Designing Conversational Agents for Energy Feedback

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Abstract. Reducing and shifting energy consumption could contribute significantly to a more sustainable use of energy in households. Studies have shown that the provision of feedback can encourage consumers to use energy more sustainably. While there is wide variety of energy feedback solutions ranging from in-home displays to mobile applications, there is a lack of research on whether and how conversational agents can provide energy feedback to promote sustainable energy use. As conversational agents, such as chatbots, promise a natural and intuitive user interface, they may have great potential for energy feedback. This paper explores how to design conversational agents for energy feedback and proposes design principles based on existing literature. The design principles are instantiated in a text-based conversational agent and evaluated in a focus group session with industry experts. We contribute with valuable design knowledge that extends previous research on the design of energy feedback solutions.

Keywords: Conversational Agent, Chatbot, Energy Feedback, Focus Group, Design Science Research.

1 Introduction

To combat climate change and reduce greenhouse gas emissions, significant investments are being made in new low-carbon technologies, renewable energy, energy efficiency, and grid infrastructure [1]. To achieve the European Union's (EU) ambitious climate goals of reducing greenhouse gas emissions by 80% by 2050, all sectors are expected to play their part [2]. Since energy consumption of the residential sector still accounts for around 25% of total energy use in the EU [2], sustainable use of energy in households could significantly contribute to reaching the EU's climate goals. Sustainable energy use includes not only reducing energy consumption, but also shifting energy consumption to times when renewable energy sources (e.g., wind or solar power) are abundant [3]. Particularly, non-time critical energy use in households, such as washing machines or dish washers, can be shifted away from peak demand periods [3].

Providing energy feedback to consumers has been found to increase energy use awareness and promote both reducing and shifting energy consumption in households [e.g., 3, 4]. Moreover, reviews of energy feedback research have found that the provision of feedback can result in average energy savings of 10% [5]. In the past, many energy feedback solutions have been developed such as in-home displays, mobile applications, or web portals [5]. Given the large-scale deployment of smart meters that collect high-frequency consumption data and the advances in algorithms for energy disaggregation, these solutions are able to provide direct, real-time feedback on the level of individual appliances [6]. Additionally, they can provide interactive feedback augmented with additional approaches (e.g., personalized recommendations) to provide greater opportunities to engage consumers over time [4]. Although much research has been conducted on their design, recent reviews of energy feedback solutions indicate that no research has been conducted on how conversational agents (CAs) can be used to provide energy feedback [5, 7]. CAs, such as text-based chatbots or voice-based personal assistants like Amazon's Alexa, promise a convenient and intuitive user interface to interact with technology using natural language (i.e., written or spoken) [8]. Because of advances in artificial intelligence and natural language processing, the capabilities of CAs have improved significantly in recent years [9]. While they are limited in their ability to provide visual information on energy consumption (e.g., in the form of graphs or dashboards), they can leverage natural language to answer questions and provide personalized feedback. Given the rising interest in CAs [10], we argue that there is an opportunity to investigate the design of CAs for energy feedback to address the lack of consumer awareness of energy use and facilitate a more sustainable use of energy in households. Although feedback solutions using SMS or email have been developed for related contexts [e.g., 11], research on how to design CAs for energy feedback is scarce. Thus, we aim to fill this gap and explore the following research question:

> *How to design conversational agents for energy feedback to promote sustainable use of energy in households?*

To address this research question, we follow the design science research (DSR) [12] approach to iteratively design and evaluate a text-based CA for energy feedback. Based on a literature review on existing energy feedback solutions, we propose four design principles for CAs for energy feedback. These principles are instantiated in a text-based CA and evaluated in an exploratory focus group session [13] with domain experts from the energy industry. The remainder of this paper is organized as follows. Section two introduces related work on energy feedback and CAs. Section three outlines our DSR project, while section four describes the proposed design of our artifact. In section five, we present and discuss the findings of our evaluation, before we conclude the paper with a short summary and a discussion of limitations in section six.

2 Related Work

2.1 Promoting Sustainable Energy Use through Feedback

Research in psychology has extensively studied feedback and its impact on behavior change (for an overview, see [14]). Feedback is commonly understood as "the process of giving people information about their behavior that can be used to reinforce and/or modify future actions" [4]. In the context of energy use, feedback has been identified as an effective intervention to promote sustainable use of energy (for a detailed review, see [4, 15]). In general, energy feedback can be provided in different ways. Direct feedback is available in real-time, whereas indirect feedback is provided after the consumption occurs [4]. Moreover, feedback can be aggregated (i.e., a household's total energy consumption) or on appliance-level [4]. Appliance-level feedback contains information about individual devices, such as electronics or water heaters [6]. Furthermore, feedback can be combined with other interventions, such as goal setting or financial incentives, to increase its effectiveness [4]. Reviews of energy feedback research have found that the provision of feedback can result in average energy savings of 10% as well as promote load shifting [5], but its effectiveness depends on the way it is provided [4].

