, within this study, the VPC will contribute to achieving Fit between the residential consumers as HEMS end-users and Pure Energie as HEMS designer and supplier. Thereby, striving to counter the lacking residential consumer adoption of the HEMS and aiming to enhance this. Furthermore, as the Dutch residential consumer electricity market is a rapidly changing environment, the iterative nature of the VPC also offers a pathway to continuously refinement of the value proposition design for the HEMS, based on potential ongoing (residential consumer) feedback, evolving market trends, iterative design decisions, etc. This suits the design science research methodology that was followed during the course of this research and will be further explained within the following chapter particularly well. Moreover, once the value proposition design will be initiated in Chapter 5 of this paper, a detailed explanation regarding both sides of the VPC, as well as the six VPC fragments will be provided.

2.5 The added value derived from the Theoretical Framework

After having extensively elaborated on all the elements of this paper's central research question and constructing the Theoretical Framework accordingly, a concise enumeration of the key takeaways is provided below:

I. The remainder of this paper will regard the HEMS according to this study's definition, which was stated as: a sophisticated IoT-based system, capable of minimizing electricity expenses for residential consumers, by generating optimal consumption schedules through an integrated DR tool that considers a multitude of factors. Furthermore, crucial smart home components under the purview of the HEMS encompass, but are not limited to, private (PV) solar panels, home batteries, heat pumps, EVs, and EV-associated charging stations.

II. Based on eleven distinct HEMS benefits for residential consumers, identified within literature, four core HEMS benefits were ultimately integrated within the Theoretical Framework of this study. Moreover, several of these incorporated (multiple) sub-benefits. The four core HEMS benefits for residential consumers, as displayed in Figure 2, were determined as: ***financial savings***, ***optimal management of electricity*** (incorporated sub-benefits: *reduction of electricity load*, *increased self-consumption*, and *reduced ecological footprint*), ***increased convenience*** (incorporated sub-benefit: *higher transparency*), and an ***innovative edge*** (incorporated sub-benefit: *providing ancillary services*, such as *prolonging battery life* and/or *energy trading*). Given that these benefits are factors that are theoretically capable of enhancing residential consumer adoption, it was essential to discover which of these benefits would practically be identified and/ or recognized by residential consumers, thereby confirmed as beneficial and which specific benefits were not perceived as such within this study. Moreover, it was crucial to ascertain the underlying factors responsible for causing the above.

III. Related to this, the *Innovation-Decision Process (IDP)* model and the *Technology Acceptance Model (TAM)* were introduced and integrated as theoretical foundation for enhancing residential consumer adoption within the Theoretical Framework of this paper. In particular, the *relative advantage* of the IDP's *persuasion characteristics* and the *Perceived Usefulness* as well as *Perceived Ease of Use* dimensions of the TAM could be leveraged within this study to emphasize the core HEMS benefits for residential consumers within the value proposition, since its ultimate design aim is to enhance residential consumer adoption of the HEMS. Therefore, the IDP and TAM were expected to portray a crucial role within this research, related to enhancing the residential consumer adoption potential within the value proposition, as well as increasing residential consumer understanding related to the four determined core HEMS benefits.

IV. Lastly, the *Value Proposition Canvas (VPC)* was integrated within the Theoretical Framework of this study as well since this tool was ultimately utilised as supporting tool to actually design a value proposition for the HEMS of this research. The following chapter will delve deeply into the processes that were conducted within this study to achieve *Fit* between the *Value (Proposition) Map* side of the VPC and the *Consumer Profile* side.

3. Methodology

This chapter will in detail describe and explain the design science research approach that was followed during this study, in an attempt to answer the central research question of this paper. Moreover, shedding light on the reasoning that underpinned the conducted decisions during this process. Therefore, the chapter will serve as a roadmap through all the iterative design stages of this study, from the initial problem identification and research motivation to the final re-design of the Value Proposition Canvas for the HEMS, as proposed treatment for the problem context of this study. Alongside this, the methods that were employed to validate and evaluate this treatment's effectiveness will be explained, by detailing the specific techniques and measures that were chosen, as well as their application and significance within the context of this design study. Furthermore, the data collection and analysis methods that were utilised will be explained, offering an overview of the data's relevance, the process through which it was gathered, and the exact analysis conducted to extract meaningful findings and insights. However, before the aforementioned will be described, the first subchapter below will be dedicated to elaborating on the collaboration with the Dutch utility Pure Energie. Then, the theoretical design science foundations for this study's research methodology will be briefly described, after which the complete design science research methodology of this study will extensively be explained.

3.1 The collaboration with Dutch utility Pure Energie

As mentioned above, this study was conducted in collaboration with Pure Energie, a growing, yet one of the more established utilities within the Netherlands. This utility's origins date back to the founding of the Raedthuys Holding B.V. in 1995, which started with the development of wind energy projects. Since then, Pure Energie has built more than 80 wind turbines within the Netherlands and installed over 50,000 solar panels. Furthermore, all of their electricity supplied to residential consumers is generated out of these RES projects. In 2022, the company was awarded as the most sustainable utility of the Netherlands for the past nine years in a row and at the time of writing, the company strived to become one of the nation's first utilities that would offer a HEMS, integrated with an automated demand response tool, to Dutch residential consumers. Furthermore, Pure Energie aimed to provide residential consumers access to the home battery smart home component, parallelly with the implementation of their desired HEMS (Pure Energie, 2023). Therefore, this collaboration strengthened the motivation and aim of this study, as it allowed the opportunity to integrate two crucial stakeholder perspectives related to the residential consumer energy sector within the design process of the HEMS value proposition. The following chapter will delve deeper into these specific stakeholder perspectives. Additionally, this collaboration enabled and fostered the gathering of first-hand data from both a utility as well as residential consumers. This, in turn, contributed to the alignment within the Value Proposition Canvas that was utilised within this study, thereby fostering Fit.

3.2 Theoretical design science foundation for this study's research methodology

According to Vom Brocke et al. (2020), design science research builds upon prior design knowledge, to create innovative designs and novel understandings. Subsequently, future design problems are able to benefit from this knowledge. Therefore, the research methodology of this study was built upon three existing as well as established contributions within the design science research literature, namely: Hevner et al. (2004), Peffers et al. (2007) and Wieringa (2014). Appendix C provides general background information, as well as the key takeaways related to these design science research contributions. Below, the detailed reasoning for integrating each of these contributions is described:

I. **Hevner et al. (2004):** While constructing the design science research methodology for this research, the seven guidelines for design science in information systems research, proposed by Hevner et al. (2004) were found as the most established contribution within design science literature. Therefore, this design science contribution was integrated as the starting point that could provide framework and scope limits for the design process of the value proposition for the HEMS.

II. **Peffers et al. (2007):** Thereafter, the DSRM of Peffers et al. (2007) was identified as the most established research methodology within design science literature. Although the DSRM is not necessarily described as a linear process, this contribution was integrated to provide guiding directions within the broad design scope that was determined. Moreover, during this stage of the research, no practical use case of a utility-supplied automated HEMS with integrated DR tool was yet available within the Dutch energy market. Therefore, the DSRM was utilised to form an established approach foundation for the design process of the value proposition from scratch.

III. **Wieringa (2014):** Thirdly, the book of Wieringa (2014) was integrated within this study to strengthen, extend and modernise the DSRM from Peffers et al. (2007), as this book was observed to emphasize greater on the validation process within design science. Moreover, the *treatment* terminology of Wieringa (2014) was deemed more suitable instead of *solution* (Hevner et al., 2004 & Peffers et al., 2007), considering the problem context of lacking residential consumer HEMS adoption. Ultimately, the four design stages composed of eleven conducted steps, were constructed from joint inspiration that was primarily gained from the design cycles of Wieringa (2014) and the DSRM of Peffers et al. (2007). Furthermore, incorporating the principles of Hevner et al. (2004) as secondary theoretical backbone layer and for determining scope limits related to the design process of the value proposition.

3.3 This study's design science research methodology

The conducted design science research methodology of this study consisted of four design stages, that were composed out of eleven conducted steps. Figure 6, which at the time of writing was entirely applied, provides a complete illustration of these four design stages as well as the subdivided steps. Below, the intended purpose of each design stage and every step of this study's design science research methodology will be extensively explained.

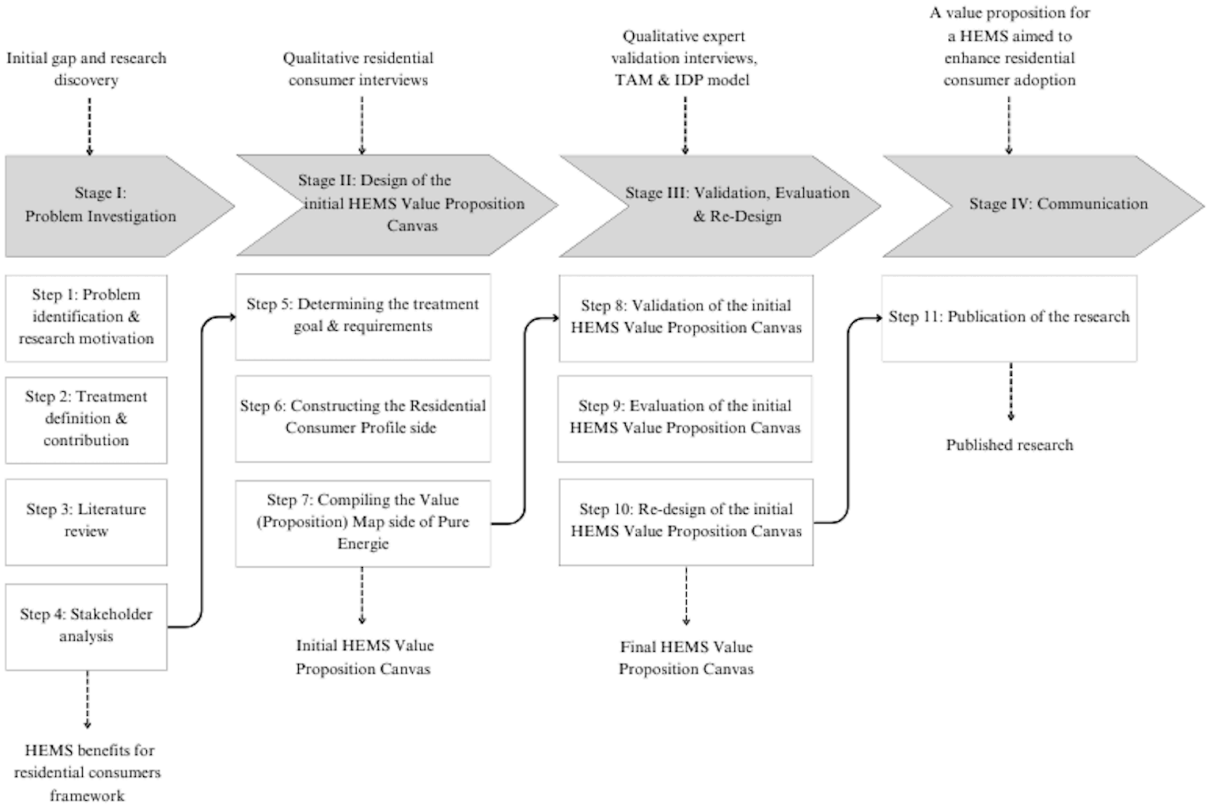

Figure 6. The design science research methodology of this study

Stage I: Problem Investigation

In accordance with both Wieringa (2014) and Peffers et al. (2007), a comprehensive problem investigation stood central within this stage of this research. Therefore, the first stage consisted of four steps to identify the problem (context), define a proposed treatment for this matter, gain a deeper theoretical understanding and an analysis of the involved stakeholders.

Step 1: Problem identification & research motivation

As described within the Introduction chapter, the first step of this research's methodology served to identify this study's central problem, as well as the problem context (Wieringa, 2014). Thereby, determining the global shortfall of HEMS adoption by residential consumers as this paper's research motivation, based on the problem's relevance (Hevner et al., 2004).

Step 2: Treatment definition & contribution

After the problem context was identified, a treatment had to be defined (Wieringa, 2014). Therefore, the design of a HEMS value proposition aimed to enhance residential consumer adoption was proposed to address the determined problem. Moreover, this treatment form was deemed as suitable for mitigating efforts towards the lacking HEMS adoption by residential consumers. As a result of this, the central research question of this paper could be stated within this step.

Step 3: Literature review

During the third step of this study's research methodology, an extensive review of existing literature was conducted, to acquire a deeper understanding of the problem and to comprehend the manner in which all elements from the central research question interrelated. Therefore, grounding the research within a solid theoretical framework (Peffers et al., 2007), as presented within Chapter 2.

Returning to the earlier statement within the Theoretical Framework chapter, regarding the relevant paper selection process in relation to the HEMS benefits for residential consumer framework: 53 initial papers emerged out of the search terminologies that are provided within Appendix B. Subsequently, this number was steadily reduced to 20, in order to construct a clear and solid framework. This reduction was based on the relevance of each contribution for determining residential consumer benefits, judged by the total number of citations. The publication year of each framework paper was considered as well. For completeness, papers from the years 2012 up to and including 2022 were incorporated within the final selection of the 20 framework papers, to cover the entire last decade. Overall, relative older papers were slightly less represented, yet more established in terms of total citations. The more recent contributions were included to a greater extent within the framework, as the technological developments related to the HEMS progress rapidly and this research aimed to design a value proposition for a HEMS that is considered as state-of-the-art.

Step 4: Stakeholder analysis

Then, an explicit stakeholder analysis was performed, in line with Wieringa (2014). By utilising the *Onion Diagram* of Alexander (2005), the stakeholder perspectives of both Pure Energie and Dutch residential consumers were dissected within the HEMS context, to foster an early Fit within the Value Proposition Canvas of Osterwalder et al., 2014. This contributed to determining the stakeholder roles of both Pure Energie and residential consumers, as to the identification of Pure Energie's underlying goals, motives and needs related to the implementation of the HEMS as a product/ service. A detailed exploration of this step will be provided in the subsequent chapter.

Stage II: Design of the initial HEMS Value Proposition Canvas

The second stage delved into the actual design process of the value proposition for the HEMS. As was determined within the Theoretical Framework chapter, the Value Proposition Canvas of Osterwalder et al. (2014) was designated as the supporting tool for this design process.

Therefore, the aim of this stage was to construct the Consumer Profile related to the residential consumers (i.e., the Residential Consumer Profile) and to compile the Value (Proposition) Map of Pure Energie. Together, these two main sides encapsulated the initial design of the HEMS value proposition. A detailed description of this process will be provided within Chapter 5.

Step 5: Determining the treatment goal & requirements

According to Wieringa (2014), a treatment's goal serves as a compass directing the design process towards the creation of a treatment that meets the specific outcomes it aims to achieve. Therefore, treatment requirements define the specific criteria or characteristics that this treatment must meet to accomplish its treatment goal (Wieringa, 2014 & Peffers et al., 2007). Moreover, treatment requirements function as a roadmap which offers tangible guidelines to address a real-world problem (Hevner et al., 2004). Hence, a specific treatment goal and clear treatment requirements for the HEMS value proposition were therefore determined within this step since these are considered indispensable for a focused and efficient design process (Wieringa, 2014).

Step 6: Constructing the Residential Consumer Profile side

Since the residential consumer needs, underlying HEMS adoption motives, potential barriers, and recognised benefits related to the HEMS adoption could not yet be completely determined during the stakeholder analysis, data related to this was gathered through the conduction of qualitative interviews with four Dutch residential consumer focus groups. For these consumer interviews, Pure Energie hired Newcom Research & Consultancy B.V., an independent research company that provides organisations full-service market research insights to meet the needs of their target audience.

Therefore, all the conducted interview sessions were carried out by two of their researchers. Moreover, each interview consisted of a brief introduction, two main sections, and a general discussion section. Hence, the duration of each session was therefore approximately two hours. Subchapter 5.2 will elaborate further on the specific context and questioning that was discussed within each part of the interview script. Next to the interview room, an additional researcher from Newcom Research & Consultancy B.V., several representatives from the Pure Energie HEMS project group (this varied per interview session) and this study's researcher were present and able to monitor the residential consumer discussions through video and audio connection. The participants were made aware of this fact during the introduction part of every interview session. In total, 36 participants were questioned, spread across four focus groups of Dutch residential consumers. After consent of all participants, the sessions were recorded as well. Two of the interview sessions occurred in the city of Utrecht and the other two sessions were held in the city of Arnhem. Both consumers of Pure Energie, as well as consumers of other utilities within The Netherlands were interviewed. The composition of each focus group was made as diverse as possible by Newcom Research & Consultancy B.V., related to the spread in gender, age, education level, etc. Moreover, the ownership of solar panels was registered for every participant and considered within the distribution.

After all interview sessions were conducted, Newcom Research & Consultancy B.V. analysed the extracted data and subsequently held a presentation at the Pure Energie office, revealing their key findings. Thereafter, this study's researcher scheduled an additional meeting with the conducting researchers of Newcom Consultancy & Research B.V., to extensively discuss their key findings further. Therefore, this study's researcher slightly revised the key findings to incorporate them within the context of this research. Subchapter 5.3 will dive deeper into this, as well as the integrated key findings from the residential consumer interview sessions. Ultimately, this data was then utilised as the foundation for construction of the Residential Consumer Profile side of the Value Proposition Canvas, creating a structured and detailed understanding of the by Pure Energie targeted residential consumer segments. Moreover, as described by Osterwalder et al. (2014), the Residential Consumer Profile consists of the Residential Consumer Jobs, Pains and Gains Value Proposition Canvas fragments, which could be completed within this step of the research.

Step 7: Compiling the Value (Proposition) Map side of Pure Energie

The final step of the second design stage involved compiling the Value (Proposition) Map of Pure Energie. This opposing main side of the Value Proposition Canvas was developed out of data gathered from bi-weekly meetings with the Pure Energie HEMS project group, strategic company documentation, several explicit internal talks that were additionally scheduled, and the notes taken during these meetings. The duration over which this data was gathered, spanned from September 2022 to June 2023. Ultimately, the compiled Value (Proposition) Map of Pure Energie encapsulated a unique combination of Products, Services, Pain Relievers and Gain Creators which Pure Energie intended to provide, related to their desired implementation of the HEMS (Osterwalder et al., 2014). Moreover, the manner in which the company envisioned to offer their residential consumers value at this specific stage of the research. Specifically, during the beginning of April 2022.

Stage III: Validation, Evaluation & Re-Design

Since the initial HEMS Value Proposition Canvas was now designed, the third stage of the design process served to validate this value proposition (Peffers et al., 2007 & Wieringa, 2014). Specifically, to validate the degree of Fit between the Residential Consumer Profile and Pure Energie's Value (Proposition) Map. Subsequently to this validation, an evaluation of the treatment goal and requirements occurred, after which the final re-design was completed to present a value proposition for the HEMS aimed to enhance residential consumer adoption (Hevner et al., 2004, Peffers et al., 2007 & Wieringa, 2014). Chapter 6 and 7 will illustrate this.

Step 8: Validation of the initial HEMS Value Proposition Canvas

According to Wieringa (2014), the validation of a treatment justifies whether this treatment would contribute to stakeholder goals once actually implemented. Moreover, whether it would treat the problem (context). Therefore, as mentioned above, the initial HEMS Value Proposition Canvas of this research was validated through the conduction of four qualitative expert interviews. Additionally, to validating the justification as described above, these expert interviews and opinions contributed to benchmarking the degree of Fit within the Value

Proposition Canvas. Moreover, it allowed for the gathering of unique insights and perspectives which could in further steps of the design process be utilised for the further *optimisation* of the initial HEMS value proposition, to evolve it into one that aimed to *maximally* enhanced the residential consumer adoption potential within the limits of this study. Below, the four qualitative expert interviews will be elaborated on more in-depth:

According to Wieringa (2014), within an expert interview, an expert (panel) discusses the designed treatment after which these experts predict the believed effects that will be caused by interaction of this designed treatment with the identified problem (context). If the predicted effects do not satisfy the requirements, this can be argued as argumentation to redesign the treatment. The first expert interview was conducted on the 21st of April 2023, with the Chief Innovation Officer of the Global Energy Business Unit within Huawei's Enterprise Business Group (Shenzhen, China department). As a global precursor regarding developments of the HEMS, this expert's expertise was instrumental in providing residential consumer preferences, a comprehensive perspective, market trends and insights regarding the feasibility of the HEMS value proposition. Subsequently, two expert interviews were conducted with key personnel from Pure Energie on the 12th and 15th of May 2023. The first group consisted of the HEMS Project Group Manager, the Energy Supply Manager within the Business Department, the Energy Storage Business Unit Manager and a Junior Energy Storage Specialist. The second group consisted of the Portfolio Manager Sustainability, as well as the Operation Manager, who is strongly linked to the ICT department as well. Given that the HEMS value proposition was intended for implementation by Pure Energie, these expert interviews played a crucial role in ensuring that the proposed Value Proposition Canvas aligned with the utility's operational capabilities and market strategies. Moreover, these two interview sessions provided direct feedback regarding the practical feasibility of the Value Proposition Canvas and illuminated potential obstacles that could affect its implementation. The fourth and final expert interview was conducted on the 17th of May 2023, with the Theme Owner Energy Storage from *"Liander"*, the largest grid operator within the Netherlands. This interview contributed crucially to understanding the manner in which the HEMS Value Proposition Canvas would interact within the wider energy system of the Netherlands. Additionally, it served to uncover any potential barriers which were not yet recognized and/ or considered. As a result of the expert interviews, a wide range of data regarding expert perspectives, opinions and feedback was gathered, which could significantly contribute towards enhancing the residential consumer adoption potential of the initial HEMS value proposition. On average, each of the four interview sessions had a duration of 40-45 minutes. Importantly, after each interview session, the interview script was revised and personalised within the light of the gathered data. This ensured the possibility for the following interview(s) to address emerging issues, enabling a thorough validation process, as well as keeping the interview script up-to-date and relevant throughout the design process (Hevner et al., 2004). Subchapter 6.1 will further elaborate on the specific design regarding the expert interview scripts.

Step 9: Evaluation of the initial HEMS Value Proposition Canvas

After the initial HEMS Value Proposition Canvas was validated through the four expert interviews, the recordings from these interviews were transcribed and colour-coded

subsequently. According to Wieringa (2014), this data preparation transforms the gathered data into a form which simplifies the analysis and extraction of results. Therefore, after the data was gathered, this data was first familiarised by multiple readthroughs of the transcripts. Thereafter, several initial predetermined structured themes were created, under which specific statements extracted from the interview transcripts could be scaled through corresponding colour-coding. While several themes were predetermined, the colour-coding process mainly followed an emergent approach. Therefore, during this analysis, additional themes were created for data that could not be scaled under the existing themes. Moreover, during the coding process, the themes were continuously altered to extract meaningful findings. Within Appendix G - J, the four coded interview transcripts are provided. The key findings extracted from the above-described process were subsequently utilised to evaluate the extent to which the treatment goal and requirements were achieved within this stage of the design process (Wieringa, 2014). Moreover, these findings were related to the stakeholder goals of Pure Energie, as well as the key findings related to the Residential Consumer Profile. Furthermore, the initial HEMS Value Proposition Canvas was critically evaluated by subjectively interpreting the main expert interview findings and discussing these results on the grounds of the theories, frameworks and models integrated within this paper's Theoretical Framework. Within subchapter 6.3, the evaluation and discussion will be extensively described in detail.

Step 10: Re-design of the initial HEMS Value Proposition Canvas

On the basis of this evaluation and discussion, the decision was conducted to iterate back to the design activities (Peffers et al., 2007). Therefore, the initial HEMS Value Proposition Canvas underwent a final re-design within the theoretical scope of this study, resulting in the HEMS value proposition aimed to enhance residential consumer adoption. Moreover, this answered the central research question of this paper. Hereinafter, conclusions were drawn, directions for future research were provided and this study's limitations were revealed. Hence, the design process of this research could progress toward its final stage.

