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Effectiveness of ICT Supported Citizen Engagement: Case Study of Solar Technology Acceptance in Heritage Area

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Abstract

Effective socially sustainable development require input from stakeholders and citizens. Citizen engagement processes are initiated by project owners or governments to capture the ideas, concerns and feedback of the citizens and other relevant stakeholders. ICT and digital technologies has the potential of lowering the barrier to entry and increasing accessibility to civic participation. Using established evaluation models and practices, this study aims to explore ways in which digital technologies can facilitate and support such a process, using solar technology at Møllenberg as a case study.

A mobile application was developed with support from experts on photovoltaic technology, with the aim of increasing citizen knowledge of photovoltaic technology, and solar potential using interactive digital mobile technology. Citizens were included in an iterative user-centered design phase. An evaluation framework was created based on a literature review, and this framework was applied in a survey included in the developed application. The application was both distributed to citizens and tested on citizens in an interview setting.

Analysis of the results and interviews demonstrated the potential of digital technologies to increase accessibility of civic participation and citizen engagement. Due to limited sample size, further research is needed to validate the evaluation framework.

Sammendrag

Effektiv sosialt bærekraftig utvikling krever innspill fra interessenter og innbyggere. Prosesser for borger-engasjement initieres av prosjekteiere eller myndigheter for å fange opp ideene, bekymringene og tilbakemeldingene fra innbyggerne og andre relevante interessenter. IKT og digitale teknologier har potensialet til å tilrettelegge og øke tilgjengeligheten til samfunnsdeltakelse. Ved å bruke etablerte evalueringsmodeller og metoder, tar denne studien sikte på å utforske måter digitale teknologier kan lette og støtte en slik prosess, ved å bruke solteknologi på Møllenberg som case-studie.

En mobilapplikasjon ble utviklet med støtte fra eksperter på solcelleteknologi, med sikte på å øke innbyggernes kunnskap om solcelleteknologi og solenergipotensial ved bruk av interaktiv digital mobilteknologi. Innbyggerne ble inkludert i en iterativ brukersentrert designfase. Et evalueringsrammeverk ble laget basert på en litteraturgjennomgang, og dette rammeverket ble brukt i en undersøkelse inkludert i den utviklede applikasjonen. Applikasjonen ble både distribuert til innbyggere, og testet i en intervjusetting.

Analyse av resultatene og intervjuer viste potensialet til digitale teknologier for å øke tilgjengeligheten for samfunnsdeltakelse og borgerengasjement. På grunn av begrenset resultatmengde er det nødvendig med ytterligere forskning for å validere evalueringsrammeverket.

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Chapter 1

Introduction

This chapter describes motivations, contributions context and research goals of this thesis.

1.1 Motivation

Effective socially sustainable development require input from stakeholders and citizens. Citizen engagement processes are initiated by project owners or governments to capture the ideas, concerns and feedback of the citizens and other relevant stakeholders. This ensures process transparency and increases the project's chance of success and acceptance. Effective citizen engagement requires both education of the public as well as a meaningful feedback process. Such a process requires work from both the initiator as well as the target audience, and must strive to be as inclusive as possible. A domain where citizen engagement is highly relevant is urban development. Helios is a project from NTNU's Faculty of Engineering which is performing research to expose and solve integration and acceptance of photovoltaic (PV) systems in the heritage area of Møllenberg in Trondheim, this includes efficiency analysis, 3D modelling, economic models and heritage regulatory analysis. The citizens of Møllenberg have expressed an interest in such a process, but have largely not been included nor presented with the findings. ICT (internet communication technology) and digital technology enables multiple interactive modelling features such as showcasing changes using augmented reality technology. There is lack of research on how ICT, digital technology, and interactive education can ease the participation in citizen engagement projects and increase accessibility, as well as ease the discussion process.

This thesis aims to explore how ICT and digital technologies can be used to increase the accessibility of local civic democratic processes such as citizen engagement, where an informed public is essential.

1.2 Project and Context

The research aims to explore ways in which ICT can aid in citizen participation and local democratic processes. Effective democratic processes are integral to socially sustainable development. Citizen Engagement (CE) is an example of a local democratic process. It aims to connect project owners with citizens to foster two-way knowledge building and feedback.

This thesis and findings are builds upon research done in a specialization project[27] which focused on identifying relevant working definitions, requirements and research gap in relation to citizen engagement and ICT. Furthermore the specialization project established affiliation with Helios, through an autumn school arranged by URSA Major. During the URSA-major project a survey was conducted on the opinions and attitudes of the citizens of Møllenberg regarding their solar panel acceptance and how they would want to be included. The most voted responses for inclusion were: visualizations, surveys, meetings, and hearings [9].

During this thesis further research on relevant requirements, design, prototyping and evaluation has been performed. This has been achieved by performing a literature review, creating an initial conceptual evaluation framework and an iterative design process of a knowledge building application. The initial conceptual evaluation framework was then applied to the developed application and analyzed to create a conceptual evaluation framework.

1.3 Citizen Engagement in Sustainable Development

This thesis aims to foster sustainable development in multiple dimensions by focusing on citizen engagement using photovoltaic potential at Møllenberg as a case study. By integrating ICT into the process, the project seeks to enhance the effectiveness of engagement, as well as facilitate the adoption of renewable energy resources.

Solar panel installation in heritage areas can contribute to environmental sustainability by promoting the adoption of renewable energy resources and sustainable development of existing buildings. By generating clean energy, solar panels help to reduce greenhouse gas emissions, limit dependency on fossil fuels, and mitigate the impacts of climate change. Citizen engagement in this process ensures that the transition to renewable energy is more inclusive and well-received by the local community.

Solar panels can provide a cost-effective, long-term source of energy that can contribute to economic sustainability in the heritage area. By generating electricity from a renewable source, communities can achieve energy independence and minimize their reliance on non-renewable energy resources and the volatile private energy market.

Citizen engagement promotes social sustainability by encouraging local participation, awareness, and ownership of sustainable development initiatives. The use of ICT can help facilitate this process by increasing accessibility and lowering barrier to entry and easing the means of participation. This approach fosters a sense of community responsibility, social cohesion, and collective decision-making, ultimately contributing to the long-term success of the initiative.

In heritage areas, the integration of solar panels must be approached with sensitivity to preserve the cultural, historical, and architectural values of the region. By engaging citizens in the process, the project ensures that solar panels are installed in a manner that respects and complements the unique characteristics of the heritage area. ICT can be employed to gather and analyze community feedback, as well as to document, visualize, and monitor the impact of solar panel installations on the heritage site.

ICT applications can lower the barrier to entry for citizens who for different reasons are disengaged in their local democracy. The technology allows for both information sharing, interactive experiences as well as efficient dialogue. This project aims to transform existing knowledge and digitization work such as 3D scans of the area to create an application where citizens can increase their knowledge both about their local area and relevant regulations, as well as making them aware of the solar area's solar potential.

1.4 Contributions

This research study contributes to knowledge and understanding of how ICT and digital technologies can enhance and assist in increasing civic participation. The process of citizen engagement goes beyond allowing citizens to give passive feedback, the theory puts emphasis of creating a public with knowledge on important local issues. The focus of this research will look at attitude change of the citizens, the changing knowledge confidence, as well as how the technology can involve citizens who are not participating currently.

Furthermore this thesis combines and utilizes knowledge from multiple fields:

- Researching the potential modern ICT has to increase civic engagement and improve public transparency
- Creating an interactive application which showcases potential, challenges and opportunities of photovoltaic technology
- Creating an engagement application designed using sound software engineering principles

1.5 Goals and Initial Research Questions

The importance of citizen engagement in local democracy is crucial for the well-being and development of communities. This project will adopt a citizen engagement theory approach to explore how ICT and digital technologies can improve citizen power and accessibility in local democracy.

The primary goals of this project are:

- To explore the potential of digital technologies in enhancing citizen power within citizen engagement
- To explore the potential of digital technologies in improving accessibility of citizens to participate in citizen engagement projects
- To identify the challenges and opportunities associated with the implementation of ICT in citizen engagement

To achieve these goals, the project will address the following initial research questions:

- **RQ1:** How can ICT be used to facilitate citizen engagement and empowerment in local democratic processes?
- **RQ2:** How can the use of digital communication technology and interactive education technologies impact citizen engagement and participation in urban planning and development projects, and what are the advantages and drawbacks of using these technologies?
- **RQ3:** How does ICT and digital interactive learning technologies impact the accessibility and participation in local democracy?

By addressing these research questions, this project aims to contribute to the existing body of knowledge on citizen engagement theory and its application within the context of ICT and local democracy. The findings will not only provide a better understanding of the potential benefits and challenges of integrating ICT in local democratic processes, but also inform strategies for effectively harnessing ICT to improve citizen power in local democracy.

1.6 Research Approach

To thoroughly explore the potential of ICT in enhancing citizen engagement and increasing inclusion in local democracy, this project employed a mixed-methods approach. The research design encompassed various methods, including a literature review, technology review, expert interviews, citizen interviews, and a user-centric design phase. This multi-pronged approach aimed to ensure a comprehensive understanding of the subject matter while providing a solid foundation for the development phase.

A literature review has previously been conducted to identify research gaps[27], and understand the current state of knowledge on the interplay between ICT, citizen engagement, and how interactive ICT can lead to engagement and participation. The review in this thesis had a focus on how ICT can be used to support the requirements of citizen engagement as well as, how established methods for user-centric design, usability design, and evaluation can effectively aid this process. The review allowed for the identification of key theories, frameworks, and empirical findings that informed the research design and provided a basis for further investigation.

Semi-structured expert interviews were conducted to gather insights from professionals and academics with expertise in the fields of ICT, citizen engagement, and local governance. These interviews aimed to identify potential solutions, application requirements, and best practices for integrating ICT in local democratic processes. The insights gathered from experts provided a valuable understanding of the practical implications and potential challenges.

A technology review was undertaken to identify potential ICT tools and platforms that could citizen engagement and empowerment in local democratic processes. This review focused on assessing existing frameworks and development tools to create an interactive application with potential to reach as many citizens as possible, in other words frameworks that targets multiple platforms. The technology review the framework's ability to complete the functional requirements. The potential advantages and limitations of each technology were examined to determine their suitability for application within the local democratic context.

In the design phase, multiple user-centric methodologies were applied to develop an ICT framework that addresses the identified research gaps and incorporates the insights gained from the literature review, technology review, expert interviews, and citizen interviews. These methodologies included participatory design, human-centered design, and usability testing, among others. This approach ensured that the resulting ICT framework was tailored to the needs and preferences of citizens while remaining practical and effective in enhancing citizen power in local democracy.

By employing a mixed-methods approach that combined both qualitative and quantitative data collection and analysis, this project aimed to provide a comprehensive understanding of how ICT can be leveraged to improve citizen power in local democratic processes. The findings from this research will contribute to the development of effective strategies for harnessing ICT to strengthen citizen engagement and empowerment in local democracy.

1.7 Thesis Structure

- **Chapter 1, Introduction**: Introduces the reader to the motivation behind this thesis and what issues are to be addressed, as well as contributions.
- **Chapter 2: Related Literature and Background**: Presents key aspects of Citizen Engagement, and gives an overview of relevant related works. Project affiliations are presented, and relevant theoretical evaluation models are presented. The conclusion of this chapter is a set of refined research questions.

- **Chapter 3: Method**: Presents the research approach and data collection strategy. This chapter also introduces how the theory is applied and the ways in which results are generated.
- **Chapter 4: Development and Technical Solution**: This chapter presents a few key results from the method chapter which guides the development of an application. A technical review is performed and its results presented, and final application architecture and choices are presented.
- **Chapter 5: First Iteration: Concept Evaluation**: The concept evaluation process and results are presented. This includes prototype, interview guide and discussion as well as changes made to the concept and requirements.
- **Chapter 6: Second Iteration: Application Usability**: Presents the second evaluation. This evaluation had a greater focus on application usability.
- **Chapter 7: Final Evaluation**: Presents the final evaluation of the thesis.
- **Chapter 8: Discussion**: Discusses potential bias in the evaluation and the demographic of the participants. The data is then analyzed through correlation analysis.
- **Chapter 9: Conclusion**: Presents conclusions to the refined research questions based on data and feedback collected from the three evaluation iterations. Also presents future work.

Chapter 2

Related Literature and Background

This section outlines background literature and theory used to motivate the research questions. Additionally preview relevant work will be presented and reviewed to identify and motivate methods used in the thesis. Digital technologies used in the finished product will also be presented.

2.1 Citizen Engagement

Citizen engagement (CE) is a method of fostering citizen participation. Citizen participation refers to the involvement of citizens in decision-making processes of governance, particularly in matters that directly impact them. Citizen participation can take on many forms and occur at various levels of governance, from local community meetings to national or even international policy dialogues. In this project we will focus on citizen participation on local community-level. The term Citizen Engagement as a term dates back to Edmund Burke's 1968 paper on citizen participation strategies[13]. In the preceding specialization project's literature review, the working definition of CE was determined as[27]:

Citizen Engagement is top-down project initiated by governments or project owners to foster two-way education, feedback and interaction.

This definition is made to be verbose, and requires case-specific definition of education and feedback. A key point provided by Dobos and Jenei[20] is that the CE process should not only be considered as the two sub-processes, we therefore have to understand the domain of application, and how to tie these concepts together.

The aim of CE is to enhance democratic processes by including a broad range of perspectives and voices. It helps ensure that decisions made by governments are more representative of and responsive to the needs and interests of their citizens. Citizen participation can increase transparency, improve accountability, and foster trust between the public and the government. Moreover, when citizens actively participate in decision-making processes, they're more likely to support and engage with the outcomes of those processes. This can enhance social cohesion, promote active citizenship, and contribute to the sustainability of initiatives and policies.

Achieving meaningful citizen participation can be challenging. It requires mechanisms for facilitating participation, as well as an open and inclusive approach to governance. It is crucial to ensure that a diverse range of citizens have the opportunity to participate.

2.1.1 Education in Citizen Engagement

The purpose of education in a CE project is limited compared to what an education process would expect. Arnstein's Ladder of participation does a good job of contextualizing this[7]:

The end goal of the education aspect in an engagement process is to make sure that the citizens have the required case knowledge to make up an informed opinion. Citizens are not expected to become experts on a topic, but for their feedback to be valuable they are required to gain some knowledge before their feedback is collected.

To further emphasize this, education models can be used to more clearly define what is expected knowledge level of the citizens. These models can used as a supplement to contextualize the expectations of the educational expectations of a citizen engagement project.

Figure 2.1: Anderson and Kratwohls adaption of Bloom's Taxonomy of Learning Attainment Levels *source: [6]*

Using Anderson's adapted taxonomy of level of learning attainment, its easier to define what is meant by the term *education* in the context of citizen engagement. The materials provided to the citizens and the depths of which they go to in terms of information sharing is dependant on the complexity of the issue at hand. In the current project the citizens will be expected to gain a surface-level understanding of the sustainability impact solar panels have in terms of social, environmental and economy. The provided materials will be based on raw-data which has already been analyzed, this means that the citizens are not required to analyze, evaluate nor create something of their knowledge. For a citizen engagement project to be successful the knowledge gained from the project must be retained/remembered until at least the citizens have been able to give their feedback.

Another relevant educational model is self-regulated learning. This is a learning approach where learners actively manage their learning process, from setting goals to monitoring progress and adjusting strategies. Confidence plays a pivotal role in this process. Research suggests that learners with high self-efficacy (confidence in their abilities) are more likely to engage in self-regulated learning strategies [8].

2.1.2 Feedback in Citizen Engagement

The effectiveness of the feedback process is highly dependant on an educated public. With understanding and knowledge of the project, relevant technologies, issues, drawbacks, and gains, the citizens are able to provide feedback and foster sustainable development. Feedback in CE plays a crucial role to establish trust between citizens and project owners. This process aims to capture the perspective of the citizens, this includes collecting and listening to their concerns, and promoting transparency in the decision making process.

2.2 Related Work

A part of the preceding literature review[27], numerous papers related to ICT and Citizen Engagement were identified. In this section two sets of related works will be presented: works or applications in the domain of solar energy knowledge building, works or applications in the domain of citizen engagement.

2.2.1 Related Citizen Engagement Works

The works presented here are all analyzing or utilizing citizen engagement through the lens of ICT and digital technologies.

2.2.1.0.1 Augmented Reality (AR) Supporting Citizen Engagement in Circular Economy

This paper uses augmented reality technology to support citizen engagement in the transition from linear to circular economy[29]. Such a case requires knowledge building among the citizens, as circular economy is a relatively large systemic concept that requires conscious effort to be implemented effectively and sustainably.

The researchers posed three research questions:

1. Is citizen engagement through AR technology inclusive for participants with low CE literacy and confidence on this topic?
2. Is citizen engagement through AR technology inclusive for participants of all age groups, educational levels and genders?
3. Is citizen engagement through AR technology inclusive for participants who have never been exposed to similar technologies?

To answer these questions, an AR application was created. This application is called CirculAR, and its features include object manipulation, virtual assistant, gamification and learning elements.

The evaluation process involved 2 datasets:

- Web survey distributed to citizens of Karditsa, Greece, who watched a demo of the application. $n = 127$
- Web survey addressed to the general population outside the municipality. $n = 101$

This survey included the User Engagement Scale (UES). The researchers performed a reliability test of the UES, and found that it was indeed reliable and suitable.

After analyzing the results the researchers found that the engagement tool increased social inclusion and community cohesion as well as increasing the citizen's knowledge of circular economy and its benefits. Interestingly the engagement levels were higher among the participants with limited exposure to the concept of circular economy, and the digital tool improved their confidence and interest in the topic.

2.2.1.0.2 ICT, citizen engagement and the governance of extractive resources in Tanzania: Documenting the practice and challenges

In this paper, the researchers examine how the Tanzanian government uses ICT to engage with their citizens[41].

Research wise they pose two critical questions:

- To what extent does the government use of ICTs promote citizen engagement in extractive resource governance?
- How does the government deploy ICTs to create and/or constrain opportunities for active citizen engagement in extractives decision-making and governance processes?

This research is motivated by the increased usage of ICT to foster governance and public participation. Furthermore the increased availability and use of ICT have transformed the ways in which governments interact with their citizens.

The researchers argue that although the government has increased their usage of ICT to inform their citizens, but this has not increased citizen engagement in the governance processes. According to the paper this is because the government has employed political and legal measures to constrain citizen engagement. This shows that although ICT has the *potential* to increase transparency and civic engagement, it is not a given, and may even decrease the means of which citizens can critically engage with their government.

2.2.1.0.3 Technology knowledge and governance: Empowering citizen engagement and participation

In this paper the researchers investigates the impact technical knowledge (T-knowledge) has on citizen engagement[14]. T-knowledge describes the ability a user has to operate specific technologies. This is valuable in the domain of citizen engagement, as digital efforts has to be inclusive for a wide array of citizens with different technical knowledge, abilities, and experience.

To answer this the researchers developed an extended TAM (Technology Acceptance Model), and applied it to online e-government services provided by a Spanish City Hall. With 307 citizens participating the researchers found that the core constructs of TAM: perceived usefulness, ease of use and attitude significantly affect T-knowledge, and revealed a general support for T-knowledge as a determinant of citizen engagement.

2.2.2 Related Solar Energy Works

Project Name and description - What area is focus - Supported Languages - What are the features

Cadastre Solaire du Grand Genève

This application is made under G2 Solaire which is a collaborative effort between Switzerland and France[1]. The application has been designed for inhabitants of Greater Geneva, and aims to increase awareness for the solar potential of the area. In total the application covers solar potential for 2000km^2.

Figure 2.2: Map

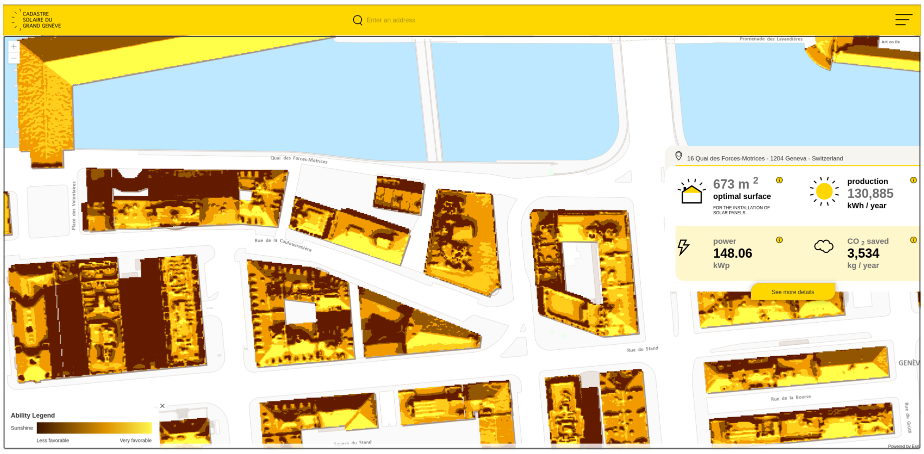

Figure 2.3: Map with house selected

The estimations and data is based on airborne altitude readings gathered using LiDAR technology, and is presented using the ArcGIS cartographic engine. It allows inhabitants to locate their homes, get an estimation of potential solar production per year and saved carbon footprint. Further the application allows users to get a brief estimation of cost associated with solar panel installation, and monthly estimated production in a graph.