Different technologies have been used to provide energy feedback such as in-home displays, web portals, or mobile applications (for a detailed review of different solutions, see [5]). Many of these energy feedback solutions visualize household energy consumption based on data collected by sensors or smart meters [16], while others focus their feedback on a single device such as a washing machine [e.g., 3]. Moreover, they usually push out information to consumers (e.g., monthly energy reports) or require consumers to pull information from them (e.g., web portal or mobile app) [4, 17]. Modern solutions also frequently include additional features such as community platforms [18] or individual/social level comparisons [17]. However, recent reviews of energy feedback solutions in research and practice indicate that no research has been conducted on how CAs can be used to provide energy feedback [5, 7].

2.2 Conversational Agents

The idea of interacting with computers using natural language has been around for decades [8]. While the literature has used different terms to describe systems with conversational user interfaces (e.g., CA, chatbot, or personal assistant), the underlying concept is always that users "achieve some result by conversing with a machine in a dialogic fashion, using natural language" [9]. In IS research, the most commonly used term is "conversational agent" that refers to both text-based CAs, such as chatbots, and speech-based CAs (e.g., Amazon's Alexa) [19]. Both types of CAs build on the same technology (i.e., natural language processing), but differ in their input/output modality (i.e., voice vs. text). CAs have their roots in the chatbot ELIZA [20] that was primarily developed to simulate human conversation based on pattern-matching algorithms. Since then, the capabilities of CAs have improved enormously and many of them have been implemented on websites and messenger platforms (e.g., for customer service). Moreover, they can be found on many mobile devices as personal assistants to support users in finding information or accomplishing basic tasks (e.g., Apple's Siri) [21].

CAs promise a more convenient and natural user interface than traditional graphical user interfaces since they allow people to interact with computers using natural language, just like engaging in a conversation with another person [8]. Particularly, less IT-savvy users could benefit from this form of interaction because they do not need to learn how to navigate through complex menus and understand detailed dashboards [8]. Moreover, CAs often display human-like characteristics (e.g., human-like appearance or embodiment and communication style) to provide more natural and engaging interactions [22] as well as to build relationships with users [23]. Therefore, CAs might also serve as a natural way to provide energy feedback and promote sustainable energy use.

3 Design Science Research Project

This research project follows the DSR approach [12] to provide design principles (DPs) for CAs for energy feedback promoting sustainable energy use in households. We argue that this research approach is particularly suited to address our research goal because it allows to iteratively design and evaluate our IT artifact in a rigorous fashion [12, 24]. Moreover, this approach enables us to involve experts and real users in the design and evaluation phases to incrementally improve the functionality and relevance of our artifact [12]. The project is conducted in collaboration with experts from an organization in the energy industry. This organization is a medium-sized service provider that offers a range of services, such as consulting, business process outsourcing, and product development, for German energy providers and other companies in the energy industry.

The DSR project is based on the framework proposed by Kuechler and Vaishnavi [24]. In the problem awareness phase, we reviewed extant literature on existing energy feedback solutions to identify potential issues in their design. Based on the results of this review, we proposed four DPs for CAs for energy feedback. These DPs were informed by existing research on the design of energy feedback solutions and feedback theory. Subsequently, we instantiated our DPs in an interactive prototype of a text-based CA (i.e., a chatbot) developed with BotPreview, a platform for building previews of chatbot interactions [25]. This prototype was then evaluated in an explorative focus group session [13] with industry experts from the cooperating company. For the evaluation, we selected the technical risk and efficacy strategy [26] because the implementation and evaluation of a CA for energy feedback in a real setting would be very costly. The evaluation in a real household with real users would require significant investments for setting up the necessary infrastructure (e.g., implementing a smart metering infrastructure, integrating different data sources, and implementing algorithms for the calculation of feedback) and recruiting participants. Therefore, we decided to first evaluate the proposed DPs with a group of industry experts to get feedback and improve our design before conducting a more complex evaluation. In a second design cycle, we will refine our DPs based on the experts' feedback and instantiate the DPs in a fully-functional prototype. This prototype will be implemented using Microsoft's Bot Framework and evaluated with real users in several households that are equipped with smart meters.

4 Designing Conversational Agents for Energy Feedback

4.1 Problem Awareness

Feedback is considered a promising strategy for promoting sustainable energy use and many energy feedback solutions have been developed in recent years [5]. Although much research has been conducted on their design, there is still a need to better understand and validate specific design features and interaction paradigms of these solutions [27]. To inform our design, we conducted a literature review and identified several issues in the design of existing energy feedback solutions, which we summarize below.

Many energy feedback solutions focus on visual feedback including numbers, text, graphics, movement, animation, pictures, icons, colors, or lights [15]. However, these solutions often overload consumers with too much information, dry numbers, and intangible units [18]. In addition, they often lack natural language descriptions of key information and a personal language that is easy to understand for consumers [7, 16]. Moreover, just providing information on energy use may not be sufficient for consumers to draw conclusions for taking effective action (e.g., identifying energy guzzlers) or changing energy use habits [16, 18]. Furthermore, many existing energy feedback solutions either push out information to consumers (e.g., in-home displays positioned in a visible place in the home) or require consumers to pull information (e.g., web portals or mobile apps) [4, 17]. However, researchers argue that effective feedback solutions should combine both push and pull approaches [17]. Furthermore, as energy is a low involvement product [28] and energy feedback is usually optional for consumers [4], there is a need to "design for the least motivated individuals" [17, p. 2]. However, many energy feedback solutions cannot be easily integrated in consumers' life or require a complex system setup and training [6].