Stage IV: Communication

While seen as part of research management by Wieringa (2014), Hevner et al. (2004) as well as Peffers et al. (2007) emphasize on the communication of conducted research. Therefore, this activity and/ or guideline was adopted as the fourth and last stage of this study's design science research methodology.

Step 11: Publication of the research

Hence, representing the final step of this study's design science research methodology, this research paper will be publicly published from the 1st of January 2025 within the University of Twente's essay database in Enschede, the Netherlands. Therefore, according to Peffers et al. (2007), the problem (context) and its importance, the designed value proposition for the HEMS aimed to enhance residential consumer adoption, its utility and novelty, the rigour of its design, and its effectiveness were communicated and offered as available to Pure Energie and after the confidentiality delay mentioned above, to researchers and additional relevant audiences as well.

4. Stakeholder Analysis

According to Wieringa (2014), a problem's stakeholder identifies as an individual, group, or institution that is influenced by the treatment of this problem. Furthermore, the objectives and constraints of a design project fundamentally originate from these stakeholders, as they form the foundation for the treatment goal and requirements. Consequently, it was critical to identify and analyse the relevant stakeholders within the scope of this study, prior to determining the treatment goal, requirements and initiating the actual design process of the value proposition (canvas) as proposed treatment (Wieringa, 2014). Therefore, this chapter will describe the stakeholder analysis which was performed as final step of this research's first design stage, namely the Problem Investigation stage. Related to the scope of this research, the main focus was on the perspectives of Pure Energie and Dutch residential consumers, their individual relation to the HEMS and the interrelation between these two parties. Moreover, since the achievement of Fit is described by Osterwalder et al. (2014) as the aim of the Value Proposition Canvas, an additional goal of this analysis was to facilitate alignment between these two crucial stakeholder perspectives from the first design stage, as this was believed to contribute towards enhancing residential consumer adoption of Pure Energie's HEMS.

4.1 The stakeholder perspective of Pure Energie

First, the stakeholder perspective of Pure Energie will be analysed below, based on data gathered from meetings with the Pure Energie HEMS project group, strategic company documentation, several explicit internal talks that were additionally scheduled, and the notes taken during these meetings.

4.1.1 The underlying stakeholder objectives of Pure Energie

Based on the data that was extracted from the internal sources as described above, the underlying stakeholder objectives of Pure Energie could be determined. These objectives were related to the utility's desire for short term implementation of the HEMS within the Dutch residential consumer energy market. Therefore, the underlying stakeholder objectives of Pure Energie were enumerated and explained as:

1. First of all, Pure Energie was and, at the time of writing, remained aware of the (emerging) transformations within the residential energy sector. Therefore, the company wished to adapt through the launch of their HEMS, in order to maintain market share and remain competitive, as HEMS implementation provides opportunities to offer (the, by Dutch standards, innovative type of) *dynamic contracts**, the home battery smart home component, (additional) private solar panels and (additional) EV charging stations to residential consumers.

2. In addition, Pure Energie felt a moral responsibility to contribute to the subsequent phase of the energy transition, as the Netherland's leading utility within the field of sustainability. Specifically, the company in general desires to lead as an example within

the Dutch energy sector. Besides this, the provision of the HEMS was believed to resonate well within their, at the time of writing, current residential consumer base and therefore believed to strengthen their portfolio USP of being one of few completely green and sustainability-oriented utilities within the Netherlands as well.

3. The main financial stakeholder objective for Pure Energie was identified as trading electricity on the Dutch *"Balanceringsmarkten"***, in order to potentially obtain large-scale financial benefits from the HEMS, integrated within residential consumer smart homes. Moreover, Pure Energie expected to acquire additional financial income through partial and/ or full sale of home batteries as well as additional smart home components that increase the effectiveness of the HEMS, such as solar panels and EV charging stations. However, at this stage of the research, Pure Energie did not yet determine whether the company definitely desired to offer the home battery smart home component to their residential consumers. Additionally, Pure Energie expected to obtain rising revenues as a result of the introduction of dynamic electricity contracts (e.g., through charge and discharge fees related to home batteries) accompanied with the HEMS, as well as additional service costs.

4. Lastly, since HEMS-integrated residential smart homes provide flexibility to Pure Energie in regulating their load profile, the HEMS offers opportunities to partially regulate electricity within the company's wind and solar parks. Moreover, this creates circumstances in which demand side management techniques, as well as *congestion and imbalance management**** might potentially be improved.

**: Dynamic contracts represent a novel approach to electricity purchasing, allowing residential consumers to respond to real-time price fluctuations. Moreover, this enables smart homes to modify their consumption in response to market signals, thereby encouraging sustainable consumption and aiding in smart grid management.*

***: The Dutch "Balanceringsmarkten" refer to the system that was designed to maintain a national equilibrium between the supply and demand of electricity. Utilities submit supply and demand bids, after which the national overarching grid operator TenneT adjusts this accordingly, to prevent grid instability.*

****: Grid congestion management pertains to the strategies and methods utilised by grid operators to alleviate congestion within the grid. This includes techniques such as curtailment of generated electricity or load, the employment of storage systems, demand response initiatives, or utilisation of interconnectors to re-direct electricity flows. Imbalance management strongly relates to grid congestion and refers to the balancing actions undertaken by the grid operators in collaboration with utilities, to ensure the supply-demand equilibrium in real-time. The overarching national grid operator TenneT manages this, by procuring balancing power from market participants (i.e., utilities) that bid their available capacity for upward or downward adjustment, mitigating imbalances and thereby maintaining grid stability.*

4.1.2 The HEMS-related stakeholder roles of Pure Energie

Within this section, the HEMS-related stakeholder roles of Pure Energie that were determined, will be explained. To achieve this, *the Onion Diagram of Product Stakeholders* from Alexander (2005) was applied within the HEMS context. This framework allows a stakeholder sociology to be graphically modelled, according to various identified stakeholder roles. Within Appendix D, the original Onion Diagram model, as well as further background information related to this framework is provided. According to Alexander (2005), each stakeholder role is represented by an individual, group and/ or institution(s) with a distinct relation to the product that is under development. Figure 7 displays the stakeholder roles of Pure Energie (determined through the aforementioned internal sources described above) related to the HEMS context of this study. Importantly, the Onion Diagram is not intended to depict stakeholder roles from a judgemental position in degrees of power, influence or interest. Therefore, the distance of each stakeholder role from the central product (i.e., the HEMS) is no indication of its importance. Below, the HEMS-related stakeholder roles of Pure Energie in relation to the design, as well as future development and implementation will be further explained.

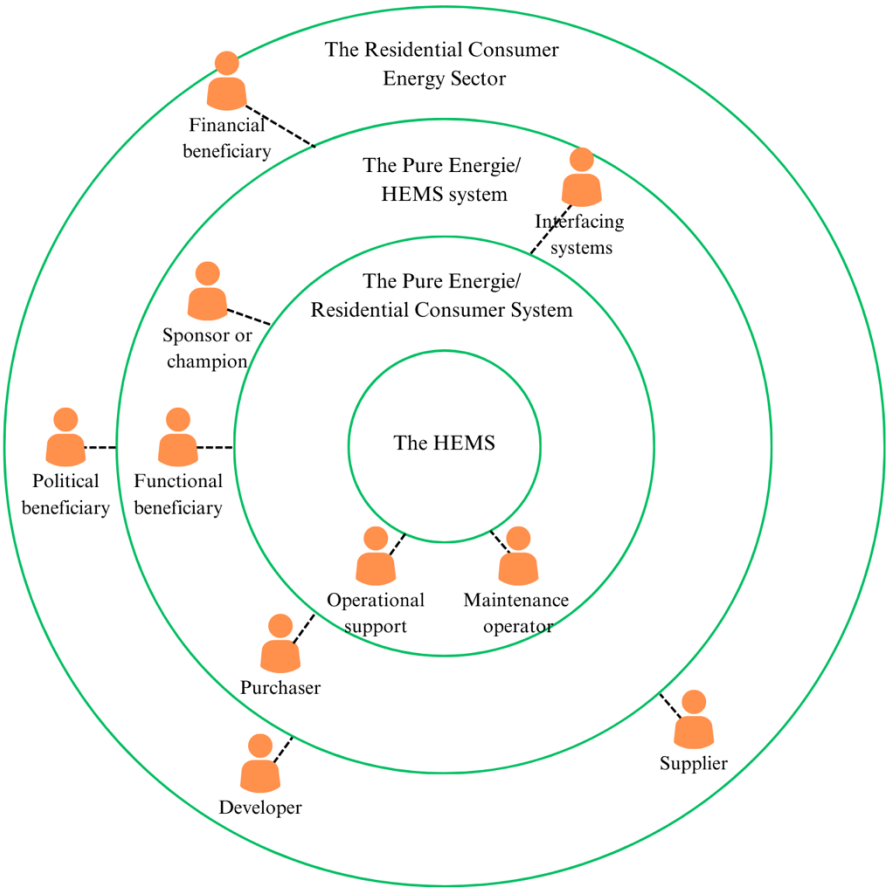

Figure 7. The HEMS-related stakeholder roles of Pure Energie

Layer I – The Pure Energie/ Residential Consumers System:

Within the layer directly surrounding the HEMS, three stakeholder roles were identified by Alexander (2005), namely *Normal Operators*, *Operational Support* and *Maintenance Operator*. These stakeholder roles interact directly with the HEMS. Therefore, this layer represents the interrelation between Pure Energie as HEMS supplier and residential consumers as HEMS end-users. Moreover, after the HEMS is designed, developed and supplied to residential consumers through interacting interfaces, Pure Energie will bear the responsibility of ***Maintenance Operator***. This role interacts with the HEMS itself and with Normal Operators, represented by the end-using residential consumers. Further explanation on this stakeholder role will be provided within subchapter 4.2.1. Potentially, Pure Energie may decide to outsource the role of Maintenance Operator. However, this was not yet decided within this stage of the design process.

Furthermore, as ***Operational Support***, Pure Energie will be responsible for providing operations-related advice to HEMS end-users. Together with maintenance, this contributes to ensuring that the HEMS infrastructure remains fully operational. Through for instance a help desk, Pure Energie can assure daily availability for interaction with residential consumers. Potentially, this task can be outsourced as well.

Layer II – The Pure Energie/ HEMS System:

The second layer represents Pure Energie related to their role as controlling host of the HEMS product once designed and practically under development. Therefore, an unmistakable stakeholder role that applies for Pure Energie regarding this HEMS, is that of ***Sponsor*** or ***Product Champion***. Moreover, Pure Energie is responsible for initiating the design and development of the HEMS, for obtaining the project's funding and for protecting the development from political pressures and financial cuts. Furthermore, Pure Energie indicates the scope and purpose of the HEMS development, the opportunities and threats, which in turn contribute to reducing the project's risks.

As ***Purchaser***, Pure Energie subsequently ensures that the HEMS actually remains in design and development. Within this role, potential interactions with other developers might occur as well. Furthermore, Pure Energie may approach consultants, marketing and beneficiaries to obtain HEMS requirements.

After the HEMS will eventually be supplied to residential consumers, Pure Energie is responsible for providing ***Interfacing Systems*** to/ from the product. However, within this stage of the design process, it was already decided that Pure Energie will partially outsource this role.

Lastly within this layer, ***Functional*** benefits, such as residential consumer data can arise from the results or outputs of the HEMS.

Layer III - The Residential Consumer Energy Sector:

Within the residential consumer energy sector as third layer, Pure Energie is one of the few parties that is directly involved within the design and development processes of the HEMS. Therefore, the utility represents the role of ***Developer*** within this layer. As developer, interactions primarily occur with potential other developers and contractually with purchasers. Ideally, Pure Energie would interact with all the other stakeholder roles as developer, to determine the requirements for the HEMS. Within the next section, further elaboration regarding the HEMS (treatment) requirements will be provided.

In terms of ***Beneficiaries*** within this layer, both identified types apply to Pure Energie, as the company will most probably benefit ***Financially*** from success of the HEMS. Moreover, given that Pure Energie is a private energy utility, ***Political*** benefits may potentially apply, in terms of power, influence and/ or prestige through success of the HEMS. Especially the relation to the Dutch government is valuable for Pure Energie within this role.

While different parties might manufacture and provide several components for the HEMS, Pure Energie will eventually represent the underlying manufacturing role of overarching HEMS ***Supplier*** to residential consumers. Although optionally proposed by Alexander (2005), this role was considered as relevant given the scope of this design research.

4.2 The stakeholder perspective of Dutch residential consumers

While data concerning the underlying stakeholder objectives of Pure Energie was already available and could be obtained during the first stage of the design process, a gap was present regarding the availability of qualitative data on these objectives for Dutch residential consumers as stakeholders. Moreover, besides the determination of the four core HEMS benefits for residential consumers within the Theoretical Framework of this paper, discovering the underlying objectives and motives for HEMS utilisation by residential consumers was one of this study's integral purposes, as these factors were believed to influence residential consumer adoption attitudes towards the system. Therefore, this subchapter will solely explain the determined stakeholder roles of Dutch residential consumers within the scope of this study. The following chapter will provide a comprehensive description related to the manner in which the underlying stakeholder objectives of Dutch residential consumers were eventually discovered through the collection and analysis of qualitative data.

4.2.1 The HEMS-related stakeholder roles of Dutch residential consumers

As mentioned above, this section will determine and explain the HEMS-related stakeholder roles of Dutch residential consumers within the scope of this research. Therefore, these roles are displayed in Figure 8. Below, the manner in which Dutch residential consumers interrelate with the stakeholder perspective of Pure Energie through different stakeholder roles will be explained as well. Moreover, the stakeholder roles of Dutch residential consumers will be described related to their influence on Pure Energie, as end-users of the utility's desired HEMS.

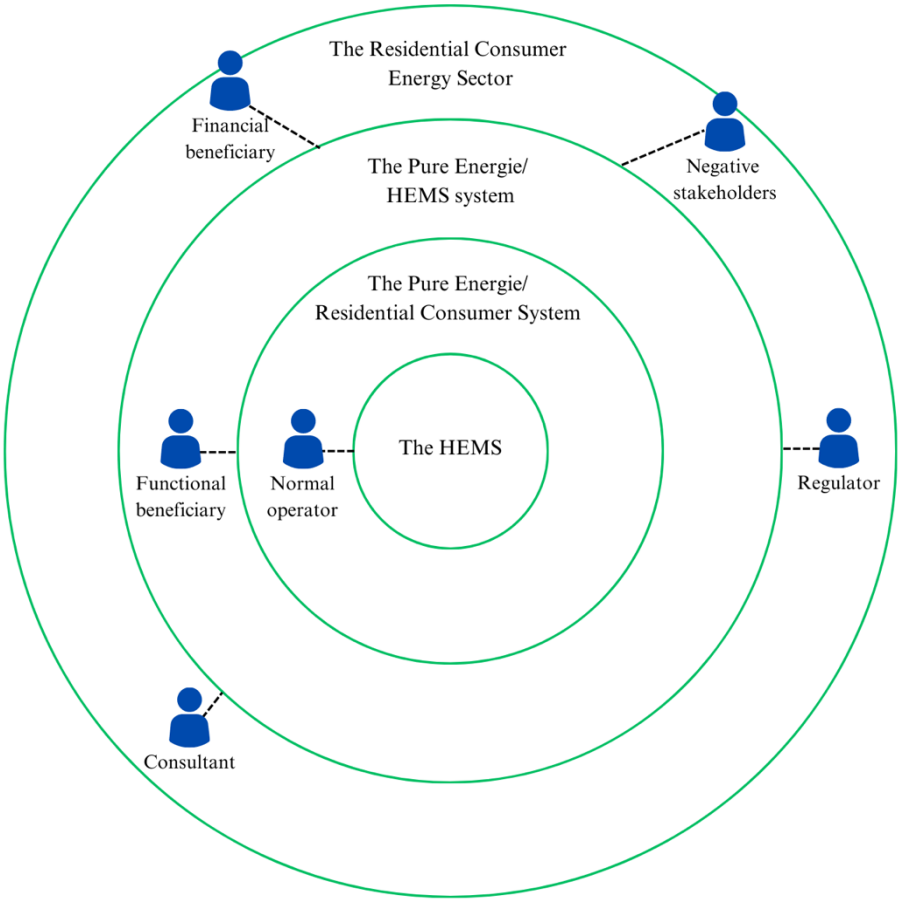

Figure 8. The HEMS-related stakeholder roles of Dutch residential consumers

Layer I – The Pure Energie/ Residential Consumers System:

As end-users, residential consumers interact directly with the HEMS and Pure Energie. Within this interaction, Pure Energie thus represents the roles of Maintenance Operator, Operational Support and Functional Beneficiary (e.g., providing residential consumers with processed information, as well as operating instructions). Therefore, the primary and most significant represented stakeholder role of residential consumers within this research, is the role of ***Normal Operators***. Their operator requirements are relevant throughout the entire design and development process, especially related to specific HEMS-related tasks, such as the design of future user interfaces.

Layer II – The Pure Energie/ HEMS system:

Within the second layer, residential consumers were identified as ***Functional Beneficiaries*** since these individuals can directly benefit from the results and/ or outputs that are provided by the HEMS, for example in terms of digital insights regarding their consumption.

Layer III - The Residential Consumer Energy Sector:

Related to the residential consumer energy sector layer, the value proposition for the HEMS was designed to ***Financially*** benefit residential consumers that decide to adopt the HEMS.

While residential consumers will not function as lead Developers of the HEMS, as provided by Pure Energie, these consumers could be directly included within the design and development of the value proposition as ***Consultants***. As mentioned within the previous chapter, specifically the 36 participants from the qualitative residential consumer interviews consulted Pure Energie to support the utility's design process, in the company's stakeholder role as Developer.

Furthermore, it can be argued that these 36 particular residential consumers partially fulfilled the role of ***Regulators*** within this research, since they acted as surrogates for future Dutch residential HEMS end-users. Moreover, Regulators impose requirements which act as qualities and constraints. However, according to Alexander (2005), rarely as functions. Nevertheless, since this research strived to design a value proposition that enhances HEMS adoption by complying with the prerequisites set by residential consumers, these individuals were important in defining the requirements for the value proposition.

In general, given the design intentions behind the HEMS value proposition, the ***Negative Stakeholder*** role should not have applied for residential consumers within this research. Moreover, the value proposition was not designed to harm residential consumers, nor was it likely that residential consumers intended to hurt the HEMS as a system, considering the benefits it can offer them. However, naturally, this possibility always remained present. Yet, within this stage of the design process, no indication that implied this was present.

4.3 The added value derived from the Stakeholder Analysis

Based on the above, the stakeholder analysis served as the concluding step of this study's Problem Investigation stage, thereby contributing to a deeper understanding of the problem context. Furthermore, the interrelation between the identified stakeholder roles of Pure Energie and residential consumers within the context of HEMS adoption was illuminated. Since the underlying stakeholder objectives of residential consumers could not yet be clearly articulated within this stage of the research, one particular significant conclusion from the stakeholder analysis was that it was deemed as necessary to identify these motives within a further stage of the value proposition design process. Moreover, it became evident that involving residential consumers as Consultants within the value proposition design process of this study, could contribute to achieve this, since this resulted in the gathering of first-hand qualitative data. Furthermore, it was argued that this inclusion could aid in solving the central research question of this paper, as the stakeholder perspective of residential consumers could be directly integrated within the final value proposition design for the HEMS this way as well.

5. The Design Process of the Initial HEMS Value Proposition Canvas

At this stage of the research, a comprehensive understanding of the problem and its context were precisely established. Furthermore, an extensive explanation was formulated concerning the anticipation that the formulation of an adoption-enhancing value proposition for a HEMS could serve as potential treatment for the lacking residential consumer adoption of the system. Also, each element derived from the central research question was examined individually. Specifically, focusing on the HEMS benefits for residential consumers and integrated models (i.e., IDP and TAM) with adoption-enhancing potential. The completion of the stakeholder analysis within the previous chapter signified the completion of the initial stage of this research, namely the "Problem Investigation" stage. This progression meant that the second stage, labelled as the "Treatment Design" stage could now be initiated.

Therefore, this chapter aims to detail all the procedures that were executed within the creation of the actual Value Proposition Canvas, commencing with the determination of a clear treatment goal, as well as the establishment of several specific treatment requirements. The conclusion emerging from the previous chapter was that the underlying stakeholder objectives and motives for residential consumer adoption of the HEMS remained inadequately charted. Therefore, this chapter will provide an elaborate explanation regarding the manner in which the Residential Consumer Profile was constructed. As described within the Methodology chapter, data was accumulated from residential consumers through qualitative focus group interviews. This data proved instrumental in unveiling valuable insights relating to the adoption attitudes of these consumers towards the HEMS. Utilising these findings, the Residential Consumer Profile was ultimately constructed. Upon completion of this task, the Value (Proposition) Map of Pure Energie was compiled. This process incorporated all the data acquired from internal (HEMS) meetings, conferences, minutes, strategic documentation, as well as numerous explicit dialogues. Specifically, data clarifying Pure Energie's vision regarding the manner that the utility intended to provide value to their residential customers.

5.1 Determining the treatment goal & requirements

As described within the Methodology chapter of this paper and substantiated by Wieringa (2014), Peffers et al. (2007) and Hevner et al. (2004), the determination of a treatment goal and treatment requirements is crucial within design science research, since these factors serve as guiding principles that shape the framework for the design process and provide a clear direction for researchers. Moreover, a well-defined treatment goal and requirements are therefore stated as contributing to ensuring that the designed artifact is both effective and fit for its purpose. The treatment goal that was determined for the HEMS value proposition of this study, as well as the requirements which the value proposition had to meet, will therefore be stated below within this subchapter. As stated within the Theoretical Framework chapter, the Value Proposition Canvas as developed by Osterwalder et al. (2014), the Innovation-Decision Process model from Rogers (2003) and the Technology Acceptance Model (Venkatesh & Davis, 1996) were integrated into this study and utilised to develop a treatment for the problem context, namely

the lacking residential consumer adoption of the HEMS. Therefore, the treatment goal that was determined for this study was to:

Present a Value Proposition Canvas for a HEMS that aligns the needs of residential consumers and their expectations with the value that Pure Energie plans to offer these consumers. Moreover, one in which the residential consumer adoption potential is optimally enhanced within the limits of this study's scope, through the application of the Innovation-Decision Processes model, and the Technology Acceptance Model.

This treatment goal translated into the following treatment requirements for the Value Proposition Canvas (VPC):

1. *The Residential Consumer Profile side of the VPC should have integrated qualitative data retrieved from (Dutch) residential consumers.*

2. *The Value (Proposition) Map side of the VPC should have integrated qualitative data retrieved from Pure Energie.*

3. *The underlying HEMS-related stakeholder objectives of Pure Energie as well as residential consumers should be considered within the VPC design.*

4. *The VPC should be capable of supporting effective communication of the HEMS definition to all residential consumers, in a manner that appeals to them and contributes to their understanding of the benefits that the HEMS can provide.*

5. *The VPC should include all four core HEMS benefits for residential consumers, that were determined within this study's Theoretical Framework chapter, as well as all under-scaled sub-benefits.*

6. *The HEMS integrated within the VPC should be scalable to fit different household sizes, electricity needs, and residential income levels. Therefore, the VPC should communicate this flexibility and adaptability.*

7. *The VPC should emphasize that the HEMS is compatible with all existing Dutch technological smart home infrastructures and other smart home technologies.*

8. *The VPC should have considered security both is terms of data, as well as relating to the physical elements that are being offered. Therefore, the VPC should emphasize the steps that strive to ensure the security and privacy of end-users' data.*

9. *Lastly, the final design of the VPC should be suited to integrate additional feedback after this research is conducted. Moreover, from residential consumers as well as Pure Energie, to ensure that the VPC for the HEMS remains relevant, adaptable and attractive, in case residential consumer needs and preferences might change/ evolve.*

Within Chapter 6 of this paper, it will be evaluated whether the treatment goal as described above was achieved and the treatment requirements were met. This, to ensure that the resulting treatment of this study was effectively tailored to address the problem context of this research.

