**COMP2213: Interaction Design**
**Hand-In # 1 (version 1)**:
Literature Review and Interview Protocol

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# A Review on Renewable Energy for Residential Use

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## LITERATURE REVIEW

Considerable efforts have been made across European countries to encourage renewable energy resources among their citizens and promote home solar power. In particular photovoltaic (PV) panels have been promoted as a viable strategy to improve energy sustainability Streimikiene and Šivickas (2008). This move has been motivated by the high energy consumption of the residential sector, which accounts for a substantial proportion of greenhouse emissions (Belussi et al., 2019). As such, a hybrid of renewable energy sources and main grid system has been identified as most feasible to sustain the energy requirements of rapid urban development (Silvester et al., 2013).

The implementation of PV panels has been widely evaluated with collective work pointing to clear advantages in their efficiencies, energy generation capacities, and their reduced environmental impact (Imteaz & Ahsan, 2018; Kalogirou, 2004; Postovoit et al., 2020). Yet, there are clear barriers to their implementation including potential energy waste, particularly for households without appropriate battery storage systems (Lazdins et al. (2021), amongst which one of the more prominent challenges is the lack of adequate installation space (Karjalainen & Ahvenniemi, 2019). While the designs of newly constructed houses often account for such issues, battery insufficiencies continue to contribute to the negative attributes of PV systems (Karjalainen & Ahvenniemi, 2019). Recent evidence suggests that energy waste may be addressed by the integration of interactive technologies, such as smart home systems. The management of domestic energy consumption which will be explored more closely further in this review, in particular, the present work set out to assess recent developments in smart home energy management systems, their related challenges, and identify potential avenues for future improvements for PV panels.

Skeledzija et al. (2014) proposed a system based on energy efficiency that aims to reduce energy consumption and optimise the energy flow. It utilises a custom build control unit control unit that is linked an interface which controls building parameters such as heating, ventilation, and air conditioning systems. This allows for the estimates to be provided for energy corrections, such as heat, using collected parameters and weather predictions. While the solution does not specifically address solar energy, it focuses on the overall reduction in energy waste. It is also limited in its capacities to incorporate user habits and routine behaviours that could be used to provide further suggestions on energy consumption.

More specific solutions, that improve the energy efficiency of renewable resource were explored by Han et al. (2014) who focused on solutions that consider both the energy consumption and generation. Specifically, they outlined a framework in which the energy data is uploaded into a home server and analysed for estimation. This is deployed by connecting multiple measurement sensors (EMCUs) in outlets and lights around the house that transfer data into the home server. Importantly, the system can be linked to renewable energy sources, informing the user about the efficiency and accumulated energy of PV panels, which when combined with data on energy usage generates an energy usage profile. What makes this valuable is the ability to generate unique energy consumption profiles with insights into energy usage of individual appliances. This is important since energy tariffs supplied via main grid are known to vary (e.g., on time of day) and should be considered when trying to model optimal energy usage.

The variability in electricity cost, which differs based on providers and tariffs, is an important aspect for home energy monitoring. Several approaches have been proposed that consider both the electricity data and renewable energy status (Kofler et al., 2011), which allow the users to identify the most optimal time to schedule tasks and minimise energy waste from renewable sources. This can be combined with data on energy usage of individual house appliances, as seen in Han et al. (2014) system, and schedule activity when it is most energy-cost efficient (e.g. during off-peak when electricity costs are lower (Kofler et al., 2011)). While the above approaches did not explicitly address automatic scheduling, the feasibility of smart appliance control has been previously tested (Chouaib et al., 2019; Patil et al., 2019). For instance, Patil et al. (2018) devised a system to measure and automatically adjust air quality in closed spaces. The data collected from hardware sensors (e.g., oxygen level, humidity, temperature) was used to automatically activate air ventilation devices (e.g., air conditioning, window opening) when air quality reached certain levels. This offers high flexibility since the sensors can be attached to any home devices, such as lamps (Chouaib et al., 2019), allowing for the data to be sent, interpreted, and processed by server and send control signals to appliances. Such automatic scheduling is no doubt advantageous, yet it relies on in-time monitoring. It would be interesting to see how such technology could be adjusted to forecast scheduling based on the patterns with which the room is occupied. Further applications could include home appliance scheduling, one that aligns with user's habitual use.