In conclusion, we argue that CAs represent a promising technology to address the identified issues in the design of existing energy feedback solutions. While significant progress has been made in the integration of real-time, appliance-level energy consumption data (e.g., from smart meters) and the transformation of data into more comprehensible units (e.g., monetary savings) [e.g., 16], there is a lack of design knowledge on CAs for energy feedback. Therefore, we believe that it is suitable to apply the DSR approach to address this research gap.

4.2 Design Principles for Conversational Agents for Energy Feedback

In this section, we propose four DPs that describe how to design CAs for energy feedback. These DPs focus specifically on the CA and the way it should provide feedback to consumers. In this paper, we do not further consider the underlying technical infrastructure that is necessary to integrate different data sources (e.g., smart meters), nor the algorithms that are necessary to, for example, calculate monetary savings or the best time to start an appliance (e.g., washing machine). Research has made great strides in developing the infrastructure and algorithms [e.g., 6, 16] that are required to implement the technical basis of our DPs. However, since our main goal is to design a CA, we argue that it is suitable to focus our DPs on how this technology can be used to provide energy feedback. Next, we derive and formulate four DPs for CAs for energy feedback.

In general, CAs differ from other technologies in that they do not provide a typical graphical user interface and rely on natural language as the main mode of interaction [8, 9]. While text-based CAs, such as chatbots, are limited to a simple chat window, voice-based CAs usually do not possess a graphical user interfaces at all. Consequently, they are not able to show complex graphs, detailed statistics, or other visual elements about current or past energy use. However, since consumers are able to chat with or talk to them like having a conversation with another human being [8], they might provide a more natural user interface for energy feedback. Consumers should be able to converse with a CA about their current and past energy use, ask specific questions about their energy consumption choices, and receive personal feedback on their energy use. For example, consumers could ask the CA about the current or past energy consumption of a specific device or the best time to start their washing machine. Since this approach might allow consumers to more quickly and effectively obtain answers to questions about energy use (i.e., to pull information), the CA should provide comprehensible feedback that enables them to draw conclusions on how to reduce or shift energy consumption. Therefore, we propose:

DP1: *Provide the CA with reactive energy feedback comprising comprehensible information in natural language in order to help consumers better understand their energy use and enable them to draw conclusions on how to use energy more sustainably.*

However, reactive energy feedback provided by CAs should not be limited to only providing comprehensible information (i.e., informative guidance [29]) but should also include personalized suggestions and advice (i.e., suggestive guidance [29]). Research argues that providing "highly personalized recommendations tailored to the sensed energy usage in the home" influences energy consumption behavior more effectively than the graphical representation of consumption values or the provision of high-level written or verbal messages [17, p. 6]. Therefore, CAs should provide reactive feedback that includes suggestions and advice on how to reduce energy consumption (e.g., by identifying energy guzzlers or "surprise" devices that they are unlikely to monitor [4]) and shift times of consumption (e.g., rescheduling the washing process [3]). Moreover, CAs should be able to support consumers in their decision to buy new energy-efficient devices by performing complex cost/benefit analyses [17]. For example, consumers could ask the CA whether buying a more energy-efficient refrigerator will reduce their energy consumption and save them money in the long term by lowering their future electricity bills. The CA could then support consumers in their purchase decision and even recommend suitable devices. Thus, we propose:

DP2: *Provide the CA with reactive energy feedback comprising personalized suggestions and concrete advice in order to enable consumers to act on it directly and encourage sustainable energy use in the future*.

In many domains, CAs show the promise of enhancing a user's productivity by proactively providing the information the user needs at the right time and at the right place [30]. Similarly, research has demonstrated that energy feedback is much more effective when delivered in the right context [31]. While DP1 and DP2 relate to reactive energy feedback that requires consumers to *pull* information from the agent, CAs can also proactively provide energy feedback to consumers (i.e., *push* information to the consumer). For example, when a water heater is consuming excessive amounts of energy, the CA should be able to promptly alert the consumer and suggest that there is a malfunction so that s/he can take appropriate action. Additionally, the CA could send contact information of a technician or apartment manager. Although solutions, such as mobile apps, can also send proactive feedback using push notifications, we argue that CAs might be more effective as their messages can serve as the starting point for a follow-up conversation and thus, might foster deeper engagement with consumers.