5.2 Design of the qualitative residential consumer interview script

As described within the Methodology chapter, four qualitative interview sessions with Dutch residential consumer focus groups were conducted to gather critical qualitative data that assisted in shaping the Residential Consumer Profile. Upon two initial rounds of feedback provided to both Pure Energie and this study's researcher, Newcom Research & Consultancy B.V. embodied the leading role during the development of the qualitative residential consumer interview script employed within this research. This script was designed based on open-ended questions. Hence, the integrated questions oriented around the "how", "who", "what" and "why" and therefore the contextual insights, obtained from the participating residential consumers, were of a qualitative rather than quantitative nature. The interview script's structure comprised a brief introduction, two main sections, and a general discussion section. These components were specifically designed to facilitate the extraction of qualitative data from the focus groups. Moreover, following *Peacock et al.'s (2017) approach*, the first main section progressively unfolded towards the interview script's *object of concern*, embedded within the second part, namely the value proposition for the HEMS. A brief overview of the two main sections, as well as the general discussion section of the interview script, will be provided below:

The first main section of the interview script was further separated into two domains. The first of these domains was designed with a particular emphasis on residential consumer behaviour, specifically on discovering the patterns of electricity consumption and prevailing attitudes towards the current situation within the Dutch energy market. Therefore, this domain encompassed questions regarding the focus groups' energy contract types, the manner(s) of energy management within their (smart) homes, and any proactive measures possibly undertaken to conserve energy. The second domain was designed towards the identification of emerging trends and developments among residential consumers. Hence, these questions sought to discover general concerns, as well as sustainable energy initiatives undertaken. Therefore, this part of the interview delved deeper into the utilisation and attitudes towards the private solar panels and home battery smart home components, devices utilised to measure residential energy consumption, and residential consumer attitudes towards granting utilities specific permissions, such as remote home battery monitoring. The second main section of the interview script was designed to provide insights into the residential consumer adoption potential of Pure Energie's initially envisioned HEMS. More specifically, this section aimed to understand residential consumer needs, their potential motivations for adopting the HEMS, to benchmark the perceived benefits of the HEMS, and to identify any potential barriers for adoption of this initial form of the HEMS. Therefore, this section of the interview script drew on global HEMS use cases (both existing and pilot studies) as were considered by Pure Energie. As a result, the second main section was able to provide residential consumers with an introduction to an automated HEMS with integrated demand response tool, explaining the

potential of the standalone HEMS, as well as the use case potential when combining this system with the private solar panels and/ or home battery smart home components. Lastly, the general discussion section of the interview script was oriented towards gathering residential consumer feedback and input, with the intention of incorporating this data into both the Residential Consumer Profile as the Value (Proposition) Map sides of the Value Proposition Canvas. Following the fourth step of *Peacock et al.'s (2017) methodology*, the design therefore sought to encourage the participating residential consumers to contribute towards *creating solutions*. Moreover, this section of the interview script design included the possibility for representatives from the Pure Energie HEMS project group and this study's researcher to ask the residential consumers final questions on the spot. Appendix E and F offer an overview of the interview script as delineated above, as well as Pure Energie's initially envisioned value proposition for the HEMS, to which the participating residential consumers were introduced.

5.3 Key findings from the Dutch residential consumers interview sessions

Below, this section will present the key findings that derived from the conducted qualitative interview sessions among the Dutch residential consumer focus groups. Initially, four domains that were found to be fundamental, related to residential consumer adoption of the HEMS will be explored. Subsequently, five distinct residential consumer groups that were identified will be displayed as well and an overview of their characteristics will be provided. Furthermore, the fundamental motives of these consumer groups, related to adoption of the HEMS, will be described.

5.3.1 Underlying domains related to residential consumer adoption of the HEMS

Based on Newcom Research & Consultancy B.V.'s analysis of the residential consumer interviews, the research team suggested four initial domains linked to the adoption of the HEMS. This proposal was suggested during their report presentation at Pure Energie after completion of all the interview sessions. Their identified domains were *Autonomy*, *Control & Trust*, *Financial*, *Sustainable*, and *Knowledge/ Vision*. According to Newcom Research & Consultancy B.V., each of these domains were found to influence the HEMS adoption attitudes of five distinct residential consumer groups, which will be described within the following section. Interestingly, the majority of these identified domains are not explicitly related to specific functionalities of the HEMS, nor did they notably emerge from the HEMS benefits for residential consumers section within the Theoretical Framework chapter of this study. Therefore, as described within the Methodology chapter, an additional discussion between the researchers from Newcom Research & Consultancy B.V. and this study's researcher was held, to gain a more profound understanding of these residential consumer interview findings, as well as Newcom Research & Consultancy B.V.'s reporting on this matter. Following this discussion, the personal experience of this study's researcher, related to the four interview sessions as well as the complete report from Newcom Research & Consultancy B.V. were integrated, to definitively establish the following underlying domains related to residential consumer adoption of the HEMS:

1. **Knowledge & Vision:** This domain pertains to the level of residential consumer knowledge regarding the HEMS. Furthermore, it refers to the future vision of residential consumers, particularly after the abolition of the *"Salderingsregeling"** by the Dutch government.

2. **Autonomy & Control:** Even if residential consumers recognised the HEMS benefits, there was a potential reluctance identified to embrace any service that might curtail their independence. Therefore, the "Autonomy & Control" domain relates to the desire of residential consumers to maintain autonomy and retain control.

3. **Trust & Transparency:** This domain reflects the level of residential consumer trust towards utilities (and the government), as well as their desire for transparency from these entities.

4. **Security & Certainty:** This domain encompasses residential consumer desires for data security and information privacy. "Certainty" relates to the dynamic tariffs associated with the HEMS, as well as future technological developments. Specifically, whether the HEMS (and associated additional smart home components, such as the home battery) is the appropriate extension of their smart home grid.

It was concluded from the interview sessions analysis that the degree to which each of these underlying domains are incorporated into the design of a HEMS value proposition significantly impacts the attitudes of residential consumers towards adoption, either positively or negatively. Furthermore, the initial "Financial" and "Sustainable" domains proposed by Newcom Research & Consultancy B.V. were dismissed, as these elements were identified as HEMS benefits for residential consumers within the Theoretical Framework chapter and were recognised by the participating residential consumers as such. Subchapter 5.4 will further elaborate on this. "Security & Certainty" was identified as an additional underlying adoption domain since data security and information privacy were identified as prerequisites for the HEMS. Moreover, given the current war crisis between Russia and Ukraine, the element of certainty portrays a crucial role within the energy market from the residential consumer's perspective.

**: The "Salderingsregeling" is a Dutch governmental initiative which permits solar panel utilising residential consumers to balance their national grid-supplied consumption with the private RES generation from their solar panels. Effectively, residential consumers pay solely for their net electricity consumption, rendering solar panels currently still as a financially attractive value proposition. However, short-term amendments to this scheme are anticipated, and it is expected that the Dutch government will abolish the scheme completely by the year 2030.*

5.3.2 The five identified residential consumer groups

Following the underlying domains related to residential consumer adoption, Newcom Research & Consultancy B.V. presented five different types of residential consumer groups to Pure Energie, namely the: *Idealists*, *Green Mathematicians*, *Followers*, *Dependents*, and *Sceptics*. After the additional discussion, this study's conducting researcher concurred with the analysis of Newcom Research & Consultancy B.V. and therefore adopted the five groups that were presented. In general, a strong urge for Autonomy & Control, as well as a considerable degree of Knowledge & Vision regarding the HEMS dominated the Idealists, Green Mathematicians, and Sceptics residential consumer groups. Of all the groups, the Sceptics demonstrated the greatest distrust towards utilities (as well as the government) and subsequently desired the most Transparency. A strong urge for Transparency was observed among the Green Mathematicians as well. While the Sceptics, Followers, and Dependent residential consumers primarily sought Transparency for digital access to their (consumption) data to exercise Control, elements of enjoyment related to Transparency were found somewhat evident among the Idealists and Green Mathematicians groups in addition to this. The Followers and Dependent residential consumer groups, however, demonstrated significantly lower degrees of Knowledge & Vision related to the concepts and were mainly motivated by the financial benefits that the HEMS offers. These two residential consumer groups exhibited a relatively higher degree of Trust towards the utility (and government), therefore generally requiring less Transparency. Yet, these groups highly valued the Security & Certainty domain, alongside the Sceptics. Moreover, especially the aspect of Certainty associated with electricity supply considering the dynamic contract type. Below, further details regarding all of the five residential consumer groups is provided:

1. **The Idealists:** For this residential consumer group, a sustainable lifestyle (beyond merely energy-related aspects), coupled with a sense of personal responsibility to contribute to the ongoing energy transition, were identified as this group's main motives related to adoption of the HEMS. Of all the groups, the Idealists were least interested in the financial aspects of HEMS adoption and were willing to prioritise sustainability over economics. Given their above-average knowledge regarding the HEMS, these residential consumers are conscious of their electricity consumption and do not necessarily require (digital) insights from utilities.

2. **The Green Mathematicians:** Sustainability and the energy transition were also foundational motives within this residential consumer group. However, transparency and the financial aspects of HEMS adoption (e.g., dynamic contract electricity tariffs) played a significant preventative role. These residential consumers primarily viewed private solar panels from a sustainability-driven motivation, yet their cost and the financial benefits took precedence in the actual purchase. As autonomy is of high value to this group, these residential consumers strive to maintain control and seek proof (e.g., of their consumed electricity), clear conditions related to the value proposition, and data security. This group is well-informed and calculates their benefits accurately. Furthermore, the group is aware of the abolition projection of the "Salderingsregeling"

and understands the opportunities that the HEMS can offer in relation to this (especially in combination with the home battery smart home component). Lastly, these residential consumers occasionally view the optimal management of electricity as a game, similar to the Idealist group.

3. **The Followers:** Residential consumers identified as Followers will not adopt the HEMS until the concept and the associated financial benefits are proven. If residential consumers within this group ultimately decided to purchase private solar panels, their motivation was influenced by the behaviour of many other Dutch residential consumers, particularly given the steep increase in their energy costs due to the war crisis between Russia and Ukraine. Furthermore, these residential consumers lack awareness of the regulations around the "Salderingsregeling". In general, the Followers do not monitor their energy consumption as closely as the two groups mentioned above. Moreover, the Followers seek convenience, clear explanations of all the HEMS-related concepts, and desire to be free from complications. Regarding data security and surrendering control this group is cautious, although not vehemently opposed. Decisions related to sharing information are oftentimes based on a gut feeling by the group.

4. **The Dependents:** This group consists of residential consumers that are mainly interested in the financial benefits of the HEMS. However, due to limiting circumstances such as living in a rental property, or being tied to a housing corporation, these residential consumers are unable to realise the full potential of Pure Energie's initially envisioned value proposition, including the home battery and/ or private solar panels smart home components. At times, these residential consumers depend on external facilities or organised initiatives to purchase green electricity, resulting in their adoption attitudes being largely dependent on personal circumstances. Like the Followers, this residential consumer group seeks convenience, thorough explanations of all the HEMS-related concepts, and relief from their burdens.

5. **The Sceptics:** Lastly, the Sceptics residential consumer group demonstrated the lowest initial adoption attitude towards the HEMS. Owners of private solar panels within this group purchased this smart home component purely for their financial benefits. As these residential consumers are sceptical and suspicious towards initiatives from utilities and/ or the government, this group wishes to retain any form of control and is extremely unwilling to share personal information. Therefore, their initial adoption attitude towards the HEMS is also generally negative. Finally, the scepticism of this group creates a sense of misunderstanding towards the motives of utilities and/ or the government.

5.4 Constructing the Residential Consumer Profile side of the initial VPC

Below, the Residential Consumer Profile related to the key findings from the qualitative residential consumer interviews could thus be constructed. Therefore, the actual design process of the initial HEMS Value Proposition Canvas will be described from this subchapter. For the sake of clarity, each of the six Value Proposition Canvas fragments as well as the elements within every fragment will be labelled. According to Osterwalder et al. (2014), the Residential Consumer Profile clarifies the understanding regarding the targeted residential consumers. Therefore, the Residential Consumer Profile describes all specific residential consumer segments related to the Value Proposition Canvas in a more structured and detailed way, by breaking this main side down into the residential consumers Jobs, Pains, and Gains. Under the umbrella of the Residential Consumer Profile side, the Residential Consumer Jobs Value Proposition Canvas fragment will be labelled as *"VPC Fragment A"*. The Residential Consumer Pains and Gains will be labelled as *"VPC Fragment B"* and *"VPC Fragment C"* respectively.

VPC Fragment A: Residential Consumer Jobs

Residential Consumer Jobs represent the objectives that residential consumers attempt to achieve in their daily lives. Osterwalder et al. (2014) proposes three main types of Residential Consumer Jobs, namely: *Functional (A1)*, *Social (A2)* and *Emotional (A3)*. Table 2 illustrates the Residential Consumer Jobs within the context of HEMS adoption, that were determined following the qualitative residential consumer interviews and integrated within the initial HEMS Value Proposition Canvas. Below, these jobs will be concisely explained further.

Table 2. The integrated Residential Consumer Jobs within the initial HEMS Value Proposition Canvas

VPC Fragment A: Residential Consumer Jobs			
A1: Functional Jobs	**A2: Social Jobs**	**A3: Emotional Jobs**	
1. Utilise the HEMS	1. Act as a role model	1. Autonomy	9. Freedom
2. Optimally manage electricity		2. Control	10. Relief/ unburden
3. Acquire financial benefits		3. Trust	11. An ethical responsibility
4. Increase RES self-consumption		4. Certainty	12. Enjoyment
5. Live a sustainable lifestyle	2. Show off	5. Security	
6. Personally contribute to the energy transition		6. Clarity	
7. Viable "Salderingsregeling" alternative		7. Transparency	
8. Suitable extension of residential smart grid		8. Flexibility	

A1: Functional Jobs

This first type of Residential Consumer Job describes jobs in which residential consumers attempt to perform or complete a specific task or solve a particular problem. The following Functional Jobs were integrated within the initial HEMS Value Proposition Canvas:

1. Except for the Sceptics, the majority of the residential consumers desired to **utilise the HEMS**. Moreover, if applicable, in combination with the home battery smart home component, private solar panels and/ or EV charging station. Furthermore, the dynamic contract type was considered as possibly beneficial.

2. Residential consumers seeking to employ the HEMS, primarily sought to **optimally manage their electricity**, due to radically risen tariffs related to the war crisis between Russia and Ukraine. Additionally, the HEMS combined with a home battery was perceived as a solution to **acquire financial benefits** and **increase RES self-consumption**.

3. Driven by their desire to **live a sustainable lifestyle**, especially the Idealist and Green Mathematicians felt a strong urge to **personally contribute to the energy transition**.

4. Anticipating the abolition of the **"Salderingsregeling"**, the Idealists and Green Mathematicians consider the HEMS in combination with a home battery combination as a **viable alternative**. Additionally, these residential consumers identify the HEMS (and home battery) as a **suitable extension to their residential smart grid**.

A2: Social Jobs

Secondly, Social Jobs are related to situations in which residential consumers desire to appear appealing, powerful and/ or influential. Therefore, concerned with perception. The Social Jobs that were integrated within the initial HEMS Value Proposition Canvas are:

1. Given their high degree of Knowledge & Vision, as well as their sustainable lifestyle, the Idealists and Green Mathematicians occasionally desired to **act as a role model**.

2. Furthermore, a few individual residential consumers stated to engage with digital insights as a tool to enhance their social standing. Hence, to **"show off"**.

A3: Emotional Jobs

Lastly, Emotional Jobs focus on situations in which residential consumers seek a specific emotional state. The Emotional Jobs that are integrated into the initial HEMS Value Proposition Canvas are:

1. **Autonomy**, **control**, **trust**, **certainty**, and **security** as the main Emotional Jobs. Furthermore, recurring emotions centre around **clarity** and **transparency** related to the explanation of the HEMS concept.

2. The perceived potential of the HEMS to offer **flexibility**, **freedom**, and **relief/ unburden** them was widely acknowledged by the residential consumers.

3. Related to their urge to personally contribute to the energy transition, the Idealists and Green Mathematicians felt **an ethical responsibility**. In addition, the residential consumer groups stated to derive **feelings of enjoyment** from electricity management, as does their social circle.

VPC Fragment B: Residential Consumer Pains

Residential Consumer Pains describe factors that (completely) impede residential consumers before, during and/ or after their attempt to complete jobs. Therefore, pains encompass undesired outcomes, obstacles and risks. Table 3 displays the Residential Consumer Pains that are integrated within the initial HEMS Value Proposition Canvas. Below, these will be clarified.

Table 3. The integrated Residential Consumer Pains within the initial HEMS Value Proposition Canvas

VPC Fragment B: Residential Consumer Pains
1. Lack of Knowledge & Vision
2. Fear of losing Autonomy & Control
3. Fear of potentially losing freedom related to electricity consumption
4. Feelings of stress related to application notifications
5. Low perceived ease of use
6. Lack of landlord permission for installation of smart home components
7. Non-adoption of smart metres
8. Perceived uncertainties around costs and security related to the dynamic contract type
9. Fear of data leaks, breaches and privacy violation by utilities and/ or government
10. Obtained data not displayed transparent

1. Primarily **the Sceptics' lack of Knowledge & Vision** related to the HEMS could induce negative perceptions towards the system. Emotional pains predominantly revolved around the **fear of losing Autonomy & Control**, as related to the Emotional Jobs. Specifically, expressing concerns regarding the **fear of potentially losing freedom** regarding electricity consumption due to the HEMS. Furthermore, several residential consumers spread across all five groups believed that the system could induce **feelings of stress**, deriving from a **low perceived ease of use,** due to a believed necessity for daily monitoring of electricity tariffs. This feeling was further fuelled by the prospect of frequent application notifications and alerts.

2. Obstacles preventing residential consumers from starting and/ or completing jobs primarily related to the Dependent group. These obstacles range from the **lack of landlord permission for installation of smart home components**, to **non-adoption of smart metres** and **perceived uncertainties around costs and security related to the dynamic contract type**.

3. The identified risks were strongly related to the Trust & Transparency, as well as Security & Certainty domain, for instance the **fear of data leaks, breaches and privacy violation by utilities and/ or the government**, were clearly discovered. Furthermore, residential consumers **feared that their data, obtained by utilities, would not be displayed fully transparent**.

VPC Fragment C: Residential Consumer Gains

Gains describe positive outcomes and benefits for residential consumer. Therefore, within this design part of the initial HEMS Value Proposition Canvas, a parallel between the four core HEMS benefits for residential consumer inferred from the 20 theoretical framework papers and the benefits that were identified during the residential consumer interviews will be drawn. According to Osterwalder et al. (2014), Residential Consumer Gains encompass *required*, *expected*, *desired* and/ or *unexpected gains*. The benefit comparison within this subchapter considers all of these four gain types. Moreover, the gains that are identified in Table 4 below are relevant to all of the five identified residential consumer groups, though with a different prioritisation within the distinct groups. In general, the interview sessions largely mirrored the four core HEMS benefits for residential consumers suggested within the Theoretical Framework chapter. Moreover, even contributing an additional HEMS (sub-)benefit, further detailed below.

Table 4. The integrated Residential Consumer Gains within the initial HEMS Value Proposition Canvas

VPC Fragment C: Residential Consumer Gains	
HEMS benefit	**Identified within the residential consumer interviews?**
1. Financial savings	**YES**
2. Optimal electricity management	**YES**
2A. Reduction of electricity load	**YES**
2B. Increased self-consumption	**YES**
2C. Reduced ecological footprint	**YES**
3. Increased convenience	**YES**
3A. Higher transparency	**NO**
3B. Time savings	**ADDITIONALLY IDENTIFIED**
4. Innovative Edge	**YES**
4A. Providing ancillary services	**YES**

Financial Savings

The five residential consumer groups unanimously perceived financial savings as a HEMS benefit. Notably, similar to the literature, this gain emerged as the most prominent HEMS benefit during the interview session.

Optimal Management of Electricity

The second core HEMS benefit of the optimal management of electricity, including its three sub-benefits, were also recognized by the residential consumers. Relating to their high degree of Knowledge & Vision, the Idealists, as well as a fraction of the Green Mathematicians acknowledged these benefits even before the introduction and full explanation of the HEMS (and home battery) concept(s). Furthermore, the benefits and sub-benefits related to the optimal management of electricity were highly desired, as they were considered to support and enhance the sustainable lifestyle these specific residential consumer groups were observed to be committed to. Interestingly, despite the minimal emphasis within literature, *a reduced ecological footprint* emerged as a significant benefit during the residential consumer discussions. Moreover, once the concepts were extensively explained, the majority of the residential consumers understood the potential which the HEMS provides for the optimal management of electricity. Furthermore, especially the introduction of the home battery smart home component clarified the opportunities for *improved self-consumption* and *the reduction of electricity load*.

Increased Convenience

The most noteworthy observation related to this core HEMS benefit was the stress several residential consumers associated with the HEMS, stemming primarily from potential application notifications and/ or alerts, as discussed within the Residential Consumer Pains subchapter. Furthermore, the lack of *transparency* was interestingly primarily identified as a residential consumer fear, rather than a sub-benefit. However, in conjunction with the core HEMS benefit of optimal electricity management, the residential consumers identified the perceived opportunities that the HEMS could provide, related to *increased convenience*. Specifically, this related to increased flexibility and time management. For example, one specific residential consumer realised the manner in which the HEMS could enable a favourable shift in residential consumers' schedules, such as a higher degree of flexibility related to laundry timings due to cost efficiency for this specific case. Therefore, the joint discussions resulted in the identification of an additional sub-benefit, arguably best fitted beneath the core benefit of increased convenience: *time savings*, a sub-benefit which was not specifically identified by this study's researcher as one emerging from the 20 reviewed HEMS benefits framework papers.

Innovative Edge

Obtaining an innovative edge through HEMS adoption was primarily recognised by the Idealists and a fraction of the Green Mathematician residential consumer group, aligning with their possession of the highest degree of Knowledge & Vision (i.e., *technological orientation*) of all five residential consumer groups. While *facilitating energy trading* was not explicitly recognised as an example of the manner in which the HEMS could *provide ancillary services*, this specific example was sporadically brought up during the joint residential consumer discussions. Interestingly, concerns were expressed regarding the lifespan of home batteries within the HEMS context, contradicting the framework papers' identification of prolonging battery life as an example of ancillary services provided by the HEMS.

5.5 Compiling Pure Energie's Value (Proposition) Map side of the initial VPC

As a result of the previous subchapters, the design related to the Residential Consumer Profile side of the initial HEMS Value Proposition Canvas was now completed. Therefore, the following subchapter serves as a description of compiling Pure Energie's Value (Proposition) Map. As stated within the Theoretical Framework and Methodology chapters, The Value (Proposition) Map within the scope of this study describes the unique combination of Pure Energie's *Products & Services, Pain Relievers* and *Gain Creators*, aimed to create value for their residential consumers. Therefore, under the umbrella of the Value (Proposition) Map side of Pure Energie, the Products & Services Value Proposition Canvas fragment will be labelled as *"VPC Fragment D"*. The Pain Relievers and Gain Creators will be labelled as *"VPC Fragment E"* and *"VPC Fragment F"* respectively. Also, as mentioned within the Methodology chapter as well, the Value (Proposition Map) side of Pure Energie was compiled during a specific stage within the research, occurring around the beginning of April 2023, on the grounds related to the internal company sources described.