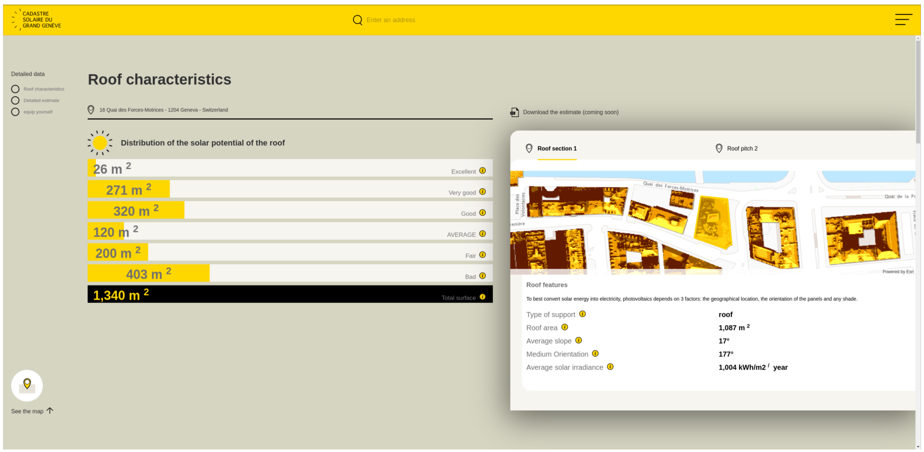

Figure 2.4: More info about house

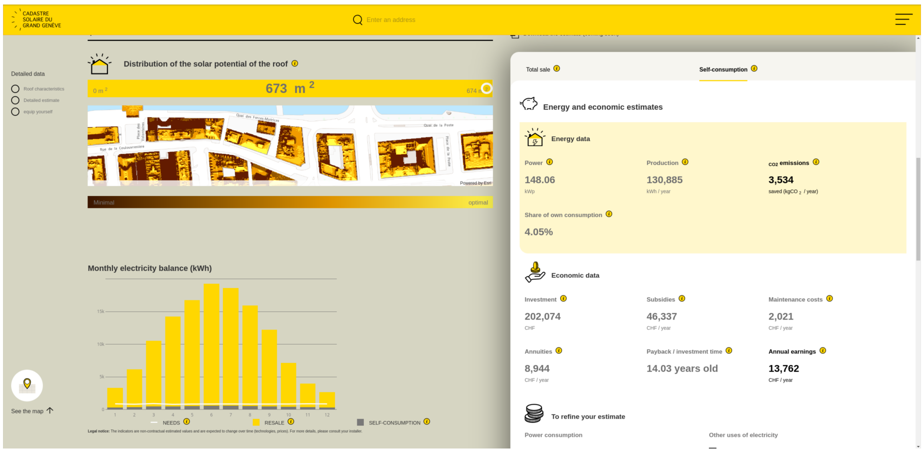

Figure 2.5: Detailed information

This application does little to increase knowledge about the technology itself, and focuses on the electricity implications. The calculations are brief, but is efficient in presenting key figures that citizens are likely to care most about: economy, environmental impact and electricity numbers. The application does little to showcase the aesthetic impact of solar panels, this is likely due to the way in which the readings and estimations are gathered.

Helsinki - Solar Energy Potential

This web-application utilizes Helsinki's open data platform to create a map of the solar potential of a large part of the city.

Figure 2.6: Area Overivew

By clicking on a surface on the 3D-map the user gets a brief technical estimation on the solar potential of the selected surface.

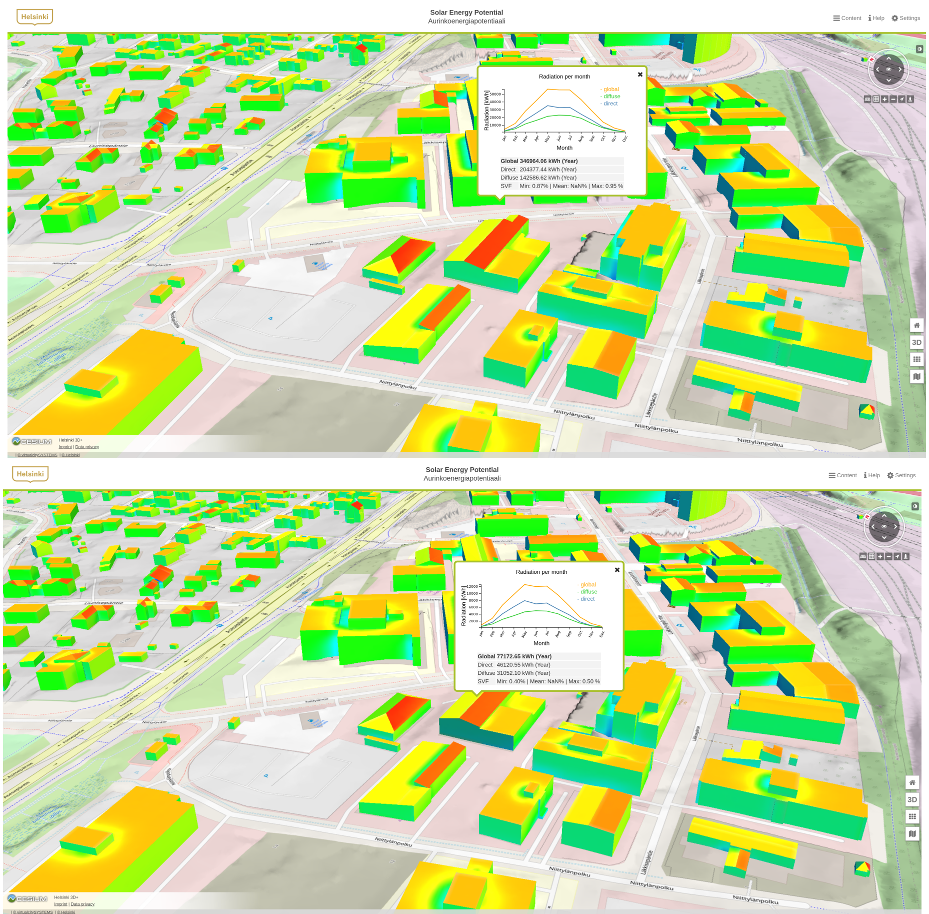

Figure 2.7: Surface Irradiation

This application is highly technical, and serves as a demonstration of the solar radiation potential rather than knowledge building of how photovoltaic technology can benefit the citizens. The 3D map gives an intuitive view of the solar potential of the different buildings as well as which surfaces are most suitable for solar technology. Another interesting bit of information is that this application is not only limited to the roofs. but also provides estimations for facades of buildings.

Google - Project Sunroof

Project sunroof uses simulations created using data from Google Earth. The web-application offers simulations of portions of all 50 states in the USA.

Figure 2.8: Project Sunroof landing page

When looking up a home, the user gets an estimation of how many sun-hours are expected to hit the roof during a given year, as well as estimated area suitable for photovoltaic panels, and estimated savings.

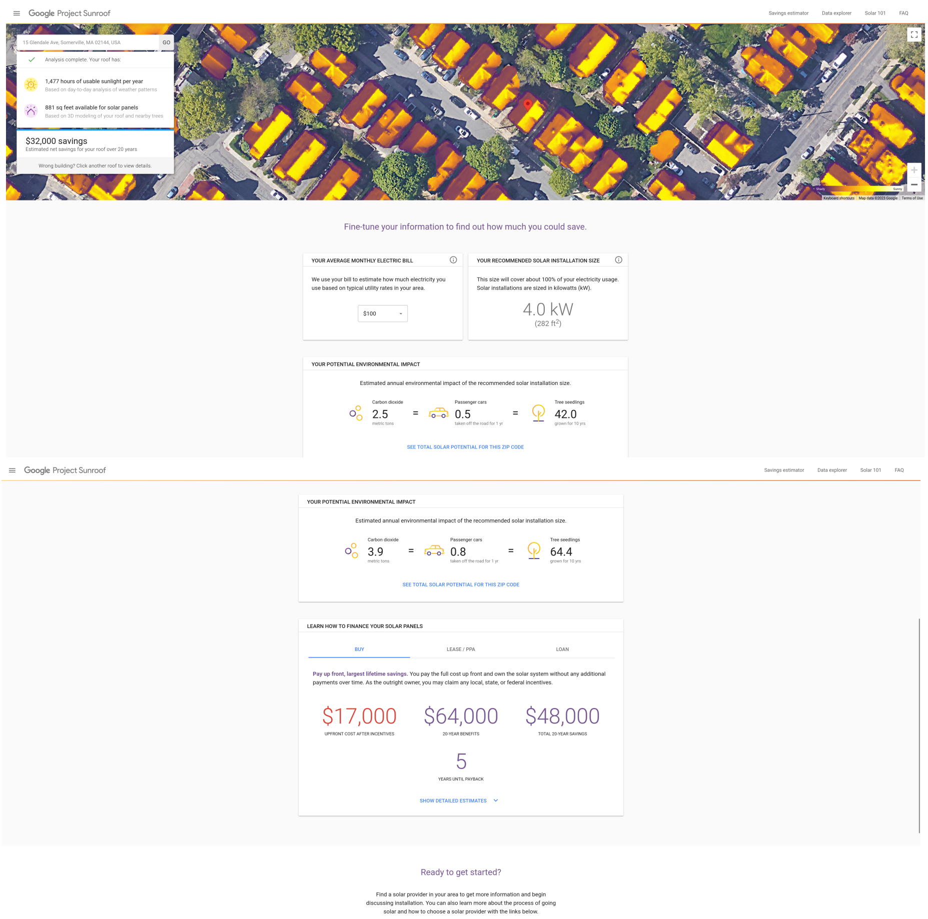

Figure 2.9: House estimations

The application gives the user a quick overview of the solar potential of their home, financing solutions and potential private solar providers. There is a brief page where the user can get an overview of how the technology works. This application gives the user the information necessary to decide whether or not to install solar panels, it does not aim to educate the user on solar technology.

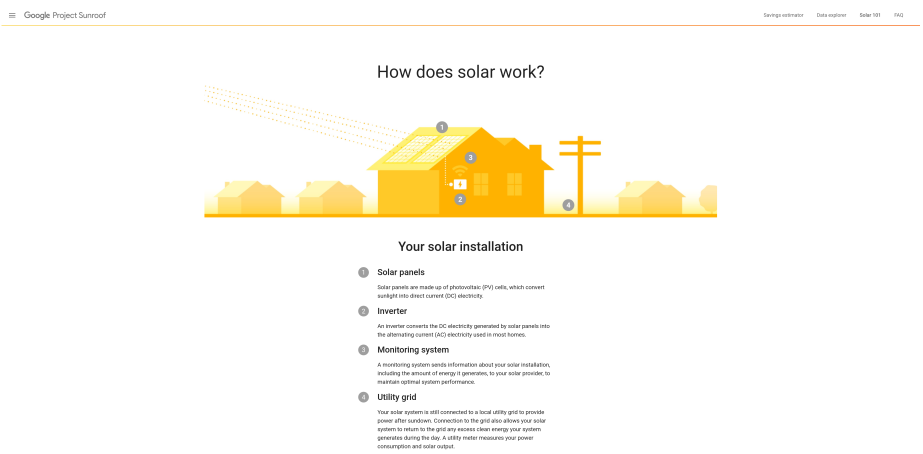

Figure 2.10: Solar explanations

2.2.2.1 Summary of Related Works

The evaluation of related works underscores a significant gap in the market, particularly in the realm of mobile applications. Firstly, the analysis reveals an evident absence of applications specifically tailored for mobile phones.

Secondly, our exploration highlighted that no existing application provides comprehensive coverage of both benefits and challenges associated with photovoltaic systems. While some applications may focus on the advantages of these systems, a holistic understanding necessitates an overview of the challenges, too. This imbalance in information delivery can potentially lead to misconceptions or incomplete understanding about photovoltaic systems.

Lastly, the lack of an application that explicitly presents the challenges for heritage areas is another void identified in the current application landscape. Although it is mentioned briefly in the Swiss-French application, the nuances related to heritage preservation is lacking.

In conclusion, the reviewed works suggest a clear demand for a more comprehensive, mobile-friendly application that provides an in-depth understanding of photovoltaic systems and the unique challenges faced by heritage areas.

2.3 Context and Affiliated Projects

This section will present project affiliations, and the case context.

2.3.1 URSA-Major

URban Sustainability in Action: Multi-disciplinary Approach through Jointly Organized Research schools (URSA-Major) is a project that works on education and transformation promoting Green Deal transformations. It is supported among others by The Research Council of Norway with project number 322317. It was during an autumn school arranged by URSA-Major that the author of this thesis became aware of the Helios project, and the sustainability challenges of heritage buildings. During this autumn school, a survey was distributed to the citizens of Møllenberg regarding participation in a process of increasing solar technology acceptance[9].

2.3.2 Helios

Helios is a project ran by NTNU's Department of Civil and Environmental Engineering, whose holistic statement is 'Enhancing optimal exploitation of solar energy in Nordic cities through the digitalization of the built environment'[2]. Helios is supported by The Research Council of Norway with project number 324243. Their research focus is on how solar energy can be exploited in the built environment and transformation of existing buildings with focus on Trondheim.

For this thesis Helios have provided their previously produced papers relating to solar technology and its application at Møllenberg. This includes analysis of current regulations, presentation and analysis of current photovoltaic technologies, energy storage, sustainability, and 3D model of the area.

Furthermore, Helios have provided experts on photovoltaic technology and during the project created simulations on the solar potential of Møllenberg, as well as regular application feedback and information validation.

2.3.3 Møllenberg

Møllenberg is a historic district in Trondheim, the third largest city in Norway. It's situated close to the city center, and characterized by a distinctive and well-preserved 19th-century townscape.

The area is renowned for its extensive collection of wooden buildings that date back to the 18th and 19th centuries. These buildings, which range from detached houses to terraced blocks, are reminiscent of the architectural style and urban planning trends of their respective eras. They form a cohesive and charming neighborhood that exemplifies Norway's historic urban residential architecture.

Møllenberg grew significantly during the 19th century as Trondheim industrialized. Many workers and their families settled in the area, leading to a construction boom of wooden houses. These buildings have been remarkably well preserved and are now regarded as cultural heritage sites, providing a tangible link to Trondheim's past.

The cultural significance of Møllenberg is recognized by its inclusion within Trondheim's Heritage Conservation Area. This means that any alterations to the buildings or new construction in the area must respect the historical and architectural value of the existing built environment.

2.3.4 Challenges for Heritage Buildings

Heritage buildings, while an integral part of cultural identity and history[28], often pose considerable sustainability challenges due to their older construction methods, materials, and technologies. These issues can make it more difficult for such buildings to meet modern environmental standards and can lead to higher costs in terms of energy consumption and maintenance. Some examples of these challenges:

Low Heat Insulation: Older buildings were generally not designed with modern insulation standards in mind. As a result, they often suffer from inefficient heat insulation. This means that in cold weather, they can lose heat rapidly, requiring more energy to maintain a comfortable temperature. Conversely, in hot weather, the lack of proper insulation can lead to excessive heat inside, again necessitating more energy for air conditioning.

High Energy Demands: Related to the insulation issue, heritage buildings often require more energy for heating, cooling, and lighting due to old, inefficient systems.

Relatively High Maintenance Cost: Heritage buildings, due to their age and the materials used in their construction, often require extensive and specialized maintenance, which can be costly. Traditional materials and techniques may not stand up as well to weather and wear as modern alternatives, leading to more frequent repair needs.

Addressing these issues often requires a balance between preserving the historical and cultural value of the buildings and enhancing their sustainability. The use of appropriate retrofitting technologies and techniques can play a crucial role in improving the energy efficiency of heritage buildings while respecting their historical integrity.

2.4 User Centered Design

User-centered design (UCD) is a design philosophy and process that focuses on understanding the needs, preferences, and limitations of end-users throughout the development of digital technology products and services [35]. The goal of UCD is to create appliactions with high usability.

UCD involves a series of iterative processes, including user research, requirement analysis, prototyping, usability testing, and iterative refinements [44]. By incorporating user feedback at various stages of development, UCD enables designers and developers to make informed decisions based on real-world data, resulting in digital products that better meet users' needs and expectations [42].

User-centered design has been widely applied in the development of digital technologies, such as websites, mobile applications, and software products, across various industries, including e-commerce, e-learning, healthcare, and entertainment [26].

2.5 Evaluation models

The theoretical evaluation models presented in this subsection were all considered as part of the evaluation model. The considerations and adaptations made were based on an evaluation framework presented in the method.3

2.5.1 System Usability Scale

The System Usability Scale (SUS) was proposed by John Brooke as "a quick and dirty usability scale"[11]. It has since become a widely adopted and well-established model for measuring the perceived usability of systems. The model itself is flexible and can be adopted for various contexts such as mobile applications, websites, and software. The

SUS template consists of ten statements. Each statement is rated on a 5-point scale ranging from 1 - strongly disagree to 5 - strongly agree. Such a scale is also known as a Likert scale. In the template the questions alternate between being positively and negatively phrased. Although short, the scale is designed to assess learnability, efficency, satisfaction and error frequency.

System Usability Scale
I found the system unnecessarily complex.
I thought the system was easy to use.
I think that I would need the support of a technical person to be able to use this system.
I found the various functions in this system were well integrated.
I thought there was too much inconsistency in this system.
I would imagine that most people would learn to use this system very quickly.
I found the system very cumbersome to use.
I felt very confident using the system.
I needed to learn a lot of things before I could get going with this system.

Table 2.1: SUS-Template

After collecting responses a SUS-score can be calculated like this:

- For odd items: subtract one from the user response
- For even items: subtract the user responses from 5
- Add up the converted responses and multiply the total by 2.5

Possible SUS-scores ranges from 0-100. This distribution is not to be considered as a percentage, and in their initial paper Brooke did not provide any guidance of score-interpretation. In a retrospective paper, Brooke cites Jeff Sauro's interpretation of 68 being considered an average score[46][12].

SUS has multiple advantages such as simplicity, ease of execution, and adaptability. It has been adapted in many previous research projects and its robustness has been thoroughly examined. However it cannot expose concrete issues, and should therefore be supplemented with other methods or models.

2.5.2 User Engagement Scale

The User Engagement Scale (UES) is a model for measureing user engagement in digital environments. UES can be used to evaluate websites, mobile applications, and online services. This model was presented as a conceptual framework by Heather O'Brien and Elaine Toms in 2008[37]. In UES, engagement is a process defined as four distinct stages: point of engagement, period of sustained engagement, disengagement and re-engagement, as well as having attributes of engagement that pertains to both the user, the system and the interaction between user and system. The survey form of UES was published by the same authors in 2010 [36]. Like SUS, the quetions in UES are rated in a Likert scale from 1 (strongly disagree), to 5 (strongly agree).

UES is built upon 5 dimensions:

- Focused Attention (FA): Feeling absorbed in the interaction and losing track of time
- Perceived Usability (PU): Negative effects experienced as a result of the interaction and the degree of control and effort expended
- Aesthetic Appeal (AE): the attractiveness and visual appeal of the interface
- Endurability (EN): the overall success of the interaction and user's willingness to recommend an application to others or engage with it in the future.
- Felt Involvement (FI): the sense of being "drawn in" and having fun

The following steps are made to calculate UES score:

1. Reverse score for items PU-1 ... PU-6, PU-8 and RW-3
2. Sum the scores for each item within a subscale
3. Divide the total by the number of items in that subscale to obtain the mean score for each subscale
4. Calculate the overall UES score by averaging the means core of all six subscales.