However, while more frequent proactive feedback provides more opportunities to engage consumers' attention, there may also be an upper limit to the amount of time that people are willing to spend on energy feedback [4]. Therefore, the CA should provide proactive feedback only in case of incidents that require the consumers' attention (e.g., device malfunction, anomalies in energy use, or significant money saving opportunities). Thus, we propose:

> **DP3:** *Provide the CA with proactive energy feedback comprising personalized suggestions and concrete advice in order to enable consumers to quickly respond to incidents that require special attention for a more sustainable energy use.*

Finally, there is a rich body of knowledge that explores the design of human-like characteristics for CAs. Following the "Computer are Social Actors" paradigm, many studies have investigated how these social cues (e.g., human-like appearance or use of natural language) enhance a CA's trustworthiness and persuasiveness as well as make the interaction more natural to users [32, 33]. Researchers argue that, to be effective in persuasion, appropriate social cues should be embedded in the design of CAs [32]. Social cues have also been found to increase the effectiveness of energy feedback [34]. For example, social feedback on the energy consumption of a washing machine provided by the social robot iCat was more persuasive than factual feedback provided by an energy meter without any social cues [34]. Therefore, CAs for energy feedback should also display social cues to make the human-CA interaction more natural and their feedback feel more social. Thus, we propose:

> **DP4:** *Provide the CA with appropriate social cues in order to make the interaction with them more natural and their energy feedback more social for consumers.*

4.3 Artifact: Energy Feedback Agent (EFA)

Our proposed DPs were instantiated in an artifact called Energy Feedback Agent (EFA). We decided to design EFA as a text-based CA (i.e., a chatbot) instead of a voice-based CA because of the ubiquity of smartphones and the proliferation of instant messaging applications [35]. More specifically, messaging has become a primary channel for both personal and professional communication across all segments of the population [9, 35]. Furthermore, since energy feedback may also contain sensitive information on personal habits, consumers may not want others to hear the content of the feedback [c.f., 36], which further supports the design as a text-based CA.

To instantiate our DPs, we selected two different scenarios based on examples in existing literature [e.g., 17], which are explained in detail in section 5.1. Fig. 1 shows the instantiation of DP1 and DP2 that illustrate how EFA provides reactive feedback based on consumers' questions. The left side of Fig. 2 depicts how EFA provides proactive feedback after an incident has been discovered that requires the consumer's attention (DP3). The right side of Fig. 2 shows the instantiation of DP4, that is, the social cues that were implemented in EFA's design. Based on insights from previous studies, we selected several social cues to make the conversation more familiar to the user and the provision of feedback more social, such as a human-like graphical representation [37], small talk [23], and emojis [38].

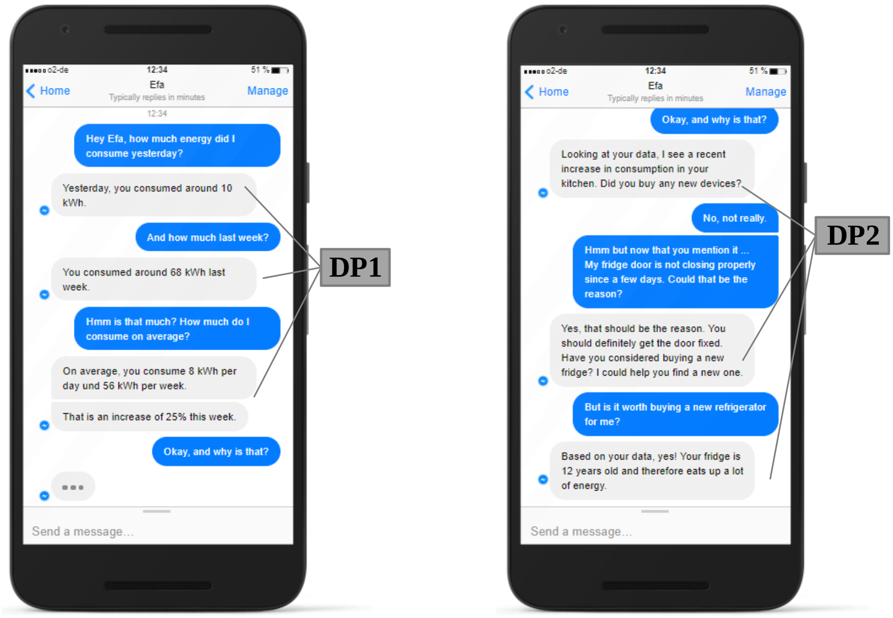

Fig. 1. DP1 and DP2: reactive feedback (information and suggestions)

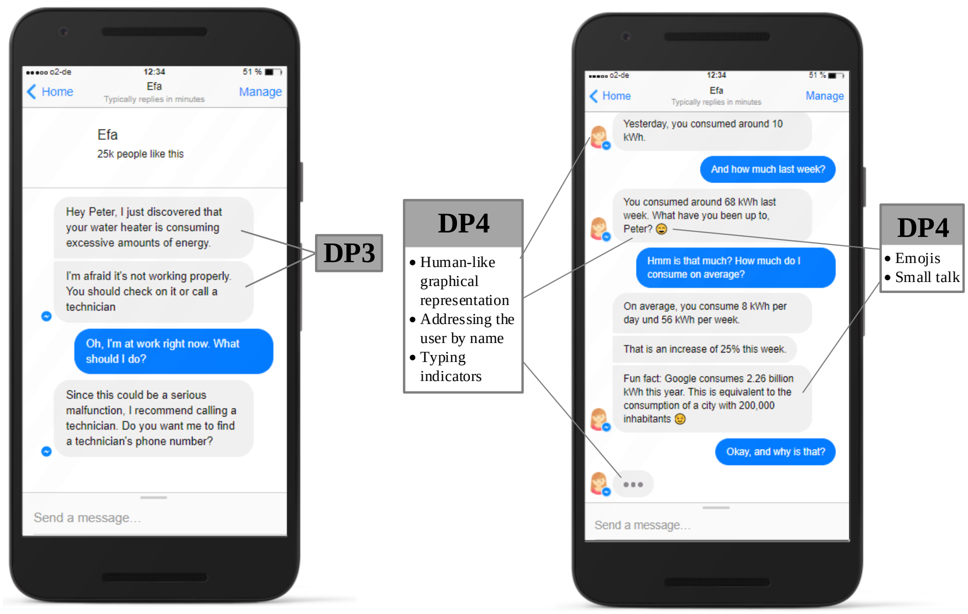

Fig. 2. DP3 (proactive feedback) and DP4 (social cues)