VPC Fragment D: Products & Services

This Value Proposition Canvas fragment illustrates all the HEMS-related products and services that Pure Energie aims to offer its residential consumers within the scope of this study. According to Osterwalder et al. (2014), these elements can be *tangible, intangible, digital* and/ or *financial*. Therefore, these products and services form the foundation of the initial HEMS Value Proposition Canvas and aid residential consumers in their functional, social and/ or emotional Jobs. Hence, this Value Proposition Fragment primarily strives to satisfy the residential consumer needs. Table 5 provides an overview of the products and services integrated within the initial HEMS value proposition. Below, these will be elaborated.

Table 5. The integrated Products & Services within the initial HEMS Value Proposition Canvas

VPC Fragment D: Products & Services				
D1: Tangible	**D2: Intangible**		**D3: Digital**	**D4: Financial**
1. The HEMS	1. The dynamic contract type	5. Customer service	1. Application and online portal	1. Fixed compensation
2. Home batteries	2. BYOD service		2. Digital insights (newsletters)	2. Warranty
3. Private solar panels	3. HEMS service bundles		3. Website	3. Home battery financing/ lease structure
4. EV charging stations	4. 100% green guarantee		4. Ensure cybersecurity	

D1: Tangible

1. The HEMS
2. The home battery smart home component
3. Private solar panels
4. EV charging stations

Despite HEMS adoption being this study's main focus, within this specific stage of the design process, Pure Energie strongly envisioned a package deal in which the HEMS was accompanied by the home battery smart home component. Given the scarce supply of home batteries within the Netherlands, this combination was believed to present a unique opportunity for Pure Energie. Additionally, they also envisioned to sell additional private solar panels and EV charging stations, which were already integrated within their Products & Services portfolio as Dutch utility. Although less significant for the focus of this study, these smart home components form a part of Pure Energie's offerings and therefore complete the tangible product overview.

D2: Intangible

1. HEMS adoption is accompanied by a ***dynamic contract type***, as of 2022 nationally introduced within the Dutch residential consumer energy sector.

2. Related to the HEMS (and home battery) launch, Pure Energie plans to offer a ***"Bring Your Own Device (BYOD)"*** service, enabling Dutch residential consumers to integrate the HEMS of Pure Energie within any residential smart grid infrastructure.

3. Additionally, Pure Energie intends to offer ***service bundles*** related to the automated operations of the HEMS within residential consumers' smart home grids.

4. Given that Pure Energie generates all of their supplied electricity out of RES, the utility can assure residential consumers of a ***100% green electricity guarantee***.

5. Lastly, Pure Energie will offer a consumer/ ***customer service*** available for HEMS-related questions that residential consumers might have before and post sales of the HEMS (, as well as other residential smart grid components).

D3: Digital

1. Like the majority of their tangible products, Pure Energie intends to incorporate the HEMS within their ***digital application and online residential customer portal***.

2. This application and portal will allow Pure Energie to ***share digital insights*** related to residential consumer data and process summaries, normally this information is shared through email in the form of ***newsletters*** as well.

3. Publicly available ***educational information*** related to the latest innovative concepts within the Dutch energy sector, is usually available on Pure Energie's ***website***. This can help to explain the HEMS functionalities in combination with other smart home components.

4. As HEMS implementation involves handling sensitive real-time residential consumer data, Pure Energie will have to ***ensure cybersecurity***. Therefore, the company will take measures to protect against vulnerabilities, cyberattacks, and unauthorised data access.

D4: Financial

1. Within this stage of the design process, Pure Energie considered offering ***a fixed financial compensation*** (e.g., yearly) in return for control over the residential consumer's HEMS (and preferably in combination with their home batteries as well).

2. Pure Energie considers providing a ***warranty***, if the utility decides to offer the home battery smart home component.

3. Pure Energie spoke about offering a ***(partially) financing and/ or a lease structure related to the home battery smart home component***, to enhance HEMS adoption by residential consumers.

VPC Fragment E: Pain Relievers

This Value Proposition Canvas fragment refers to specific ways in which the Products & Services described above are able to alleviate Residential Consumer Pains. Moreover, within this fragment, strategies to mitigate or completely eliminate frustrating factors for residential consumers during their pursuit to accomplish Jobs, or that prevent them from starting a Job. Importantly, Pain Relievers therefore address obstacles and barriers related to residential consumer adoption of the HEMS. Since a significant amount of Residential Consumer Pains relate to the underlying adoption domains that were explained within subchapter 5.3.1, the manner in which Residential Consumer Pains can potentially be relieved, is briefly described below in correspondence to specific related pains within each of the four underlying adoption domains.

Pain Relievers related to Pains within the Knowledge & Vision domain
The customer service of Pure Energie can contribute to reduce Residential Consumer Pains within the Knowledge & Vision domain, such as a lack of understanding regarding the HEMS and related concepts (e.g., the core HEMS benefits, combination of the HEMS with the home battery/ private solar panels/ EV's, etc.). Therefore, customer service can respond to consumer questions regarding the HEMS, clarify concepts and share additional knowledge. Furthermore, supplementing this, the utility's website provides educational information, supplying residential consumers with digital insights into the functionalities and potential benefits of the HEMS, when integrated within (smart) household grids. In addition, informative and accessible

animation videos with integrated financial calculation examples can be provided, to demonstrate the potential financial savings and the additional core benefits of the HEMS.

Pain Relievers related to Pains within the Autonomy & Control domain
Several Products & Services designed to ease residential consumer concerns regarding the loss of Autonomy & Control were considered by Pure Energie. Residential consumers are able to manage their desired moment of electricity purchase due to the dynamic contract type. Furthermore, the BYOD service offers residential consumers to retain control over the existing smart home components within their residential smart grids. Thirdly, the digital application and online residential consumer portal offer insights into consumption and HEMS processes, thereby increasing the degree of control that residential consumers can exercise.

***Pain Relievers related to Pains within the Trust & Transparency* domain**
In response to the observed general distrust towards utilities and the government, the introduction process of the HEMS could actually be utilised to build trust. Moreover, providing clear and concise information related to the potential profits Pure Energie as well as residential consumer can extract from the Dutch *"Balanceringsmarkten"*, by transparently illustrating the manner in which residential smart home components can be managed to profit from national grid imbalances. Furthermore, through ensuring transparency in data handling and providing residential consumer with digital insights into their consumption and profits, through the application and online portal, was expected to foster trust.

Pains Relievers related to Pains within the Certainty & Security domain
The security fears related to data leaks were seriously considered by Pure Energie. Upon implementation of the HEMS, Pure Energie therefore plans to apply strict cybersecurity measures, such as firewalls, antivirus software, and regular security audits. Also, financial services as for instance the partial financing or lease structures for home batteries, together with the offering of warranties and fixed financial compensations, could potentially contribute to reduce the residential consumer worries related to (financial) uncertainty.

VPC Fragment F: Gain Creators

This final fragment of the initial Value Proposition Canvas for the HEMS outlines the manner in which the proposed Products & Services generate benefits for residential consumers (Osterwalder et al., 2014). Therefore, this fragment strongly relates to the four determined core HEMS benefits for residential consumers within this study's Theoretical Framework. Below, a brief description of the manner in which Pure Energie envisioned to deploy (various combinations of) their Products & Services, to create Residential Consumer Gains within this specific stage of the design process is provided:

In particular, the combination of the HEMS, the dynamic contract type and a service bundle, supplemented by a home battery, private solar panels, and/ or EV charging stations, allows residential consumers to realise (large) potential financial savings. Moreover, this system is capable of optimally managing electricity for residential consumers. Subsequently, the digital

application and online residential consumer portal provide real-time updates and insights, offering HEMS end-users with an overview of their energy consumption as well as savings, thus increasing transparency. Furthermore, the offered Products & Services automate a variety of processes, relieving residential consumers from their burdens and thereby increasing convenience. For instance, the BYOD service, affords residential consumers with the convenience to incorporate existing smart home components within their residential household grids, providing a sense of flexibility and autonomy. Furthermore, the HEMS and home battery smart home component not solely facilitate financial savings and the optimal management of electricity, but this combined system is capable of extending the home batteries' lifespan as well and therefore provides an innovative edge for potential peer-to-peer energy trading in the future. Within the scenario in which energy trading strongly emerges in the Netherlands, this could serve as an additional source of revenue for residential consumers. Furthermore, financial solutions such as the partial financing or lease structures related to the home battery can aid in mitigating the financial impact on the residential consumers within their transition to these technologies. Collectively, these Gain Creators therefore amplify the value that Pure Energie's proposed Products & Services deliver residential consumers, thereby enriching overall experience and satisfaction related to the HEMS.

Concluding from the above, Gain Creators are crucial elements for achieving fit between the Value (Proposition) Map side of Pure Energie and the Residential Consumer Profile side, similar to the Pain Relievers that were described above as well. Therefore, during the Evaluation activity of this paper, specifically within the Discussion subchapter, these Value Proposition Canvas fragments will be thoroughly analysed again, and further explanation will extensively be provided. Moreover, this particular design stage related to the expert validation interviews. Therefore, the following chapters will provide various perspectives on the manner in which (Pure Energie's) Products & Services can be utilised to enhance residential consumer adoption of the HEMS as well.

6. Validation & Evaluation

Below, this chapter will validate the initial HEMS Value Proposition Canvas that was outlined within the previous chapter of this paper. Furthermore, it will be evaluated whether the HEMS Value Proposition Canvas met the treatment goal and requirements that were determined within subchapter 5.1. Lastly, the key findings of this study will be discussed in relation to the application of the Innovation Process-Decision model and the Technology Acceptance Model, on the basis of which the final design for the HEMS value proposition aimed to enhance residential consumer adoption was designed in Chapter 7.

6.1 Design of the qualitative expert interview scripts

As mentioned within the Methodology chapter, four expert interviews were conducted as validation method, related to the initial Value Proposition Canvas for the HEMS. Below, further elaboration regarding the specific design of the qualitative interview scripts that were utilised for this is provided:

Since the expert interviews were essential parts within this research to ensure that the proposed HEMS Value Proposition Canvas aligned with the aim of enhancing residential consumer adoption, four slightly altered versions of qualitative expert interview scripts were designed. Each iteratively revised for all distinct interview sessions. Yet, the initial Value Proposition Canvas stood at the centre of all separate interview script designs. Delving into each fragment of the initial proposition, questions were developed aimed at both the constructed Residential Consumer Profile side, as well as the compiled Value (Proposition) Map side of Pure Energie. These questions facilitated discussions around all integrated fragments, as well as the key findings from the residential consumer interviews. Moreover, questions related to the Residential Consumer Profile further explored the understanding and identification of the Residential Consumer Jobs, Pains and Gains. For the Value (Proposition) Map side of Pure Energie, questions were formulated to explore the degree to which the experts thought that the initial Products & Services, Pain Relievers and Gain Creators fragments could provide value for residential consumers. Additionally, the interviews benchmarked the perceived Fit as described by Osterwalder et al. (2014), discussing the degree to which the initially designed HEMS Value Proposition Canvas was capable of enhancing residential consumer adoption according to the experts. Therefore, a significant fraction of the questions oriented around the HEMS and its determined core benefits. These questions aimed to extract expert opinions related to the concept of residential consumer adoption and the underlying adoption domains associated with the Residential Consumer Profile. Summarizing, the aim of each script was to explore the design of the initial HEMS Value Proposition Canvas, as well as to gather supplementary data from experts on enhancing residential consumer adoption. This additional data significantly contributed to revising and refining the initial Value Proposition Canvas into the final version, after ultimately incorporating the expert perspectives during the final design stage. As mentioned, all four (coded) interview transcripts can be found within Appendix G-J.

6.2 Key findings from the qualitative expert interviews

As described within the Methodology chapter, after the four expert interviews were conducted, these sessions were transcribed, and colour coded. Therefore, the interview data was analysed, and several key findings were extracted. These findings will be articulated and briefly explained below:

I. The first key finding was that the statement of Sanguinetti et al. (2018), related to the lacking status of residential consumer HEMS adoption, was confirmed on the basis of the conducted expert interviews within the scope of this study. Moreover, primarily emerging from the Huawei expert interview, this globally oriented expert argued that the HEMS is nowadays not promoted to a degree in which large-scale residential consumer adoption can be achieved. Furthermore, it was identified that while the channel for residential consumers to adopt the HEMS is available, the manner in which the system is marketed and communicated by stakeholders responsible for supply of the HEMS, does not facilitate effortless adoption for residential consumers. In terms of technical developments, the HEMS complies with state-of-the-art industry standards. However, active communication to raise awareness is noticeably lacking, resulting in the residential consumer adoption of the HEMS falling short of global expectations.

   Specifically for the case of Pure Energie and the Netherlands, the experts within the additional three validation interviews identified the "Salderingsregeling" as the main gatekeeper of HEMS adoption by Dutch residential consumers. Primarily, since these residential consumers are currently still able to redeliver their excess RES-generated electricity to the national grid, in return for a remunerative compensation.

   However, despite the above, the experts generally perceived the HEMS as a potentially suitable tool related to the subsequent phase of the (global) energy transition within all of the four expert interviews, as the experts were confident in the system's future potential.

II. In relation to the four core HEMS benefits for residential consumers, as defined within the Theoretical Framework of this paper, the experts also unanimously determined financial savings as the driving benefit related to HEMS adoption, in line with the prevailing literature and the key findings from the residential consumer interviews. Moreover, the financial beneficiary aspect of the HEMS was identified as influential for the reduction of concerns related to (sharing) personal data and capable of persuading residential consumers to relinquish Autonomy & Control.

   Furthermore, the optimal management of electricity as well as the increased convenience benefits were widely acknowledged as HEMS benefits during the expert validation interviews. Related to the optimal management of electricity, particularly the sub-benefit of increased self-consumption was extensively recognized. The reduction of electricity load sub-benefit was deemed as a more important HEMS benefit within

countries in which the national electricity grid is less stable, and a higher number of peaks occur on a daily basis. Furthermore, the innovative edge benefit was affirmed by the experts as well. Additional explanation regarding the core HEMS benefits for residential consumers will be provided within the subchapter 6.3.2 below. Furthermore, a notable benefit-related key finding which also already emerged from the residential consumer interviews during an earlier stage of the design process, was that sustainability featured prominently within the four expert interview sessions, in contrast to the related literature. Moreover, this sub-benefit was designated by the experts as one of the main drivers for HEMS adoption. Therefore, sustainability was determined as a core HEMS benefit for residential consumers within the expert validation interviews.

III. Regarding the identified underlying residential consumer adoption domains related to the HEMS, the Knowledge & Vision domain as well as the Transparency & Trust domain were particularly deemed as important by the experts. This importance of the Knowledge & Vision domain also correlated to the first key finding described above. Furthermore, especially the Transparency aspect was considered as crucial to increase the degree of Knowledge & Vision among residential consumers, reduce their urge for Autonomy & Control as well as Security & Certainty domain-related concerns and to foster the degree of Trust towards utilities and the government.

Furthermore, the (data) Security aspect within the Security & Certainty domain was considered as a prerequisite of the HEMS, as the experts legitimately acknowledged the data concerns of residential consumers. Moreover, the safe development of software as well as responsible data management was argued to always be the standard goal.

IV. Fourthly, related to the widescale implementation of the HEMS, as well as the emergence of the home battery smart home component, a shift regarding the role of utilities was expected by the experts. Specifically, shifting away from their original role as energy suppliers and steering further towards the role of facilitating service providers, supporting residential consumers whose smart homes are becoming increasingly decentralised.

6.3 Evaluation of the initial HEMS Value Proposition Canvas

Since the initial Value Proposition Canvas for the HEMS was validated within the previous step of this study's design process, the evaluation of this initial version will be described below. This evaluation was conducted by relating the expert perspectives to the treatment goal and treatment requirements that were determined within subchapter 5.1 of this paper. Following this, all key findings of this research, related to both the qualitative residential consumer interviews, as well as the expert validation interviews, will be discussed.

6.3.1 Evaluation of the treatment goal & requirements

As explained within the Methodology chapter, the treatment goal of this study served as a compass to direct the design process towards the creation of a value proposition that met the outcomes aimed to achieve (Wieringa, 2014). The treatment requirements that were set, therefore defined specific characteristics which should be included within the Value Proposition Canvas to accomplish its treatment goal (Wieringa, 2014 & Peffers et al., 2007). Moreover, according to Wieringa (2014), evaluation of a treatment's goal and requirements should occur after the validation process, to sustain a focused and efficient design process. Therefore, this section will provide an evaluation regarding the treatment goal and requirements that were set during the initial design stage of this study. As stated within subchapter 5.1, the treatment goal determined within this study was to:

Present a Value Proposition Canvas for a HEMS that aligns the needs of residential consumers and their expectations with the value that Pure Energie plans to offer these consumers. Moreover, one in which the residential consumer adoption potential is optimally enhanced within the limits of this study's scope, through the application of the Innovation-Decision Processes model, and the Technology Acceptance Model.

While the design of the initial Value Proposition Canvas for the HEMS served to align the needs of residential consumers and their expectations with the value that Pure Energie planned to offer these consumers, the Innovation-Decision Processes model and the Technology Acceptance Model were not yet applied. Therefore, the following subchapter will discuss the application of these models in relation to enhancing the residential consumer adoption potential of the HEMS. Furthermore, below, the specific treatment requirements that were determined within subchapter 5.1 and not yet (satisfactorily) met during this stage of the design process, are re-stated below:

- *The VPC should be capable of supporting effective communication of the HEMS definition to all residential consumers, in a manner that appeals to them and contributes to their understanding of the benefits that the HEMS can provide.*

- *The VPC should have considered security both is terms of data, as well as relating to the physical elements that are being offered. Therefore, the VPC should emphasize the steps that strive to ensure the security and privacy of end-users' data.*

- *The final design of the VPC should be suited to integrate additional feedback after this research is conducted. Moreover, from residential consumers as well as Pure Energie, to ensure that the VPC for the HEMS remains relevant, adaptable and attractive in case residential consumer needs and preferences might change/ evolve.*

Within the following subchapter below, these specific treatment requirements will therefore be discussed as well, together with the application of the Innovation-Decision Processes model and the Technology Acceptance Model on the initial Value Proposition Canvas for the HEMS and the key findings of this study.

6.3.2 Discussion of the key findings

Since the main objective of the value proposition designed within this study was to enhance HEMS adoption by residential consumers, the first key finding from the expert validation interview with Huawei, which is described within subchapter 6.2, was crucial. This discovery contributed to gaining a deeper understanding on the specific reasons which caused the system's lacking adoption status. At this stage of the design process, first-hand information clarified that the HEMS adoption potential among residential consumers was already suboptimal from the Knowledge stage within the Innovation-Decision Process model (Rogers, 1971 & 2003). Moreover, primarily since the HEMS-supplying stakeholders, such as utilities, did not actively promote the system. This observation was very similar to the third key finding within subchapter 6.2 regarding the Knowledge & Vision underlying adoption domain, which was already identified earlier through qualitative focus group sessions with residential consumers and explained in subchapter 5.3.1. Furthermore, the Huawei expert pointed out that a global issue is present regarding the creation of awareness of the HEMS's availability among residential consumers, which prevents widescale adoption globally. Because of this, residential consumers have to put in effort solely to discover that the HEMS exists. Therefore, the value proposition is initially crucial for filling the lack of Knowledge & Vision among the majority of residential consumers. However, as explained within subchapter 5.3.2, several residential consumer groups, namely the Idealists, Green Mathematicians, and Sceptics, possessed an above average degree of Knowledge & Vision. Within the HEMS context of Sanguinetti et al. (2018), these groups correspond to Rogers' (1971 & 2003) *Innovators*, *Early Adopters*, and *Laggards*. Therefore, together, these groups represent approximately 2,5% (Innovators) + 13,5% (Early Adopters) + 16% (Laggards) = 32% of the residential energy sector. Since individuals within the Dependent residential consumer group are (partially) dependent on personal circumstances, this group is expected to adopt the HEMS relatively late, which is also in line with Rogers' *Late Majority* and *Laggards* groups. Moreover, the problem within the Dependent residential consumer group is not necessarily their adoption attitude towards the HEMS. Therefore, providing Knowledge & Vision through the value proposition and creation awareness of HEMS is expected to have the largest positive effect on the Followers residential consumer group. This fits with the description of this consumer group provided within subchapter 5.3.2, where it was identified that this group and the Dependents had the least amount of Knowledge and Vision regarding the HEMS and related concepts.

While Rogers (1971 & 2003) did not describe the Innovation-Decision Process model as a linear path the importance of the Persuasion Stage following the Knowledge Stage was stretched. Once the value proposition has provided residential consumers with Knowledge & Vision, they must be convinced of the HEMS's Relative Advantage (Rogers, 1971 & 2003) and, according to the Technology Acceptance Model, its Perceived Usefulness and Perceived Ease of Use, to increase the likelihood of HEMS adoption and thus actual use (Venkatesh & Davis, 1996). It is expected that the core HEMS benefits for residential consumers will play a crucial role in this. As explained within the second key finding section of subchapter 6.2, the experts identified financial savings as the main driver of HEMS adoption by residential consumers as well. Also, emerged from the validation interviews, it became evident that increased sustainability was additionally a major driver of HEMS adoption. Therefore, Figure 2 within this paper's Theoretical Framework, which illustrated the initially determined core HEMS benefits for residential consumers, was revised based on this key finding. Figure 9 therefore illustrates the final five core HEMS values for residential consumers. Moreover, all corresponding sub-benefits are listed below each of the five core values.

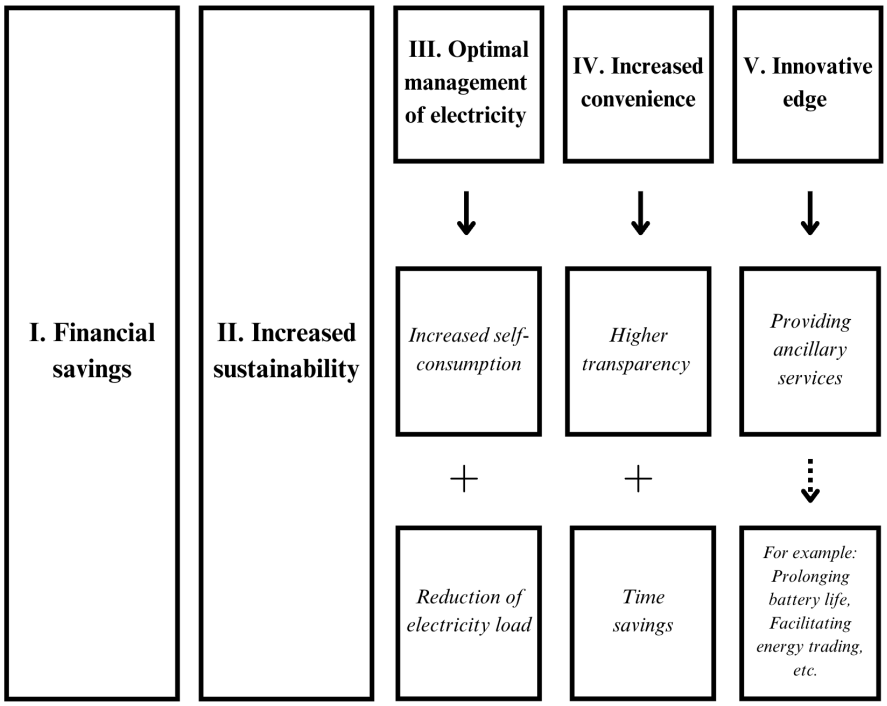

Figure 9. The final five core HEMS values for residential consumers

Idealists and Green Mathematicians are expected to adopt the HEMS relatively rapidly if the value proposition proclaims a key message that is both financially and sustainability driven. This, since these were the main adoption motives among these residential consumer groups. Products & Services from subchapter 5.5 that can contribute to this include: the 100% green guarantee, TV/ radio/ online campaigns, animated videos of financial calculation examples on the Pure Energie website, and a fixed compensation combined with specific HEMS service

bundles. Furthermore, within the third key finding of subchapter 6.2, it was stated that the Trust & Transparency adoption domain, along with the Knowledge & Vision domain, was especially important for HEMS adoption as well. Therefore, a high level of transparency within the value proposition, aimed to openly explain the motive of utilities, grid operators, and the government to control HEMSs within residential smart homes, could strengthen the position of these major stakeholders. This is expected to increase trust towards utilities and the government, which is expected to ease the concerns of Followers, Dependents, and Sceptics related to the Security and Certainty domain. Moreover, in line with the fourth key finding of subchapter 6.2, transparency in combination with HEMS providers (e.g., utilities) actively positioning themselves as service providers will likely reduce the urge for Autonomy & Control of residential consumers. Furthermore, transparency is also expected to clarify the core HEMS values of increased convenience and the innovative edge which the HEMS can offer residential consumers.