These dimensions contain a total of 31 questions. The UES model can be adopted, and removing dimensions is possible. Adopting or altering UES in this way will according to Kazdin threaten the construct validity[30]. Furthermore, removing dimensions also means that the adapted UES score is no longer an engagement score as defined by O'Brien. In a paper from 2018, O'Brien, Cairns and Hall presented a practical approach to the UES[38]. They also created a short-form of UES (UES-SF). UES-SF was created by identifying items that could be altered or removed, but still retain the ability to predict the full UES score.

The steps for UES-SF are:

1. Reverse items PU-S1, PU-S2, PU-S3
2. Engagement score is the average score of all items

When fully applied both UES and UES-SF can give an indication of what aspects of engagement an application satisfies, and help identify general issues with the application. This can be helpful when considered with target audience in mind.

2.5.3 TAM

The Technology Acceptance Model (TAM) was first proposed by Fred Davis in 1986 as an adaptation of the Theory of Reasoned Action (TRA) to predict and explain the factors affecting user acceptance of technology[18]. TAM has since become a prominent and extensively tested model in the field of information systems research, demonstrating its utility in predicting user behavior and technology adoption.

The Technology Acceptance Model (TAM) is a widely recognized theoretical framework for understanding and predicting users' acceptance and adoption of new technologies [18]. Developed by Fred Davis in 1986, TAM is grounded in the Theory of Reasoned Action (TRA), which posits that an individual's intention to perform a specific behavior is determined by their attitude toward the behavior and subjective norms [24].

TAM posits that users' acceptance of technology is primarily influenced by two key factors: perceived usefulness (PU) and perceived ease of use (PEOU) [18]. Perceived usefulness refers to the extent to which a user believes that a technology will enhance their job performance, while perceived ease of use is the degree to which a user expects a technology to be effortless to use. According to TAM, both PU and PEOU determine users' attitudes towards using a technology, which in turn influences their behavioral intention to use it, ultimately leading to actual system use [18].

TAM has been widely applied in various contexts, including software, mobile applications, e-commerce, e-learning, and healthcare, to explain and predict technology adoption behavior [51, 17]. The model has been extended and modified over the years, with notable extensions such as the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al., which incorporates additional factors and moderators to improve the prediction of technology acceptance [52].

2.5.4 Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) was proposed by Venkatesh et al.[52] in 2003 as a comprehensive model that integrates elements from eight prominent technology acceptance models, including TAM. UTAUT aims to provide a unified framework for understanding user behavior and technology adoption across different contexts.

UTAUT comprises four main constructs that are hypothesized to directly influence user acceptance of technology:

Performance Expectancy (PE): The degree to which a user believes that using a particular technology will help them attain gains in job performance. Effort Expectancy (EE): The degree to which a user believes that using a particular technology will be easy and free of effort. Social Influence (SI): The degree to which a user perceives that important others believe they should use the new technology. Facilitating Conditions (FC): The degree to which a user believes that an organizational and technical infrastructure exists to support the use of the technology.

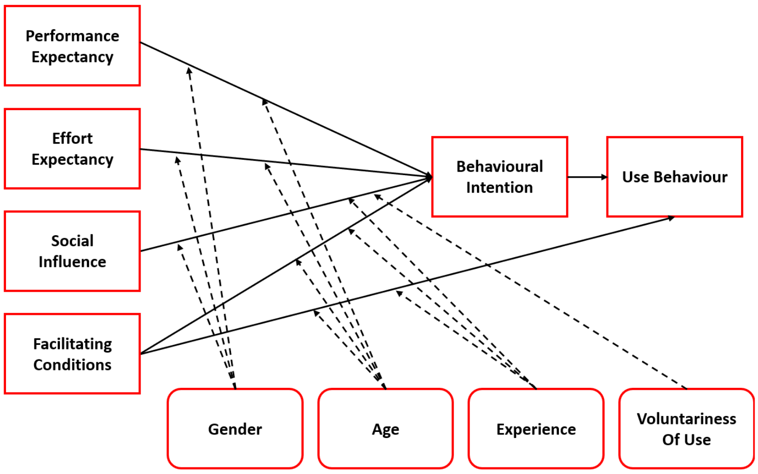

Figure 2.11: A graph representation of UTAUT-1 *source: https://acceptancelab.com/unified-theory-utaut*

UTAUT also incorporates four moderators: gender, age, experience, and voluntariness of use, which can affect the relationships between the main constructs and technology acceptance.

Several extensions of UTAUT have been proposed to address specific contexts or additional factors affecting technology acceptance. Notable examples include UTAUT2, which incorporates hedonic motivation, price value, and habit to explain consumer technology adoption, and UTAUT-B, which integrates the model with the Theory of Planned Behavior (TPB) to examine technology adoption in healthcare settings.

The Unified Theory of Acceptance and Use of Technology is a valuable model for assessing technology adoption across diverse contexts. But its complexity can make it challenging to adapt and implement.

2.6 Refined Research Question

Given the broad scope of citizen engagement, it quickly became unrealistic to conduct research on all facets. The research scope was therefore narrowed to focus on the learning process, and how digital technologies can facilitate and support the learning process of citizen engagement. Facilitation is solutions or applications that enable citizens to participate in a citizen engagement process using digital means. Support is solutions or applications that utilize the opportunity space or solutions that are not possible to recreate using analogue means.

By shifting focus, the initial research questions had to be refined. The research will aim to answer the following refined research questions:

- **Refined Research Question 1:** How can digital technologies be used to facilitate citizen engagement?
  - **Refined Research Question 1.1:** What is citizen engagement?
  - **Refined Research Question 1.2:** How can digital technologies be used to facilitate and support the learning process of citizen engagement?
- **Refined Research Question 2:** How does the use of specialized digital interactive learning technologies impact the attitudes of the citizens in regards to citizen engagement?
- **Refined Research Question 3:** How does usage of digital learning technologies impact perceived knowledge confidence in citizen engagement?

Chapter 3

Method

This chapter present the research approach and methods used for data generation, analysis, design, and development. The results of the various steps will be presented in 4

3.1 Research Approach

In this thesis, an multiple methodologies and activities were employed. These methods were identified and selected through literature reviews and consultation with the supervisor, to make best use of resources and ensuring the quality of data acquisition and analysis. The methodologies adopted build upon those identified in a prior literature review[27].

The present research approach included several tasks: a technology review, user and expert group interviews, design and heuristic investigations, development of an evaluation model, collection of survey feedback, and interpretation of evaluation results.

3.2 Data Collection and Management

According to NTNU's guidance on collection of personal data for research projects place of residence is classified as personal data[3]. In this project the target user user group all live in Møllenberg. It was therefore necessary to create both a data collection and data management plan.

In order to comply with relevant regulations, procedures recommended by NTNU and NSD (Norwegian Centre for Research Data) were followed. All data collected was stored directly on servers operated by NTNU or by partners such as NTNU's Microsoft 365.

3.3 Evaluation Model

An evaluation model is used to answer the research questions. It can also be helpful to adopt a flexible evaluation model which can evaluate both concept and prototype in different ways at various stages of the research process. In this project the evaluation model has to evaluate both the technical solution, as well as the impact the technology had on citizen engagement. The engagement evaluation includes both education and feedback. To develop the evaluation model a literature review was conducted to gain familiarity with standard evaluation models used for software. The models were then analyzed for their applicability in the context of a mobile application, and their flexibility as part of an iterative research process.

This project followed an iterative development process. This allowed for multiple evaluation steps with different focus. For instance the prototype testing had greater focus on the potential of the technology and the citizen's previous experience with citizen engagement projects, whilst initial testing with the developed application could have a greater focus on the technical aspects. Ultimately the final evaluation has to include all of the mentioned metrics, but the flexibility of the evaluation model allows for a more efficient research and development process.

To create a suitable evaluation model for each iterative step an evaluation framework was established to identify necessary metrics. Additionally the framework allows to aggregate and adapt established evaluation models for use in this project.

3.3.1 Evaluation Framework

An evaluation framework is a structured model containing a collection of relevant performance metrics to a project such as performance and effectiveness. By establishing clear criteria, indicators, and methodologies, an evaluation framework facilitates creation of adaptable evaluation models. This is especially helpful when used in an iterative development process, as different evaluation steps can have different focus areas, and the evaluation model can be adapted to reflect this focus.

The evaluation framework was created by analyzing established evaluation models and their underlying theory and concepts. Additionally key concepts and engagement metrics of citizen engagement were included. Furthermore for the evaluation framework, these features were valued:

- Adaptability and modularity - Do we have to use an entire model, or can we use select features?
- Scoring and tangibility - Does the model give us a score, and how easy is it to compare results?
- Theoretical assumptions - Does the assumptions and theoretical basis align with the definitions and theory used in this project?

To identify relevant evaluation models a literature review was performed on the topic of technology evaluation, and a review of the evaluation models adopted in the related works. These models were presented in the theory chapter: System Usability Scale (SUS), Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT) and User Engagement Scale (UES).

The SUS evaluation proposes that the usability of a system is dependant on:

- Effectiveness - To which degree can users complete their tasks
- Efficiency - How much effort is needed for the user to complete their tasks
- Satisfaction - Did the user find the experience/system satisfactory

TAM is one of the oldest and most established of the identified evaluation models. It proposes that the success of a software system is based on two factors:

- Perceived Usefulness
- Perceived Ease of Use

The UTAUT model was developed as an expansion of TAM. It builds upon four constructs:

- Performance Expectancy
- Effort expectancy
- Social influence
- Enabling conditions

UES is a model made to measure user engagement. It proposes that engagement is determined by 6 dimensions:

- Focused Attention
- Perceived Usability
- Aesthetic Appeal
- Endurability
- Felt Involvement

Based on these selected models, a proposed framework was built. The framework is based on the hypothesis that the success of a system to enable citizen engagement is determined by:

- Perceived Usability
- Ease of use
- Endurability and Novelty
- Felt involvement

Furthermore to evaluate the effect the application has had on the user in terms of learning in a citizen engagement context:

- Increase in knowledge
- Increase in confidence
- Curiosity

After analyzing the literature, the conceptual evaluation framework was created. The framework is created to evaluate the research questions whose focus are:

- Support and facilitate learning process of citizen engagement
- Attitudes
- Knowledge confidence

For this evaluation framework we make 7 assumptions. Three of these assumptions are factors for a successful CE-knowledge step, and four of these are potential outcomes of the CE-knowledge step. We label them as Precondition (P).

- **P1** - Aspects related to previous engagement projects or attitudes to participation in local democracy projects. A citizen who is already engaged and participating in citizen engagement projects are likely to stay engaged.
- **P2** - Aspects related to the perceived usefulness and usability of the system. These points are largely adapted from TAM and SUS. The usability and perceived usefulness of the application is a determining factor for how successful the CE project is.
- **P3** - Aspects related to how the system manages to capture the attention of the user, and involves the user. These facets are a part of the UES, and capture how the user is engaging with the application.

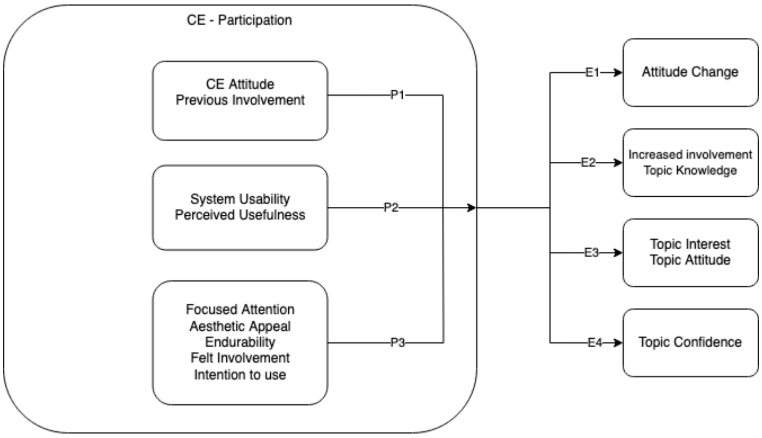

Figure 3.1: Diagram - Initial Evaluation Framework

To measure the effects of citizen engagement's knowledge and participation four constructs were created. The constructs were created to answer the adapted research questions, and are potential outcomes of citizen engagement participation. We label them as effect (E).

- **E1** - Attitude change focuses on attitude towards participation with the use of ICT.
- **E2** - Increased involvement focuses on whether this approach makes it easier or more likely for the user to participate in citizen engagement projects or local democracy in the future.
- **E3** - Topic interest and topic attitude focuses on what the user's opinion on the topic at hand has changed. In this study the topic is Photovoltaic Technology. Note that a positive response is not necessarily that the user is positive to the usage of photovoltaic technology, but that they have a better reasoning for their attitude.
- **E4** - Topic confidence is an important aspect and is an extension of *E3*, as it measures if the user feel confident in giving their opinion.

This evaluation framework is used in the various evaluation iterations, such that an evaluation iteration can have a clearer focus.

3.4 Evaluation Method

This section will present different *methods* used as part of evaluation. The distinction between an evaluation model and evaluation method, is that an evaluation model is a general set of questions leading to a score or result, while a method is a set of steps or approaches to conduct an evaluation in which an evaluation model is applied.

The means of data collection will be presented when the methods are applied in chapter 5, 6 and 7.

3.4.1 Usability Test

A key part of the design process was the usability test. This was done to validate application design both in terms of user experience, and feature set.

Usability testing is a user-centered evaluation method that aims to assess how effectively and satisfactorily a system is used and perceived by its target users [44, 34]. This method involves observing users as they interact with the system, often while given a set of predefined tasks, and gathering feedback on their experiences, difficulties, and preferences [21, 22].

There are various types of usability testing, two of these are formative and summative evaluations, which serve different purposes in the design and development process. Formative evaluations are conducted during the early stages of development to identify usability issues and inform iterative design improvements[44]. This can be performed on a non-functional prototype. Summative evaluations, on the other hand, are carried out towards the end of the development process or after the system has been released. In summative evaluation the goal is often to assess the system's overall usability and then it can be compared it against pre-defined benchmarks or relevant competitors [34].

Usability testing can be conducted in a controlled laboratory setting, in the users' natural environment, or remotely using online tools[44, 50]. The literature identified these relevant usability testing methods:

1. **Think-aloud protocol**: Users verbalize their thoughts and decision-making processes while interacting with the product, providing valuable insights into their mental models and expectations [23].
2. **Task-based testing**: Users perform specific tasks using the product, allowing evaluators to measure task completion rates, time on task, and error rates as indicators of usability [34].
3. **Heuristic evaluation**: Expert evaluators assess the product against a set of established usability principles, or heuristics, to identify potential usability issues [33].

3.4.2 Structured and Semi-Structured Interview

Structured and semi-structured interviews are qualitative research methods commonly used for gathering in-depth information about participants' experiences, perspectives, and opinions [10, 19].

Structured interviews are characterized by a fixed set of predetermined questions, which are asked to all participants in the same order [10]. This approach ensures consistency across interviews, allowing for easier comparison of responses and facilitating quantitative analysis of the data [25]. However, the rigid structure of this method may limit the ability to explore new or unexpected topics that arise during the interview [25].

Semi-structured interviews, on the other hand, involve a flexible interview guide that contains a list of open-ended questions and topics to be covered, but also allows for probing and follow-up questions based on the participant's responses [10, 43]. This approach provides a balance between ensuring consistency in the topics covered and allowing for exploration of new themes and ideas that emerge during the interview [43]. Semi-structured interviews can generate rich and detailed data, but the analysis of this data can be more time-consuming and complex compared to structured interviews [19].

In both structured and semi-structured interviews, it is essential to establish rapport with the participant, and ensure confidentiality to encourage open and honest sharing of information [10, 25].

3.4.3 A/B testing

A/B testing has become a crucial tool for optimizing digital applications, including websites, mobile applications, and software products, by identifying the most effective user interface (UI) and user experience (UX) design elements [32]. This experimental approach allows developers and designers to create different versions of a digital application, present them to a randomly selected group of users, and analyze the performance of each variant using predefined metrics [31].

In the context of digital applications, A/B testing can be used to assess a wide range of elements, such as button colors, layouts, headlines, images, and features, to determine which variants lead to higher user engagement, conversion rates, or other desired outcomes [15]. In this project A/B testing is used in an interview setting where the user themselves state their preferred interface.

3.5 Design and Development Process

This subsection describes the methods and process used during the application development process. These steps produced non-functional and non-functional requirements, as well as worked to validate intangible aspects found in the design phase.

3.5.1 User Persona

In the field of ICT-supported citizen engagement, it is crucial to understand the needs, motivations, and behaviors of various user groups in order to design and develop effective solutions. One powerful tool to achieve this is through the creation of user personas. User personas are fictional representations of the different user groups that might interact with a digital platform or service. User personas were made in the design process of the application for this project.

The first step in creating user personas is to identify the different user groups among the citizens. These groups can be based on various factors, such as age, occupation, education level, location, or interests. The purpose is to create a diverse set of categories that accurately represent the potential users of the citizen engagement platform. Once the user groups have been identified, the next step is to create a persona for each group. In this project the personas had these features:

- **Technology experience**: What technologies does the user interact with on a regular basis? This can be recreational usage such as mobile games, or their professional endeavours such as graphic design or software development.
- **Hobbies and interests**: What are the hobbies and interests of the persona? When creating the user persona this feature should strive to applicable to as big part of the demographic as possible.
- **Concerns**: What do we expect the persona's greatest concerns? In this project a concern is related to solar panel installation, an example of a concern is aesthetic heritage.
- **Influences**: This feature aims to capture the greatest influences on the persona. This can vary from specific people such as family members, or more general such as a group of people or organizations.
- **Civic Participation**: This feature aims to give an idea of the persona's attitude, experience and participation in local democratic processes.

Each demographic group is represented by a user persona, and each user persona is given a name to be easily identified.

3.5.2 Nielsen's Design Heuristics

Nielsen's Design Heuristics, also known as Nielsen's Heuristics or Nielsen's Usability Heuristics, are a set of ten general principles for improving the usability and user experience of digital interfaces [33]. These heuristics, developed by Jakob Nielsen, serve as a practical guideline for evaluating and designing user interfaces. The ten heuristics are as follows:

1. Visibility of system status: The system should always keep users informed about its current status, using appropriate feedback within a reasonable time.
2. Match between system and the real world: The system should speak the users' language, using words, phrases, and concepts familiar to the user, and should follow real-world conventions.
3. User control and freedom: Users should have the ability to easily undo and redo actions, and the system should provide an "emergency exit" to quickly leave an unwanted state.

4. Consistency and standards: The system should maintain consistency in its design, adhering to platform conventions and using terminology consistently throughout the interface.

5. Error prevention: The system should be designed to prevent errors from occurring, using techniques such as intelligent defaults and user confirmation for critical actions.

6. Recognition rather than recall: The system should minimize the user's memory load by making objects, actions, and options visible and easily accessible.

7. Flexibility and efficiency of use: The system should cater to both inexperienced and experienced users, allowing them to tailor frequent actions for efficiency.

8. Aesthetic and minimalist design: The interface should be visually appealing and uncluttered, with irrelevant information removed to increase the visibility of essential content.

9. Help users recognize, diagnose, and recover from errors: Error messages should be expressed in plain language, precisely indicating the problem and suggesting a solution.

10. Help and documentation: The system should provide easily accessible help and documentation, offering concise and task-focused guidance.

Nielsen's Design Heuristics have been applied to various digital platforms, including websites, mobile applications, and software products.

3.5.3 Domain Expert Validation through Interviews

A prerequisite for the success of a citizen engagement project is that the information presented to the citizens is correct and as unbiased as possible. If this is not the case, then the wanted effects of transparency, and increased citizen leverage is lost. It is therefore desirable to ensure validity and create traceability for the information presented to the citizens. To achieve this the application underwent scrutiny from domain experts.

Domain expert validation is a method used to ensure the validity of information presented in a study or project by consulting experts in the given domain [21]. This method involves interviewing or collaborating with individuals who possess extensive knowledge and experience in a specific subject area to provide valuable insights, identify potential errors, and suggest improvements [45]. Domain expert validation is particularly useful when dealing with complex or specialized topics, as the experts' input can help enhance the credibility, accuracy, and comprehensiveness of the information presented [47].

Involving domain experts in the validation process can be done through various approaches, such as structured interviews, focus groups, or participatory design sessions [44]. The process of information validation and creating information traceability was done as as interviews, both individual and as a group. These interviews were conducted and repeated at different stages of the application design phase, and each meeting had slightly different goals.

