Thinking about Eco-feedback and Smart Plugs via a Survey and Thematic Analysis

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Abstract
This paper continues a trend that looks at smart plugs as a means to promote more sustainable and pro-environmental behaviors via, for example, *just-in-time* feedback information delivered at the source of consumption (i.e., the plug). We showed a video of one of these eco-feedback smart plugs to 50 participants via an online survey and asked them to design plausible scenarios that draw from and improve upon the interactivity, functionality, and ultimately the sustainability effect of these devices. Results were analyzed through a thematic analysis and resulted in seven overarching themes: (1) what are participants' needs and (2) which energy-centered objectives would they like to achieve; (3) what energy-related information and/or functionality would participants wish to access via a smart plug; (4) what strategies would be most effective in supporting participants attain their energy-related objectives over time; (5) what would be the most effective ways to control smart plugs and other connected devices; (6) which would be the most effective triggers to cue energy-related user actions; and (7) how can the previous themes come together to form new behaviors around energy use.

Keywords
Eco-feedback, sustainability, smart plug, IoT, thematic analysis

1. Introduction and Related Work

The majority of ICT-based proposals to address global warming partly rely on the Internet-of-Things (IoT). Examples include demand response with smart-grids [1, 2] or occupancy-driven energy management systems [3]; and, in general, are well perceived and often adopted by end-users [4]. However, while these technologies can be part of the solution, often they are also part of the problem – for example, when artifacts aimed at energy efficiency never recoup the equivalent energy spent in their manufacturing. Moreover, energy efficiency improvements have been found to generate rebound effects that lead to increased energy use [5, 6]. In the same vein, over-reliance on automation may lead to reduced personal responsibility for action [7]. A solution to relies on assistive and interactive cues to complement automation by presenting

Proceedings of ETIS 2022, November 7–10, 2022, Toulouse, France
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contextual information that helps users associate energy-related information to their everyday practices [8, 9]. This research field revolving around feedback, nudging, and persuasion was first described by Froehlich et at. as eco-feedback [10].

Eco-feedback has the potential to transform users' decision-making process from habit-driven to conscious and deliberate [11]. Further, not only has the effectiveness of eco-feedback information been validated already, but countless prototypes have been devised to explore different ways in which to present this information – from tangibles to smartphone applications, social media [12] to software agents [2], to chat bots [13], etc. These interfaces are relevant proof-of-concepts, but they often lack the properties of other systems developed via more holistic and user-centered approaches. More importantly, we argue that there is a research gap on *what* effective eco-feedback information to display over longer time; particularly information that is bespoke to different users and dwellings.

The contribution of our work describes a information gathering approach based on scenarios and plausible ideas from participants to personalize eco-feedback centered around the Wattom smart plug. Essentially, we designed an online survey asking participants to complete three scenarios in which they had to describe: i) *what* energy-related information and/or functionality they would wish to access and why; ii) *how* should smart plugs or other connected devices present this information along the time; iii) *which appliances* or systems does this information/functionality relates to depending the context of use; iv) *where* would the ideal location for this smart plug be; and v) *when* should this information be conveyed to them. Finally, we frame our results around a series of insights for future research on smart plugs and smart devices around sustainable HCI and new energy flexibility markets that start to flourish [14].

2. Study Design

There are many complex, socially-based phenomena that cannot be easily quantified or experimentally manipulated. Therefore, identifying users' social drives and perspectives; their motivations, expectations, trust, identity, social norms and so on; are paramount for creating more than "just appealing" designs such as those reviewed in the previous section [15]. To address this challenge, and taking into account that our study is related to contemporary energy display systems, this study follows a user-center approach that asks participants for their input on scenarios created by us and inspired by the ideas of Dunne and Raby [16]: "assuming it is possible to create more socially constructive imaginary futures, could design help people participate more actively as citizen-consumers? And if so, how?". Furthermore, scenarios are a simple way to ask for participant input without having to implement a novel system, and to gather diverse responses from participants spread across the globe. Our survey, participant responses, and analysis results can be found at [17].