Lastly, as pointed out within the first key finding of subchapter 6.2, the ongoing "Salderingsregeling" was found to be the main gatekeeper for Dutch residential consumer HEMS adoption. Even though this finding is related to the residential energy sector of the Netherlands, the rise of the home battery as state-of0the-art component within smart household grids is a rising trend observed around the world. Therefore, the gradual ending of the "Salderingsregeling" by 2030 is expected to accelerate the addition of home batteries to smart home grids within the Netherlands. Moreover, since residential consumers will get an increasingly lower financial compensation for their excessively generated electricity from private RES, which is subsequently redelivered back to the national grid, as a result of the phasing-out of the "Salderingsregeling". When stretching this expected situation of the Netherlands globally, the optimal management of electricity core HEMS value will become significantly more important. Elaborating further, since the Theme Owner Energy Storage from Liander expected the subsequent phase of the global energy transition to be characterized by a radical increase in uncontrolled generated electricity from RES, both on the residential consumer level as on a nation-wide scale, the costs related to managing and maintaining national grid stability are expected to significantly increase for grid operators as well. Meaning, these costs will be indirectly passed on to residential consumers, in terms of higher electricity grid utilisation tariffs and taxes, thereby raising the value of the HEMS and increasing the likelihood of adoption.

7. Presentation of the Final HEMS Value Proposition Canvas

In this chapter, the final design of the HEMS Value Proposition Canvas will be presented. After that, the canvas will be reflected on, resulting in the description of conclusions that were drawn. Finally, this study's limitations will be addressed and directions for future research will be provided.

7.1 Conclusions

To conclude, the Value Proposition Canvas from Osterwalder et al. (2014) was utilised to design a value proposition for the HEMS, aimed to optimally enhance residential consumer adoption within the scope of this study. Below, Figure 10 therefore presents the final design of the Value Proposition Canvas.

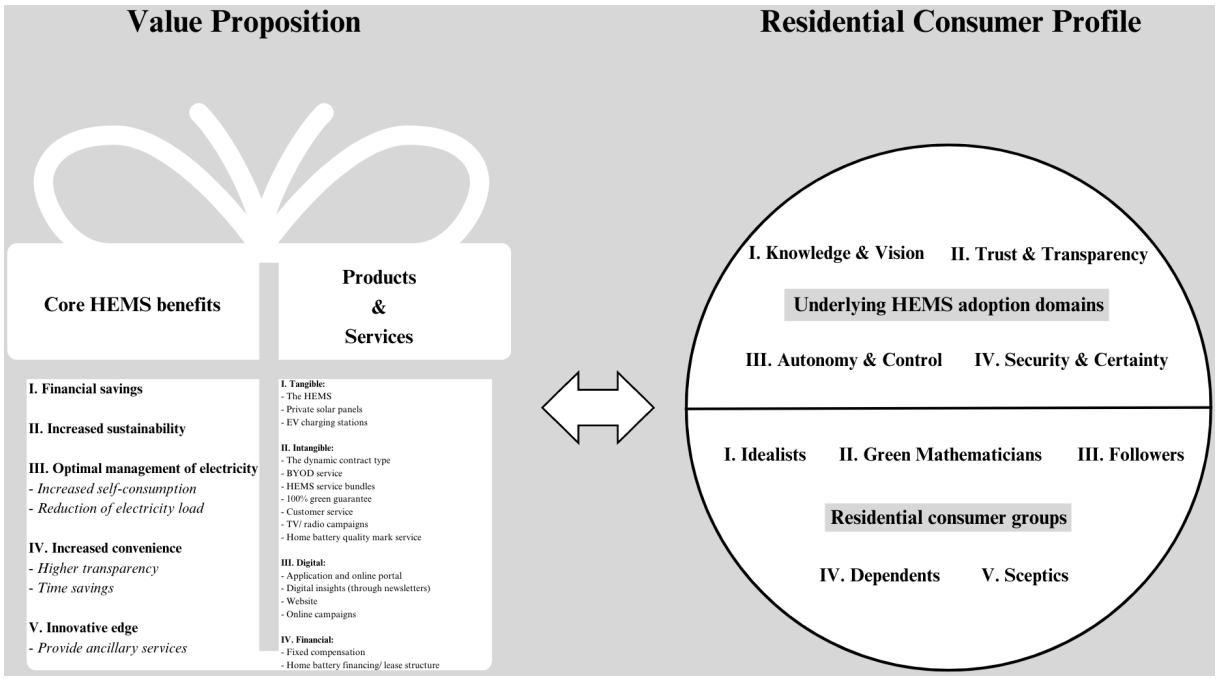

Figure 10. The final design of the Value Proposition Canvas for the HEMS

Since the design above integrated principles from the Innovation-Decision Process model (Rogers, 1971 & 2003) as well as the Technology Acceptance Model from Venkatesh and Davis (1996), to align the needs of (Dutch) residential customers with Products & Services that offer value from Pure Energie, the treatment requirements and treatment goal of this study were achieved. Therefore, the central research question of this design science paper was answered as well. The eventual feasibility, as well as the effectiveness of the designed value proposition has to be proven through practical implementation (by Pure Energie). However, according to Wieringa (2014), this activity belongs to the engineering cycle. Therefore, falling beyond the limits of the design cycle and this design study's scope. In general, the HEMS is considered as a suitable tool to serve a supporting role within the subsequent phase of the global energy transition. Moreover, the HEMS has the potential to contribute to an optimal, mutually

benefiting infrastructure, as stated by Nizami et al. (2019) within the introduction of this paper. However, utilities, grid operators and governments seem primarily willing to prioritise their individual stakeholder objectives. Residential consumer adoption of the HEMS as an enabler for the financial and demand side management objectives of utilities, grid operators and governments therefore conflicts with the personal interests of residential consumers, who generally limit their scope to their smart household grid. Hence, utilities that want to enhance HEMS adoption by residential consumers must realise this requires a drastic change of their primary role, namely that of service provider. The significance of this matter is becoming increasingly evident and noteworthy, particularly in light of the globally rising trend of home battery integration within residential smart grids. Furthermore, with the increasing decentralisation and self-sufficiency of residential smart homes, their reliance on utilities is diminishing rapidly. In order to persuade residential consumers to adopt their HEMS and effectively achieve their demand side management objectives, utilities must therefore present a realistic and transparent value proposition. The findings of this study showed primarily the core HEMS values of financial savings and increased sustainability are able to enhance residential consumer adoption of the HEMS. Furthermore, the core values of optimal management of electricity, increased convenience, as well as the provision of an innovative edge together with all associated sub-benefits can contribute significantly to furthering this objective. In addition, the four underlying adoption domains of the HEM, namely Knowledge & Vision, Trust & Transparency, Autonomy & Control, and Security & Certainty, must be considered by HEMS suppliers as well, to optimally enhance residential consumer adoption attitudes. Lastly, besides these key messages that should be implemented within a value proposition for the HEMS, the role of governments regarding future laws and regulations within the energy sector was observed as crucial and decisive for the residential consumer HEMS adoption around the world as well, as the government of each separate country determines the permeability of the global energy transition course within national borders and thus strongly impacts the plausibility of residential consumer HEMS adoption directly.

Following the above, this study academically contributed through the design science research methodology, which was followed, to solve the central research question of this paper and present a value proposition for the HEMS aimed to enhance residential consumer adoption. Furthermore, the study contributed academically by clarifying the reason behind the globally lacking status of HEMS adoption by residential consumer, through the provision of four underlying HEMS adoption domains, five residential consumer groups related to HEMS adoption and five core HEMS values for residential consumers. Practically, the value proposition of this study can be implemented and/ or utilised as a guideline for utilities, grid operators and governments aiming to deploy the HEMS among residential consumers, to achieve their demand side management objectives. Furthermore, the Products & Services that were provided within the scope of this study can be utilised in practice to foster HEMS adoption.

7.2 Limitations of this study

Within this final subchapter, the limitations identified within this study will be enumerated and explained:

1. Opposed to the results of a quantitively research, the results of qualitative research lack statistical representation. Therefore, the key findings of this study were primarily of subjective nature and could not be verified and/ or duplicated. Hence, generally difficult to accept as factual by neutral readers. Ambiguities regarding the gathered data might therefore potentially arise.

2. Two out of the four expert interviews were conducted online. Although on both occasions the camera was turned on, this still removes a dimension opposed to interviews that are conducted in person. Moreover, an atmosphere that is present if the interviewee is actually within the room. Furthermore, the impact of nonverbal communication is significant related to qualitative interviews since it portrays an important role regarding the interpretation of given answers. Therefore, these factors might have had an influence on the outcomes of this research paper.

3. Thirdly, two expert validation interviews were conducted with key personnel of Pure Energie. While these interview sessions were crucial to ensure that the proposed Value Proposition Canvas aligned with the utility's operational capabilities and market strategies, several of these interview participants were related to the HEMS project group of Pure Energie. Therefore, their opinion could possibly be biased.

7.3 Directions for future research

Below, several directions for future research will be provided, related to the key findings as well as the opportunities that emerged from this study:

1. As mentioned above, a HEMS value proposition aimed to enhance residential consumer adoption was designed and presented within this research. To optimally enhance the residential consumer adoption potential of this value proposition, principles from the Innovation-Decision Process model were integrated. However, this related to the Knowledge, Persuasion and Decision stages of the model. Therefore, this research primarily shed light on the factors that influence residential consumer adoption and did not consider the impact of the HEMS value proposition within the Implementation and Confirmation stages of this model. Therefore, future research should *implement* the (main elements of the) HEMS value proposition that was designed during this study into practice and investigate its effectiveness, as well as determine if the value proposition has the potential to actually enhance residential consumer adoption of the HEMS.

2. Emerging from the Huawei expert interview, a large potential regarding the role of the HEMS, as connector of the residential energy sector and overarching sectors was identified. Moreover, this expert argued that the small picture fits within the larger vision, due to the electricity management capability of the HEMS and capabilities of large-scale energy storage systems. While the role of the grid operators (i.e., Liander) was slightly covered within this research, through one of the four expert interviews, the

primary focus was on the relation between utilities and residential consumers within the HEMS context. Therefore, future research should extend this, by including the grid operators, corporate businesses and/ or the government as stakeholders in-depth, to investigate the interrelation of these stakeholders related to an optimal HEMS incentive structure as described by Nizami et al. (2019) within subchapter 1.1 of this paper.

3. Due to confidentiality, the perspective of Pure Energie was the only integrated perspective to represent the utility perspective within this research. Furthermore, qualitative focus group interviews with merely 36 Dutch residential consumers were conducted. Therefore, it would be interesting to validate these perspectives within a larger-scale future research, to validate these perspectives and gain a deeper understanding regarding the HEMS-related roles of these stakeholders within the residential energy sector. Moreover, this is necessary for grounded statements on national and/ or global scale to be made.

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Appendix A: Statement of AI technologies utilisation

During the preparation of this work, the researcher of this paper used ChatGPT in order to re-write several by the author written English sections into a more “Native English writing style”. These actions were solely performed in order to increase the academic quality of this research paper. Furthermore, the researcher of this paper did never ask ChatGPT to generate full chapters/ subchapters/ sections from scratch. As mentioned above, the ChatGPT input was solely provided in the form of originally written English sections and the ChatGPT output was always manually revised and edited multiple times. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the work (Elsevier, 2023).

Appendix B: The complete list of search terminologies for the HEMS benefits for residential consumers framework

“Home energy management system” AND “consumer” AND “benefit”
“Home energy management system” AND “user” AND “benefit”
“Home energy management system” AND “customer” AND “benefit”

“Home energy management system” AND “consumer” AND “advantage”
“Home energy management system” AND “user” AND “advantage”
“Home energy management system” AND “customer” AND “advantage”

“Consumer-centric” AND “home energy management system”
“Consumer-centric” AND “home energy management”
“Consumer-centric” AND “home” AND “energy management”

“User-centric” AND “home energy management system”
“User-centric” AND “home energy management”
“User-centric” AND “home” AND “energy management”

“Customer-centric” AND “home energy management system”
“Customer-centric” AND “home energy management”
“Customer-centric” AND “home” AND “energy management”

“Smart home” AND “energy management system” AND “consumer” AND “benefit”
“Smart home” AND “energy management system” AND “consumer” AND “advantage”

“Smart home” AND “energy management system” AND “user” AND “benefit”
“Smart home” AND “energy management system” AND “user” AND “advantage”

“Smart home” AND “energy management system” AND “customer” AND “benefit”
“Smart home” AND “energy management system” AND “customer” AND “advantage”

Appendix C: Background information and key takeaways related to three established contributions within the design science literature

Below, general background information as well as key takeaways from Hevner et al. (2004), Peffers et al. (2007) and Wieringa (2014) is provided, as described within section 3.2 of the Methodology chapter:

I. Below, Table 6 presents the seven guidelines for design science in information systems research, as proposed by **Hevner et al. (2004)**. This contribution is the most established work within design science literature regarding information systems. The authors state that design science is the foundational paradigm to the information system discipline, together with behavioural science, as both approaches are positioned at the confluence of people, organisations, and technology. Moreover, the behavioural science paradigm seeks to develop and verify theories that explain or predict human or organisational behaviour. Complementary, the design science paradigm seeks to extend the boundaries of human and organisational capabilities by creating innovative, state-of-the-art artefacts. The purpose of their seven established guidelines is to assist researchers, reviewers, editors and readers to understand the requirements for effective design science research. Since within design science, knowledge and understanding of a problem domain and its solution are achieved during the building and application of a designed artefact, the guidelines contribute to understanding, executing, and evaluating the research. However, advice is emphasised against mandatory or rote use of these guidelines, as in every research should be determined when, where, and how to apply each of the guidelines by researchers, reviewers, and editors.

Table 6. The seven guidelines for design science in information systems research (Hevner et al., 2004)

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

II. Within the field of design science in information system research, **Peffers et al. (2007)** analysed prior research to design a Design Science Research Methodology (DSRM), displayed in Figure 12. Their aim was to design a methodology that can serve as a commonly accepted framework for carrying out research, based on design science research principles. While desiring to apply a consensus-building approach to produce this design, their DSRM process is based on seven representative papers and presentations within IS literature, as well as literature of other disciplines. Consensus was built, as these authors agree substantially on common elements. Therefore, it was ensured that the DSRM is based on well-accepted elements. Nowadays, their DSRM process model is the most established research methodology within the field of design science. While adhering to this order is not a DSRM prerequisite, the framework proposes six activities in a nominal sequence. These activities will be explained below.

Activity 1: Problem identification and motivation

Defining the specific research problem and justifying the value of a solution. The problem definition will be used to develop an artefact that can effectively provide a solution. Justifying the value of a solution accomplishes two objectives: it motivates the researcher and the research audience to pursue the solution and accept the results, and it helps in understanding the reasoning associated with the researcher's understanding of the problem.

Activity 2: Defining the objectives for a solution

Objectives of a solution from the problem definition and knowledge of what is possible and feasible should be determined in this stage. These objectives can be quantitative or qualitative. However, they should be inferred rationally from the problem specification.

Activity 3: Design and development

Here, the actual artefact is created. A design research artefact can be any designed object in which a research contribution is embedded within the design. Therefore, this activity includes determining the artefact’s desired functionality and its architecture. Afterwards, the actual artefact can be created.

Activity 4: Demonstration

Demonstrate the use of the artefact to solve one or more instances of the problem.

Activity 5: Evaluation

Observe and measure how well the artefact supports a solution to the problem. Furthermore, comparing the objectives of a solution to actual observed results from use of the artefact in the demonstration. Conceptually, such evaluation could include any appropriate empirical evidence or logical proof. At the end of this activity, the researchers can decide whether to iterate back to Activity 3 to try to improve the effectiveness of the artefact, or to continue on to communication and leave further improvement to subsequent projects. The nature of the research venue may dictate whether such iteration is feasible or not.

Activity 6: Communication

Finally, the problem and its importance, the artefact, its utility and novelty, the rigour of its design, and its effectiveness should be communicated to researchers and other relevant audiences, when appropriate.

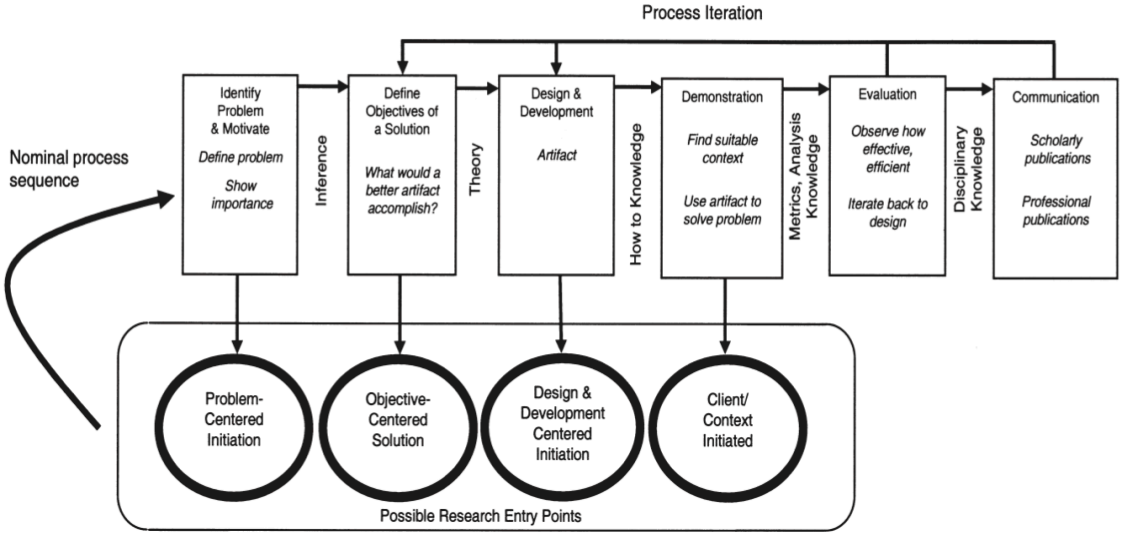

Figure 11. The Design Science Research Methodology (Peffers et al., 2007)

III. Thirdly, a relatively modern yet established contribution within design science literature is integrated within this study, namely that of **Wieringa (2014)**. This work covers an enormous proportion of the information systems field and provides many diverse and clearly defined guidelines for doing design science research within this domain. This work utilises the terminology of a *treatment* for the solution of a design problem and argues that these problems are treated by following the design cycle, which consists of an iteration over problem investigation, treatment design, and treatment validation. The design cycle is incorporated within the engineering cycle. Both of these cycles are displayed below in Figure 13.

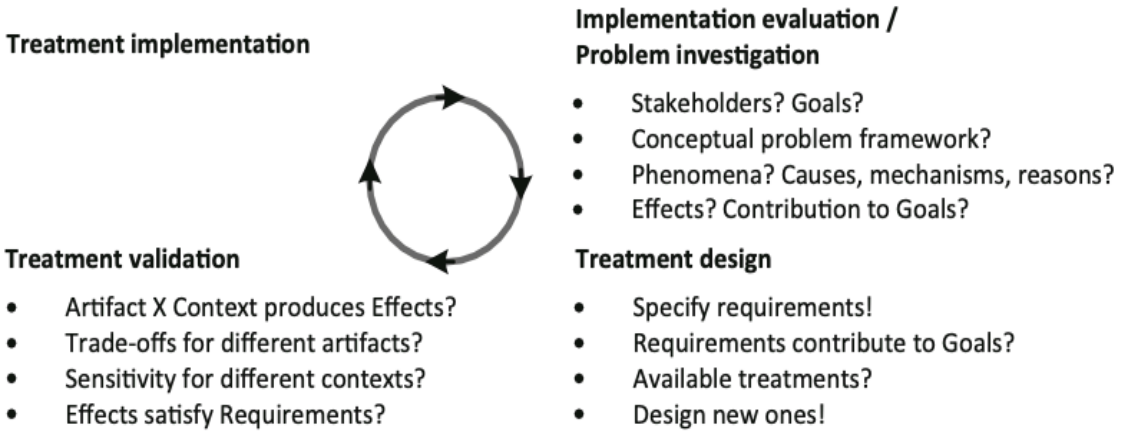

Figure 12. The engineering and design cycles (Wieringa, 2014)

Design science research projects do not perform the entire engineering cycle but are restricted to the design cycle. The definitive transfer of new technologies or treatments to the real-world context may be done after the research project is finished but is not part of the research project. However, since both the engineering and design cycle provide a logical structure of tasks, but do not prescribe the exact process of engineering or designing, they do not prescribe a rigid sequence of activities. Therefore, incremental implementation of a treatment within a fragment of the real-world context is possible to validate treatments. The goal of validation is to predict how a designed artifact will interact with its context, without actually observing an implemented artifact in the definitive real-world context. In validation research, an artifact is therefore exposed to diverse scenarios presented by a representation of the context, to analyse the effects it causes. Therefore, to design a treatment within the design cycle, the problem and its context must first be understood before it can be treated. Furthermore, the decision for choosing a specific treatment must be justified, by validating it before definitive transfer (i.e., implementation) from the problem context into the real-world context occurs. After a treatment is implemented within a (fragment of the) real-world context, evaluation occurs to learn from the implementation.

Appendix D: The original Onion Diagram of Product Stakeholders from Alexander (2005)

Below, Figure 13 displays The Onion Diagram of Product Stakeholders from Alexander (2005). This framework allows a project's stakeholder sociology to be graphically modelled. Moreover, it provides an overview of a project, oriented around a product and therefore serves as a taxonomy of stakeholders. Within the diagram, different stakeholder roles are identified among the four circles of the onion model. Each stakeholder role is represented by a person, group of persons and/ or institution(s) with a distinct relation to the product that is under development.

1. **"The Kit" or "The Product":** Represents the item under development.
2. **"Our System":** "The Product" plus its human Operators and the standard operating procedures or rules governing its operation.
3. **"The Containing System":** "Our System" plus any human Beneficiaries of Our System (whether these are involved in operations or not).
4. **"The Wider Environment":** "The Containing System" plus any other stakeholders.