The first meeting was conducted for the application designer and domain experts to gain understanding of each others aims with the collaboration, and to explore the different ways in which knowledge and technology could be combined to create an interactive and interesting experience for the end-user. This interview had the effect of a workshop, and had a direct effect on the requirement elicitation. Source material and previous papers were exchanged to gain traceability of statements and information to be presented in the application.

Multiple such meetings were conducted with different goals. The group interviews were lead by a list of keywords, and non-leading questions to allow the experts to give as accurate and correct feedback as possible.

3.5.4 Requirements Elicitation

A helpful method in sorting the collected needs of an application is to translate needs and wishes into requirements. Functional requirements and non-functional requirements are two distinct categories of system requirements that help define and shape the design and development of a software application or product [49].

> *Requirements engineering is the process of eliciting individual stakeholder requirements and needs and developing them into detailed, agreed requirements documented and specified in such a way that they can serve as the basis for all other system development activities.[40]*

Functional requirements describe the specific features, functionalities, and operations that a system is expected to perform in order to fulfill its intended purpose [53]. These requirements are typically expressed in terms of inputs, processes, and outputs, and are derived from the users' needs, and in this case requirements posed by the citizen engagement process.

Non-functional requirements, on the other hand, refer to the characteristics, qualities, or attributes of a system that contribute to its overall performance, usability, reliability, and maintainability [16]. Non-functional requirements are often related to the user experience, system performance, and other quality factors required for high user satisfaction. Examples of non-functional requirements include response time/responsiveness, and accessibility [53].

Both functional and non-functional requirements play a critical role in software development, as they help guide the design, implementation, and evaluation of a system [49]. Identifying and documenting these requirements is a vital part of the requirements engineering process, which aims to ensure that the resulting system meets the needs and expectations of its users and stakeholders [40].

3.6 Wireframe

Wireframes are conceptual visual representation of the planned application. These can be especially helpful in a user-centered design process, as it enables users to be involved in the evaluation at an earlier stage before any code has been written. The scope of a wireframe varies between project and can be created both on physical paper, or using digital tools.

In this thesis, the online digital tool Figma was used to create a non-functional prototype. Figma allows for creation of wireframes with functional buttons and navigation. This gives the user a better understanding of the application flow during testing.

In this development process the wireframe was created to evaluate these aspects:

- **Concept Evaluation -** Concept evaluation aims to capture how the users feel about the application and application purpose. This can also include an evaluation of how the application purpose is communicated to the user.
- **User Interface Placement -** This evaluation aims to identify issues with placement of elements on the page. This can be buttons that are hard to identify or understand, or content that is contextually confusing.
- **User Experience Planning -** An efficient user interface guides the user and outlines how the application is intended to be used. Wireframes can test whether the proposed interface leads to the intended flow and user experience.

The process of creating a wireframe is usually after or in the late stages of the requirement elicitation process, but can also guide the requirements planning. Creation of the wireframe can guide abstract ideas or concepts, and guide a hollistic application plan. This was especially helpful in the creation of this application, as the application design have to draw in and engage the user, and prioritize the most interesting features, while still communicating the available information.

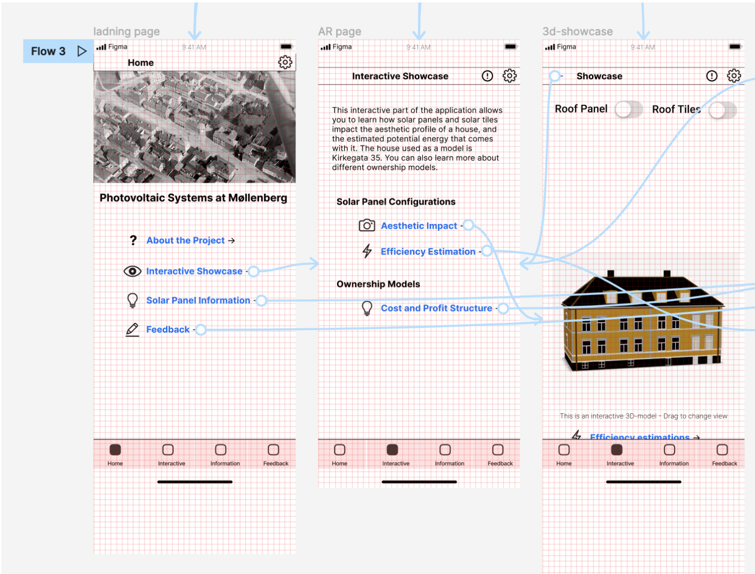

Figure 3.2: Image showcasing an interactive prototype in Figma

3.7 Technology Review

A technology review is a process of identifying existing technologies and frameworks. This process is helpful when determining requirements for application development. The technology review ensures that ideas, requirements, and plans are possible both technically and practically implementable within a given time frame.

In this project a technology review was performed to explore and identify potential frameworks for developing cross-platform applications which could meet the holistic application requirements. The review was not only limited to the framework itself, but also included the library ecosystem. This was done to understand the intended development workflow, and potential for feature expansion.

To identify potential frameworks and technologies, a technology search was performed.

This technology search included both official documentation of identified frameworks, as well as exploring supporter libraries for 3D model showcase and creating a sample application to test the workflow. Additionally the search looked at how many users a given framework had, feature perceived feature completeness of the 3D model libraries, example code, and example projects. Where applicable these example projects were locally compiled and briefly altered to get an idea of the development cycle and workflow. These steps gave an overview of how the technology would be to work with and how realistic it would be to complete an application within the time frame of the thesis. The result of this review will be presented in 4.

Chapter 4

Development and Technical Solution

This section will present the results and relevant conclusions made during the various method steps.

4.1 User Persona

The following section will present the user personas generated of the citizens of Møllenberg. All the names were generated using the online tool https://behindthename.com. These personas are used when developing requirements and when identifying suitable candidates for evaluations.

4.1.1 Persona 1

Sylvester Darden is a student who has been living at Møllenberg for 5 years. Sylvester owns their apartment. Sylvester moved to Møllenberg due to its central location relative to the city center and relative proximity to their campus, but have also grown fond of the aesthetic profile of the area. Sylvester is environmental conscious and dislikes the high electricity consumption of his home due to poor insulation. As a student, Sylvester is highly concerned with the electricity price. Sylvester have never participated in local hearings or projects related to area development.

Tech

- Computer Games
- Programming

Hobbies and interests

- Paddle
- Skiing

Concerns

- Environmental issues
- Aesthetic heritage
- Price and Economic Sustainability

Who influences Sylvester?

- Friends
- Environmental NGOs

4.1.2 Persona 2

Silvia Lilach has been living at Møllenberg for the last 20 years. Silvia have lived at Møllenberg their whole life, and own multiple houses in the area. As a house-owner Silvia is concerned with the high maintenance cost of the old homes and have a vested interest in local renovation. They do not like the strict heritage regulations in the area, but recognises the economic value heritage homes bring.

Tech

- Social Media
- Mobile Games

Hobbies and interests

- Hiking
- Interior design

Concerns

- Longevity
- Economy

Influences

- Friends
- Tenants

4.1.3 Persona 3

Olav Herleif is an older citizen who has been living at Møllenberg for 50 years. They are fond of the area and are very engaged in the development and always participates in local hearings about area development. They are less skilled with modern technology, and may need a simplified experience.

Tech

- Social Media (Facebook only)

Hobbies and interests

- Board Games
- Movies

Concerns

- Aesthetics

Influences

- Friends

4.1.4 Persona Usage

The defined user personas were used when recruiting users for the first two evaluation iterations. This was done to ensure that the feedback and evaluation data was generated from a diverse set of citizens with different civic participation experience, concerns and technical prowess.

4.2 Requirements

This section will present the resulting functional and non-functional requirements elicited through the aforementioned methods. Each requirement has a unique ID and description.

4.2.1 Functional Requirements

Functional Requirement	
ID	**Requirement**
FR1	The application should provide all information and features in both English and Norwegian
FR2	The application should provide information about the thesis project
FR3	The application should provide information about PV technology
FR4	The application should provide information about the sustainability of PV technology
FR5	The application should provide information about the issues related to PV technology on heritage buildings
FR6	The application should provide information about energy storage solutions
FR7	The application should provide information about economic models
FR8	The application should provide sources and traceability of the information presented
FR9	The application should provide links to external resources
FR10	The external resources should be split into English and Norwegian resources
FR11	The application should provide an interactive showcase of how solar panels and solar tiles change the aesthetic profile of a building
FR12	In the interactive showcase the application should provide at least 2 tiles
FR13	In the interactive showcase the application should provide at least 2 panels
FR14	The application should provide an interactive estimation of how much energy can be produced with different solar configurations
FR15	The application should allow the user to select which sky-directions to estimate and showcase estimated efficiency
FR16	The application should allow the user to compare the estimated efficiency of two different products side by side
FR17	The application should interactively showcase how the estimated electricity generation is spread out over the months of the year
FR18	The application should showcase a radiation map of the focus building
FR19	The application should showcase a radiation map of the focus building and proximity area (about 200m)
FR20	The radiation map should be in the form of a 3D model

Table 4.1: Table of Functional Requirements

4.2.2 Non-functional Requirements

Non-Functional Requirement	
ID	**Requirement**
NR1	The application should be available for both iOS and Android
NR2	The application should be responsive
NR3	The application should not require a lot of technical knowhow
NR4	The application should be easy to navigate
NR5	The application should respect the user's privacy

Table 4.2: Table of Non-Functional Requirements

4.3 Technology Review - Flutter and React Native

React Native and Flutter are two leading frameworks for cross-platform mobile application development. This paper aims to provide a comprehensive comparison between these two frameworks in terms of design, language, development workflow, and 3D modelling support. The goal is to enable developers and researchers to make informed decisions when choosing a framework for their projects.

Cross-platform mobile application development enables developers to create applications that work on both Android and iOS devices with a single code-base. React Native, developed by Meta, and Flutter, supported by Google, are two of the most widely-used frameworks for this purpose. This section compares the key differences between these frameworks and their suitability for this project.

4.3.1 Design and Language

React Native follows the design principles of ReactJS and supports both JavaScript and TypeScript languages. It also enables developers to write platform specific code. These are known as native modules.

Flutter, on the other hand, uses Dart, a type-safe language created specifically for cross-platform development. Dart applications support native applications on Android, iOS, web, Windows, macOS, and Linux. Flutter also allows for platform specific code, for Android these modules are written in either Java or Kotlin, while iOS modules are written in Swift or Objective-C.

4.3.2 Development Workflow

Both React Native and Flutter support modern development workflows with features like hot reload. React Native recommends the use of Expo to manage development, dependencies, building, and shipping of applications. Flutter handles these aspects without an additional framework, making it easier to set up and reducing potential errors.

During testing the Expo-application had stability and debug-issues, and was generally unpleasant to work with. Dependency issues were also encountered early which were difficult to troubleshoot and fix.

4.3.3 Documentation and Ecosystem

React Native is built upon Node, and it benefits from a vast ecosystem of packages available on the Node Package Manager (NPM). These packages often target web development, and many can also be used in React Native applications. This extensive library ecosystem accelerates development and simplifies the process of adding new features.

However, not all web-focused packages are fully supported or functional in mobile applications, which can lead to compatibility issues. Additionally, the React Native ecosystem can inherit dependency issues often experienced in web development. These problems can also manifest in different ways depending on the platform, because iOS applications requires the usage of Safari's WebKit browser engine. Android on the other hand does not have such constraints, but defaults to the Chromium engine. These engines have different feature sets and API support

Although Flutter is a relatively younger framework compared to Node, its ecosystem has grown rapidly. The Dart package manager, Pub, hosts a wide range of packages designed specifically for Flutter development. These packages are more likely to be compatible since they are built explicitly for the framework. Additionally null-safety packages and code is encouraged to be developed as null-safe by the dart-compiler, leading to a development experience with few surprise crashes. According to Google more than 1,000 new mobile apps using Flutter are published to the Apple and Google Play stores every day. And the Flutter package ecosystem comprises of over 25,000 packages[48]. During the exploration phase packages required for filling all the functional requirements were found for Flutter.

4.3.4 3D Modelling Support

React Native faces challenges in 3D modelling, as the required libraries depend on web engines. Due to platform constraints, some popular 3D libraries, such as threeJS, are not supported on both Android and iOS. Flutter, however, offers native support for Google's ModelViewer, which is compatible with both iOS, Android, and Chromium, making it a more desirable choice for 3D-intensive applications.

4.3.5 Discussion

Based on the analysis, it is evident that both React Native and Flutter have their strengths and weaknesses. React Native's flexible design and support for JavaScript and TypeScript can be advantageous for developers familiar with these languages. However, its challenges related to 3D modelling is a major drawback for the vision of this project.

Flutter's ease of setup, reduced error potential, and native support for 3D modelling make it an attractive option for various projects, especially those involving 3D graphics. Dart's type-safe nature and cross-platform capabilities further strengthen Flutter's appeal.

During the technology review Flutter stood out as the most appealing framework and was therefore chosen for the application.

4.4 Material Design 3 in Flutter

Material design is a set of open source components and design guide developed by Google, and is available for Flutter. During the technology review this component library was often referenced in beginner-documentation and tutorials. These components respect system accessibility features and settings. Material design 3 allows for theme creation using a color seed, this makes it so that developers don't have to spend much time designing and implementing components interface and can focus more on the user experience.

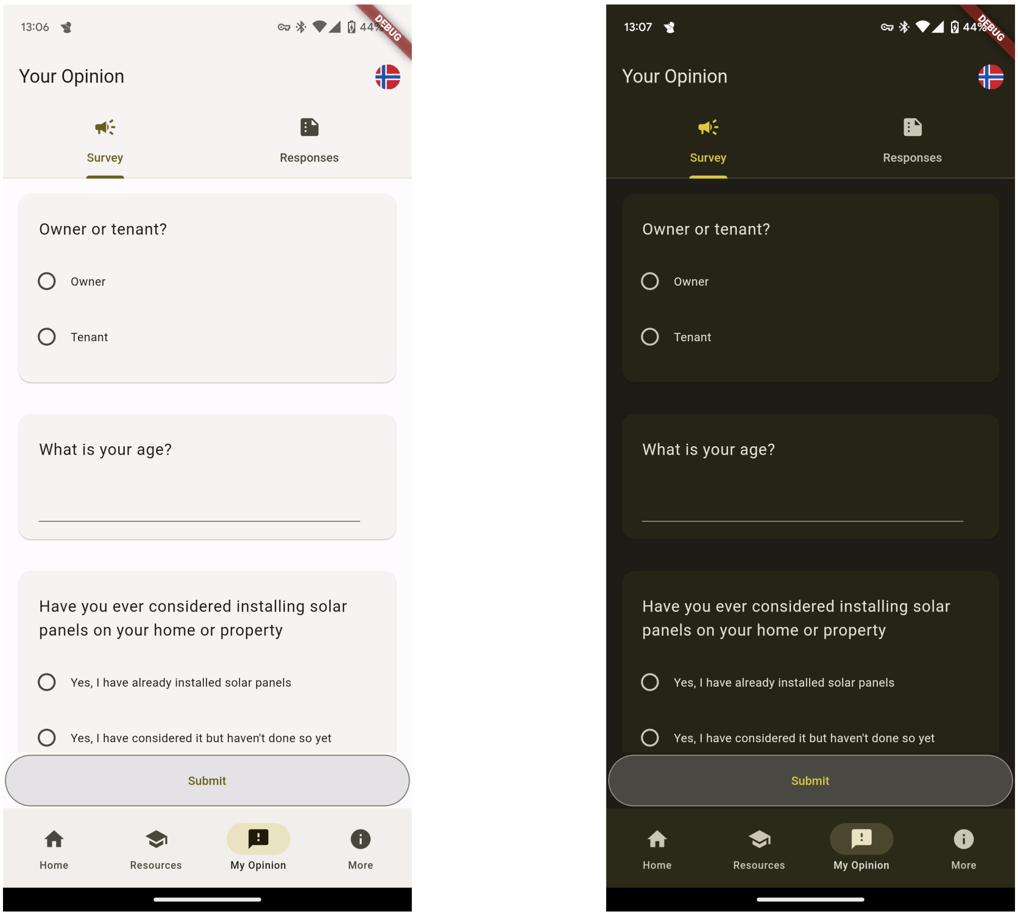

Figure 4.1: Example of how material design 3 respects system light and dark mode

Material Design principles align with many well-known usability heuristics, including a clear visual hierarchy, consistency, and feedback to user actions. For example, the Material Design specification suggests using system components and layouts that are familiar to the user. Flutter also supports text scaling for Material Design apps, which allows text to be automatically resized to respect the system setting, making it more accessible for users who prefer larger text.

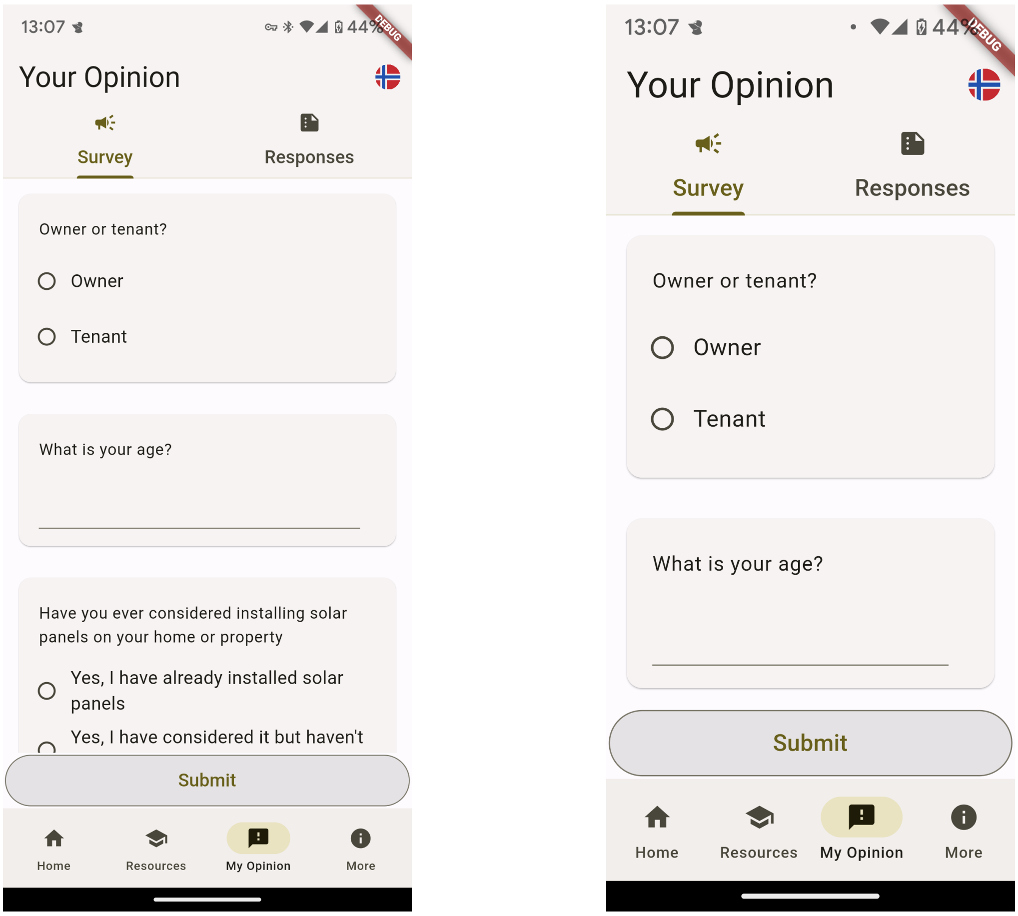

Figure 4.2: Example of how material respects accessibility features such as increased font and screen size

Material Design has a clearly defined specification for creation of an accessible application[4]. This design guide was used in tandem with Nielsen's usability heuristics.

4.5 Application Architecture

The architecture for this application was made as a monolith. In other words no API-calls were necessary to fetch images, models, or text, as everything were bundled as part of the binary. This choice was made to reduce the overall workload, as a web-API would require development of a backend-server as well as server configuration for hosting. This choice is was not without drawbacks, as bundling of 3D-models lead to a relatively large application file size (210MB).

If further work is done on the application, creation of an API should be a consideration for future requirements to lower the storage requirements.

Code-wise the application consists of 3 main widgets:

- **Home** - Contains the home-page with links to different features of the application.

- **Interactive -** Contains both static and interactive information. The information itself is broken into multiple widgets:
  - **Estimations** (interactive)
  - **Regulations**
  - **SolarPotential**
  - **PageEnergyStorage**
  - **RegulationsPage**
  - **PageSustainability**
  - **ExternalPage**
  - **EconomicModels**
  - **SolarTechnology**
  - **SourcesPage**
- **Feedback**

Additionally the navigation-bar and headers were seperated into reusable components.