2.1. Method

In order to inform the design of energy feedback systems (e.g., home energy displays such as Wattom) we created an online survey to help end-users evaluate three scenarios related to energy efficiency or the use of energy from renewable sources and how it related to load shifting. As pointed out by Braun et al. [18], surveys allows to access data that range from

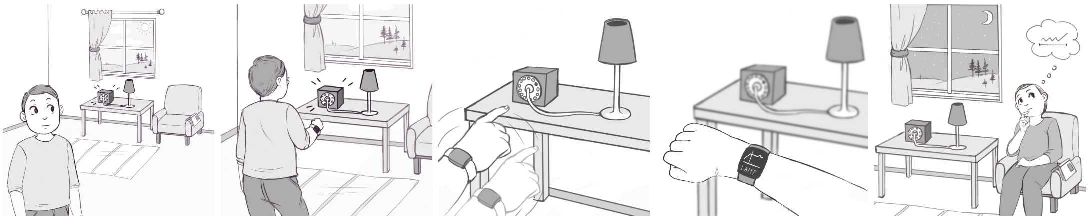

Figure 1: The figures provided in our online survey when asking participants to report on when they would wish to receive energy-related information. From the left to right: at any point before the interaction (*priming*); immediately before the interaction (*about-to*); during the interaction (*just-in-time*); immediately after the interaction (*advise/praise*); and after the interaction (*reflection).*

people's views, experiences, or material practices, through representation or meaning-making practices, which in this specific case, meant energy consumption practices. For each scenario, participants were asked the following four questions:

1. Description and rationale of an eco-feedback information idea (***what***), via free-form text.
2. Description of how a smart plug would display this information (***how***), via free-form text.
3. Description of which location would this information be most useful in (***where***). This was provided via three sub-questions: (i) four multiple choice options (home, work, shared home, other); (ii) a free-from text with more specific location information; and (iii) 23 multiple choice options with color-coded icons of various appliances and devices.
4. Description of when should this information be displayed throughout time (***when***). This was provided via five multiple choice options with the images illustrated in Figure 1.

2.2. Design artifact: Wattom

As part of the introduction to the survey, participants were presented to the concept of smart plugs via the latest version of Wattom [19] – a highly interactive smart plug first introduced at ACM TEI '19 [20]. For that, participants were invited to watch a three minute video that illustrated its capabilities as both an energy-aware display and an interactive device[1]. Regarding the former, information can be obtained: (i) via moving lights of different colors, speeds, and directions; (ii) via background colors; and (iii) via a smartwatch display. The moving lights facilitate interactivity in the form of direct input to the plug via what is known as motion matching [21]: an interaction paradigm where interface elements move in continuous and distinct trajectories, and where users engage with these by tracking their movement with their bodies. In Wattom, this user input is captured using the IMU on users' smart watches [22]. The lack of a rich graphical display in the smart plug means these moving targets are displayed with a ring of LEDs. The video also illustrated four features that were easily generalizable:

- Turning a connected appliance on or off. This is done through a blue target if the appliance is on, or white if not. This target's speed and the plug's background color change according to the amount of renewables present in the grid at the moment of interaction [23, 24].

[1] https://youtu.be/xM6ynzK1VCw

- Using the smartwatch as a second display for richer data visualizations. This relies on Wattom's non-intrusive load monitoring (NILM) capabilities to distinguish between multiple concurrent appliances connected to a single plug. Wattom displays a colored target per appliance (up to 12 appliances), which upon selection displays the latest energy consumption of that device as a colored plot on the user's smart watch. This data can also represent the user's personal consumption of a connected appliance, as Wattom logs the ID of the smart watch used as input to power or disable the appliance.
- Creating operational schedules for connected appliances. The goal is to provide users with a finer control over their electrical consumption, for example, planning certain activities when the electrical costs are excepted to be lower (e.g., night plans), or when the user expects more electrical availability from photo-voltaic installations on-site.
- Using the smart plug as an ambient display via its LED ring.