The above approaches focus on coordinating energy consumption and reaching optimal levels between supply and demand. Yet, some management systems that utilise solar energy control begin to recognise the importance of human's comfort (Al-Kuwari et al., 2018). This primarily relates to thermal (e.g., temperature), hygienic (e.g., light quality) and visual (e.g., air quality) comforts, where home devices and appliances can be automatically or remotely adjusted by the user to help tailor and maintain desired comfort levels. This is important since perceived usefulness and compatibility of home smart technologies have been shown to influence users' engagement and satisfaction (Hubert et al., 2019; Marikyan et al., 2019). While the proposed architecture offers the conveniency via automatic execution, it evidently lacks capacities to recognise user behaviour and automatically adjust according to their routines. This could further improve the devices' previewed usefulness, particularly if the system was to learn to adjust to habitual behaviours of specific members of the household.

Together, the discussed literature points to an extensive range of methods that can be effectively used to monitor and control energy efficiently in residential housing. The designs offer automation systems suitable for both electricity and renewable energy sources (e.g., PV panels) which have been found effective in improve energy efficiency by reducing consumption. While the effectiveness of such technologies seems well established, there appears to be a considerable gap in the application of Artificial Intelligence (AI) tools. Systems that incorporate AI and have the capacity to learn and adjust to specific needs of the users, such as their thermal comfort, could bring unique solutions to energy efficiency. This may be of particular benefit to, for instance, ageing population whose optimum thermal conditions may differ to those of younger adults (Collins et al., 1981; Natsume et al., 1992; Schellen et al., 2010) and thus require more tailored approaches. Consequently, this highlights a rapidly emerging need for assistive architectures where smart home systems not only mitigate the issues linked to energy consumption but also improve the quality of lives and comfort of the users. Focusing on forecasting of human behaviour, our work set out to explore what specific aspects of AI technology may be seen as particularly useful among the users of smart home systems.

**INTERVIEW PROTOCOL: Design principles**

**Participants**

Considering budgetary and time restrictions, participants will be recruited using a convenience sampling method among the friends and families of the researchers who will be selected based on their availability (Martínez-Mesa et al., 2016). Using non-probabilistic sampling improves the feasibility of the study as it required less recourses compared to other approaches (e.g., random sampling). We intend to recruit 5 participants which for a small-scale qualitative study involving thematic analysis is expected to generate an adequate amount of data (Dworkin, 2012). The target population will be adults (18 years or older) who are familiar with smart home technology. We aim to address the current users to better understand what would they like to be able to achieve when it comes to the electricity management using their smart home devices.

**Objectives and sources of data**

The data will be collected using semi-structured interviews (Kallio et al., 2016). The collected data will help us explore participants' views on using renewable energy in their homes and their approaches towards utilising smart home monitoring and automation systems. The interviews will be conducted face-to-face in participants' homes or online via online-audio chat depending. Each interview will be carried out using a pre-design questionnaire and incorporate follow up questions that include closed (yes/no) and open-ended (descriptive) questions. Predesigning questionnaires improves consistency in the topics covered, which is important since data will be collected by several interviewers (Adams, 2015).

The proposed interview protocol consists of a combination of 11 core questions related to 3 areas of interest, namely (1) electricity consumption, (2) solar panels, and (3) smart homes. The questionnaire was designed in accordance with the principles of good research practice outlined by Clifford et al. (2016). Specifically, a considerable effort was made to ensure that the questions were: (1) directed the answer the research question, (2) not leading, (3) clearly worded and avoided jargon terms, and (4) open-ended (Kallio et al., 2016). The first question was also design to help to develop a rapport with the participants by focusing on familiar aspects (Cridland et al., 2015).