Link to the application code can be found in the appendix.

Chapter 5

First Iteration: Concept Evaluation

This section will present the first iteration of the application. The motivation and key concerns will be presented following the adapted evaluation model and interview guide. Lastly the results will be analyzed and lead to changes for second iteration.

5.1 Prototype

At this point of development an interactive prototype had been developed. This was created using Figma. With the prototype every button press had an action.

Although the information sections all lead to a page with intended information, the content was not completed. The interactive sections worked in such a way that the configuration buttons all gave a response, but the intended 3D features were not possible to implement in Figma.

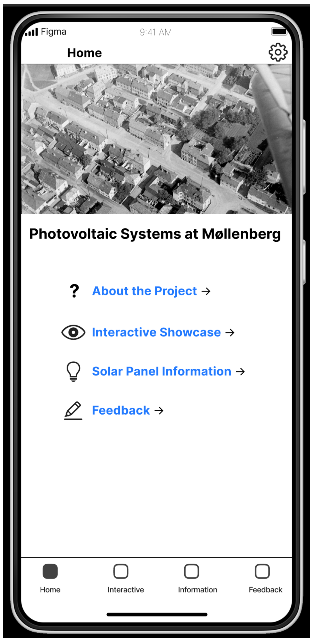

Figure 5.1: Home page

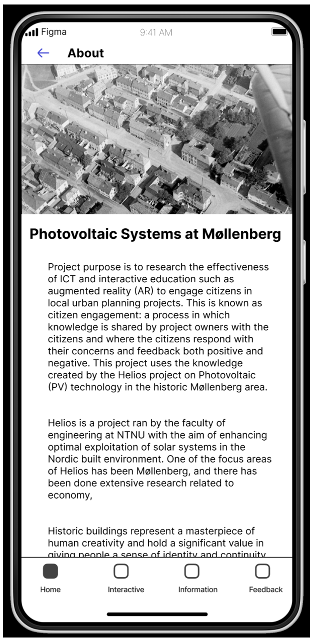

Figure 5.2: About page

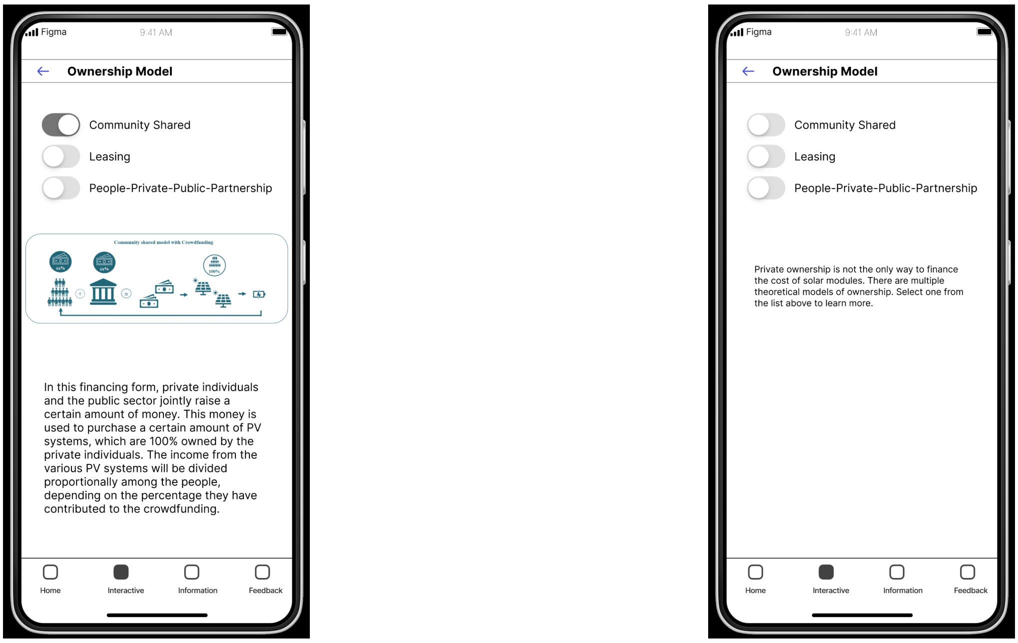

Figure 5.3: Information ownership models

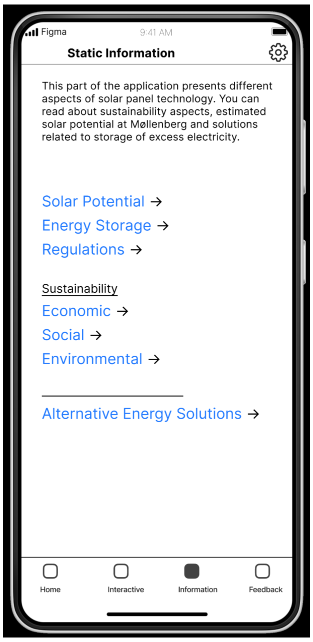

Figure 5.4: Static information table of contents

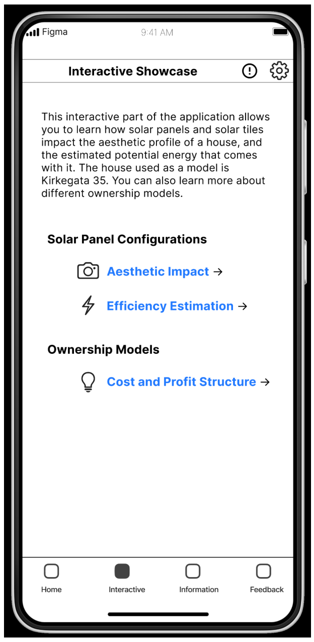

Figure 5.5: Interactive showcase table of contents

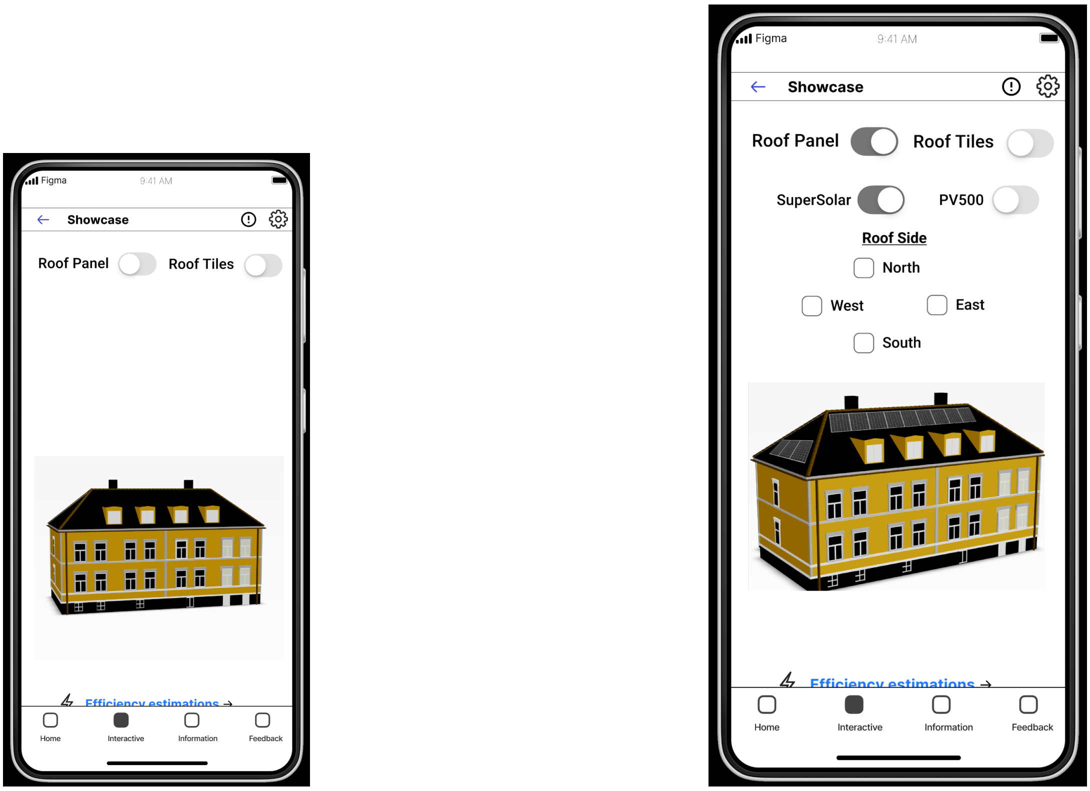

Figure 5.6: Aesthetic showcase

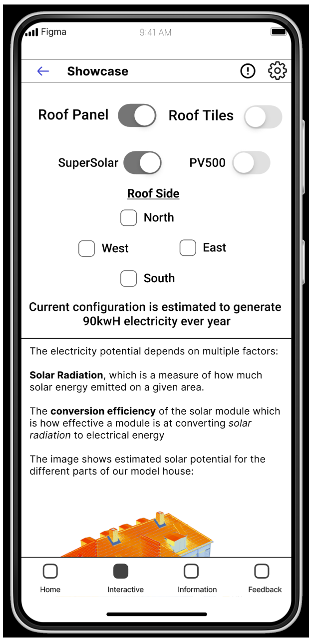

Figure 5.7: Solar Efficiency Showcase

5.2 Evaluation Method

For this iteration of the evaluation, the style of evaluation was chosen to be interview. We wanted to gather individuals who fit the user personas defined earlier in the design phase, as this would broaden the citizen engagement experiences and technical prowess. Task-based testing was chosen, to identify the usage pattern of the users. This would also guide the users to visit all the indented features of the application and indirectly showcase how effective the navigation design of the application worked. Since this evaluation was to happen in an interview setting, think-aloud protocol was also chosen as a method.

5.2.1 Data Collection

The usage sequence with the participants were screen recorded. All thoughts and feedback mentioned by the participants during the test itself was written down. Finally questions and answers were given verbally.

5.3 Evaluation Model

The evaluation for this step was found using the defined evaluation framework. Since the system was a prototype, there was little point in spending a lot of time evaluating usage metrics such as perceived ease of use.

System Usability	
QS ID	**Statement**
QS1	This application seems valuable
QS2	I found the application to be unnecessarily complex
QS3	The application was easy to navigate
QS4	I think I would need support of a technical person to be able to use this application
QS5	I found the various functions of this application to be well integrated
QS6	The various functions worked well together to create a coherent experience
QS7	I think most people would learn to use this application quickly
QS8	The application was cumbersome/annoying to use
QS9	I felt confident using the application
QS10	I needed to learn a lot in order to use the application effectively

Table 5.1: Evaluation: Adapted System Usability Scale

A note is that in this adaptation of SUS, QS5 have been inverted from a negative statement to positive, which means that a high number is desirable. This makes it so that during calculation of the SUS-score item number 5 has to be treated as an even item.

To satisfy the citizen-engagement aspects of the evaluation framework, a set of interview questions were made. These questions were designed to get an idea of the current living arrangement and relationship with Møllenberg of the interview subject.

5.4 User Interview Guide

To conduct efficient and consistent interviews, an interview guide was created.

Before the test

Inform the user that:

- This is a non-functional prototype, some of the pages may be blank, and lines may not be symmetrical
- Generic inputs such as text and numbers are currently placeholder-design and will use standard form in the product
- During the test they are encouraged to say their thoughts out loud

Interview Questions
How long have you lived at Møllenberg?
Do you own/rent your house/apartment?
How is your living arrangement? Collective/Share/Family?
How long is your current contract?
Do you participate in local hearings or area development meetings? Why/Why not?
Do you have any experience with citizen participation programs, or similar civic engagement projects? Do you think digital technology could help getting you engaged?
How do you use your phone? SMS only? Social Media? Games? Work? Learning? etc.

Table 5.2: Questions before the test

During the test

Application tasks
Read the project purpose
Open the interactive learning section
Alter PV configuration and view the changes
Compare the estimated effectiveness of two PV products
Select an economic model
Give your feedback

Table 5.3: Evaluation Tasks

After the test

- How would you summarize this application?
- Would the application be more engaging if you could see estimations and solar panels on your own home?

Ask questions outlined in SUS.

5.5 Interview Result

In total three interviews were conduced, two were with citizens, and one was with an expert on photovoltaic technology. Their closest persona will be presented and a summary of their thoughts, attitudes, general notes on how they completed the tasks given to them, and feedback.

5.5.1 Interview 1 - Citizen

This citizen is closest to Persona 1, and has never participated in any form of local governance or civic participation programs, they are positive to the idea that ICT can support and increase their citizen engagement.

During the test this user had no issues performing the given tasks. The user also noticed noticed and mentioned all the changes in the interactive sections. A stated pain-point was the navigation between aesthetic and energy estimation. The user also disliked the feel of the estimation page, as they have no relation to how much energy 70kWh is.

This user summarized the application as a knowledge building application for solar panels, and stated that it would be more engaging if they could see estimations and solar panels on their own home.

5.5.2 Interview 2 - Citizen

This citizen is closest to Persona 3, and is experienced with civic participation. They are positive that ICT can increase the general civic participation.

This user had a few issues when it came to navigation, especially the path from aesthetic visualization to estimations. They also had some issues identifying the changes and electricity estimations. During the test they expressed confusion as to what the difference is between static and interactive information.

The user summarized the application as an information application on solar panels, and noted that they enjoyed the idea of having an application where one can learn interactively, as well as reading theory. They stated that having estimations on their own house was of lesser importance in terms of engagement.

5.5.3 Interview 3 - Expert

This expert on solar panels had previous experience with local participation projects.

During the evaluation they provided a lot of feedback and ideas:

- There is too much text, and too few diagrams and lacking in dynamic content

- The homepage is very boring and gray
- The term interactive is confusing
- The amount of electricity should be put into perspective, for example what is the yearly energy consumption of the house, or a household at Møllenberg.

The user summarized the application as a knowledge building application, but is lacking in terms of user engagement.

5.5.4 Score

Question	**Subject 1**	**Subject 2**	**Subject 3**
QS1	4	4	5
QS2	2	2	1
QS3	4	4	5
QS4	1	2	1
QS5	3	4	3
QS6	4	5	4
QS7	4	4	5
QS8	2	1	1
QS9	5	4	5
QS10	1	1	1

Table 5.4: SUS-responses Concept Evaluation

The responses yields SUS-scores of:

- Subject 1: 80
- Subject 2: 82
- Subject 3: 92.5

Which gives an average SUS-score of ≈ 84.

5.6 Discussion and Takeaways

During the test a a lot of issues with the design were discovered. The biggest hurdle is the connection between the different features of the application. From observing the users there were issues navigating between aesthetic and interactive showcase. Additionally the separation of interactive and static information seemed to create confusion both in terms of navigation and in terms of understanding the feature set of the application.

Although the SUS-score was relatively high, the sample size is too small to make any definite judgements. All three participants were positive to the concept of the application. The interviews gave valuable feedback on what features of the application worked and what features were lacking. It was evident that the application should have a more cohesive design. The idea behind separating interactive and static information was to make the feature set of the application easier to identify, however it seems from the interviews that this works against its intention. Especially the interactive aesthetic and estimation-pages should be reworked.

Chapter 6

Second Iteration: Application Usability

This section will present the second iteration of the application. The motivation and key concerns will be presented following the adapted evaluation model and interview guide. Lastly the results will be analyzed and lead to changes for second iteration.

6.1 Application State

At this point a working application had been developed using the aforementioned flutter framework. All of the buttons lead to a page where information was presented, this information was not expert validated and therefore not at a state for final evaluation. The application also had interactive features such as aesthetic visualization using 3D-models, efficiency estimations and radiation showcase.

Changes in design was motivated both by feedback gathered during the concept evaluation as well as accessibility heuristic theory and the material design guide. The cog-wheel in the header was changed out for a flag for swapping language. The application was at this stage available in both English and Norwegian. Some pages had the word *_placeholder*, this was used for sections which had not been translated yet.

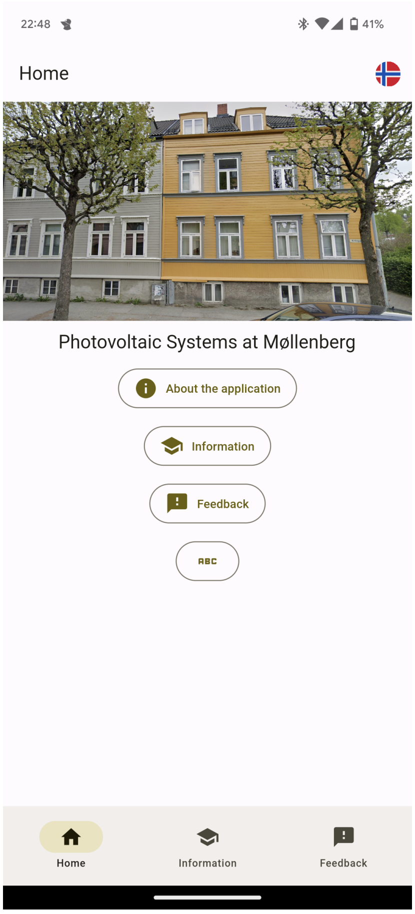

Figure 6.1: Home page - A

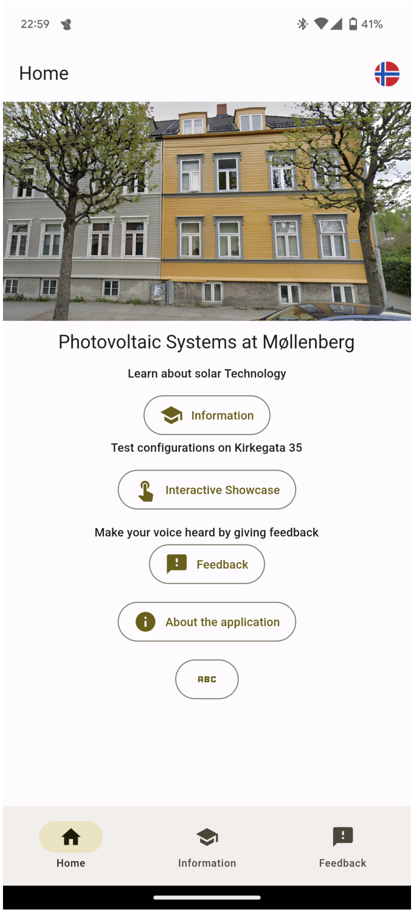

Figure 6.2: Home page - B

The home page now uses buttons found in the material design library, pressing the *abc* button opened an alternative home-page layout. This was used as a part of the evaluation.

The about page now had greater focus on the thesis project and Helios, as opposed to the concept evaluation, where the focus was on Møllenberg. Additionally the about page has a video provided by Helios and concoct info to both Helios and the author of this thesis.