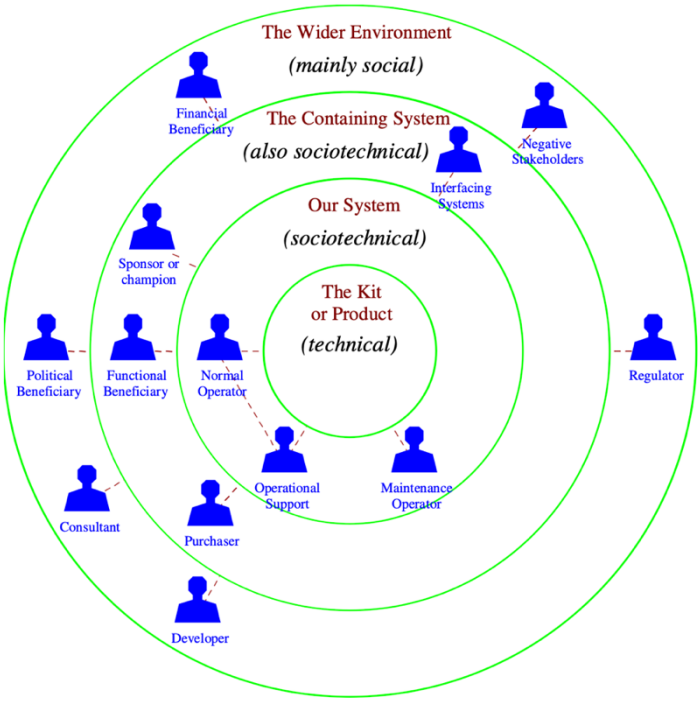

Figure 13. The Onion Diagram of Product Stakeholders (Alexander, 2005)

Since "The Kit" or "Product Circle" represents the part of "Our System" that can be sold, this part does not include humans. Therefore, this circle does not contain stakeholders. Furthermore, the diagram is not intended to depict stakeholders from a judgemental position in degrees of power, influence or interest. The distance of every stakeholder role from the central product is therefore no indication of stakeholder importance.

Appendix E: Newcom Research & Consultancy B.V.'s design of the qualitative residential consumer interview script

Appendix F: Pure Energie's initially envisioned value proposition for the HEMS

Appendix G: Coded expert interview transcript – Huawei

Interviewer: First of all, thank you again for taking the time. My name is as mentioned Wouter Evertzen, currently 25 years old and close to completing my master's thesis in Innovation Management, Entrepreneurship and Sustainability at the University of Twente as well as the Technical University of Berlin. So then, about you, I saw you had a long history of working at **Huawei**? Could you maybe explain what your function exactly entails and how it relates to **home energy management systems and home batteries**?

Edwin Diender: Sure. Thanks for having me, pleasure to support. There is a good history of relationship between the Technical University that you are a part of and the company that I represent. Although the history sits with our local team, which is probably the Netherlands, where I started at the end of 2011. To help set up. **So, I was hired to help set up industry solution sales practices for the West European region. In the different industry domains and technology sectors that we were addressing. I became a spokesperson for the international media and global analyst organizations in the course of 2013. In 2014, I was asked if I would like to join a couple of activities in our headquarter in Shenzhen in China, which I gratefully said yes to. I started working out of Shenzhen, which is where the headquarter of the company that I represent is established in January 2015, as the Chief Technology Officer for the unified communication, and collaboration portfolio and product line, which is an R&D-related product management kind of function, towards products that go to market and products that need to be adapted according to customer requirements and market inputs, and so on and so forth.**

I've made a few terms within the company since then, for example, the idea was that I would be there for a year 12 to 18 months, maybe a year and a half and go back to Europe. To put in place further of what we've learned from a headquarter point of view and from the other way around what I was able to bring in for the region and the countries that I was working for into headquarter and back and forth. That still is the case, I still do that. I support our customers and our partners with digital journey from different industry domains. Currently I am Chief Innovation Officer in the electric power digitization business unit, in which I support the digital journey of customers in the electric power industry, and specifically to your research item, which is about energy management, energy storage, I'd like to add a few items that relate to what I do. Other than or on top of or adjacent to energy management that energy storage. I also look at energy mobility, energy distribution, energy transmission, and energy generation and for that, I am working with a large group of people that worldwide as I said before, are supporting customers and partners in the electric power industry with their digital journey basically, using digital technologies and using equipment. To help do better what they already do best in a non-digital way. So, helping them with automation, business process optimization, more efficiency in daily operations by using digital technology as a tool versus a lot of time wasters when it's not digital but very analogue: pen, paper, clipboards,

Excel files and what have you?

Interviewer: Okay, thank you, that is very clear! To specify a bit more than, my research is really focusing on, **the residential consumer adoption related to home energy management systems.** And yeah, I'm designing it from the utility's perspective. So, like one of the Dutch utilities. Also, if I mention the term utilities, I specifically mean, the energy suppliers. Just for your information. And then, in general terms, how would you describe the **global status regarding the residential consumer adoption of the Home Energy Management System in 2023?**

Edwin Diender: **I would say it's at a very early adoption stage, maybe even before that, actually.** And that's because basically, there are different kinds of solutions available. **But consumers, as far as I can see, don't really see the opportunity yet, don't really feel the potential that it has, and probably also don't know exactly where to get it. If they read about it somewhere, it'll probably going to be somewhere in the newspaper, or it's going to be in the news. So, it doesn't come from experts, it doesn't come from the industry itself. It doesn't necessarily come from advertisements, or a wide set of information handouts and publication and promotion. Regarding it as a solution domain for home users to use.** What they do then is they ask their questions, probably to the one who provided them with their solar panels and the inverter and what have you. And sometimes they can say something like, well, you know, we got the Tesla, this and this product, or we got the Huawei, Luna and something product, or we've got another vendor's product, which is basically sort of a battery that you can use at home. **But the pricing is not very clear yet. Implementation is not very clear yet. So, it is a bit ambiguous. So, I would say they are a little before the early adoption stage.**

Interviewer: Okay. Thank you. Very interesting. **So yeah, there's also not really a good channel right now where the information is provided to the consumer? So, it is more like the consumer has to find out about it themselves, you mean, to specify?**

Edwin Diender: In a way yeah, in a way, yes. But coming back to your earlier point, with what you just started with: the channel is there, you can get these kinds of, let's say, home use or residential, specific or residential targeted energy storage systems, IKEA, for example, is a very good chain, where you can get these kinds of solutions. **But the consumer, then it's not promoted by IKEA in such a way that it's in your face, and that you don't have to search for it. It's available to you, and you're aware of it. And more and more organizations, and people and institutions are also talking about it. That's what I mean. So, from a promotion and an awareness point of view, I would say that is a channel like a communications channel. I think the communication about it is a little further behind than the actual availability for it. Because you can get solutions like this. But you have to source them yourself. Maybe even calculate for yourself, which one is the best fit and so on and so forth.**

Interviewer: Very clear, thank you. **And then what are your general thoughts related to the**

HEMS and home batteries in the next phase of the energy transition? Like the feasibility? Do you believe in this concept, or?

Edwin Diender: **Oh, very much, very much for a couple of reasons. The first reason being that I represent a company that is very strong in information and communication technology. In this domain, there are many parallels you could make to energy. We are working with data, and bits and bytes. Data management, data storage, data mobility, data distribution, are very common principles used in an infrastructure in a network, which is a computing network or communications network that has a copper cable that is linking all of these systems and services and pieces of equipment to make it work at once. In the past, it wasn't like that. It was a copper cable, but not with all this information inside and all these features like data management and data mobility and data storage.** But today it is, and this copper cable is more than 100 years old, it is the plain old telephone network. And the company that I represent is one of the key drivers together with others that has transformed this copper cable capability not to be an analogue telephone network anymore, but to be the worldwide web of computing and the worldwide web of communications. **So, in parallel to the other copper wire cable, which is the electricity network. There are many parallels you can make, there are many analogies that you can extract out of it. For example, when we talk about data management, data storage and data mobility and data distribution and data analytics, thinking that if we change data for energy, we will have an ability to think about the electricity network being capable of not data management, but energy management. For this, we would need information from that network about the energy just like in computing networks, we would need data or information from the computing networks, in the electric network or in the electricity network, we would need energy or electrical information or information from electricity, to put it in a data system to manage it, and to understand what it means if it gets distributed. So, the parallels are very apparent. And I see a tremendous uptake when it comes to the informatization and the digitalization of the regular, non-digital native copper cable, which is the electricity cable. By reasons that I've just tried to explain. So, data management versus energy management data mobility versus energy mobility, data storage, and analytics versus energy storage and energy analytics. So that's the first angle or chain of thoughts, I would say that resonates very well with me. Another thing that resonates very well with me is the fact that the regular power grid is not very utilised yet to be capable of taking more energy on it. So, for example, if we are generating more energy via solar panels, and wind and hydro technology, and what have you, on top of, and next to the original, already existing and available ways of how energy is being generated and put into this network, this network will go down in an instant. So in order to manage that, it needs to be stored somewhere, like a proxy, or like in data management, you have a data lake, maybe there's an energy lake or an energy storage compartment that is holding energy in and depending on the demand and, and the requirements of people and items and systems and services and devices that require the electricity of energy, it can be transformed or transmitted or distributed to that. And the second thing that sits on top of this, so this is let's say this is 2A, 2B would be if more and more organizations are using their rooftops and their parks and their available free spaces, for example, solar energy creating solar farms and so on**

and so forth, they might do the same as home users could do. So, the big picture and the small picture fit together. The home user can generate more energy than it actually needs instead of putting this on the power grid, bringing the stability of the power grid a bit into a risk, you can store it you can use it for your own use and for your home use in the evening when the times when there is no sunshine for example. So, the bigger picture and a smaller picture in this case also go hand in hand. The demand, the usage and the huge opportunity for energy management and energy storage systems. Also, for residential areas creates small energy generating opportunities, including the storage and the distribution and the mobility of it. A practical example would be a freelance worker who is an electrical engineer or who is a garden landscaper who needs power tools, which require energy the pickup truck can be charged in the evening at home and it has I don't know how many kilovolts or how many megawatts this car can take, or this pickup truck can take if they drive one hour away from home to their job where they do the landscaping or where they are a plumber or where they are an electrical engineer or what have you. And they need to power the power tools you could say that this vehicle that has the battery that stores all this electricity for the power tool now has become not a vehicle anymore of the person itself, but it also has become a vehicle to transmit or to distribute energy, right? So, energy mobility now is the vehicle for energy mobility is the electric vehicle which is a tablet on wheels. So huge potential, huge potential. Which I don't only strongly believe in there's many examples where this already is working.

Interviewer: Yeah. Yeah, indeed, very interesting. **And in that case, the Netherlands is a bit lagging behind the rest of the world I would say. So therefore, just short answer but to specify like it can also work the other way around I guess like a utility that has problems with too much generated energy. Are there like opportunities to store that energy in the in the home batteries of residential consumers. So, like a bit of a mutual benefiting system?**

Edwin Diender: **The answer would be yes. But the devil is in the details, of course, what would be the benefit for the home user would be a good example.** I can understand the benefit for the Electric Power Company, if they can store energy in home user battery packs. But what would be the benefit for the home user, if they don't need it or don't require it, they already are connected to the power grid, whatever power they need, they flip the switch, and the electricity is on. If they don't need it anymore, they switch the switch the other way around and the electricity is off. **In the case where they (i.e., residential consumers) are generating more energy via their solar panels than they need, they could store this into a battery pack that the Electric Power Company provides under certain conditions or the other way around. The energy company could say you are currently generating part of your energy yourself with your rooftop solar, it is almost close to a 50/50, right? So, half of the electricity that you need is being produced or generated by your solar farm and the rest is what you take from our network. Instead of taking it from our network, we will guarantee you that you have a battery pack that is charged to a fully 100% by the time the sun goes down. And the usage of your electricity in the evening or in the darkest hours until early morning is from that battery pack. That could be part of a subscription that the electric power company could provide to them. In return, the electric power company**

can say this battery pack is actually storing more energy than your evening use, or your evening needs. So, we have the freedom to take more energy out than you need in the evening, Mr. Home User. That could be a conversation I can imagine an electric power company representative would have with a home user or homeowner for these kinds of things. In addition, it can also be a conversation that the electric power company representative has with a home user who does not have solar at all. But who could be foreseen and provisioned with evening energy out of a battery pack rather than being directly connected to the power grid and taking it directly from the power grid? I can also imagine that.

Interviewer: Okay, yes and exactly those talks like between the utility and the consumer that you just described? That's, that's a bit my, my business case. So therefore, just in short terms, what do you think are the main benefits that residential consumers actually desire through HEMS adoption? **So, like in terms of financial or?**

Edwin Diender: **I can imagine there's an incentive, which is either financial or converted into something monetized like discounts, or what have you. I can also imagine that a benefit for the home user is allowing them to look at their residence area or the residential area, as a green area. And the more of these solutions are in place, the greener the area is which could help increase the value of living in that area. So, it will help increase the value of houses, or rent that should be paid for people who live there or for people who have houses and want to sell it. So that's a beneficial part.** Another beneficial part I can imagine is that the electricity company, who is today a provider of electricity, where the switch is on and there is electricity and the switch is off and it is off, so they provide electricity. **Instead of being that they could become a partner to a residential area or a partner to a home resident, in terms of jointly working on creating a green living space, a carbon neutral, or net zero climate, living space, where electricity is a by-product of what the electricity company together with the residential user are aiming for, or looking at. Then, in that chain of thinking and in that line of thought, you can imagine perhaps the value of such a HEMS solution becomes a driver for such journey and for such initiatives and for such programs. In other words, instead of looking at a residential area, as consumers, it becomes you know, more sustainable it becomes greener it becomes carbon neutral, it is lowering greenhouse gas emissions, which is subject to carbon offsets, carbon credits and carbon trading where the home user today don't see much other than from an investment point of view. But now they become a real player within this, or they become one of the players within such a game plan if you like. So, there's a lot of benefits that you can or a lot of a lot of value that you can think about and create. By the way, we're just talking about it right now. They have to be aware of that. Similar to why they don't know yet that there is very good solutions for all of this, because no one told them or it's not in their face, let alone it's not in their face that this is the upper case for that.**

Interviewer: Yeah. And that's actually very **interesting that you also relate to the sustainable aspect and the zero carbon emissions, like, out of all your experience, just in your whole career, did you identify the sustainable aspects as really something that the consumers on**

an individual level value or that they see as a benefit?

Edwin Diender: **Yes. And not only that, but the answer is also yes towards people who are consumers. The answer is also yes to people who are consumers and who, in their professional life perhaps are working in the in the in the energy industry, or people who are working in the industry or education or healthcare or somewhere else, because they are, they are not just consumers from a home use point of view, or from an individual point of view, but they're also a user, that sees the benefit of all these sustainability, sustainability items in their professional life. If you're the managing director of I don't know what whatever company, then I think there is a, there is a there is a blurred line a little bit when it comes to in my home, I'm carbon neutral, I recycle my waste and what have you. But, in my office, actually I don't, I don't really care versus I am sustainable, green, recycle everything in a very, I'm very aware of the environment. Throughout my daily activity, whether I'm at work, whether I'm in the office, on the road, or home, or on vacation, or what have you. And that's, that's a key differentiator and something really different than a couple of years ago, where it was either this or that, and maybe such and maybe so that is a huge differentiator, which changed. Elements of being environment aware, the component of green, a greener and sustainable future, and all these all these great words that we're using for playing a specific role in decision making processes, not just in the home environment, but also in the professional life of these people. Also, your question related to throughout my career: from the moment I started working after I graduated, this has been something that sits in the front end of my thinking, I got a PhD in economics, with, with a specialization towards digital economy, and sustainable business models, and so on and so forth. And that means from day one, that I spoke to customers, I've always tried to see whether we could do something, not just as a project as a one off as just a straightforward delivery rather linear, but make it more holistic, make it more inclusive, make it more sustainable. Back in those days, the word sustainable wasn't used very much. But the principle of sustainability was definitely part of at least the way how I approached my job, my key messages to customers. If I need to change the thinking of a customer in a certain way, and instead of walking the walk and talking the talk about technical descriptions and terms and why from a feature functionality, my product is bigger and better than the others, I will usually try to the other way around. It will either be more sustainable, it's more durable, it was a word that we use very much. It's lower on power consumption, you know, that sort of thing?**

Interviewer: Yeah. **So, it's, like becoming more of a standard and the I would say global trend then is actually continuing also to a bit of the more original groups that are more towards, let's say, sustainability, so like maybe the late adopters and such groups?**

Edwin Diender: **Yeah, agree, yeah, fully agree. What you could say now is that this very specific item becomes less specific, and it becomes less specific and is more mainstream and a general given. People expect it to be sustainable people who don't even require it anymore. They just take it as "of course it is". And if it's not, you're out of the game, so to speak. Including a home user going to supermarkets, where, you know, specific kinds of**

foods are either processed or more, let's say carbon neutral or environmentally friendly, that sort of that sort of stuff, right? It becomes less specific, and less asked for its demanded that you got to have it. Otherwise, people don't even look at it.

Interviewer: Okay, yeah, very interesting. Then I would skip through a few questions. So, just to be sure: you have, like around 10 o'clock the time is up, right?

Edwin Diender: Yeah.

Interviewer: Okay.

Edwin Diender: Yeah, so if you want to be more specific, I got about between five to 10 minutes and then. Okay, so five if you want, if you want to make it more, yeah, if you want to make more specific 10, five to 10 minutes, because then I have some time to prepare for the other meeting, Okay? Which doesn't mean that this has to end. If you want to speak to me again, we can reschedule to another time. That's no problem.

Interviewer: Okay, that will be very nice, then I can actually revise everything as well. So, but then for now, I will skip to the to the most important questions again. Let me take a look. **Yeah, so then, in terms of implementing the HEMS from this utility's perspective? What would then be the elements that you would include in the initial message? So, to make it in their face as it's not? Right now? The proposition?**

Edwin Diender: Okay, that's a marketing question aimed towards consumers I would say.

Interviewer: Yeah

Edwin Diender: which is not really where I am.

Interviewer: Okay.

Edwin Diender: The side of the business that I'm part of is enterprise, which is corporations, businesses and companies and that sort of thing. But I think from a messaging point of view, it resonates on both sides of the same coin, which is the home user who is a user, who is a person, and whether at home or at the office or on the road, or in a restaurant or anywhere, **I think certain words resonate always very well: be independent, like, less dependent on the Electric Power Company more dependent on your own 24/7 energy management, energy mobility, energy analytics. With the right application integration, I can even imagine that there is an app on my phone that understands how much energy I have in my battery pack. It's my daughter's birthday tomorrow. So, I would like to give her a gift card, I would like to give her 10 kilowatt hours of electricity from my battery pack, which of course is impossible to do. I cannot take 10 kilowatt pieces of electricity out of my battery pack and put it in hers. But from an application and from an app information point of view, I certainly can. I can send via mobile applications, my daughter, a gift card. And**

when she activates it, somewhere in the back end, there are different boxes ticked, that say, "you know starting from tomorrow morning, until those ten-kilowatt hours have been consumed, her dad is going to pay for that.". Regardless of who the electricity provider is, because in the app it says her dad will pay. So, if my daughter has in the Netherlands, for example, has this electricity agreement with Nuon. But I have one with Essent, or I have one with Vattenfall. Then, Nuon and Vattenfall need to talk to each other, or my app, make sure that Nuon and Vattenfall talk to each other, so Nuon doesn't charge my daughter. Nuon charges Vattenfall because I'm a customer for Vattenfall and the ten-kilowatt hours of my daughter should be on my bill and not on hers. And my discussion with Vattenfall is also a very interesting one. Because I will tell Vattenfall, you don't charge me at all, this is in my battery pack. And my battery pack has been charged with what I have on my roof, here's the proof in my app, so you deduct you'll give me a discount or something like that. These kinds of conversations, these kinds of abilities and future opportunities, I think will resonate very well with people. They understand immediately what that means. Because just like Amazon gift cards, you can give a Nuon gift card, you can give an Edwin gift card, it's my energy for my battery pack, that sort of thing. From another point of view, my home doesn't become an item that needs electricity to work, my home becomes a space that is adding to a greener future. Because it is not carbon zero. It is you know it's doing better than that. It's carbon negative, maybe, or it's you know, you get the point. I guess what I'm trying to say… So, these kinds of wordings resonate very well with people who are ahead of the curve, who are in the front end of their thinking who are looking for ways to maximize this greener thing and the greener the better. So, these kinds of wordings you can put on top of having an item that is a HEMS. Why should you have a car? Well not because it costs so much money, but because it's gives you so much value or because it gives you so many benefits and so on and so forth. So why should you have a HEMS? These are the benefits for you as a home user. **You know, you could share it with your family members just like your mobile phone subscription or Netflix you know it is one account, daddy pays, but the whole family uses the password and the login. Or friends do this, you know, let's all pay 2,50 a month, we give it to one guy, this one guy pays, and we are with five, or we are with 10. So that's a $10 or $12,50 fee, you know that one of us pays to Netflix, or I don't know what… HBO, Disney Channel and we use it. All of us use it, you know, that sort of thing. With these kinds of thoughts and these kinds of messaging and these kinds of stories that help you create awareness, you can blend this into a marketing campaign, you can blend this into a publication, into a promotion into a message that you can send out to homeowners and residential users.**

Interviewer: Very interesting take and then from what you just said, **I would say that, actually the transparency in this sense, like right now we have in the Netherlands that you can see per hour for how much you've utilised energy-wise, but then you would also say or almost say that we will go to like, real time transparency in the sense like also with the proof involved there?**

Edwin Diender: Yeah, true fully agree! And with the right application integration and feature functionality, I can also imagine that if I'm generating energy from my solar

panels on my roof today, in my application on my mobile phone, I can see how much energy that is, I can see how much my home is using and I can perhaps also see how much I'm giving back to the grid, for which I get a fee, a kickback fee or what have you? Maybe I can imagine an application on my mobile phone that says I have a slider and I will slide for the coming hour to not turn it into my home but turn it into my battery pack. If my battery pack is fully charged at 3pm then I'm sliding it back, which means by sliding it back, it goes back into the power grid. Or instead of going into the power grid, it goes to a battery pack or instead of going into a battery pack, I'm putting it back into the power grid. similar ideas I can also imagine occur if I'm going on holiday so for a week I'm not at my home. That means my home doesn't need that energy, my battery pack is charged for the full 100%. But my rooftop solar is generating energy. So, for the coming week or for the coming two weeks, I want someone else to use that energy, maybe my neighbour or my parents or again my daughter, you know as an anniversary gift or what have you. Those kinds of things from a digital point of view and from a mobile integration point of view allows an analogue power grid a non-digital power grid to become more interesting and to become a new kind of, well, a worldwide web of energy rather than a world wide web of information. The Energy Verse by the way, is how I call this feature, but from a promotion point of view I can very much imagine that this will resonate very well with people. Who, once they hear it, will get interested and say, "this is what I didn't hear before which prevented me from going forward with expanding my rooftop solar capability or adding battery packs to my home." Or maybe the battery pack is too expensive. It doesn't do much, so let's not spend 10,000 euros on a battery pack. But maybe with these kinds of arguments and with these kinds of examples and with these kinds of possibilities, they might even be willing to pay 12,500 for a battery pack instead of 10,000.

Interviewer: Yeah. Again, very, very interesting take. I'm just relating it to the questions I have written down here. So then to relate back on that: **like the more knowledge or actually vision that you provide these consumers with, this can also contribute to the trust that they have towards utilities and the government because that's also a big issue in the Netherlands right now, as you might know, like based on the corona pandemic, there's a general distrust against the government and utilities. So yeah, information like that can also help with that problem. I would suggest.**

Edwin Diender: I would not even suggest it. I would take that as a given because the answer is yes. The more transparency and the more openness within the availability of the information. For example, an application that is showing you this, is not the government that tells you what or how, it is your application that relates to YOUR home situation. And this is a visibility of what goes on regarding you, your energy consumption, your energy generation, your energy storage, your energy need, but also the freedom of use for and from your energy. It's not the government that says "no, you cannot do this", or it's not the electricity company that says, "well, we don't have really good facilities for that". It is your application, it is YOU and it is your peers and your group of people that are just part of it or become more part of it, become more inclusive, become more open,

more transparent. And I think these combined create a higher level of trust.

Interviewer: Okay, thank you. Then I would suggest that I ask one final question and like you mentioned, after I've analysed this interview, then I probably would very much like to have another session if that's okay with you.

Edwin Diender: Yeah, not a problem! Somewhere next week that would be then. Or the week after that, but sure.

Interviewer: Yeah, perfect, I'll schedule it then.