**Interview procedure**

Participants will be given verbal description of the procedure entails and and asked to provide a consent by verbally indicating their agreement to participate in the study. The interviews will be audio recorded using digital voice recorders and later transcribed using verbatim approach. To minimize participants' fatigue, the interviews are expected to take no longer than 30 minutes (Adams, 2015). Upon the conclusion of interviews participants will be debriefed about the aims of the study and will have the opportunity to answer any questions they may have (see Appendix 1 for Debriefing Sheet).

**Ethical considerations**

Full permission for conducting interviews was obtained in advance from the University of Southampton Ethics and Research Governance [ERGO/FPSE/19473]. The interviews will be conducted in accordance with the Code of Ethics and Conduct, and Code of Human Research Ethics (BPS, 2021a, 2021b). The collected data will be handled in line with ethical guidelines Allmark et al. (2009) whereby (1) participants' names will be anonymised and replaced with ID numbers, (2) the interview recordings will be securely stored on password protected laptops, and (3) the collected data will be solely used for the initial indented purpose.

**INTERVIEW QUESTIONNAIRE**

| | | | |
|---|---|---|---|
| **Participant ID:** ______________ | **Age bracket:** 18-24 [ ] 25-34 [ ] 35-44 [ ] 45-54 [ ] 55-64 [ ] 65+ [ ] | **Date:** ______________ | **Recording Device:** ________________ |
| **Interviewer:** ______________ | | **Time:** ______________ | **Interview Type:** Face to face [ ] Online-audio chat [ ] |

## RESEARCH PROJECT: RENEWABLE ENERGY FOR RESIDENTIAL USE

**Thank you for your interest in participating in our research. Before we start the interview, we need to ask you a few questions to confirm that you meet criteria for participation and that you agree to take part in the interviews.**

**Verbal Consent for ERGO/FPSE/19473:**

[ ] I understand that my participation is voluntary and that I am free to withdraw at any time
[ ] I consent for recordings made during the interview to be used by the research team for analysis
[ ] I agree to take part in the above study.

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### INTERVIEW QUESTIONS

**Electricity consumption**

Q1: What appliances do you think require the most energy in your home?

Interviewer's notes:

Q2: When do you use them?

Interviewer's notes:

Q3: How much do you consider the electricity cost when you run these appliances?

Interviewer's notes:

Q4: Some electricity providers have a less expensive tariff depending on the time of day. What are your thoughts on using appliances at different times of day to reduce the cost of your electricity bill?

Interviewer's notes:

## Solar Panels

Q5:  How would you describe your attitude towards solar panels?

Interviewer's notes:

Q6: If you have them, why? If not, why not?

Interviewer's notes:

Q7: What are your thoughts on using solar panels to supplement the energy in your home?

Interviewer's notes:

Q8: What challenges do you think people face when using solar panels?

Interviewer's notes:

## Smart Homes

Q9: What are your thoughts on smart homes?

Interviewer's notes:

Q10: Do you use any devices that use “smart” features, that help you with your every day?

Interviewer's notes:

Q11: In what ways do you think a smart home could allow you to be more energy efficient?

Interviewer's notes:

## Closure

Thank you for your help and your contribution to this research study, reflecting on this interview and what has been said, is there anything else that you would like to add?

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**APPENDICES**

**Appendix 1 – Debriefing Sheet**

University of Southampton

**DEBRIEFING SHEET**

Thank you very much for your contribution to this research.

**If you have any questions, please feel free to discuss these now with the researcher.**

The over-arching aim of the current research is to explore the use of renewable energy and smart home devices to identify potential improvements in the current technologies. It will help us to inform which areas are in need of most improvements. In recent years renewable technologies, such as solar panels, have become particularly popular, yet there are still notable challenges to implementing the technology. Many solutions have been provided to improve the efficiency of solar panel systems using smart home devices, but there seems to be a need for further improvements in that area. The interviews collected here will help us to identify which specific issues related to renewable electricity sources could be resolved via smart home management and monitoring systems.

*If you have any further questions or concerns please do not hesitate to get in touch with your interviewer.*