5 Evaluation

5.1 Evaluation Methodology

To evaluate our proposed design, we conducted an exploratory focus group [39]. Exploratory focus groups have been used regularly in DSR to evaluate initial designs and artifacts [e.g., 40, 41]. As shown in Table 1, the participants of the focus group session were five employees of our partner organization and one employee of a major energy provider. Upon arrival, the participants were asked to read and sign informed consent forms, provide demographic information and answer three questions about their experience with smart metering technology as well as their use of CAs and messaging applications (using a Likert scale from 1=daily to 6=never). Our focus group consisted of four males and two females, with an average age of 34 years and an average experience with smart metering technology of 6 years. While most participants stated that they use messaging applications daily (83%), their indicated use of CAs was only a few times a month (50%) or even less (50%). Because of their broad industry experience and familiarity with smart metering technology, we argue that they can be regarded as industry experts and represent an adequate sample for the evaluation as they are "familiar with the application environment for which the artifact is designed so they can adequately inform the refinement and evaluation of the artifact" [39, p. 127].

Table 1. Focus group participants

Participant	Affiliation	Business Unit
Expert 1 (EX1)	Service Provider	Product Management
Expert 2 (EX2)	Service Provider	Product Management
Expert 3 (EX3)	Service Provider	Business Development
Expert 4 (EX4)	Service Provider	Business Development
Expert 5 (EX5)	Service Provider	Sales
Expert 6 (EX6)	Major Energy Provider	Piloting & Operations

Two of the authors performed the focus group session, in which one researcher actively moderated the session, while the other one took notes throughout the session. The focus group lasted a total of two hours and was structured as follows. First, the moderator welcomed all participants and briefly explained the procedure of the focus group session. After signing the informed consent forms, we started the audio recording. Next, the participants were given an introduction on energy feedback and CAs. Subsequently, we presented and explained our DPs for CAs for energy feedback and demonstrated how they were instantiated in EFA. We used two scenarios to evaluate the DPs one by one by showing how EFA would work in its intended environment.

The first scenario was used to evaluate EFA's reactive feedback (i.e., DP1 and DP2). In this scenario, participants should imagine that they are watching a news report on the TV showing the consequences of climate change and therefore, wonder if they could also do something to reduce their energy consumption. Realizing that they do not know much about their current energy use, they open a messenger and start a conversation with EFA. During the conversation, EFA answers several questions about current, past, and average energy consumption (DP1). When EFA mentions that energy consumption in the kitchen has been unusually high, they realize that a broken door (i.e., not closing properly) of their refrigerator leads to a waste of energy. In this context, EFA also indicates that the refrigerator is rather old and suggests buying a new, more energy-efficient one to save energy and money in the long term (DP2). After stating their possible interest, EFA calculates the time until the investment pays off and recommends two suitable devices. Next, the same scenario was shown again, however this time, EFA was designed to display social cues (DP4) as described in section 4.3. Apart from these changes, however, the content of scenario was identical.

The second scenario was used to evaluate EFA's proactive feedback (DP3). In this scenario, EFA starts the conversation by alerting the consumers that their water heater has consumed excessive amounts of energy over a long period of time, indicating a technical problem with the device. Then, EFA suggests contacting a technician and provides the phone number of a suitable technician to take care of the malfunction.

During the evaluation, we stopped the demonstration several times to explain how the DPs were implemented. Therefore, participants could provide feedback on EFA and the DPs at any time during the demonstration. After each demonstration, we asked open-ended question about the artifact and the proposed design (e.g., "How did you like the feedback provided by EFA?"). Depending on the course of the discussion, we asked more specific questions about the proposed DPs and the interaction between EFA and the consumer. After the session, we analyzed the participants' feedback using our notes and the audio recording. In the next section, we present the results of the analysis and discuss the feedback of our focus group participants in detail.

5.2 Results and Discussion

In general, the industry experts who participated in our focus group session liked the idea of using CAs to provide energy feedback to consumers in households. They pointed out that EFA would be easier and more comfortable to use than many existing feedback solutions because consumers would not need to install an additional app or buy a new device. Moreover, since consumers frequently use instant messengers to communicate with their friends and family members, EFA would be able to "*pick up consumers right where they always communicate*" (EX6). The experts further argued that the use of existing communication channels (e.g., Facebook Messenger or WhatsApp) represents a low entry barrier for consumers, "*especially for elderly people or people with low IT affinity who might have difficulties installing an app*" (EX3). In addition, the experts stated that EFA would be of interest for energy providers looking for products based on smart metering technology. Many consumers in Germany seem to be skeptical of this new technology, but energy providers are legally required to implement them on a large scale within the next years. Therefore, solutions like EFA could help to reduce skepticism and facilitate the acceptance of smart meters in private households as "*such feedback can help to provide an added value to the customer*" (EX6).