Edwin Diender: Ask your last question then for today.

Interviewer: In case of data security, because that's also a big risk then, if we go towards a system like this. Could you maybe give your thoughts about data security and the breach of privacy or yeah, maybe like, yeah, terrorist hacks? Yeah, those topics.

Edwin Diender: Sure. So, one by one, because you're stacking it in three layers. The first layer, if you if you follow the analogy of what you and I have been talking about doing this Q&A, and we come to the point where there are applications on your smartphone, that take care of the insights, information, the payment and so on and so forth, we as a consumer are very comfortable, we're very okay with using our smartphone, that it is connected to an app store. It is doing auto updates, you know, our login name and password are safe. We use our smartphone or tablet safety and security features when it comes to logging in by having a password on that one as well. So not only the application has a password, the login name and the identity of the user have a security setting, but also activating the application on your smart device. And using your smart devices have different features and functionalities for safety and security and privacy potential. We're very comfortable with that. So, I would say if you stayed in that space, and if you bring it into that space, in the analogy and in the examples that I just mentioned when it comes to having applications that understand how much energy has been generated, can I create something interesting out of it? Easter or Christmas or summer break kind of activity or a gift card to my daughter and so on and so forth. If this was from that application, then you are within the safe zone of an application. Technically speaking, this is all very possible and all very, very doable. A little deeper into the technology that means that all the other systems underneath need to follow all those safety and security settings for it. That means the electricity company that provides you with a battery pack that tells you that with a login and a password, you can see what the information of that battery pack is doing for you, should also be as secure and as safe as it can be. Just like your home Wi-Fi or your home broadband or your home cable connection or whatever you have smart boxes, set top boxes, this should be similar, either protected or provisioned with features to protect it. The same goes for information that's been taken out of it and it goes into your billing system. In order for it to go there, it needs to go to the provider first, the electricity providers. So, they need to have and probably they already do a little… It needs to have safety and security measures for that as well. And it should apply to all these items

and to all of these more intelligent features to a non-digital native infrastructure, like the electricity network. That means that the electricity company needs to think more like an IT company and like a computing and communications infrastructure provider, which they are not. So, the risk sits with them not being aware or them being a little biased or them thinking it's all okay, but you know maybe it isn't. So, you need to have a higher level of digital savviness digital competency and maybe even computing mobile software code writers and people, engineers and computer engineers to your pool of electricity engineers.

Interviewer: Okay. Yeah, thank you very much. I made a couple of notes as well during the interview and I recorded everything so I think I will be fine with analysing that. After months of theoretical investigation, and like the company where I'm conducting the research, they are not very progressed yet within this concept. So, it's actually very nice and interesting to talk to someone who's a bit further into these concepts. So, thank you for that. I really enjoyed the conversation.

Edwin Diender: My pleasure.

Interviewer: Yeah, and then good luck with your next meeting. Thank you again for your time and then I will contact you through email for another session or any additional questions if necessary.

Edwin Diender: Wonderful, Wouter, my pleasure.

Interviewer: Thank you very much! Perhaps speak to you soon, bye bye!

Edwin Diender: See you, bye bye!

Appendix H: Coded expert interview transcript – Pure Energie group 1

CONFIDENTIAL

Appendix I: Coded expert interview transcript – Pure Energie group 2

CONFIDENTIAL

Appendix J: Coded expert interview transcript – Liander

Wouter (00:01)
Allereerst eigenlijk gewoon een introducerende vraag: **Kunt u of kan je allereerst kort uitleggen wat precies je functie is en op welke manier deze relateert aan de HEMS en thuisbatterijen?**

Jochem Kuiper
Ja, zeker! Ik werk dus voor Liander, de netbeheerder in Noord-Holland, een deeltje van Zuid-Holland, Flevoland, Gelderland, en Friesland. Mijn rol is themaeigenaar energieopslag. Dus ik hou mij bezig met eigenlijk alle plekken waar energieopslag raakt aan onze energienetten. Met name gericht op elektriciteitsopslag, dus batterijen. Warmteopslag komt daar waarschijnlijk ook bij, maar die heeft op dit moment net even iets minder aandacht **en ik probeer dus een overzicht te houden van alles wat er met opslag gebeurt en hoe wij daar, ja, wat wij daarvan vinden of hoe wij daarop reageren, wat we er zelf mee kunnen.** Dus een vrij brede rol in een onderwerp dat zeker het afgelopen jaar veel aandacht heeft gehad. **De relatie met thuisbatterijen en HEMS: Ik kijk naar zowel de gigantische batterijen als thuisbatterijen, dus eigenlijk de hele schaal door de energienetten heen. Ja en wat de rollen van thuisbatterijen zijn dus, ik denk dat dat voor zich spreekt hoe die raken aan mijn rol. Home Energy Management Systemen, ik denk dat die een grote rol spelen in het dusdanig aansturen van thuisbatterijen dat ze ook... Nou dat heeft impact op een netbeheerder en dat kan positief zijn of het kan negatief zijn. Ik denk dus dat dat ook een relevant onderwerp is inderdaad. Zowel de aansturing als de batterij zelf.**

Wouter
Ja, nee zeker, dat denk ik ook en je zei het zelf eigenlijk ook al: Dat het onderwerpen zijn die het afgelopen jaar extreem veel aandacht hebben gekregen en iets wat impact gaat hebben op de netbeheerder. Daarom heb ik eigenlijk meteen al een vervolgvraag, namelijk: **Hoe denk je in het algemeen over deze twee onderwerpen als volgende fase van de energietransitie?**

Jochem Kuiper (02:28)
Een volgende fase van de energietransitie... Het wordt denk ik met name gedreven door heel veel meer opwek die niet gestuurd is. Dus eigenlijk het verschil tussen de momenten waarop energie geproduceerd wordt en het verbruikt wordt. Dat gaat niet altijd meer op dezelfde plekken meer plaatsvinden, dat gaat niet vanzelf goed. Dus het verbruik zit niet direct op wanneer de zon schijnt of wanneer de wind waait, dus daar zijn slimme dingen nodig. Ofwel dus gewoon slimmer verbruiken, flexibeler gebruiken of energie tijdelijk opslaan. Ik denk dat zowel thuisbatterijen als de HEMS daar een rol in spelen, dus in het… Zowel het slimmer verbruiken als het tijdelijk opslaan. Ja, het is moeilijk om te kwantificeren hoe groot die rol wordt en er zijn nu ook wel een paar barrières waardoor thuisbatterijen bijvoorbeeld niet van de grond afkomen, maar ik denk dat ze allebei belangrijk gaan zijn. Voor ons is het eigenlijk van belang dat onze energienetten zo effectief mogelijk benut worden en hoe meer pieken we hebben en hoe meer pieken er

gelijktijdig zijn, hoe ellendiger het eigenlijk is. Hoe inefficiënter het net gebruik wordt. Dus, voor ons is het heel prettig om die pieken zoveel mogelijk te spreiden, zodat we onze netten een beetje gelijkmatig kunnen belasten. Dat maken de maatschappelijke kosten lager en dat is voor een netbeheerder belangrijk, want uiteindelijk maken wij geen winst, maar proberen we gewoon met zo min mogelijk geld zo effectief mogelijk energiesystemen te bouwen. Dus een beetje context erbij wat eigenlijk niet je vraag was maar…

Wouter (04:20)
Nee, nee, maar het hoeft toch niet 100% op de vraag in te gaan hoor, want uiteindelijk ga de interviews gewoon nog analyseren en ga ik eigenlijk de hele teksten bekijken, dus dat is alleen maar goed voor mij hoor. Dus, voel je vooral vrij! Even zien, want ik hoorde je net ook zeggen een aantal barrières voor thuisbatterijen?

Jochem Kuiper (04:45)
Ja, de grootste en meest voor de hand liggend is de Salderingsregeling. Die maakt het nu eigenlijk gewoon niet interessant om een thuisbatterij te kopen, omdat je gewoon de energie kunt wegstrepen. Daar kun je je thuis batterijen niet mee terugverdienen. Nou ja, die gaat er hopelijk vanaf. Tenminste, dat is ook de wens van de netbeheerders, dat de Salderingsregeling afgebouwd wordt. Dan ontstaat er vanzelf, als het goed is… Ja, dan kan de business case hopelijk uit en een barrière is ook nog steeds gewoon de prijs van een batterij. Dat daalt wel, het is wel wat gestagneerd. Ja, de afgelopen tien jaar is het sterk gedaald en de laatste twee jaar, een beetje sinds COVID19 is dat een beetje gestabiliseerd. Ja en een andere is ook wel gewoon een beetje, en dan is een lastig vraagstuk, van "hoe verhoudt een thuisbatterij zich nou tot bijvoorbeeld een buurtbatterij of oplossingen die hoger in het systeem zitten?". Allebei hebben ze voor- en nadelen. Een thuisbatterij heeft iets inefficiënts in zich, omdat het ergens inefficiënt voelt om er een in elk huis dat een batterij zou kunnen hebben, één neer te zetten met elke keer een aparte omvormer. Dan zou je misschien beter één omvormer en dan meer opslagcapaciteit en meer vermogen kunnen plaatsen, die problemen voor meerdere huizen tegelijk oplost. Dus dan kom je een beetje in de buurt bij een buurtbatterij, maar buurtbatterijen hebben weer eigen nadelen. Dus, allebei hebben ze hun nadelen, maar ik denk dat Saldering gewoon echt een hele grote is.

Wouter (06:32)
Ja, zeker en bijvoorbeeld het duurzame aspect van die batterijen, want daar hoor ik ook nog wel het een en ander over?

Jochem Kuiper (06:40)
Eens, dat is ook een terecht probleem. Heel strikt gezien, zijn wij als netbeheerder daar… Kijk, wij hebben uiteraard een mening over duurzaamheid. Dat is voor ons een beetje zoeken tussen neutraal blijven en een voorkeur uitspreken. Kijk, als de overheid morgen besluit: "we gaan gewoon weer vijftien nieuwe kolencentrales bouwen", dan hebben wij gewoon de energie die uit die kolencentrales komt te transporteren. Dat is gewoon onze taak. Wij hebben uiteraard een mening dat we dat liever niet hebben, net zoals dat we

inderdaad het liefst zo schoon mogelijke opslagtechnologieën hebben, maar uiteindelijk zijn wij niet de partij die die keuze maakt, wat er wat geplaatst wordt. Zolang het veilig is voor ons en ook dus voor onze netten. Dus, ja, daar hebben we een mening in, maar dat is een beetje een lastige positie eigenlijk.

Wouter
Nee, snap ik. Jullie belangrijkste taak is natuurlijk dat de kwaliteit van het net hoog blijft.

Jochem Kuiper
Klopt en we proberen ook daar zoveel mogelijk techniek-neutraal in te zijn en we kijken in principe gewoon naar een aansluiting. Het is voor de stabiliteit van het net belangrijk om te weten wat erachter zit, maar of wij nou een sigarettenfabriek aansluiten of een ziekenhuis, die moeten we hetzelfde behandelen, terwijl we weten, een sigarettenfabriek is gewoon schadelijk voor mensen. Neutraliteit is daar soms wat lastig.

Wouter (08:28):
Ja, snap ik. Dan ga ik hem even ietsjes terugpakken weer, want ja, wat je net ook zei over eigenlijk die pieken en dat er soms best wel wat schommelingen plaats kunnen vinden op het net. **Dan vraag ik me af: Hoe kijken jullie dan eigenlijk naar de potenties van een HEMS en thuisbatterijen met dat soort schommelingen op het net?**

Jochem Kuiper (08:57):
Ja… Laten we eerst de situatie bedenken zonder dat je er een HEMS of gewoon een slim systeem bij je thuisbatterij hebt. Als je gewoon alleen een batterij plaatst, in principe, heb je dan eigenlijk de domste variant van een thuisbatterij die gaat laden op de momenten dat er gewoon een energieoverschot is. Dus, wanneer je zonnepanelen meer produceren dan dat je verbruikt. In die situatie schieten we er als netbeheerder eigenlijk nauwelijks wat mee op, eigenlijk helemaal niets, omdat, een beetje afhankelijk van de omvang en vermogen van zo'n batterij, maar vaak zijn die dan zo rond 11.00 's ochtends wel een beetje vol, 12:00 's ochtends en dan moet de echte zon-piek nog komen. Dus als je een thuisbatterij echt heel dom laat laden, dan helpen ze eigenlijk niet. Dan helpen ze wel om energie achter je meter te houden, binnen je huis, maar het energienet krijgt alsnog om 13:00 's middags, of hoe laat het dan ook is, van alle huizen tegelijkertijd weer die volle zon-piek te verweken. Dus, dan moeten we alsnog onze netten daarop dimensioneren. Dus, dat maakt dat we eigenlijk geen voorstander zijn van een domme thuisbatterij. Dat vraagt dus om slimme aansturing en zo'n HEMS kan daar hopelijk bij helpen, die dus beter nadenkt over wanneer zo'n batterij gaat laden en ontladen. Dus, ik neem aan dat dat ook in de definitie van zo'n HEMS zit toch? Dat die ook invloed heeft op wanneer er geladen en ontladen wordt?

Wouter (10:33):
Ja, zeker! Eigenlijk hoe ik het zelf inderdaad ook zie, is dat de thuisbatterij eigenlijk een los component op zich is binnen de smart home grid en die HEMS is eigenlijk de manager (van de smart home grid) als het ware, maar dan in de vorm van een algoritme.

Jochem Kuiper (10:51):

Ja, kijk, die is dan dus inderdaad essentieel. Nog even los van hoe die dan bepaalt wanneer de batterij gaat laden, het is essentieel om een batterij op het goede moment te gaan laden, wil de netbeheerder er wat aan hebben. Dan wil je echt de piek om 13:00 ’s middags zo ver mogelijk naar beneden brengen en dat is op zichzelf allemaal best lastig. Dus een opwek-piek of een verbruikspiek in de winter en daar is dan zo’n HEMS dus ook weer heel belangrijk voor, om dus te zorgen dat niet alleen de thuisbatterij slim aangestuurd wordt, maar ook een warmtepomp of het elektrisch laden of andere grote verbruiker in het huis. Die zijn belangrijk inderdaad. Kan ik dat verder onderbouwen? Ja, alle huizen in de straat, die zitten op dezelfde midden-spannings-ruimte, zoals wij die noemen, en eigenlijk wil je daar de belastingen ook zo laag mogelijk houden, dus je wil het liefst dat zo’n HEMS niet alleen binnen het huis kijkt, maar reageert op prikkels van buiten het huis. Dus, misschien in de straat of de landelijke energiemarkten, dat die daar op basis van stuursignalen stuurt, maar zeker voor bijvoorbeeld een winterpiek. Als je dus een warmtepomp hebt draaien is het voor het net eigenlijk ideaal als daar een algoritme bijzit dat dus bedenkt “oké, dan gaat nu een half uurtje hier de warmtepomp aan en dan daarna een half uurtje in een ander huis en daarna in een ander huis en dat je zo veel mogelijk de warmte, de energievraag, drukt. Zeg maar in de breedte spreidt en de pieken naar beneden brengt.

Wouter *(00:12:25):*

Ja, nee, zeker en daar wil ik ook wel even over door eigenlijk, **want voor mij ziet het er een beetje uit alsof er zeker voordelen aanzitten voor de klant, wat ik nu ook met het onderzoek gemerkt heb, met name financieel. Dus dat de klant er financieel op vooruit kan. Alleen is het soms een beetje moeilijk als er voordelen komen kijken voor de leverancier of de netbeheerder. Dus bijvoorbeeld een leverancier die hun onbalans kan managen door middel van de HEMS en de thuisbatterij, of netbeheerders die het net stabieler kunnen houden.** Wat ik dus eigenlijk ook een beetje probeer uit te vinden, is: wat is nou een incentive voor zo'n klant om zeg maar mee te gaan met de **leverancier en de netbeheerder**?

Jochem Kuiper (*00:13:17):*

Ja, dit is echt een hele goeie vraag en die is ook tegelijkertijd heel ingewikkeld, want kijk, wij proberen onze netten zo efficiënt mogelijk te gebruiken. Dus, zoveel mogelijk pieken spreiden. Je zou willen dat je dus door inzet van zo’n HEMS, dat je ruimte vrijmaakt, zodat daar andere mensen op kunnen komen. Zodat we zonder het net uit te breiden, meer mensen kunnen aansluiten. Daardoor dalen dan de nettarieven voor iedereen. Kijk, vanuit de consument gezien is het inderdaad het fijnst als je dan… Als de netbeheerder eigenlijk een soort van bijdrage kan leveren in zo'n HEMS. “Want het heeft kwantificeerbaar nut voor een netbeheerder, dus daar kunnen we in bijdragen” en netbeheerders hebben wel ruimte om… Dat heet het “verzwaren tenzij kader”. In principe als het net het niet aan kan, gaan we verzwaren, tenzij er andere betere oplossingen zijn en dan kunnen we dus eigenlijk de kosten die we uitsparen door het net niet te hoeven te verzwaren, die mogen dan dus uitgeven worden aan andere oplossingen,

bijvoorbeeld dit soort HEMS systemen. Dus in theorie kan dat. In de praktijk is het wel moeilijk, omdat, eigenlijk twee redenen: de netten zijn eigenlijk relatief goedkoop. Dus het bedrag dat je dan kunt bijdragen in zo'n HEMS is laag, plus we moeten dan zeker weten dat het werkt. Dat zo'n HEMS samen met batterijen en slimme aansturing erin slaagt om af en toe een piek weg te halen, is prettig, maar we moeten eigenlijk echt zeker weten dat dat het hele jaar door lukt, want als het af en toe lukt, maar die ene keer of twee keer per jaar niet, moeten we alsnog voor die twee keer per jaar het net zo zwaar maken. Dus dat maakt het lastig.

Wouter ***(00:15:10):***
Ja, oké. Dit ging dus eigenlijk wel een beetje in over waar ik ook een beetje naartoe probeerde te sturen, namelijk of je het bijvoorbeeld mogelijk vindt dat er op den duur een nationale infrastructuur komt waarin eigenlijk consumenten, **netbeheerders**, **leveranciers** en misschien nog de staat kun je daar als stakeholder pakken, maar dat die eigenlijk gezamenlijk voordeel creëren?

Jochem Kuiper ***(00:15:52):***
Ja en dat is dus ingewikkeld en op de andere netvlakken als in midden spanning en hoogspanning met batterij is dat ook de puzzel: "Hoe kunnen we nou capaciteit vrijmaken waarmee we echt andere mensen kunnen aansluiten?" Dat daar een beetje de crux in. Even denken wat daar nog meer bij hoort. Ja, want er zitten meerdere kanten ook aan als je puur naar de business case kijkt. Kijk, het moet voor een huishouden interessant zijn, maar dus ook voor de aanbieder van de batterij en de exploitant. **Het hoeft niet per se het huishouden zelf te zijn, maar die HEMS moet worden aangestuurd door een partij: een leverancier of een *aggregator*. Er zijn wat verschillende rollen die dat zouden kunnen doen.**

Wouter ***(00:17:03):***
Ja, ik kan anders wel even aansluiten daarop, want binnen mijn onderzoek is het inderdaad zo dat bijvoorbeeld een Pure Energie nu zit te kijken om dan de besturende rol in te nemen daar, dus dat zij echt bundels gaan verzorgen aan klanten. Dat ze bijvoorbeeld per maand wat betalen, maar dat het dan allemaal automatisch geregeld wordt voor hen en een vraag voor mij die daar dus een beetje overblijft: Wat kunnen leveranciers bijdragen? Wat moet nou die trade-off worden? Want je gaat eigenlijk tegen een klant zeggen "wij willen jouw batterij en je HEMS gebruiken, maar ja, waar moet zo'n klant dan aan denken? Bijvoorbeeld iets van een vaste vergoeding per jaar of? Dat is denk ik echt het wat je uit wil vinden. Waarom zo'n klant daar dan mee in zee gaat, met zulke initiatieven.

Jochem Kuiper ***(00:18:01):***
Ja, ik denk dat… Misschien is het wel het makkelijkste om die geldstroom eigenlijk een beetje bij de klant weg te houden. Dus, stel je vraagt een abonnementsprijs, dat je dan de inkomsten die je vanuit de netbeheerder zou krijgen of vanuit een andere partij, dat je die bij de exploitant houdt en dat die dan vervolgens de prijs verlaagt voor de klanten. Dan is het voor klant overzichtelijker, want die heeft dan gewoon een bepaalde prijs, die die

betaald aan Pure Energie of de andere exploitant. Het alternatief is volgens mij dat er dan tijdens de exploitatie dat het… Oh, dit is een lastige vraag. **Je wil het voor een klant zo makkelijk mogelijk houden denk ik. Die moet gewoon kunnen beslissen van "dit is geschikt voor mij of niet en ik denk zo veel te kunnen gaan besparen in mijn energierekening, dus het is het waard om dit te doen".** Dat is volgens mij eigenlijk hoe de meeste huishoudens er nu naar kijken. Poeh, ik weet het niet. Is dat een antwoord?

Wouter ***(00:19:24):***
Nee, zeker! Dat is geen probleem. **Ik merk namelijk ook wel, dit is natuurlijk het laatste interview en een deel, zeker in de situatie van Nederland, is ook gewoon nog een beetje gissen. Wij zijn natuurlijk als land denk ik best wel uniek. Volgens mij is dat helemaal niet in super veel landen, maar die Salderingsregeling, dat maakt het ook allemaal wel weer ingewikkeld.** Ik kan in die zin wel een andere vraag stellen: lijkt het je realistisch…

Jochem Kuiper ***(00:19:56):***
Oh, trouwens, ik bedacht me er nog eentje! Hoe dit wel direct voordeel bij klanten op kan leveren, is als je nu als klant zo'n HEMS inslaat… Kijk, je hebt verschillende aansluit categorieën voor huishoudens. Je hebt één keer 25 ampère, drie keer 25 en drie keer 35. Als zo'n HEMS je er in laat slagen om, en dit zijn niet heel veel huishoudens dus daarom… Een huishouden met drie keer 35 ampère, dat is echt een huishouden met waarschijnlijk een jacuzzi, elektrische auto, echt heel veel elektrische apparatuur. Als je er met een thuisbatterij en/ of de HEMS erin kunt staan om die naar een drie keer 25 ampère kunnen brengen, dan scheelt je dat per jaar volgens mij € 1.000 aan netbeheerkosten. Dan kom je echt in zo'n lagere staffel terecht. Dus in zulke gevallen kan het je... Kijk, het heeft geen zin om dat via een leverancier of een exploitant te spelen, dan levert het dus echt direct voordeel op voor een klant, maar ja de drie keer 35, als het 1% van de huizen in Nederland is, dan is het al veel wil denk ik. Maar goed, die schoot me nog even te binnen en wilde hem toch nog even noemen.

Wouter ***(00:20:59):***
Nee, zeker! Het kan in die zin voor een bepaalde campagne vanuit de leverancier ofzo, kan het altijd een paar klanten wel raken denk ik. **Dan de vraag die ik net in gedachte had, van: Is het realistisch om te denken dat we misschien in de korte termijn toekomst, dat we misschien ook belasting gaan zien voor juist het terugleveren op het net?**

Jochem Kuiper ***(00:21:23):***
Poeh…

Wouter (*00:21:27):*
Want dan wordt het natuurlijk ook wel weer veel interessanter als je dat efficiënt kan managen, zodat je eigenlijk… Nu wil je eigenlijk over het algemeen of zoveel mogelijk zelf verbruiken of wat je niet zelf kan verbruiken juist terugleveren. Alleen dan refereer ik ook even naar het artikel van Tennet dat ze zeiden dat in 2030, dat het best wel dreigt dat er niet genoeg regelbaar vermogen is en dat de dat de netten heel overspannen kunnen

raken. Dus ik kan me juist voorstellen dat ze dan niet meer die en omdat je alleen maar meer zonnepanelen krijgt, mensen gaan alleen maar… Er is nu nog een hele groep mensen die eerder geen zonnepanelen wilden die ze nu toch nog aanschaffen.