2.3. Results

In this section we report on the seven themes emerging from a thematic analysis approach [25], a qualitative method in which codes are generated from the data rather than relying on pre-existing categories. These were analyzed by three researchers, across the four main questions asked in each scenario. Inter-rater reliability was promoted by having unique pairs of researchers individually generate codes for each answer of the three scenarios [26]. For each of these answers, the researcher outside of the pair was responsible for consolidating the available codes. Finally, one of the researchers assessed the consolidated codes across the three scenarios and proposed a final classification. All the content provided in this section is supported by the tables in the annex which provide more insights into each individual answer.

79 participants completed our online survey using Prolific [27] (with a $3.5 incentive for participation), and 50 participants were selected for analysis (35 females, 15 males). Our selection process started by flagging participants taking less than 15 minutes to complete the survey, and also by assessing their final answers. Working together, three researchers excluded participants that did not understand or read the instructions, either by their own admission or by the answer itself. These 50 participants were aged between 18 and 69 (M = 32.58, SD = 12.01); 48% were employed, 20% were unemployed, 16% were students, 10% were self employed, and 6% were retired. Using a 5-point Likert scale, participants knowledge on renewable energy was normally distributed (M = 2.84, SD = 0.93, higher is better). These participants generated a total of 150 scenarios, and completed the survey in approximately 24 minutes (SD = 12).

Description and rationale of eco-feedback information (*what*): our analysis of the first question resulted in 25 codes, which were observed 371 times in the 150 answers analyzed (see Table 1). Using an online whiteboard[2] and mimicking the axial coding phase from Grounded Theory [28], we worked together to identify relationships and cluster these 25 codes together. Figure 2 depicts the relationship between the themes, as well as the quantity of codes associated with each theme.

***How* to display this eco-feedback information:** these answers were again coded using thematic analysis, but this time by a single researcher due to unambiguous nature of the answers

[2] Miro (http://www.miro.com)

Figure 2: The seven themes that emerged from a thematic analysis approach on participants' descriptions of their eco-feedback information ideas. The diagram was inspired by nascent theories to illustrate the relative power, scope, and direction of the themes, as well as the connections between them for linear narrative purposes – it should not be understood as a predictive or causal model [29]. Finally, the numbers on the top-right corners indicate the frequency of codes associated with the theme (out of 371).

– e.g. "(...) background colors to show how long the appliance has been on, for example green for one hour or less, orange for two hours (...)" (P20). This approach wielded 43 codes from the 150 answers analyzed, which were observed 205 times in total. These 43 codes were then consolidated under seven broader clusters such as "Feedback control in the watch" or "Color coding information with lights" (the most recurrent clusters). The specific frequency for each cluster and relation with the seven identified themes can be seen in Table 2. The results from the additional multiple choice question describing which of the four Wattom functions better relates to this eco-feedback information, in relation of the seven themes, can be seen in Table 3.

***Where* would this eco-feedback information be most useful:** a single researcher coded the free-form answers related to where the smart plug would be placed during these interactions; having identified 20 unique locations (e.g., the kitchen). The frequency and relation of these locations to our main seven themes can be seen in Table 4. Likewise, the frequency and relation of various appliance and devices to the same seven themes can be seen in Table 5. Popular pairings included a need for "Information" in the kitchen, or for "Control" in the bedroom.

***When* should this information be displayed:** the last question on each scenario related to *when* should participants' eco-feedback ideas be displayed. The relation between the five options available and our seven main themes can be seen in Table 6. Examples included participants' matches between "Priming" and "Control", or "Reflection" and "Information".

3. Discussion

Our results provide broad insights into a wide range of topics relating to eco-feedback information. This comes at a time where potential users are increasing aware of such topics, as illustrated by the self-assessment of our participants on their knowledge of renewable energy. When modeling what information participants would appreciate in this domain (see Figure 2), it is hard not to notice its similarity to existing behavioral models: from codes relating to establish objectives (i.e., goal-setting); to what would enable such goals (e.g., energy literacy); to defining personalized strategies to achieve them; to smart plug interface properties that support these strategies; to ultimately looking to enduring and long-lasting behavior changes.