Besides this general discussion, the experts also provided feedback on each DP. Concerning DP1, one expert mentioned that "*typical consumers have no relation to energy consumption*" (EX5) and their interest in finding out how to reduce or shift energy consumption is rather low. Thus, when EFA provides clear answers to consumers' questions immediately, it would "*address the consumers at the right level*" (EX6) and help them to better understand the abstract and intangible concept of energy [15]. Another expert liked that EFA "*leaves the technical level*" (EX1) of energy feedback by not only using standard energy metrics, such as kilowatt-hours (kWh), but also metrics that are well understood by consumers (e.g., € instead of kWh). Moreover, it was received positively that EFA provided consumers with a reference (e.g., by showing reference consumption values, providing comparisons between devices, and explaining causal relationships). The experts argued that most consumers have difficulties to understand whether a certain amount of energy indicates high or low consumption. Thus, they found EFA's ability to answer specific questions (e.g., "Is the energy consumption of my fridge high?" or "Why is my consumption higher than last week?") and provide tailored feedback to be a great advantage. The experts believed that such feedback would not only increase general energy literacy, but also motivate consumers to use energy more sustainably (e.g., reduce or shift energy consumption) because they would not have to invest the time and effort to look up information about their energy use themselves. They suggested to go even further by identifying the consumer's skill and knowledge level and adapting EFA's reactive feedback based on the consumer's answers to questions such as *"Are you technically/commercially interested? Do you have a technical background? Do you want the information in kWh or in €?"* (EX6). For example, inexperienced consumers would not be confronted with energy metrics at all, while more knowledgeable consumers with a deeper interest in energy should also receive more complex feedback.

During the session, experts also stressed that energy feedback should not be limited to the provision of pure information but should always include a possible explanation: "*With '25% more' [i.e., energy consumption], it should be explained directly why this could be the case, for example: 'It could be the new device'*" (EX5). Consequently, one expert concluded that it is DP2 that makes the energy feedback effective. He argued that when EFA provides personalized suggestions and advice on how to use energy more sustainably, it would make it easier for consumers to respond to this feedback and follow the suggestions rather than draw conclusions themselves. The experts also noted that these suggestions should focus on small changes that can be implemented directly rather than on overly complex or high-level advice. Furthermore, EFA's ability to perform cost/benefit analyses using data from publicly available appliance databases [c.f., 20] was regarded an important aspect of DP2 to help consumers understand the significant energy and cost savings potential of new energy-efficient devices. Again, the reduction of effort for consumers was positively evaluated (e.g., consumers would not need to search for suitable devices themselves).

In general, the experts also liked the fact that EFA "pushes" feedback proactively to consumers (DP3). They argued that EFA should not remain passive because, after some time, consumers naturally begin to disengage with an energy feedback solution [42]. However, one expert argued that proactive feedback should always "*include concrete suggestions and advice so that [one] can rule out possible causes*" (EX2). This point was also addressed by another expert who criticized that a consumer "*[needs] more information in addition to the message to act accordingly*" (EX1). Furthermore, they would not want to receive daily reports on their energy use from EFA, but rather specific messages as a reaction to an important event or incident. However, one expert suggested that EFA should follow up on proactive feedback if consumers do not respond (e.g., "*for less important events, a continuous reminder should come up*" (EX1)). In case of emergencies (e.g., when an oven malfunctions), EFA could even make an automatic phone call to a dedicated emergency number.

The industry experts also believed that appropriate social cues displayed by EFA (DP4) would help to increase consumer engagement and make the energy feedback appear more natural. For example, one expert stated that, by displaying social cues, "*EFA tends to come across as a friend; the flow is more natural and maintains communication. In the second example [i.e., with social cues / DP4], [he] would have asked more questions than in the first example [i.e., without DP4]*" (EX1). Moreover, incorporating social cues, such as emojis, also helps to make the conversation appear more familiar to consumers and thus, might increase feedback effectiveness. However, one expert cautioned that these social cues should be designed carefully to not distract from EFA's main purpose to provide energy feedback: "*The bot should be less cheeky and a little more formal because it's about money*" (EX3). Table 2 summarizes the key findings of our focus group discussion with industry experts.