Jochem Kuiper ***(00:22:09):***
Ik weet niet zeker of daar echt belasting op geheven gaat worden. Ik denk wel dat het naar een situatie toegaat waar… Bedoel je met belasting gewoon echt... Even denken hoor, kijk je kunt met flexibele tarieven kun je... Ik denk dat het sowieso toegaat naar dus flexibele tarieven. Dus dat je voor je zonne-energie krijgt wat het op dat moment waard is, maar het kan zijn dat energieprijzen negatief zijn en dan zou je moeten betalen om die zonne-energie om 13:00 ‘s middags op het net te zetten. Bedoel je dat met belasting, of bedoel je echt dat er energiebelasting geheven gaat worden op teruglevering?

Wouter (*00:22:47):*
Ja misschien beide, want flexibele tarieven is denk ik dynamische contracten denk ik? Dat we daar op één lijn zitten?

Jochem Kuiper (*00:22:55):*
Ja, die bedoel ik inderdaad, klopt! Die ook nu veel worden aangeboden en nu vooral voor mensen zonder zonnepanelen interessant, maar er loopt ook zo'n discussie namelijk… Stel dat je zo'n dynamisch tarief hebt en de energieprijs is negatief, zouden consumenten dan echt moeten betalen om hun energie op het net te zetten? Daar is heel wat discussie volgens mij over in de Tweede Kamer: dat je nooit moet… Dat het dan op nul gezet moet worden, dus dat je er dan niks voor krijgt, maar dat je er niet voor hoeft te betalen. Die discussie loopt ook volgens mij. Ik denk in ieder geval dat de energieprijzen gewoon meer reëel worden voor consumenten, want dat zijn ze dus nu door salderen helemaal niet.

Wouter (*00:23:51):*
Ja, nee dat is ook wel een lastige. Dat is ook een beetje wat ik bedoel met dat “gissen”. Dit soort dingen zijn natuurlijk best wel doorslaggevend.

Jochem Kuiper ***(00:24:02):***
Klopt! Het eerlijke systeem zou natuurlijk zijn dat als je zon produceert op het moment dat eigenlijk niemand het wil hebben, ja dan moet je geen zon produceren, maar omdat huishoudens en consumenten die zijn beschermd, dus ik snap wel dat daar discussie over is. Alleen energetisch gezien zou het logisch zijn dat je dan moet betalen, omdat je gewoon een product maakt waar geen vraag naar is.

Wouter (*00:24:30):*
Ja, aan de andere kant is het natuurlijk wel weer zou dat de laatste 15 tot 20 jaar dat eigenlijk het hele land juist gestimuleerd is en juist gestuurd is naar zonnepanelen. Dus in die zin snap ik de discussie ook wel weer goed.

Jochem Kuiper (*00:24:44):*
Is waar, maar de meeste (zonnepanelen) zijn altijd terugverdiend. Ik heb toevallig zelf in 2019

de zonnepanelen geplaatst, toen hield ik nog rekening met een terugverdientijd van zeven of acht jaar en volgens mij heb ik ze nu al terugverdiend. Dus eigenlijk alles wat ze nu nog opleveren, is mooi meegenomen.

Wouter (*00:25:02*):
Oké, dat is wel heel snel inderdaad.

Jochem Kuiper (*00:25:06*):
Maar ja, mensen die het vorig jaar hebben besloten, daar zit wel wat oneerlijkheid, want die hebben ook vanuit zonnepaneleninstallateurs waarschijnlijk voorgeschoteld gekregen "Dit is je terugverdientijd, je kunt nog salderen", ja.

Wouter (*00:25:22*):
Dat zal ook op den duur wel een keer… Volgens mij 2030 willen ze alles er af hebben toch? Saldering?

Jochem Kuiper (*00:25:30*):
Ja, het is een geleidelijke afbouw, maar ik weet eigenlijk niet wat nu echt de laatste status is, maar het plan was inderdaad ooit om in 2023 afbouwen naar 2030. Mag ik een vraag tussendoor stellen trouwens? Want dat HEMS, wat zit daar voor jou zeg maar in de scope in wat dat allemaal aanstuurt? Sowieso thuisbatterij, maar gewoon alle energieverbruikers in het huis die stuurbaar zijn o? Wat is een beetje jouw definitie van zo'n HEMS?

Wouter: ***(00:25:56):***
Hoe ik dat eigenlijk nu meekrijg vanuit Pure Energie is dat ze eigenlijk eerst op de echt grote componenten focussen. Dan heb je het bijvoorbeeld over een elektrisch voertuig, laadpaal, warmtepomp willen ze op den duur en dan bijvoorbeeld thuisbatterijen, dus echt de grote dingen.

Jochem Kuiper (*00:26:17*):
Nee logisch, oké! Want je zou in principe alles kunnen aansturen, maar op het gegeven moment vraagt het veel effort om zeg maar kleine wattages nog aan te sturen, zeg maar een wasmachine zou je nog kunnen overwegen, dat is ook lastig omdat je dan moet zorgen als consument dat je was er op tijd in zit, dat er wasmiddel inzit enzo. Je bent dan apparaten nodig die daar wat mee kunnen, of je moet heel veel handwerk doen. Ik zag ook laatst trouwens dat je een op afstand bedienbare knop hebt. Zeg maar mechanische dingetjes dat je een signaal kan sturen van "nu moet dit apparaatje het knopje indrukken van mijn wasmachine dat die aangaat". Dat soort dingen kun je ook aansturen natuurlijk, maar oké! Helder.

Wouter (*00:27:05*):
Ja, maar dat is wel… Kijk, op den duur wil je natuurlijk wel kijken of je dat soort dingen ook kan doen. Ik weet dat ze in de literatuur, maken ze dan wel weer onderscheid tussen, ja eigenlijk "shiftable" en "non-shiftable" appliances. Dus sommige apparaten hebben

bijvoorbeeld gewoon een ja een manual aan-knop en als jij er niet bent en het is bijvoorbeeld een waterkoker die ja, zo naar onder gedrukt moet worden, ik zeg maar wat...

Jochem Kuiper (*00:27:31*):
Ja, daar heb je dus nu dingetjes voor. Waar echt gewoon iets beweegt dat zo op het knopje drukt dat die aangeraakt is. Ik kan me niet voorstellen dat dat al uit kan.

Wouter (*00:27:42*):
Vijf minuten voordat je thuis bent, kun je dan het koffiezetapparaat aandrukken?

Jochem Kuiper (*00:27:48*):
Ja, bijvoorbeeld! Of het is nu inderdaad dat als je niet een slimme aansturing hebt voor je wasmachine en wel dus je wasmachine midden op de dag aan... Want daar zit vaak ook gewoon nog een fysieke aan-knop op van "nu moet die aan". Sorry, dat was even tussendoor!

Wouter (*00:28:05*):
Nee, dat is geen probleem hoor! Dat is wederom gewoon raakvlak met het onderzoek, dus dat is helemaal prima. Ja, vroeg ik me nog wel af, dan weer even iets algemener, dat heb je nu met zonnepanelen natuurlijk ook gezien: **vind je dat er partijen zijn die thuisbatterijen deels of geheel moeten financieren voor particuliere klanten en zo ja, welke partijen zouden dat dan moeten doen?**

Jochem Kuiper (*00:28:38*):
Als in, dus of er subsidie moet komen?

Wouter (*00:28:40*): **Ja bijvoorbeeld of bijvoorbeeld iets van een lease structuur of lenen.**

Jochem Kuiper (*00:28:46*):
Ja oké. Dat zijn twee verschillende dingen volgens mij. Bij subsidie dan maak je het gewoon aantrekkelijker. Bij leasen dan zorg je dat ze bijvoorbeeld de eerste investering niet zelf hoeven te doen, maar over de gehele looptijd betaalt dan alsnog een klant dat hele systeem. Het algemene antwoord en ik weet niet of je daar wat mee kunt… Sorry, ik ben even in mijn hoofd het antwoord aan het structureren. Er zitten een aantal aspecten aan, namelijk. **Nou, in algemene zin: als thuisbatterijen met HEMS een positieve bijdrage leveren aan het slimmer gebruiken van het energienet, dan zien we ze als netbeheerder graag komen. Het liefst zien we dat de markt dat zelf… Dat dat uit zichzelf lukt, dus dat de businesscase voor een klant gewoon werkt. Door stuurbar apparaten, dat het eigenlijk automatisch goed gaat. Mocht dat niet het geval zijn, dan zou je inderdaad kunnen overwegen of daar subsidie bij zou moeten, maar dat heeft zeker niet de voorkeur. Het liefst heb je gewoon een model waarin het gewoon werkt, waarin het voor een energieleverancier of een aggregator en hun huizen allemaal gewoon klopt. Dat het gewoon logisch is om dat te doen. Dat is dus echt het subsidie vraagstuk: moeten we mensen stimuleren om thuisbatterijen en HEMS te nemen door middel van een tegemoetkoming? Dan heb je nog**

het andere aspect: je kunt inderdaad, stel het is wenselijk, het komt niet helemaal van de grond, dan kun je wel zonder subsidie nog kijken inderdaad of zo'n leaseconstructie nuttig kan zijn. Dat kan inderdaad een alternatief zijn, dat is misschien nog wel een tussenstap inderdaad. Ze zijn nuttig voor Nederland en het systeem, het komt niet van zichzelf, voor veel mensen is er nog een barrière om ze aan te schaffen, dus dan moeten we kijken of we de kosten op een andere manier kunnen verdelen en daarna pas, als dat ook niet werkt, dan zou je volgens mij pas subsidie moeten doen. Dat is een beetje hetzelfde als met elektrische auto's nu, want die zijn gewoon in aanschaf veel duurder dan benzineauto's. Op de lange termijn zijn ze wel goedkoper, maar… Dus dan heb je een soort aanschafstimulans nodig, of inderdaad in een leaseconstructie, dat het dan wel werkt, maar het liefst heb je gewoon dat het vanzelf goed gaat.

Wouter (*00:31:52):*
Ja, ik zit even te kijken met het oog op de tijd... In principe denk ik dat ik alle vragen kan behandelen hoor, maar even kijken welke ik nu het beste kan vragen. Ja, gewoon even heel kort tussendoor, want deze wilde ik ook nog wel graag even bij de netbeheerder neerleggen: **Hoe staat het momenteel met de slimme meter allocatie in Nederland? Want er zijn nu al wel wat flexibele of dynamische contracten in omloop. Ik weet dat Tibber en ANWB, die doen het, maar dat is natuurlijk ook nog zeker voor de HEMS wel belangrijk: hoe vaak eigenlijk zo'n meter uitgelezen kan worden.**

Jochem Kuiper *(00:32:45):*
Je kunt sowieso, in je slimme meter kun je in de P1-poort zo'n ding steken en dan kun je hem gewoon real-time uitlezen. Dan kan je binnenshuis, die wordt dus niet extern uitgelezen, die kun je gewoon in je huis hebben. Daar zijn ook al wel apparaatjes voor op de markt. Dus ik zou vermoeden dat een HEMS systeem ook… Dat weet ik eigenlijk niet, dat is misschien een aanname die helemaal niet klopt, maar ik zou denken dat zo'n home energy managementsysteem aan de slimme meter zit via de P1-poort, want dan heb je dus zicht op de real-time energieverbruik.

Wouter (*00:33:34):*
Nee, dat is volgens mij is dat inderdaad wel de planning dat die dan op de slimme meter aangesloten wordt.

Jochem Kuiper *(00:33:41):*
En de route zeg maar… Als de slimme meter uitgelezen wordt door de netbeheerder en dat dan weer doorgestuurd wordt naar leveranciers, daar heb je volgens mij altijd een dag vertraging en dan heb je… Welke waarde krijg je dan? Kwartier-waarde? Ik denk dat ik dit zou moeten weten, maar…

Wouter *(00:34:06):*
Geen probleem.

Jochem Kuiper (*00:34:06*):
Nee, ik zit niet zo dicht bij de slimme meter expertise. Volgens mij heb je dan de kwartier-waarde inderdaad.

Wouter (*00:34:15*):
Ja, volgens ook. Ik weet nog dat het eerst per dag ging en dat ze nu dan richting per kwartier willen.

Jochem Kuiper (*00:34:24*):
Ja en je kunt het instellen hè. De smalste resolutie is volgens mij kwartier-waarde, maar je kunt ook zeggen "de netbeheerder mag het maar één keer per dag volgens mij, misschien zelfs maar één keer per kwartaal uitlezen", maar aangenomen dat je zo'n HEMS neemt, wil je ook dat die actuele informatie heeft. Dus volgens mij is het uitlezen van een slimme meter via een P1-poort wel essentieel.

Wouter (*00:35:01*):
Ja en stel nou dat er mensen zijn die eigenlijk dataveiligheid en privacy heel hoog in het vaandel hebben staan? Het lijkt mij dat het wel nodig is om zo'n machtiging af te geven?

Jochem Kuiper (*00:35:20*):
Ja, je kunt het dus… Hangt er dus ook een beetje vanaf of je de route kiest via de data die… Kijk, wij lezen die slimme meter uit. De basisfunctie ervan is facturatie en dan heb je het volgens mij niet over meer dan één keer per jaar, maar bindt me niet vast op die frequentie, maar als je een slim wil aansturen, dan heb je denk ik P1 data nodig en die wordt sowieso niet door de netbeheerder uitgelezen. Dus, als je ervoor kiest is zo'n HEMS te nemen, ja, dan kies je er volgens mij ook voor dat je dus dat ding laat reageren op je actuele energieverbruik. Ik vind het een goeie vraag hoor, want ik zat te denken aan, want inderdaad… Heb je iets aan een HEMS? Kan een HEMS iets voor je betekenen als je geen hoogfrequent inzicht hebt in je energieverbruik? Of kun je dat doen terwijl je de energie-informatie binnen je huis houdt en niet deelt met andere partijen? Dat weet ik niet. Volgens mij is het wel lastig, want ja, als Pure Energie iets aan aansturing wil doen, dan heb je die informatie nodig. Dus een huishouden zal of wel de informatie via de netbeheerder aan een aanbieder slash exploitant willen delen, of via de P1 poort en dan via een web interface of zo, maar dat is wel een aanname bij mij.

Wouter (*00:37:04*):
Ja, we hebben gedurende het onderzoek ook wel een aantal vragen bij consumenten neergelegd, dus niet alleen klanten van Pure Energie, maar ook van andere leveranciers. **Daar was eigenlijk het deel transparantie en vertrouwen of wantrouwen eigenlijk, dat was toch wel een groot onderwerp. Dus ik ben ook een beetje aan het onderzoeken van "wat kunnen leveranciers nou doen om dat wantrouwen toch een beetje weg te halen en wat transparanter naar hun klanten te zijn?" Dus dat die drempel om die gegevens te delen ook lager wordt.**

Jochem Kuiper *(00:37:40):*
Ja, ik denk van een afstandje bezien: als het aantoonbaar een waarde heeft voor een klant, dan zullen ze snel geneigd zijn om wel informatie te delen en dat is niet echt het standpunt van de netbeheerder of zo, **maar zodra je er als huis echt wat aan hebt en je aantoonbaar een lagere energierekening krijgt, als je het voelt in je portemonnee, dan zijn mensen geneigd om makkelijk informatie te delen. Dat is niet alleen energie-gerelateerd, maar dat zie je eigenlijk ook met elke willekeurige app die je op een smartphone installeert. Zodra het leuk is of zodra je er wat mee kunt verdienen, dan zijn mensen al snel geneigd om informatie te delen en apps allerlei dingen te laten registreren.**

Wouter (*00:38:49):*
Ja, dus dat wordt echt een beetje de achterliggende informatie slash de boodschap: duidelijk en transparant overbrengen, dus echt…

Jochem Kuiper (*00:39:01):*
Ik denk, ja en altijd voldoen inderdaad aan de "AVG" en de "GDPR", de…

Wouter (*00:39:12):*
Privacywet bedoel je?

Jochem Kuiper (*00:39:13):*
Ja, de privacywetgeving inderdaad. Dat je inzicht moet hebben in wat er over je geregistreerd wordt en je kunt er altijd volgens voor kiezen om zo'n dienst stop te zetten, maar dan stoppen ook de besparingen denk ik.

Wouter (*00:39:32):*
Ja precies. Dat zou ook wel een goeie optie zijn nog.

Jochem Kuiper *(00:39:39):*
Maar dit is niet mijn expertisegebied hè.

Wouter (*00:39:44):*
Nee. Ik zit heel even door vragen weer te kijken, want ik denk dat ik het grootste gedeelte heb. Dan ga ik nog even twee afsluitende vragen stellen. **Eentje dat is eigenlijk een hele specifieke, maar ik vind het zelf ook wel leuk om iedereen zijn perspectief hierover te horen. Die is gerelateerd aan de dynamische contracten nog een keer: stel er is een scenario waarin er spontane prijsdalingen of stijgingen optreden, waardoor particuliere klanten eigenlijk geen elektriciteit meer af willen nemen of juist terugleveren, wat kan bijvoorbeeld een netbeheerder doen in zo'n situatie? Je gaat straks steeds meer dynamische contracten krijgen namelijk, waar mensen ook echt per uur hun prijzen kunnen kiezen.**

Jochem Kuiper (*00:40:40):*
Stel dat je de prijs weet inderdaad, die kunnen hun gedrag aan gaan passen op de daadwerkelijke energieprijs.

Wouter (*00:40:45*):
Ja, of die HEMS die dat bijvoorbeeld voor hen doet en dat er dan bijvoorbeeld een tekort dreigt op het net, waardoor bepaalde bedrijfsgebieden niet voorzien kunnen worden. Dat soort situaties.

Jochem Kuiper *(00:41:00):*
Ja, daar zijn heel veel… Op zich is dit allemaal wel geregeld gewoon in het energiesysteem. Energie wordt ver vooruit al verhandeld en hoe dichter je bij het punt van gebruik komt, dan blijken dingen toch niet te kloppen. Dus, op zich, het energiesysteem in Nederland is er wel op ingericht om dit soort schommelingen aan te kunnen en dan dus tegenovergestelde incentives te starten. Dat doen wij als netbeheerder, als regionale netbeheerder doen we dat nog beperkt. Er is een platform om congestieproblemen op te lossen enzo, maar hier heeft TenneT de belangrijkste rol. Dus die bewaakt of vraag en aanbod altijd in het energiesysteem in balans zijn. Het kan ook zijn dat er bijvoorbeeld een kolencentrale of een gascentrale opeens uitvalt en daar kan het systeem ook mee omgaan, want dan wordt er op een hele korte frequentie, wordt er binnen een paar seconden wordt er noodvermogen afgeroepen en dan wordt heel snel in de tijd daarna, als het dan nog nodig is, wordt er ook extra vermogen afgeroepen. Dus er zijn processen om ofwel andere verbruikers dan meer te laten produceren of minder te laten produceren. Je krijgt eigenlijk altijd tegengestelde prikkels. Dus, als inderdaad de prijzen te hoog zijn voor consumenten om af te nemen, vaak wordt dat ook al veroorzaakt doordat er te weinig productie is. In principe is dat juist een signaal dat de prikkel werkt, want dan is de prikkel zo hoog dat dus mensen gaan besluiten om niet af te nemen. Dan stabiliseert juist het systeem weer.

Wouter *(00:42:43):*
Dat zijn ook een beetje die Balanceringsmarkten toch?

Jochem Kuiper (*00:42:47*):
Ja, exact, ja en daar kunnen batterijen dus ook weer op inspelen. De grote puzzel is hoe al die incentives niet elkaar tegenwerken. Het zou kunnen zijn dat op landelijk niveau dat er een probleem opgelost moet worden, maar dat er dan bijvoorbeeld een landelijk signaal een lokaal probleem veroorzaakt. Dus dat er gevraagd wordt aan heel veel thuisbatterijen in een woonwijk om allemaal vermogen te leveren om een probleem ergens heel ver weg op te lossen, terwijl dat het probleem in die woonwijk juist verergert. Dat is theoretisch mogelijk, maar opzich kan het systeem hier mee omgaan.

Wouter (*00:43:37*):
Oké! Nee. Dat is goed om te weten. Even zien, want ik kreeg net een melding “nog een paar minuten in de vergadering”.

Jochem Kuiper (*00:43:45*):
Ik had hem tot tien voor ingepland inderdaad, klopt.

Wouter (*00:43:47*):
Volgens mij gaat die dan automatisch sluiten. Ja, dus in die zin wil ik je alvast nogmaals bedanken voor het meewerken. Ik heb denk ik weer veel informatie waar ik wat aan heb, dus dat moet ik allemaal nog analyseren, maar ik zie voor mezelf al wel het plaatje, dus de discussie en de conclusies zal ik voornamelijk op basis van de interviews gaan schrijven.

Jochem Kuiper (*00:44:12*):
Ja, essentie is denk ik dat het op dit moment moeilijk is voor de netbeheerder om te kwantificeren wat vanuit ons een bijdrage zou kunnen zijn aan thuisbatterijen.

Wouter (*00:44:29*):
Ja, snap ik! Nee, maar het is wel handig om jouw kijk ook mee te nemen, want jullie hebben natuurlijk wel een mening ook weer over wat er voor de klant in zit. Hoe de klant wil handelen en of dat in de praktijk ook daadwerkelijk kan bijvoorbeeld. Dat is ook een beetje de praktische limiet die ik daarin opzoek.

Jochem Kuiper *(00:44:52)*:
Ja en het slim aansturen van wat voor prikkels zo'n HEMS dan geeft, of die bijvoorbeeld kijkt naar de real-time energieprijzen, dat is misschien wel een laatste punt om even te benoemen: Helemaal in het begin hadden we het over de domme thuisbatterij, die gewoon laadt als er overschot is. Het wordt al wat slimmer als zo'n thuisbatterij gaat kijken naar de groothandelsprijzen van energie. Dan zit je dus overdag en dan is de prijs laag, dan is het dus slim om even te gaan laden en 's avonds terug te gaan leveren, dan heb je al een slimmere batterij. Dan zijn er nog steeds wel situaties waar het mis kan gaan, als je bijvoorbeeld in de winter heel veel wind op zee hebt, dus het waait hard en het is donker. Dus dan heb je alsnog lage energieprijzen, maar tegelijkertijd staan in huizen warmtepompen aan en gaat dan die batterij laden omdat de lage energieprijzen zijn. Dan krijg je dus een warmtepomp die tegelijkertijd aanstaat als ook een thuisbatterij aanstaat. Dan krijg je extreem veel afname, dan leidt het juist ook weer tot een piek. Het zullen een paar momenten per jaar zijn dat het dan alsnog misgaat. Maar ja, sturen op energieprijzen gaat op zich vaak goed.

Wouter (*00:46:03*):
Ja oké! Dan nogmaals: voordat die dan automatisch afsluit, denk ik dat we het dan hierbij af kunnen sluiten.

Jochem Kuiper (*00:46:14*):
Ja en mocht je nog even dingen willen overleggen, terwijl je je rapport aan het schrijven bent, of dat je denkt van "zei die dit nou zo?", mag je het prima nog even naar me toe sturen, dat ik even naar kan kijken hoor. Ik ben de komende paar dagen even weg, maar ik ben volgende week gewoon aan het werk. Dus voel je niet bezwaard om nog een keer terug te komen met een vraag!

Wouter (*00:46:35):*
Nee, is helemaal goed, dankjewel! Dan weet ik je te bereiken!

Jochem Kuiper *(00:46:40):*
Goed! Succes dan en alvast veel plezier met afstuderen!

Wouter (*00:46:43):*
Ja, komt goed! Dankjewel, fijne dag nog en werk ze!

Jochem Kuiper (*00:46:51):*
Joe!