Not surprisingly, 65.5% of all codes were related to defining user needs (including information and energy literacy), as these are arguably the easiest to articulate. Of these, participants were quite interested in monitoring their energy use (23.04% of all "Needs and Enablers" and "Information and Literacy" codes), in planning such use (22.22%), and assessing the source of the energy they consume (22.22%); the latter two exemplified by P17: "I don't think that it would be all that useful to go to use an appliance, and find out then that it's not a great time to use it [referring to Wattom's function of providing real-time feedback on the source of energy in the grid]. I think it would be much more useful for the device to create a sustainability graph of when the best times during the day are to use appliances so that I can plan around that". While this participant is not aware that the percentage of renewables in the grid can vary greatly [30], this opens up interesting future work in modeling and predicting such data using – e.g., weather forecast information – and highlight the importance of work such as the FORE-Watch that nudge people to use their appliances at more sustainable times via a wearable device [31].

Data visualization: when asked for further Wattom functions, seven participants asked for these smart plugs to be paired to richer displays, while four others were interested in more varied data visualizations (than the ones presented on the smartwatch): "I think that the (LEDs do not provide) enough information and can be confusing" (P17). This matches Castelly et al.'s assessment of advanced information visualization as a gap in sustainable HCI research [32].

Buying into smart devices: participants reported conflicting views on having smart plugs interact with other smart devices. On one hand, they describe pairing Wattom with richer displays and having eco-feedback information shared across smart devices (9.11% of all *how*-related information): "a way for it [smart plug] to get and use temperature data so it can be better used with AC / heating appliances" (P38). P47 described a version of these devices for showering and water sustainability. On the other hand, two participants shared some concerns about the cost of all these devices. P31 was concerned if a smart plug was needed per appliance, despite this not being case with Wattom. Further, P23 reported wanting less functionality and dependencies, for a simpler UX. This conflict has been highlighted before in He et al.'s work [33], and might explain the lack of mainstream adoption of more general home energy management systems (HEMS) systems such as Powerly. In sum, defining the target audience and marketing efforts for an eco-system of such devices is another necessary future work in this domain.

Smart plug controls: automation was referred to 48.84% of the time in the "Control" theme: "I would want to (...) set the plugs (to turn on) the kettle before I wake (up) and once I get in from work" (P41). Three participants were critical of the mid-air gesture approach, citing accessibility (P15) and older demographics (P26). Voice commands were referred to once in the "Control" theme; a more popular input proposition referred to by six participants would use some form of remote access (via, e.g., a web browser, smartphone app): "phone app customization – (i.e. the) ability to program it to suit your own needs" (P16). This type of dashboard approach is well known in sustainable HCI [34], and still seems to resonate with users.

4. Conclusion

Eco-feedback is hardly a novel research topic. What it is still a relevant research question is how to think of eco-feedback information when we consider it as a very particular and personal need. To that end, our paper conducted an online survey with 50 participants that required them to produce three speculative scenarios around what, how, where, and when to display this type of information. A smart plug was chosen as a design artifact to support participants in this exercise, mostly due to its familiar form factor and ubiquitous nature.

References

[1] H. T. Haider, O. H. See, W. Elmenreich, A review of residential demand response of smart grid, Renewable and Sustainable Energy Reviews 59 (2016) 166–178.

[2] E. Costanza, J. E. Fischer, J. A. Colley, T. Rodden, S. D. Ramchurn, N. R. Jennings, Doing the laundry with agents: a field trial of a future smart energy system in the home, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, 2014, pp. 813–822.

[3] M. V. Moreno, A. F. Skarmeta, L. Dufour, D. Genoud, A. J. Jara, Exploiting iot-based sensed data in smart buildings to model its energy consumption, in: 2015 IEEE International Conference on Communications (ICC), IEEE, 2015, pp. 698–703.

[4] P. Ponce, K. Polasko, A. Molina, End user perceptions toward smart grid technology: Acceptance, adoption, risks, and trust, Renewable and Sustainable Energy Reviews 60 (2016) 587–598.

[5] S. Gavankar, R. Geyer, The rebound effect: state of the debate and implications for energy efficiency research, Bren School of Environmental Science and Management (2010).