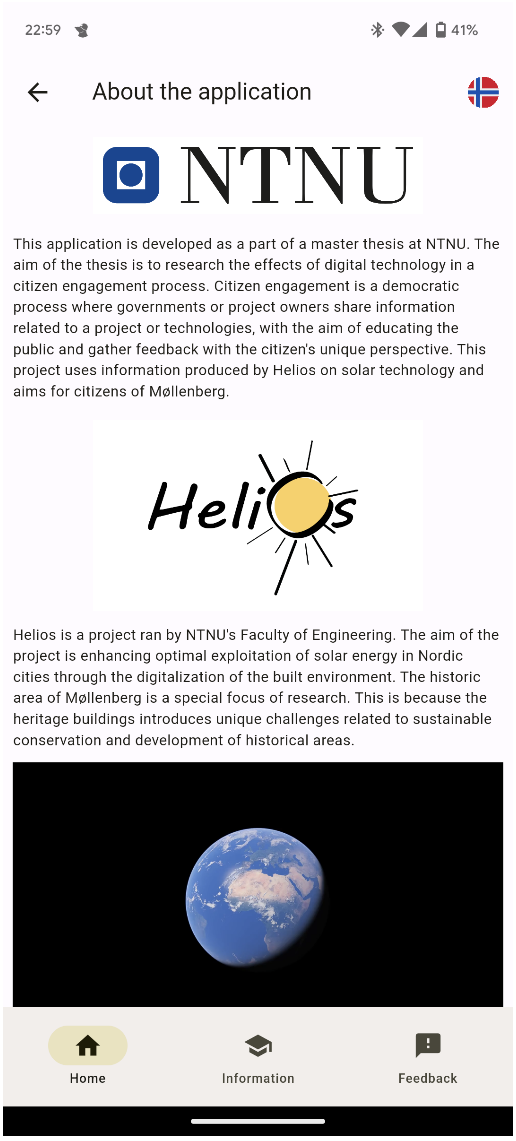

Figure 6.3: About page

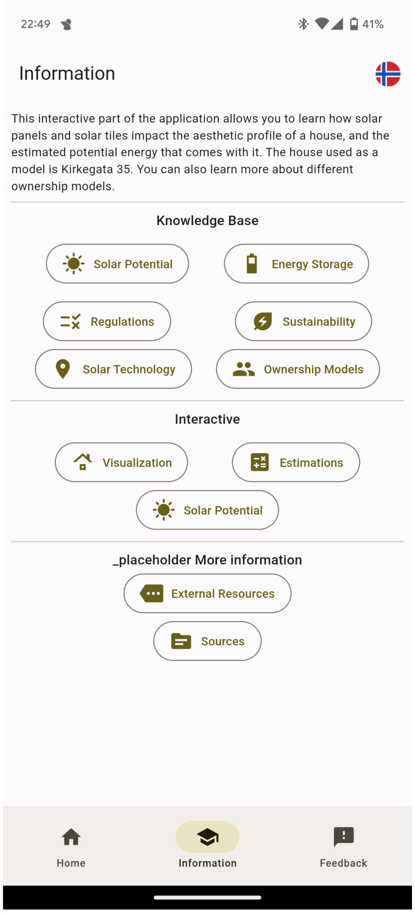

Figure 6.4: Information page - A

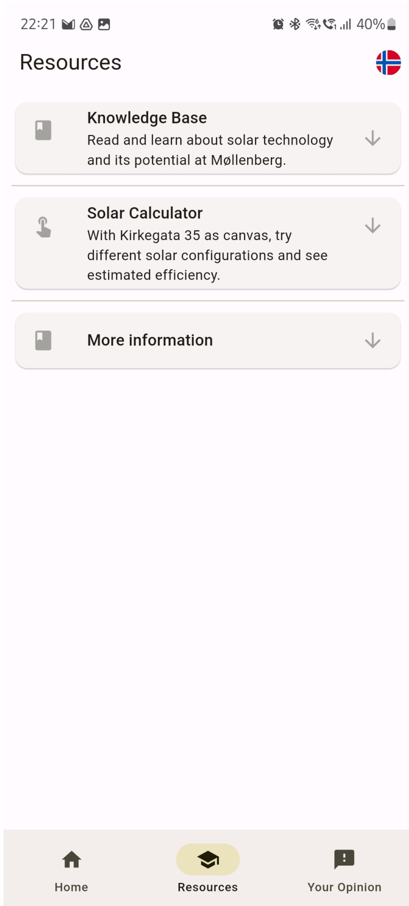

Figure 6.5: Information page - B

The pages static information and interactive information found in the concept were merged to a single information page. This was done because observation and discussion during the concept evaluation found that the users were confused at the difference between the two. With a single information page, the users would hopefully be more encouraged to visit all available information and sections.

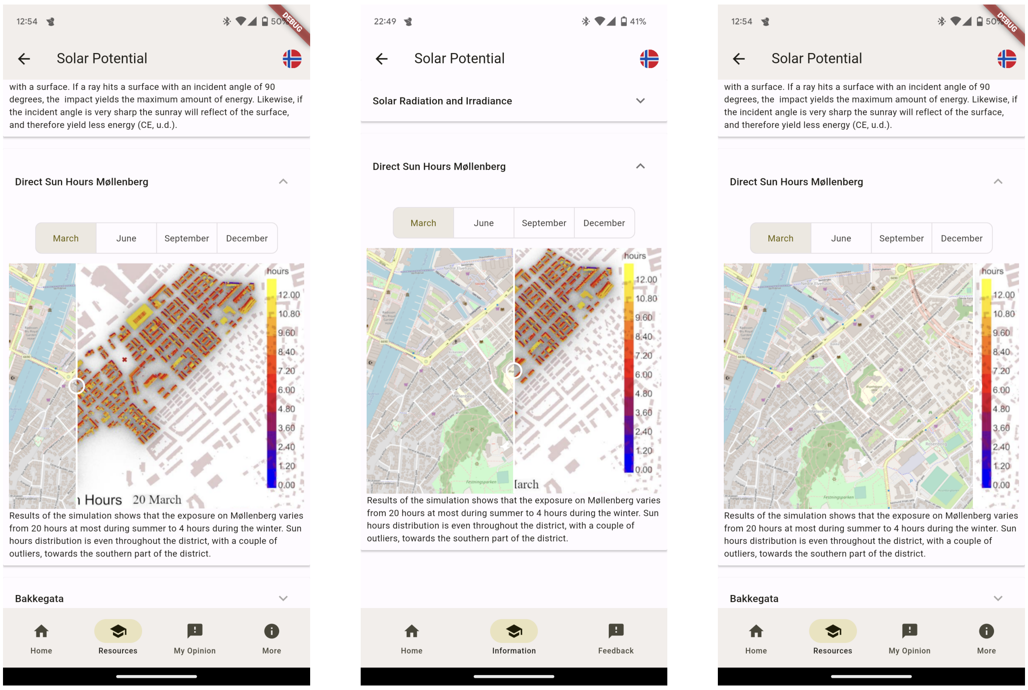

Figure 6.6: Solar Potential with image slider

The Solar Potential page is an example of the knowledge-base pages. The various information is collected into a drop-down-list. By pressing on a header, the user can read more about the topic. In the "Direct Sun Hours Møllenberg"-section a map is overlayed next to an analysis of the sun hours expected at Møllenberg at 4 distinct months. The user can drag the overlay-button to change which image is viewed. By incorporating the map it is easier for the user to contextualize where in Møllenberg the radiation is focused.

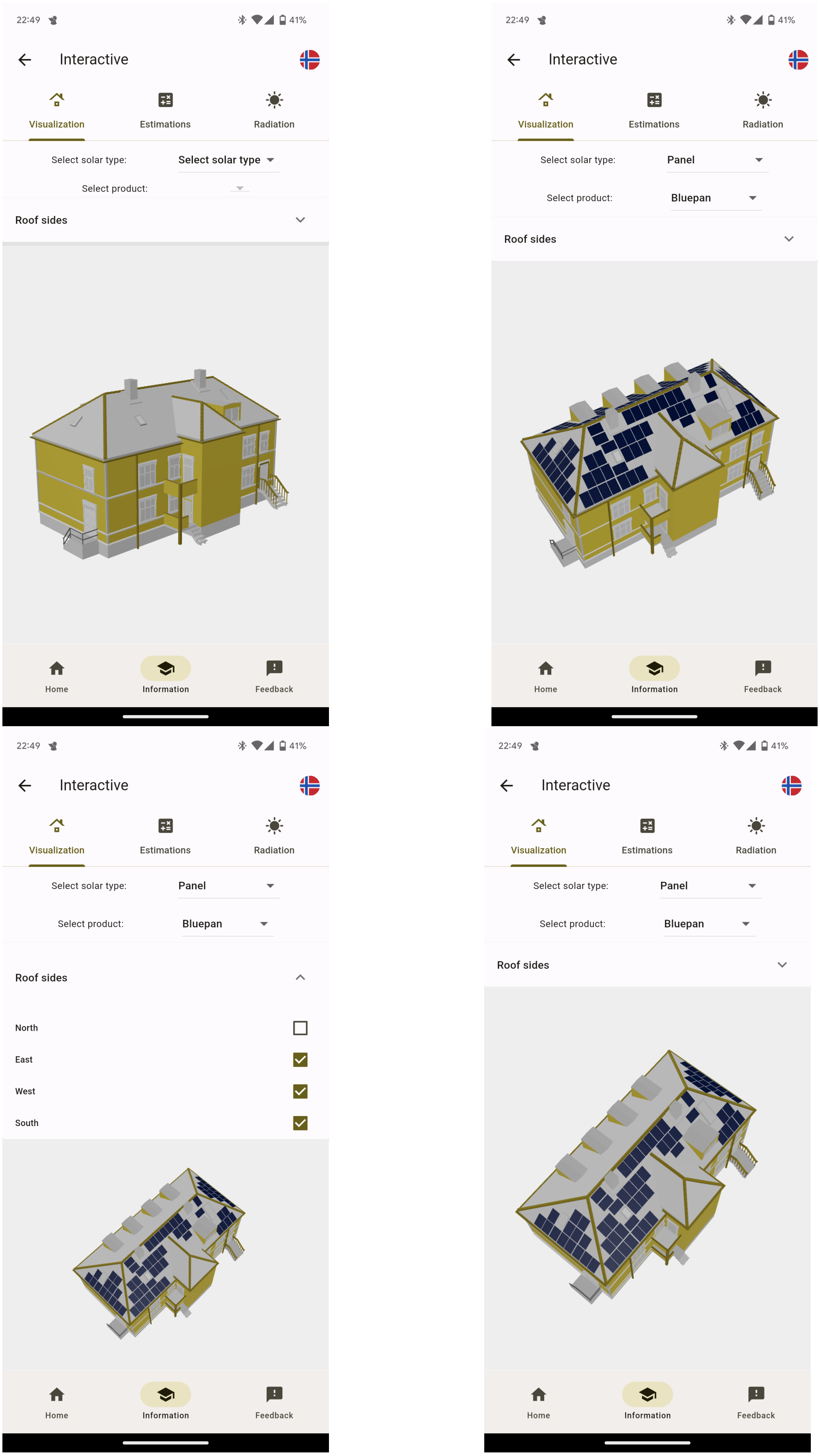

Figure 6.7: Aesthetic visualization

The concept-iteration of the interactive section had several issues. The biggest issue was feature clarity, meaning that the user had issues identifying available features. Utilizing a tab-navigator it is both easier and more intuitive to the user. Furthermore the tab-design allows for intuitive configuration continuity between aesthetic visualization and efficiency estimation. For this evaluation 4 solar-products were finished, two panels and two tiles. All had distinct models.

For the aesthetic visualization, the focus was on allowing the 3D-model to use as much space as possible, the selector for roof sides is therefore hidden behind an ExpansionPanel.

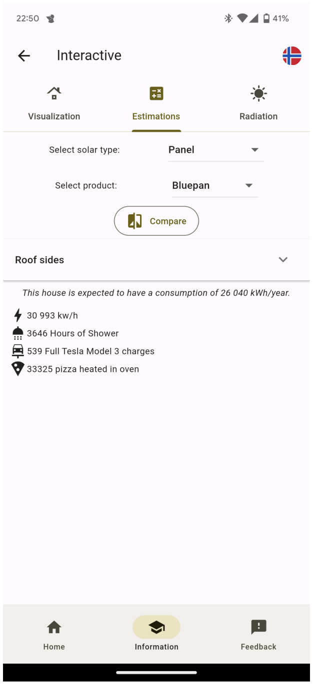

Figure 6.8: Efficiency estimations

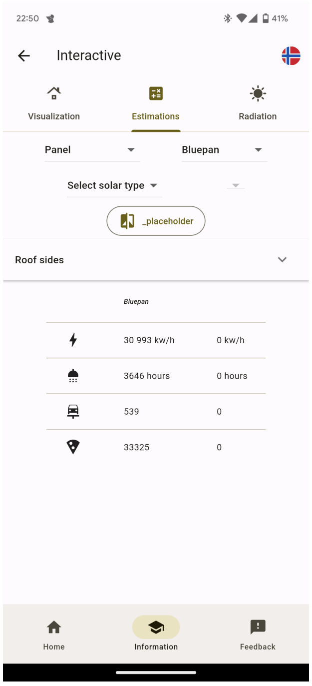

Figure 6.9: Efficiency estimations

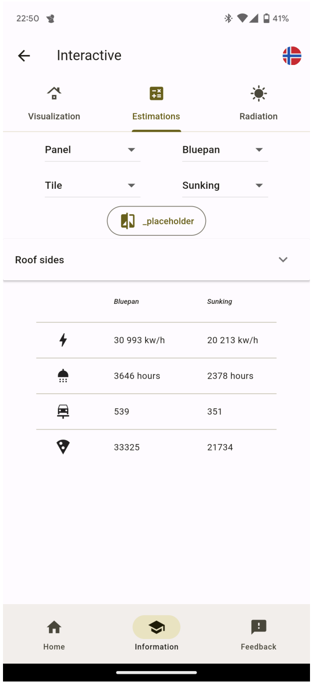

Figure 6.10: Efficiency comparison

In the concept interface, both estimations and radiation was showcase on the same page. Furthermore the prototype only gave the user a number of estimated energy. Without contextualizing what this number implies for a regular consumer it is likely of little use. Some common uses were therefore selected and presented using icons and explanatory text.

Furthermore the application allowed for comparison between two different products. Using the same icons as in the single-showcase, the user got a table with the corresponding numbers side by side.

Figure 6.11: Radiation model

A feature which was not a part of the concept prototype was a 3D-model showcasing the radiation estimation of the focus house. This allows the user to see which side of the house has the best solar energy potential.

6.2 Evaluation Method

In the last test the users were given a descriptive and rigid set of tasks. For this evaluation it would be more interesting to get the usage pattern of a user who has never seen the application or know its features before. For this reason the number of tasks were severely limited. We also wanted to give less contextual information before starting the test, and rather encourage the user to seek out information about the project and its purpose within the app itself.

Just like the last iteration we wanted to incorporate the think-aloud protocol. Once again the usage sequence was filmed.

6.2.1 Data Collection

This evaluation iteration followed the same data collection method as the concept evaluation. The usage sequence with the participants were screen recorded. All thoughts and feedback mentioned by the participants during the test itself was written down. Finally questions and answers were given verbally.

6.3 Evaluation Model

The evaluation for this step was found using the defined evaluation framework. For this test we wanted to focus on the usability of the application, as well as the perceived usefulness of the features developed. We also wanted the users to give critical feedback on the features they liked, what they would change, any particular challenges etc.

With the application being in a functional state it was now possible to also make use of the more concrete models and questions.

TAM was therefore adopted and we used the questions relating to perceived usefulness:

Question ID	**Statement**
QP1	Without the system it is difficult to participate in citizen engagement projects / Has the application made it easier to get engaged?
QP2	The system gives me greater overview of the project and relevant issues
QP3	The system is more effective than traditional citizen engagement means
QP4	The system addresses my needs to provide valuable feedback
QP5	The system addresses my needs to gain access to information and learn in an effective manner.
QP6	The system improves the quality of feedback I can give and my confidence on the topic
QP7	The system makes it easier to participate in citizen engagement projects
QP8	I would not participate in citizen engagement projects without the system

Table 6.1: Perceived Usefulness

To have continuity between the evaluations we use the same SUS-adaptation as in the concept evaluation, with the same modifications to the SUS-score calculation.

6.4 User Interview Guide

To conduct efficient and consistent interviews, an interview guide was created.

Before the test

Inform the user that:

- Information presented is not validated and can vary in terms of correctness
- During the test they are encouraged to say their thoughts out loud

Interview Questions
How long have you lived at Møllenberg?
Do you own/rent your house/apartment?
How is your living arrangement? Collective/Share/Family?
How long is your current contract?
Do you participate in local hearings or area development meetings? Why/Why not?
Do you have any experience with citizen participation programs, or similar civic engagement projects? Do you think digital technology could help getting you engaged?
How do you use your phone? SMS only? Social Media? Games? Work? Learning? etc.

Table 6.2: Questions before the test

During the test

Application tasks
Change the language to English
Explore the application

Table 6.3: Evaluation Tasks

Encourage the user to try as many aspects of the application as they can, but don't lead them anywhere, and don't give any technical assistance with the application itself.

After the test

Present the two possible information and home-pages and ask which one they prefer.

Question ID	Question
QI1	How would you summarize the application?
QI2	How was your overall experience with the application?
QI3	Were there any pain points when using the application?
QI4	If you could change something about the system, what would it be?
QI5	How would the application benefit your overall experience when engaging in local democracy?

Table 6.4: Interview Questions

6.5 Interview Result

In total three interviews were conduced, two were with citizens, and one was with an expert on photovoltaic technology. Their closest persona will be presented and a summary of their thoughts, attitudes, general notes on how they completed navigated and utilized the features of the application, as well as their feedback.

6.5.1 Interview 1 - Citizen

This user was most similar to Persona 1, and has no experience with neither civic participation nor local democratic engagement. They had no issues switching language.

During the test their first action was to visit the page about the application. They stated that they wanted to explore the application in the presented order.

They visited all the sections of both static and interactive information. During the test they tried to zoom in on images, and remarked that not all images had a caption. Furthermore they wanted supplementary images for theoretical information such as solar technology.

Their responses to the questions asked after the test were:

1. This is an information building application on solar panels where you can learn about installation potential and possibilities, as well as relevant regulations and challenges.
2. I liked the application, but I want more images
3. The only pain points were when I wanted to have a closer look at the images
4. I would probably make it so that when a list box is opened, the surrounding list boxes are closed

5. It would make it easier to get engaged and participate since it lowers the barrier to entry and time requirement

When presented with the alternative home-page they preferred option B.

When presented with the alternative knowledge-base page they preferred option A.

6.5.2 Interview 2 - Citizen

This user was closest to Persona 1, and has no experience or knowledge regarding civic participation, citizen engagement nor solar technology. They had no issues switching language.

Their first remark was that the homepage felt useless, since it only served to repeat the elements found in the navigation bar. Other than that they had few remarks on the application itself during the test. They enjoyed the features and especially the interactive 3D-models.

Their responses to the questions asked after the test were:

1. This is an application where citizens can learn about solar potential at Møllenberg and its challenges.
2. I overall enjoyed the application
3. I disliked the home-page.
4. I would remove the home-page.
5. It would make it more likely for me to participate in local development programs, as I can learn a lot from home.

When presented with the alternative home-page they preferred option B.

When presented with the alternative knowledge-base page they preferred option B.

6.5.3 Interview 3 - Expert

This user was most similar to Persona 2, and has no experience with civic participation. They had no issues changing the application language.

During the test it became apparent that they had issues identifying the feature of altering roof installation sides.

As an expert on solar panels this user had a lot of feedback:

- They thought contact information was missing on the "About Page"

- They wanted more images and technical information
- In the interactive-section they wanted specifics on solar products and the possibility of downloading product specification sheets
- They wanted more information about how the energy estimation was calculated, as well as how the energy production changes with the seasons of the year.

Their responses to the questions asked after the test were:

1. The application gives information about solar panels and what potential electricity I can get using different products, on my roof.
2. Overall I liked the application
3. No Pain points
4. I would add more information about the economic implications of solar panel installation, eg. how much can I change and what are the environmental impacts. I would also add facade calculations
5. It would make it easier for me to get engaged

When presented with the alternative home-page they preferred option B.

When presented with the alternative knowledge-base page they preferred option B.

6.5.4 Score

Question	Subject 1	Subject 2	Subject 3
QU1	4	5	4
QU2	2	2	1
QU3	4	4	5
QU4	1	1	1
QU5	5	5	5
QU6	5	5	4
QU7	5	4	5
QU8	1	1	1
QU9	5	5	5
QU10	1	1	3

Table 6.5: SUS-responses Concept Evaluation

The responses yields SUS-scores of:

- Subject 1: 92.5
- Subject 2: 92.5
- Subject 3: 90

Which gives an average SUS-score of ≈ 91.

6.5.5 Usability Result

	Citizen 1	**Citizen 2**
QP1	4	5
QP2	6	6
QP3	7	7
QP4	6	6
QP5	6	6
QP6	6	5
QP7	6	6

6.6 Discussion and Takeaways

Again the sample size of responses is too low to make any definite judgement of the SUS-score, but the responses all indicate that the users had a positive experience with the application. The changes made since the concept evaluation had a positive impact on the usability of the application. It seemed by observation that the testers all understood the connection between the interactive stages of the application.

All users requested more images with the static information. The application could need technical details for the most interested users, and make the information more interesting and easy to consume by adding more images.

Chapter 7

Final Evaluation

This section will present the first iteration of the application. The motivation and key concerns will be presented following the adapted evaluation model and interview guide. Lastly the results will be analyzed and lead to changes for second iteration.

7.1 Application State

At this point the application filled the application requirements necessary for an MVP. The information and interactive calculations were all validated by the experts at Helios. We could therefore distribute the application as well as evaluate the change in knowledge, confidence and attitude change.