Table 2. Summary of key findings of the focus group discussion

DP	Key Findings
DP1	• Provides easy access to information on energy use in natural language • Facilitates consumers' understanding by quickly giving comprehensible answers • Could be individually adapted to the consumer's skill/knowledge level and preferences
DP2	• Helps consumers to directly respond to feedback by pointing out specific measures • Reduces effort for consumers to find out how to use energy more sustainably
DP3	• Facilitates re-engagement or continued interaction with EFA • Needs to include further information about the potential causes of an incident
DP4	• Encourages consumers to interact with EFA (e.g., ask more questions) • Needs to be designed carefully to not distract from EFA's main purpose

The focus group discussion also brought up some interesting aspects about the modality (i.e., text vs. voice) used by CAs for energy feedback. One expert suggested that consumers should be able to communicate with EFA using text messages (e.g., on the phone when they are not at home) and using voice input (e.g., if they own a device like Amazon Alexa). Moreover, they argued that, in some cases, using a voice-based EFA would further reduce the effort for seeking energy feedback since consumers do not need to enter a text message. One expert mentioned that the modality (text vs. voice) could also be automatically selected based on the consumer's current location. Moreover, EFA's functionality could be extended to be able to turn devices on and off, similar to existing smart home solutions.

In conclusion, the industry experts believed that with CAs, such as EFA, energy feedback could take an important step into consumers' daily life and help them to use energy more sustainably. Moreover, they argued that such a solution would provide energy providers with the opportunity to offer their customers a benefit from smart metering technology, which further indicates the relevance of our proposed design for a real-world context. According to the experts, technological advances within the next years will make it possible to easily extract and integrate the data that is required to provide the basis for the implementation of our design. However, they also noted that

EFA needs to possess advanced natural language processing capabilities to provide accurate feedback and ultimately, to ensure adoption and continued use by consumers.

6 Conclusion

This paper presents the findings of our DSR project on how to design CAs for energy feedback to promote sustainable use of energy in households. We identified several issues in the design of existing energy feedback solutions and proposed four DPs to address these issues by designing a CA for energy feedback. We instantiated our DPs in a text-based CA called EFA and evaluated it in an exploratory focus group session with industry experts. Overall, the results of our evaluation indicate that CAs represent a promising technology for energy feedback and designing these CAs based on our DPs could enable consumers to use energy more sustainably. We therefore contribute with valuable design knowledge that extends previous research on energy feedback solutions and serves as a starting point for future research on designing CAs for energy feedback.

Although our research follows established guidelines for conducting DSR [12, 24], there are some limitations that need to be discussed. First, we instantiated our DPs in a text-based CA (i.e., chatbot). However, as also illustrated in the feedback by industry experts, voice-based CAs seem to be a promising medium for energy feedback as well, possibly even in combination with a text-based CA. Therefore, future research could instantiate and evaluate our DPs in a voice-based CA such as Amazon's Alexa. Moreover, the evaluation was conducted with industry experts who might be biased because of their familiarity with energy feedback solutions. Thus, another focus group session with real, non-expert users could provide an important complementary perspective on our DPs. Finally, we used an interactive prototype without real data or algorithms to demonstrate EFA's capabilities in two scenarios. Although we argue that this approach is appropriate for a first evaluation of EFA, further research implementing a full infrastructure is needed. Therefore, we plan to implement a fully functional prototype in several households and perform a field-based evaluation study in our future research.

References

1. International Energy Agency (2017) World Energy Investment 2017. https://www.iea.org/publications/wei2017/. Accessed 28 Jan 2018
2. European Commission (2017) 2050 Low-Carbon Economy Roadmap. https://ec.europa.eu/clima/policies/strategies/2050_en. Accessed 15 Jan 2018
3. Kobus CBA, Mugge R, Schoormans JPL (2013) Washing when the sun is shining! How users interact with a household energy management system. Ergonomics 56:451–462
4. Karlin B, Zinger JF, Ford R (2015) The Effects of Feedback on Energy Conservation: A Meta-Analysis. Psychol Bull 141:1205–1227
5. Karlin B, Ford R, Squiers C (2014) Energy feedback technology: A review and taxonomy of products and platforms. Energy Effic 7:377–399
6. Weiss M, Helfenstein A, Mattern F, Staake T (2012) Leveraging Smart Meter Data to Recognize Home Appliances. In: 2012 IEEE International Conference on Pervasive Computing and Communications. IEEE, pp 190–197