[6] A. Druckman, M. Chitnis, S. Sorrell, T. Jackson, Missing carbon reductions? exploring rebound and backfire effects in uk households, Energy Policy 39 (2011) 3572 – 3581. URL: http://www.sciencedirect.com/science/article/pii/S0301421511002473. doi:https://doi.org/10.1016/j.enpol.2011.03.058.

[7] N. Murtagh, B. Gatersleben, L. Cowen, D. Uzzell, Does perception of automation undermine pro-environmental behaviour? findings from three everyday settings, J. of Environmental Psychology 42 (2015) 139–148.

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

[9] M. Madsen, S. Gregor, Measuring human-computer trust, in: 11th australasian conference on information systems, volume 53, Citeseer, 2000, pp. 6–8.

[10] J. Froehlich, L. Findlater, J. Landay, The design of eco-feedback technology, in: Proceedings of the SIGCHI conference on human factors in computing systems, ACM, 2010, pp. 1999–2008.

[11] X. Zhuang, C. Wu, The effect of interactive feedback on attitude and behavior change in setting air conditioners in the workplace, Energy and Buildings 183 (2019) 739–748.

[12] V. Sunio, J.-D. Schmöcker, Can we promote sustainable travel behavior through mobile apps? evaluation and review of evidence, International journal of sustainable transportation 11 (2017) 553–566.

[13] U. Gnewuch, S. Morana, C. Heckmann, A. Maedche, Designing conversational agents for energy feedback, in: International Conference on Design Science Research in Information Systems and Technology, Springer, 2018, pp. 18–33.

[14] G. Pressmair, E. Kapassa, D. Casado-Mansilla, C. E. Borges, M. Themistocleous, Overcoming barriers for the adoption of local energy and flexibility markets: A user-centric and hybrid model, Journal of Cleaner Production 317 (2021) 128323.

[15] A. Adams, P. Lunt, P. Cairns, A qualititative approach to hci research, in: P. Cairns, A. Cox (Eds.), Research Methods for Human-Computer Interaction, Cambridge University Press,

Cambridge, UK, 2008, pp. 138–157.
[16] A. Dunne, F. Raby, Speculative everything: design, fiction, and social dreaming, MIT press, 2013.
[17] F. Quintal, D. Casado-Mansilla, A. Esteves, Socio-economic information and preferred interaction modalities related to eco-feedback systems, 2022. URL: https://doi.org/10.5281/zenodo.6947129. doi:10.5281/zenodo.6947129.
[18] V. Braun, V. Clarke, E. Boulton, L. Davey, C. McEvoy, The online survey as a qualitative research tool, International Journal of Social Research Methodology 24 (2021) 641–654. URL: https://doi.org/10.1080/13645579.2020.1805550. doi:10.1080/13645579.2020.1805550. arXiv:https://doi.org/10.1080/13645579.2020.1805550.
[19] A. Esteves, F. Quintal, F. Caires, V. Baptista, P. Mendes, Wattom: Ambient eco-feedback with mid-air input, in: 2019 5th Experiment International Conference (exp.at'19), 2019, pp. 12–15.
[20] F. Quintal, A. Esteves, F. Caires, V. Baptista, P. Mendes, Wattom: A consumption and grid aware smart plug with mid-air controls, in: Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction, TEI '19, Association for Computing Machinery, New York, NY, USA, 2019, p. 307–313. URL: https://doi.org/10.1145/3294109.3295642. doi:10.1145/3294109.3295642.
[21] E. Velloso, M. Carter, J. Newn, A. Esteves, C. Clarke, H. Gellersen, Motion Correlation: Selecting Objects by Matching Their Movement, ACM Trans. Comput.-Hum. Interact. 24 (2017) 22:1–22:35. URL: http://doi.acm.org/10.1145/3064937. doi:10.1145/3064937.
[22] D. Verweij, A. Esteves, V.-J. Khan, S. Bakker, WaveTrace: Motion Matching Input Using Wrist-Worn Motion Sensors, in: Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '17, ACM, New York, NY, USA, 2017, pp. 2180–2186. URL: http://doi.acm.org/10.1145/3027063.3053161. doi:10.1145/3027063.3053161.
[23] F. Heller, J. Borchers, Powersocket: towards on-outlet power consumption visualization, in: CHI'11 extended abstracts on human factors in computing systems, ACM, 2011, pp. 1981–1986.
[24] A. Gustafsson, M. Gyllenswärd, The power-aware cord: energy awareness through ambient information display, in: Extended abstracts of CHI'05, ACM, 2005, pp. 1423–1426.
[25] V. Braun, V. Clarke, Thematic analysis. (2012).
[26] J. L. Campbell, C. Quincy, J. Osserman, O. K. Pedersen, Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement, Sociological Methods & Research 42 (2013) 294–320.
[27] S. Palan, C. Schitter, Prolific. ac—a subject pool for online experiments, Journal of Behavioral and Experimental Finance 17 (2018) 22–27.
[28] K. Charmaz, L. L. Belgrave, Grounded theory, The Blackwell encyclopedia of sociology (2007).
[29] K. Charmaz, Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis, SAGE Publications, 2006.
[30] G. Gowrisankaran, S. S. Reynolds, M. Samano, Intermittency and the value of renewable energy, Journal of Political Economy 124 (2016) 1187–1234. URL: https://doi.org/10.1086/686733. doi:10.1086/686733. arXiv:https://doi.org/10.1086/686733.