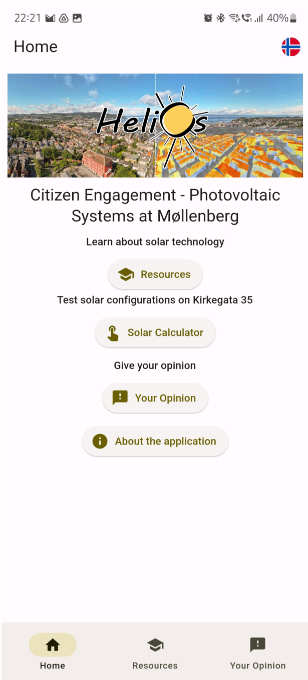

Figure 7.1: Home page

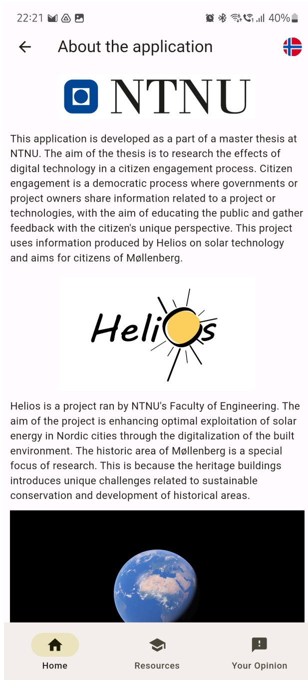

Figure 7.2: About page

On the home page, the header image was changed to be more inviting and descriptive. The outline of buttons also changed according to the evaluation done in iteration 2. A slight change was also to change from Flutters OutlinedButton to ElevatedButton. Terminology was also changed, as information was changed to resources, and *Interactive Showcase* was changed to *Solar Calculator*.

The about page remained unchanged from iteration 2.

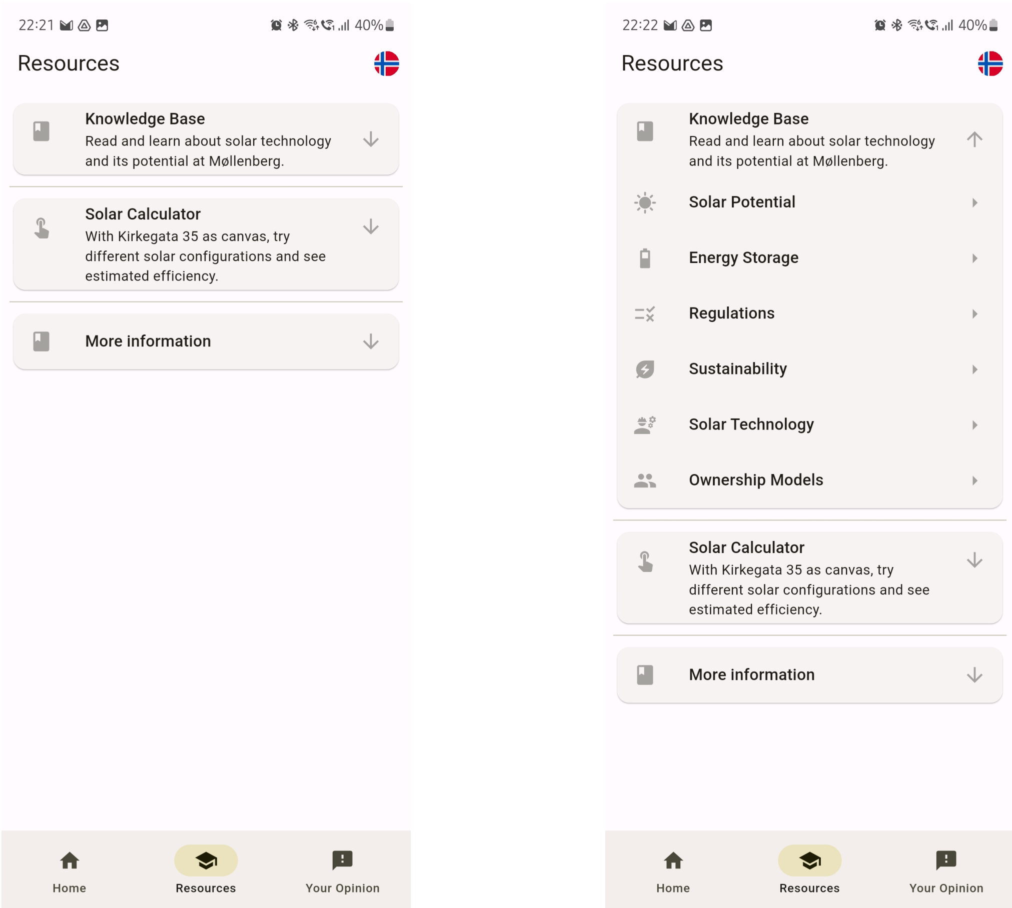

Figure 7.3: Resources page

The *Resources Page*, previously known as *Information*, changed from being a collection of buttons, to three ListTiles. This change was made because the old button-layout was found to be overwhelming during testing, additionally it performed poorly on wider screen sizes.

In terms of functionality little changed with the various static information pages. During the previous test multiple users had issues closing the header button, and therefore a change was made so that pressing anywhere on the header would open or close the section.

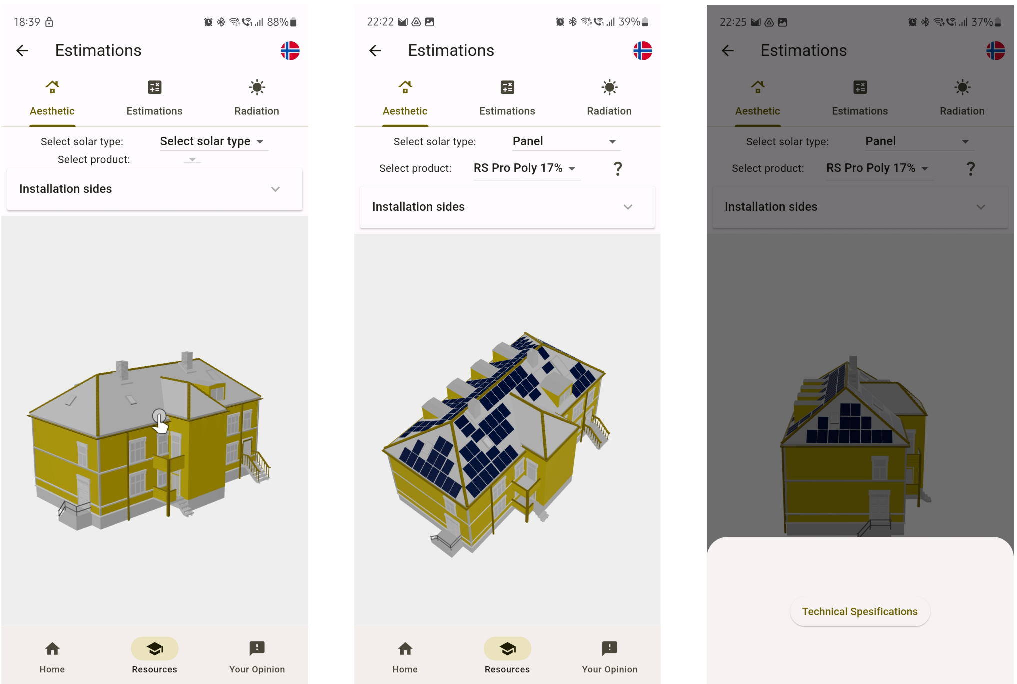

Figure 7.4: Visualization Page

In the visualization page a new button was added for technical information about the product. When pressing this button a modal would open where the user could download the technical specification sheet of the panel showcased. Additionally the drop-down menu and product would also have the solar efficiency appended to their name.

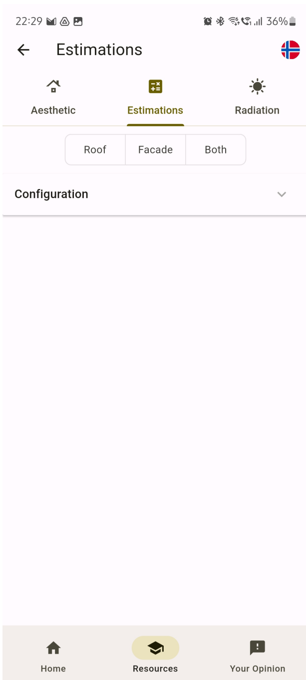

Figure 7.5: Estimation page

For the estimation page a change was made to differentiate the solar potential of roofs and facades. Therefore a new menu was added where the user would select either roof, facade or both. This would change the estimated energy. In order to not make the page too busy, the configuration was hidden under a drop-down menu.

Additionally a slider was added which correlated to the electricity price. This shows what the cost of the estimated electricity produced would be on the electricity market. This feature was made to further put the electricity estimations into perspective.

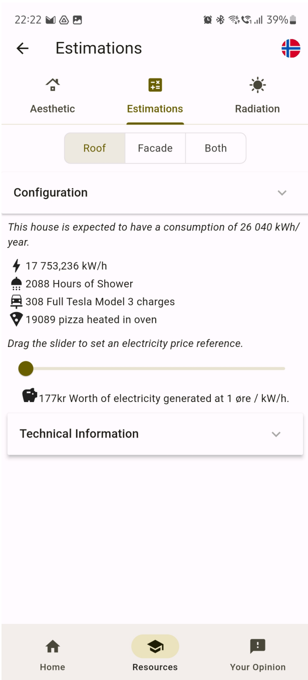

Figure 7.6: Roof estimation

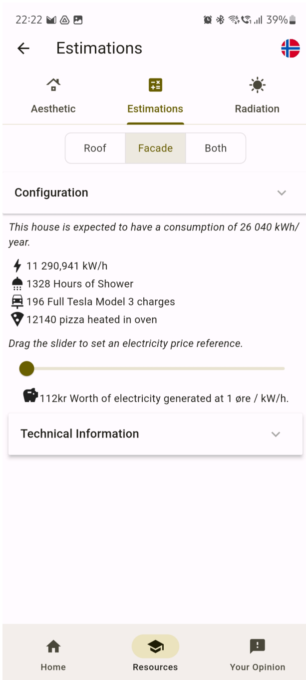

Figure 7.7: Facade estimation

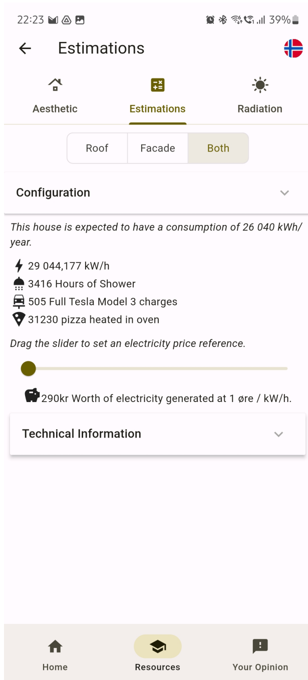

Figure 7.8: Estimation both

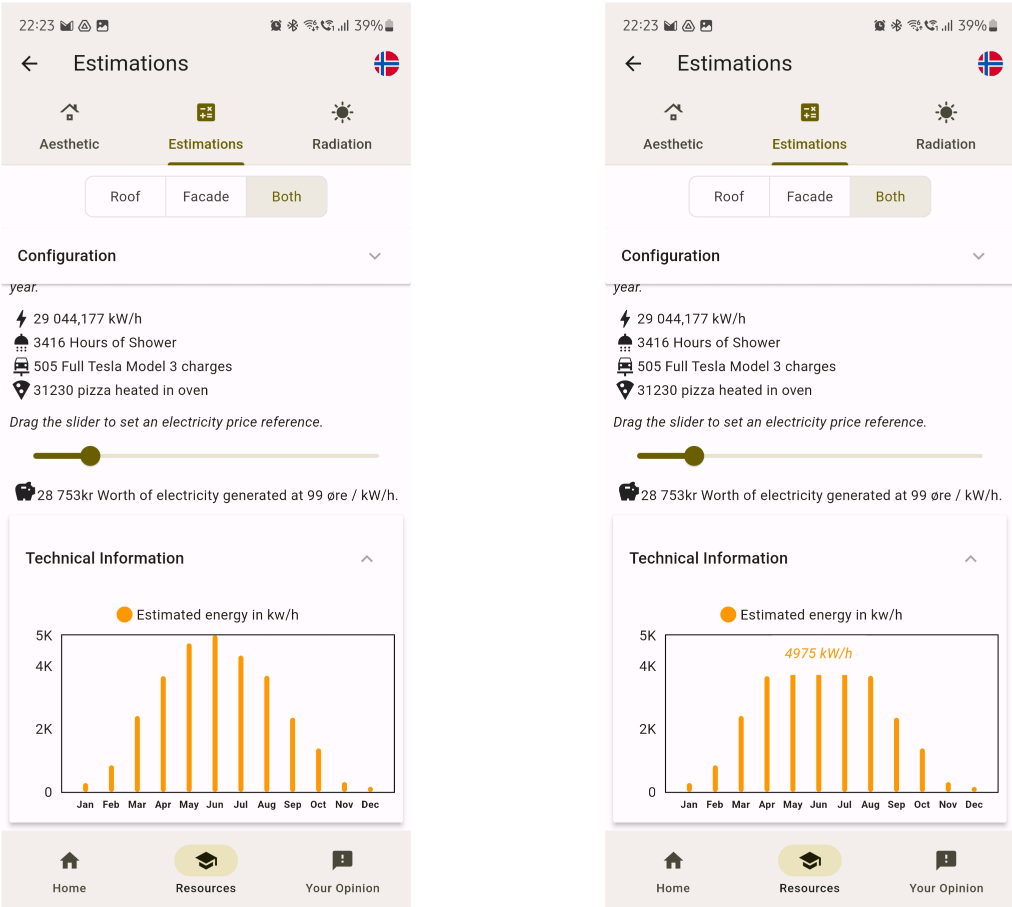

Figure 7.9: Estimations Page technical information

A section with a graph showcasing the electricity distribution over the months of the year was also added. When tapping one of the bars a hover text with the accurate number is displayed.

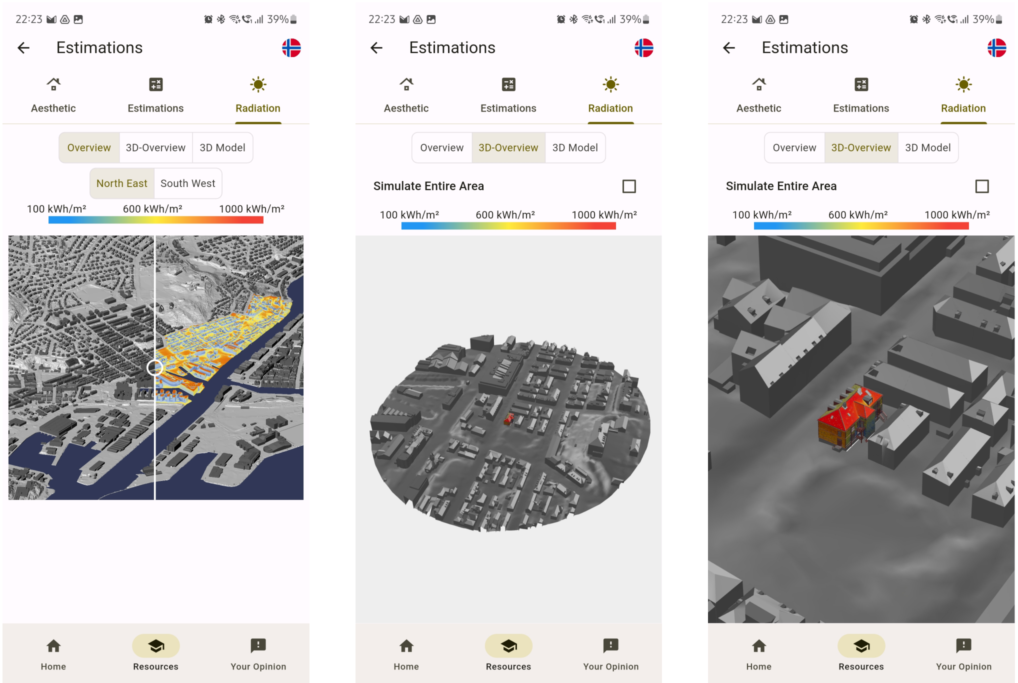

Figure 7.10: Radiation showcase, overview and focus area.

The radiation page had a large feature expansion. Thanks to the experts at Helios, the simulations were re-made to create an interactive 3D-radiation-model. This model is 200m proximity radius of the focus house, Kirkegata 35. The user can see the radiation model with only the focus house radiated, or with the entire area radiated.

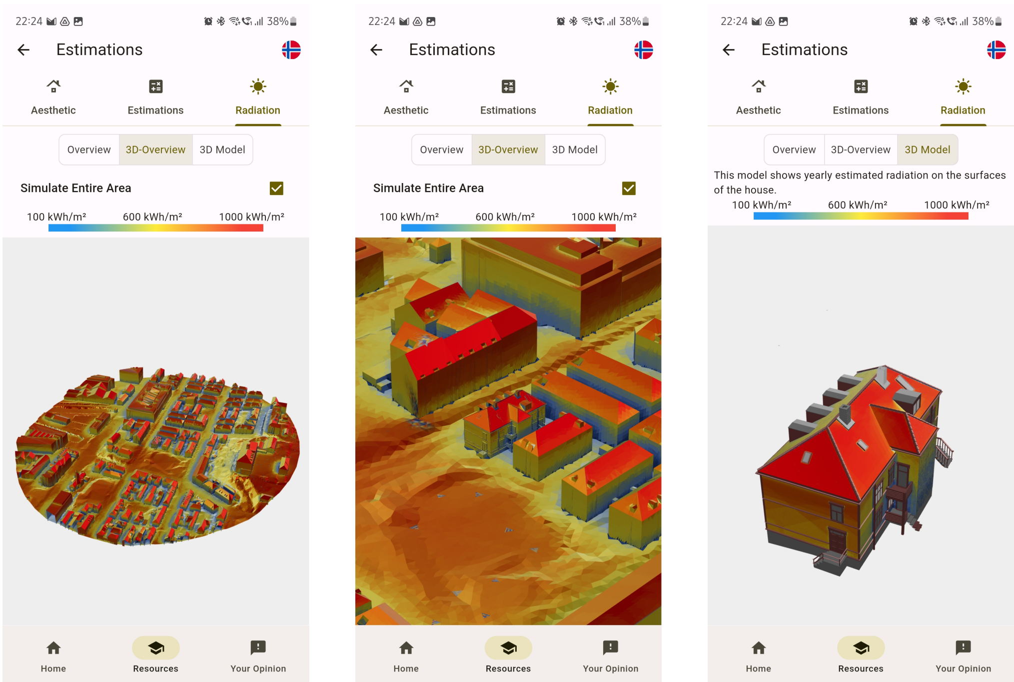

Figure 7.11: Radiation showcase, simulation of focus area and focus house

Finally the radiation model of the single house was also improved to be more true to reality.

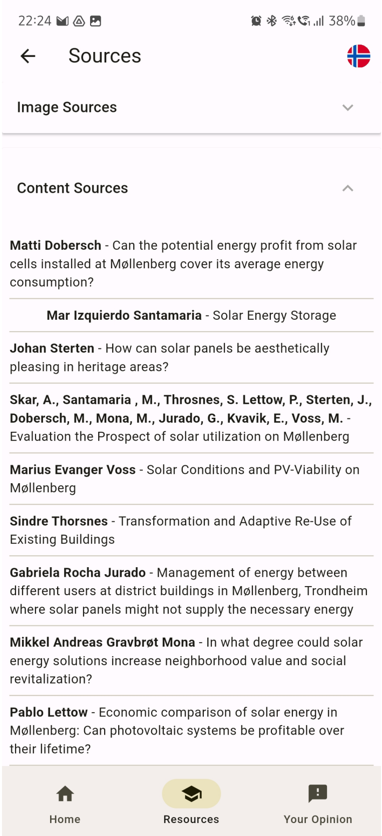

Figure 7.12: Application sources page

7.2 Evaluation Method

The application was easily distributable for Android, users who wanted to participate in the evaluation could either install the application on their phone, or test the application in an interview setting. Both groups would end their usage with the same evaluation survey.

In total 4 interviews were conduced, and an additional 6 users tested the application on their personal phone outside of an interview setting.

Additionally in the interview-setting, the users were asked to state their thoughts out-loud, but that they would not receive technical support for the application itself, as to make the environment for both user-groups as equal as possible. These 6 users were given the following context and instructions:

> The topic of the application is increasing citizen engagement using ICT, and aims to increase your knowledge and confidence in the topic of photovoltaic (solar panel) technology. If you want to try it out and participate in the

evaluation you can download and install it for android. The evaluation is the form under the feedback tab.