7. Pullinger M, Lovell H, Webb J (2014) Influencing household energy practices: a critical review of UK smart metering standards and commercial feedback devices. Technol Anal Strateg Manag 26:1144–1162
8. McTear M, Callejas Z, Griol D (2016) The Conversational Interface: Talking to Smart Devices. Springer
9. Dale R (2016) The return of the chatbots. Nat Lang Eng 22:811–817
10. Gartner (2017) Top Trends in the Gartner Hype Cycle for Emerging Technologies. https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/. Accessed 20 Dec 2017
11. Bourgeois J, Linden J Van Der, Kortuem G, van der Linden J, Kortuem G, Price BA, Rimmer C (2014) Conversations with my washing machine: an in-the-wild study of demand-shifting with self-generated energy. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing. pp 459–470
12. Hevner AR, March ST, Park J, Ram S (2004) Design Science in Information Systems Research. MIS Q 28:75–105
13. Tremblay MC, Hevner AR, Berndt DJ (2010) Focus Groups for Artifact Refinement and Evaluation in Design Research. Commun Assoc Inf Syst 26:599–618
14. Kluger AN, DeNisi A (1996) The Effects of Feedback Interventions on Performance: A Historical Review, a Meta-Analysis, and a Preliminary Feedback Intervention Theory. Psychol Bull 119:254–284
15. Sanguinetti A, Dombrovski K, Sikand S (2018) Information, timing, and display: A design-behavior framework for improving the effectiveness of eco-feedback. Energy Res Soc Sci 39:55–68
16. Dalén A, Krämer J (2017) Towards a User-Centered Feedback Design for Smart Meter Interfaces to Support Efficient Energy-Use Choices. Bus Inf Syst Eng 59:361–373
17. Froehlich J (2009) Promoting Energy Efficient Behaviors in the Home through Feedback: The Role of Human-Computer Interaction. In: Proc. HCIC Workshop
18. Weiss M, Staake T, Mattern F, Fleisch E (2012) PowerPedia - Changing Energy Usage with the Help of a Smartphone Application. Pers Ubiquitous Comput 16:655–664
19. Gnewuch U, Morana S, Maedche A (2017) Towards Designing Cooperative and Social Conversational Agents for Customer Service. In: Proceedings of the 38th International Conference on Information Systems (ICIS). Seoul, South Korea
20. Weizenbaum J (1966) ELIZA - A Computer Program for the Study of Natural Language Communication between Man and Machine. Commun ACM 9:36–45
21. Maedche A, Morana S, Schacht S, Werth D, Krumeich J (2016) Advanced User Assistance Systems. Bus Inf Syst Eng 58:367–370
22. Beale R, Creed C (2009) Affective interaction: How emotional agents affect users. Int J Hum Comput Stud 67:755–776
23. Bickmore T, Cassell J (2001) Relational Agents: A Model and Implementation of Building User Trust. In: Proceedings of the 2001 SIGCHI Conference on Human Factors in Computing Systems
24. Kuechler B, Vaishnavi V (2008) Theory Development in Design Science Research: Anatomy of a Research Project. Eur J Inf Syst 17:489–504
25. Gall M (2018) BotPreview.com. https://botpreview.com/. Accessed 28 Jan 2018
26. Venable J, Pries-Heje J, Baskerville R (2016) FEDS: a Framework for Evaluation in Design Science Research. Eur J Inf Syst 25:77–89
27. Miller W, Senadeera M (2017) Social transition from energy consumers to prosumers: Rethinking the purpose and functionality of eco-feedback technologies. Sustain Cities Soc 35:615–625

28. Watson A, Viney H, Schomaker P (2002) Consumer attitudes to utility products: a consumer behaviour perspective. Mark Intell Plan 20:394–404
29. Morana S, Schacht S, Scherp A, Maedche A (2017) A Review of the Nature and Effects of Guidance Design Features. Decis Support Syst 97:31–42
30. Sarikaya R (2017) The Technology Behind Personal Digital Assistants: An Overview of the System Architecture and Key Components. IEEE Signal Process Mag 34:67–81
31. Tiefenbeck V, Goette L, Degen K, Tasic V, Fleisch E, Lalive R, Staake T (2016) Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation. Manage Sci 1–19
32. Fogg BJ (2002) Computers as Persuasive Social Actors. In: Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann Publishers, San Francisco, CA, USA, pp 89–120
33. Nass C, Steuer J, Tauber ER (1994) Computers are social actors. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. Boston, MA, USA, pp 72–78
34. Ham J, Midden CJH (2014) A Persuasive Robot to Stimulate Energy Conservation: The Influence of Positive and Negative Social Feedback and Task Similarity on Energy-Consumption Behavior. Int J Soc Robot 6:163–171
35. Statista Number of mobile phone messaging app users worldwide from 2016 to 2021. In: 2018. https://www.statista.com/statistics/483255/number-of-mobile-messaging-users-worldwide/. Accessed 28 Jan 2018
36. Easwara Moorthy A, Vu KPL (2015) Privacy Concerns for Use of Voice Activated Personal Assistant in the Public Space. Int J Hum Comput Interact 31:307–335
37. Appel J, von der Pütten A, Krämer NC, Gratch J (2012) Does Humanity Matter? Analyzing the Importance of Social Cues and Perceived Agency of a Computer System for the Emergence of Social Reactions during Human-Computer Interaction. Adv Human-Computer Interact 2012:1–10
38. Klopfenstein LC, Delpriori S, Malatini S, Bogliolo A (2017) The Rise of Bots: A Survey of Conversational Interfaces, Patterns, and Paradigms. In: Proceedings of the 2017 Conference on Designing Interactive Systems. pp 555–565
39. Tremblay MC, Hevner AR, Berndt DJ (2010) The use of focus groups in design science research. In: Hevner A, Chatterjee S (eds) Integrated Series in Information Systems. Design Research in Information Systems. Springer US, Boston, MA, USA, pp 121–143
40. Morana S, Schacht S, Scherp A, Maedche A (2014) Designing a Process Guidance System to Support User's Business Process Compliance. ICIS 2014 Proc 1–19
41. Zheng G, Vaishnavi VK (2011) A multidimensional perceptual map approach to project prioritization and selection. AIS Trans Human-Computer Interact 3:82–103
42. Snow S, Buys L, Roe P, Brereton M (2013) Curiosity to cupboard: self reported disengagement with energy use feedback over time. In: Proceedings of the 25th Australian Computer-Human Interaction Conference. pp 245–254