Table 1
Frequency of each of the 25 codes that emerged from participants' descriptions of their eco-feedback information ideas, clustered around seven themes.

Codes	Frequency	Themes
Energy literacy	22	Objectives
Energy efficiency	5	Objectives
Energy monitoring	56	Needs and Enablers
Consumption planning	54	Needs and Enablers
Forecast	9	Needs and Enablers
Energy source information	54	Information and Literacy
Energy consumption information	27	Information and Literacy
Disaggregated consumption information	24	Information and Literacy
Energy/tariff cost information	8	Information and Literacy
Grid state	5	Information and Literacy
Energy storage state	5	Information and Literacy
Standby information	1	Information and Literacy
Real-time information	11	Strategies
Historical information	10	Strategies
Disaggregated consumption comparisons	6	Strategies
Rankings	4	Strategies
Social comparisons	3	Strategies
Automation	21	Control
Appliances/devices control	11	Control
Consumption scheduling	10	Control
Voice input	1	Control
Alerts	8	Triggers
Tips	3	Triggers
Request/response	1	Triggers
Change routine/habits	12	Behavior

[31] J. Schrammel, C. Gerdenitsch, A. Weiss, P. M. Kluckner, M. Tscheligi, Fore-watch–the clock that tells you when to use: persuading users to align their energy consumption with green power availability, in: International Joint Conference on Ambient Intelligence, Springer, 2011, pp. 157–166.
[32] N. Castelli, G. Stevens, T. Jakobi, Information visualization at home: A literature survey of consumption feedback design (2019).
[33] H. A. He, S. Greenberg, E. M. Huang, One size does not fit all: applying the transtheoretical model to energy feedback technology design, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '10, ACM, New York, NY, USA, 2010, pp. 927–936. URL: http://doi.acm.org/10.1145/1753326.1753464. doi:10.1145/1753326.1753464.
[34] D. Filonik, R. Medland, M. Foth, M. Rittenbruch, A customisable dashboard display for environmental performance visualisations, in: S. Berkovsky, J. Freyne (Eds.), Persuasive Technology, Springer Berlin Heidelberg, Berlin, Heidelberg, 2013, pp. 51–62.

Table 2

Frequency of each of the seven clusters that emerged from analyzing the second question of each scenario (*how*). The frequency of these are matched to the seven themes identified.

	Obj.	Needs	Inform.	Strat.	Control	Triggers	Behavior
Feedback/control in the watch	3	26	25	10	21	4	1
Color coding inform. w/ lights	17	79	89	24	13	7	13
Animations via the plug's lights	4	17	17	6	10	5	1
Information as a graph	2	17	21	5	4	0	1
Using the plug's lights as chart	0	11	8	3	0	0	0
Numerals on the smart plug	3	16	19	4	2	0	1
Feedback on other devices	8	11	15	4	6	5	2

Table 3

Frequency of each of the four Wattom functions, matched to our main seven themes.

	Obj.	Needs	Inform.	Strategies	Control	Triggers	Behavior
Powering appliances	5	21	24	6	19	0	2
Smartwatch as 2^{nd} display	10	36	44	18	5	5	3
Operational schedules	7	31	25	3	15	3	5
Ambient display	5	31	31	7	4	4	2

Table 4

Frequency of each location matched to our main seven themes. The top of the table illustrates multiple choice answers about broad locations (e.g. home, work); the bottom the written answers about specific places within those locations. While 20 individual locations were described, six were clustered under "Anywhere" (e.g., "any room", "any socket") and three under "Central location" (e.g., "hub of the house").

Home	23	101	107	27	39	8	11
Work	1	10	7	2	2	2	1
Shared home	2	5	7	3	0	0	0
Other	0	1	2	1	4	0	0
	Obj.	Needs	Information	Strategies	Control	Triggers	Behavior
Kitchen	12	55	49	13	8	6	4
Living room	5	31	31	10	9	4	2
Hallway	6	20	24	9	9	0	4
Bedroom	3	8	4	0	10	0	1
Office	1	3	3	1	4	0	1
Meeting room	0	2	3	1	1	1	1
Desk	0	1	1	0	0	1	0
Entrance	0	0	1	0	0	0	0
Garage	0	0	0	0	0	0	0
Laundry room	1	0	1	0	0	0	0
Central location	0	6	5	2	0	0	1
Anywhere	1	9	11	1	8	0	1

Table 5

Frequency of each appliance or device matched to our main seven themes. These were presented to the user in color-coded multiple choice options grouped by general locations, the kitchen, or as devices to be charged. Finally, the option 'None' was chosen to represent information that does not relate to a specific appliance but to, for example, grid information.

	Obj.	Needs/Enablers	Inform.	Strategies	Control	Triggers	Behavior
General	2	24	19	5	15	3	2
A/C	0	4	4	0	2	1	1
Game Console	0	2	1	1	0	0	0
PC	0	4	5	2	1	0	1
Personal Lamp	1	1	0	0	0	0	0
Lighting	1	2	0	0	5	1	0
Radio / Stereo	0	1	0	0	2	0	0
Fan	0	0	0	0	0	0	0
Heater	0	7	4	0	2	0	0
Alarm clock	0	0	0	0	1	0	0
TV	0	3	5	2	2	1	0
Kitchen	7	33	26	7	3	3	4
Washer	2	10	9	4	2	1	1
Fridge	0	0	0	0	0	0	0
Kettle	4	7	7	1	1	2	2
Dishwasher	0	6	1	1	0	0	0
Coffee Mach.	0	2	2	0	0	0	1
Cooker	1	7	5	0	0	0	0
Elec. Stove	0	1	2	1	0	0	0
Microwave	0	0	0	0	0	0	0
Chargers	4	7	4	0	8	3	0
Laptop	0	1	1	0	0	1	0
Smart Phone	3	3	2	0	5	2	0
Electric Car	1	3	1	0	3	0	0
Other	0	3	3	1	1	0	0
All / most	14	55	66	20	16	3	8
None	1	5	9	1	0	0	0

Table 6

Frequency of each of the five options on when to interact with the eco-feedback ideas proposed, matched to our main seven themes. These represent different times of interaction: at any point before the interaction (*priming*); immediately before the interaction (*about-to*); during the interaction (*just-in-time*); immediately after the interaction (*advise/praise*); and after the interaction (*reflection)*.

	Obj.	Needs/Enablers	Information	Strategies	Control	Triggers	Behavior
Priming	12	43	35	8	16	5	4
About-to	0	0	1	1	1	1	1
Just-in-time	0	0	0	0	0	0	0
Advise/praise	3	7	1	1	1	1	0
Reflection	3	13	21	8	4	0	2