In the interview setting the users were informed that they would not be given any technical assistance with the application during the test. Furthermore they were asked to say their thought out loud to once again follow the think-out-loud protocol.

7.2.1 Data Collection

The aforementioned evaluation survey was created using Microsoft Forms, to be in accordance with NTNU's data collection guidelines. Both the citizens performing the evaluation in their own environment, and the participants evaluating the application in an interview setting gave their feedback using the form. Their thoughts and feedback uttered during their usage was written down.

7.3 Evaluation Survey

The evaluation survey was created using Microsoft Forms, and distributed as a link in the final application. The survey included the questions defined in the evaluation model, and some questions about the user:

What role describes you:

- Citizen of Møllenberg
- Expert on solar panels
- Home owner
- Interested in solar panel technology

Is your home in a heritage area?

- Yes
- No

What best describes your living arrangement?

- Own house
- Rent house
- Own apartment
- Rent apartment

Have you participated in local hearings or area development meetings?

- Never
- Once
- Used to do it but not any more
- Regularly

7.4 Interview Observations

The interview observations were not a core construct of this evaluation iteration, but they can provide valuable insight into potential user patterns and issues. The user personas were not determined prior to the test, and the observations and feedback was ultimately aggregated:

- With the improvements made to the interactive solar-radiation page, the citizens who lived close by to the focus house and whose home was a part of the overview-map were observed to seek out their own house
- The home-page was multiple times stated as bland and lacking in colors
- The knowledge-base pages could benefit by having emphasis on key points or point-summary
- It would be nice to have a link to the sources on the information pages themselves rather than collecting it on its own page, or numbering of the sources
- It would be nice if the image would be expanded when tapping on them, as the zoom on smaller images is challenging

7.5 Survey Results

7.5.1 Respondees Age

How old are you? (Optional)	**Count**
18-29	5
30-50	2
51-68	3
68+	0

Table 7.1: Responses participant age

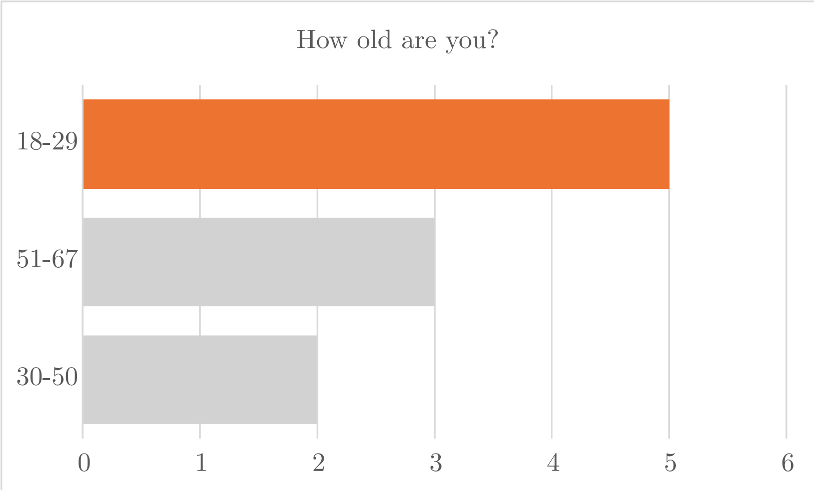

Figure 7.13: Chart - Responses Age

7.5.2 Living arrangement

What best describes your living arrangement?	Count
Own House	4
Rent House	0
Own Apartment	3
Rent Apartment	3

Table 7.2: Responses home ownership

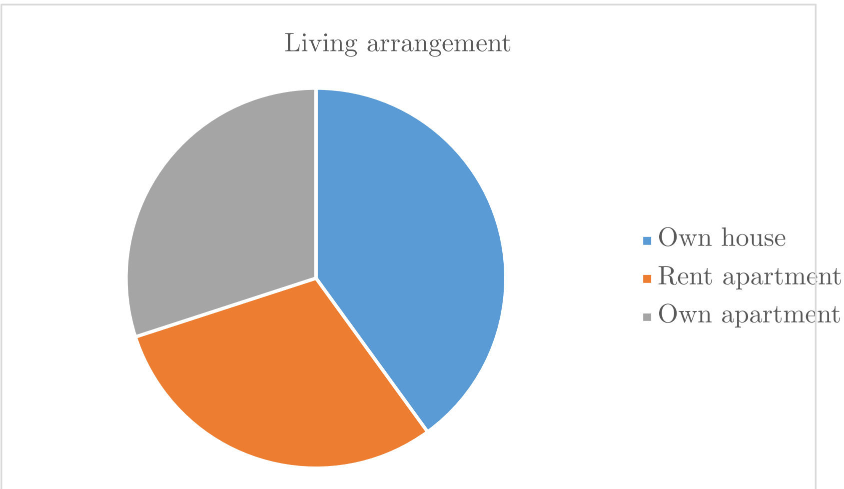

Figure 7.14: Chart - Responses house ownership

7.5.3 Previous CE Experience

Have you previously participated in local hearings or area development meetings?	**Count**
Regularly	2
Previously	0
Never	8

Table 7.3: Responses home ownership

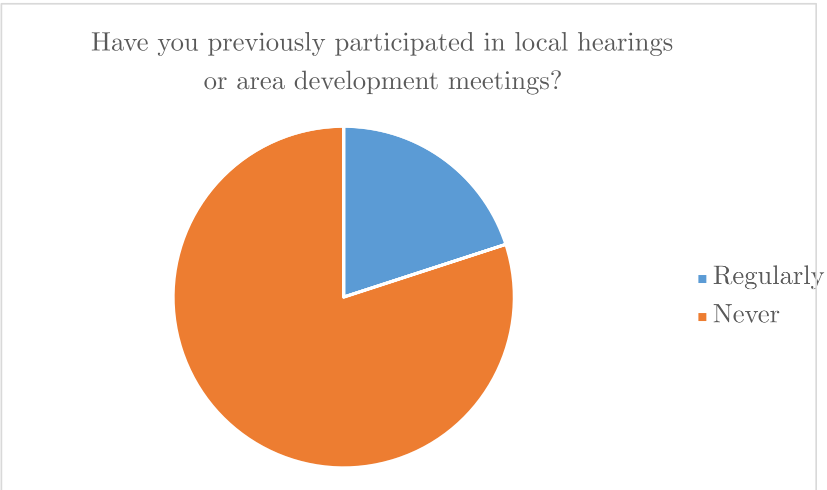

Figure 7.15: Chart - Responses previous participation

7.5.4 Perceived Usability - SUS

Question	Mean	SD
This application seems valuable	4,2	0,42
I found the application to be unnecessarily complex	2,2	0,92
The application was easy to navigate	3,8	0,63
I think I would need support from a technical person to be able to use this application	1,6	0,97
I found the various features of this application to be well integrated	3,8	0,63
The various features worked well together to create a coherent experience	4,1	0,57
I think most people would learn to use this application quickly	3,9	0,74
The application was cumbersome/annoying to use	1,9	0,57
I felt confident using the application	3,9	0,57
I needed to learn a lot in order to use the application	1,7	0,95

Table 7.4: Results: SUS - Mean and Standard Deviation

7.5.5 Endurability - UES

Question	Mean	SD
Learning on this application was worthwhile	4,2	0,42
I consider my experience a success	3,9	0,57
Using the application did NOT work out the way I planned	1,8	0,79
My experience was rewarding	3,8	0,42
I would recommend this application and approach to my friends and family	4	0,67

Table 7.5: Results: Endurability - Mean and Standard Deviation

7.5.6 Novelty - UES

Question	**Mean**	**SD**
I continued to read about solar technology in the app or external sources out of curiosity	3,4	0,70
The content of the application incited my curiosity	3,9	0,32
I felt interested in the application	4,1	0,57

Table 7.6: Results: Novelty - Mean and Standard Deviation

7.5.7 Aesthetic Appeal - UES

Question	**Mean**	**SD**
This application was attractive	3,9	0,32
This application was aesthetically appealing	3,8	0,63
I liked the graphics and images of the application	4,3	0,48
The application appealed to my visual senses.	3,8	0,79

Table 7.7: Results: Aesthetic Appeal - Mean and Standard Deviation

7.5.8 Felt Involvement - UES

Question	**Mean**	**SD**
I was really drawn into learning about solar technology	3,4	0,52
I felt involved in this process	3,5	0,53
This experience was fun	3,9	0,57

Table 7.8: Results: Felt Involvement - Mean and Standard Deviation

7.5.9 Topic Attitude - UES

Question	Mean	SD
Before using the system, I was positive to solar photovoltaic technology in general	4,3	0,48
After using the system, I am positive to solar photovoltaic technology in general	4,4	0,52
Before using the system, I was positive to integrating solar panel technology on heritage buildings	4,8	0,92
After using the system, I am positive to integrating solar panel technology on heritage buildings	4,2	0,63

Table 7.9: Mean and Standard Deviation: Topic Attitudes

7.5.10 Topic Confidence

Question	Mean	SD
Before using the system, I was confident in my knowledge on photovoltaic technology	3	0,82
After using the system, I am confident in my knowledge on photovoltaic technology	3,8	0,63
Before using the system, I was confident in giving an opinion on the use of photovoltaic technology	3	1,1
After using the system, I am confident in giving an opinion on the use of photovoltaic technology	4,1	0,74

Table 7.10: Mean and Standard Deviation: Topic Confidence

Would the application be more engaging if you could see the solar panels on your own home?	Count
Yes	9
No	1

Table 7.11: Response Final Question

7.6 Survey Data Analysis and Correlations

7.6.1 User Engagement Scores

The user engagement scale was adapted in the final evaluation with the aims of capturing the engagement aspects of endurability, novelty, felt involvement and aesthetic appeal.

The UES scores and standard deviation calculates to:

Construct	Mean Score	SD
Endurability	4,02	0,36
Novelty	3,8	0,39
Felt Involvement	3,6	0,38
Aesthetic Appeal	3,94	0,35

Table 7.12: UES-Scores

7.6.2 System Usability Score

The calculated SUS-score and standard deviation (SD) for the final evaluation were:

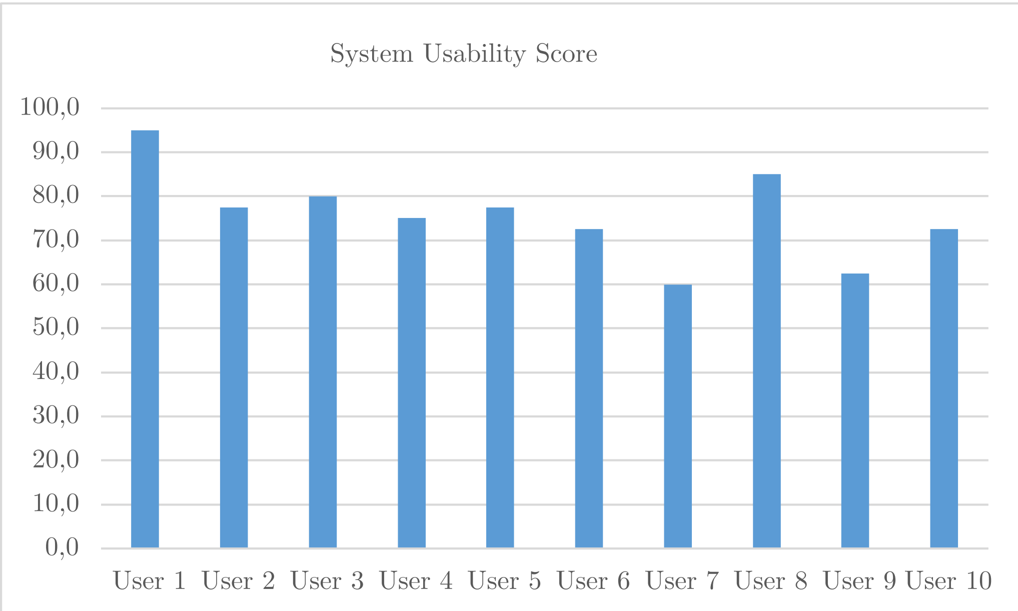

Figure 7.16: Chart - System Usability Scores

User	SUS-Score
User 1	95,0
User 2	77,5
User 3	80,0
User 4	75,0
User 5	77,5
User 6	72,5
User 7	60,0
User 8	85,0
User 9	62,5
User 10	72,5
Mean	75,8
SD	10,1

Table 7.13: Calculated SUS-Score final iteration

7.6.3 Correlations

In order to understand the relationships between our pre-determined constructs of our responses we performed a correlation analysis. In order to perform this analysis, the following operations were made:

- Responses to question UES-END-3 (Using the application did not work out the way I planned), were reversed as per the UES-guidelines.
- Responses to yes/no questions were transformed such that yes became 1 and no became 0

The correlations were determined using Pearson's Correlation Coefficient (Pearson's r). This statistical method measures the linear correlation between two data sets. For Pearson's r, we assume that the relationships are linear. The abbreviations found in the correlation-table are as follows:

Abbreviation	**Term**
AE	Aesthetic Appeal (UES)
END	Endurability (UES)
NOV	Novelty (UES)
FE	Felt Involvement (UES)
CONF	Perceived knowledge confidence post application usage
KNOW	Perceived knowledge post application usage
ATT-GEN	Attitude towards photovoltaic technology usage in general
ATT-HER	Attitude towards photovoltaic technology usage on heritage buildings
PREV	Previous citizen engagement / civic participation experience
SUS	System Usability Scale - Score

Table 7.14: Caption

When analyzing Pearson's r we also have to calculate the p-value. The p-value is an indication on whether the observed outcome happens by chance.

Table 7.15: Pearson's r

Coeff table	**AE**	**END**	**NOV**	**FE**	**CONF**	**KNOW**	**ATT-GEN**	**ATT-HER**	**PREV**	**SUS**
AE	x	x	x	x	x	x	x	x	x	x
END	0,43	x	x	x	x	x	x	x	x	x
NOV	0,39	0,51	x	x	x	x	x	x	x	x
FE	0,07	0,07	0,65	x	x	x	x	x	x	x
CONF	0,20	0,24	0,33	0,42	x	x	x	x	x	x
KNOW	0,34	0,51	0,27	0,09	0,52	x	x	x	x	x
ATT-GEN	-0,14	-0,22	0,18	0,06	-0,52	-0,44	x	x	x	x
ATT-HER	-0,10	0,67	0,44	0,34	0,17	0,61	-0,27	x	x	x
PREV	-0,21	-0,03	0,04	0,32	-0,43	-0,25	0,67	0,10	x	x
SUS	0,28	0,30	-0,03	-0,11	-0,09	0,11	-0,11	0,04	-0,04	x

Table 7.16: P-Table

	AE	**END**	**NOV**	**FE**	**CONF**	**KNOW**	**ATT-GEN**	**ATT-HER**	**PREV**	**SUS**
AE	x	x	x	x	x	x	x	x	x	x
END	0,21	x	x	x	x	x	x	x	x	x
NOV	0,27	0,13	x	x	x	x	x	x	x	x
FE	0,86	0,86	0,04	x	x	x	x	x	x	x
CONF	0,59	0,50	0,35	0,22	x	x	x	x	x	x
KNOW	0,34	0,13	0,45	0,80	0,12	x	x	x	x	x
ATT-GEN	0,70	0,55	0,62	0,87	0,12	0,20	x	x	x	x
ATT-HER	0,79	0,03	0,20	0,33	0,63	0,06	0,45	x	x	x
PREV	0,56	0,94	0,90	0,36	0,22	0,49	0,04	0,78	x	x
SUS	0,44	0,40	0,94	0,77	0,81	0,76	0,76	0,91	0,91	x

Chapter 8

Discussion

In this chapter the results of the evaluation iterations will be discussed. First the potential bias and outside factors of the participating citizens such as age, living situation, and previous citizen engagement experience will be discussed and contextualized. These factors are of individual nature, but can have an impact on the results.

8.1 Survey Participants

In this section we will explore the data we gathered about our participants that can be skew the result. In this case we consider age, and home ownership the biggest outside-factors. We will also discuss the number of citizens who have previous experience with civic participation, as this is a core construct of our evaluation framework.

8.1.1 Age Distribution

The survey received response from 10 citizens, who spanned three age groups: 18-29 (50%), 30-50 (20%), and 51-67 (30%). No respondents were aged 68 and above.

The relatively smaller sample size (n=10) and the absence of the older age group (68+) in our sample could limit the generalizability of the findings and conclusions. In the future it might be necessary to conduct further research or adjust our outreach methods to involve a broader and more balanced representation of age groups, and maybe even targeting older age citizens.

The age-related results may impact the interpretation of the responses to other survey questions. We can expect variations in responses based on the age demographic due to factors such as technological proficiency, attitudes towards novel energy solutions, and preferences or experiences in civic participation.

For instance, younger respondents (18-29) may be more familiar with ICT and might have more positive or open attitudes towards the integration of photovoltaic technology, even on heritage buildings, due to their likely higher exposure to climate change discourse and sustainability initiatives.

8.1.2 Home Ownership

The survey respondents were divided evenly between those owning their place of residence (70%) and those renting (30%). Among those who own their residence, a majority live in houses (57%), while the rest live in apartments (43%). All the renters reside in apartments.

These living arrangement dynamics carry important implications for the topic at hand, as photovoltaic system is a long-term investment for a residence. The ownership status and type of residence may significantly influence individuals' perspectives and decisions regarding residence upgrades and longevity. The home owners can be expected to have a greater interest in home upgrades with a long-term perspective as this can increase the price evaluation of their residence, or give the owner savings in the long term.

Citizens renting in apartment represent 30% of the sample and all live in apartments. Their ability to implement photovoltaic installations in general is more constrained due to their dependency on property owners' approval. Furthermore the longevity prospects of photovoltaic technology may lower the citizen's interest in the technology from an economic point of view.

In the future it may be important for the success of the citizen engagement project to involve landlords in the discussion and foster collaborative decision-making processes. Still, the living dynamics are important to keep in mind when analyzing the rest of the results.

8.1.3 Civic Participation Experience

Previous experiences of civic participation among the respondents were relatively low. A majority of participants (80%) indicated that they had not participated in any citizen engagement projects before, whereas only 20% had previous participation experience.

The lack of previous experience among most respondents might be indicative of limited exposure to the potential benefits, processes, and challenges associated with citizen engagement projects.

It would be essential to consider these variations in civic participation experience as we explore respondents' changes in knowledge confidence, opinion confidence, and attitudes towards photovoltaic technology. In the future, a tailored approach could be beneficial in engaging both experienced and inexperienced participants effectively in this ICT-supported initiative. For instance, additional education and support could be offered to those without prior experience, while individuals with past experience could be engaged in roles that leverage their familiarity with civic participation.

The results demonstrate that ICT and digital technologies can make civic participation and citizen engagement projects more accessible to the citizens who have less participation experience.

8.2 Direct Result Implication

In this section we will discuss the direct implication of the results, and what the results can tell us about the potential of a digital technology-supported approach to citizen engagement.

8.2.1 Change in Knowledge Confidence

The survey results indicate a positive shift in respondents' confidence in their knowledge about photovoltaic technology after using the application. Prior to using the system, respondents exhibited a mixed distribution of confidence levels. A small number agreed (30%) that they were confident in their knowledge, an equal number disagreed (30%), and the largest group remained neutral (40%).

Following the use of the system, there was a notable increase in confidence. A majority of respondents either agreed (60%) or strongly agreed (10%) that they were confident in their knowledge about photovoltaic technology, while the rest remained neutral (30%). Notably, there were no responses in the "disagree" or "strongly disagree" categories post-system use, demonstrating a unanimous increase in self-perceived knowledge confidence. This data suggests that the use of the ICT-supported system had a positive impact on respondents' self-perceived knowledge of photovoltaic technology. The shift in knowledge confidence demonstrates the value of the digital system as an educational tool and potential for increasing knowledge confidence, which is vital for effective citizen engagement.

8.2.2 Change in Confidence on Sharing Opinion

The survey results show a positive shift in respondents' confidence in sharing their opinions on the use of photovoltaic technology after using the application. Prior to using the system, respondents were evenly split, with 50% agreeing that they were confident in sharing their opinions and the remaining 50% disagreeing. There were no respondents who remained neutral or expressed strong agreement or disagreement.

After using the application, there was a significant increase in confidence. A majority of respondents either agreed (50%) or strongly agreed (30%) that they were confident in sharing their opinions about the use of photovoltaic technology. The remaining respondents chose a neutral stance (20%), and, notably, there were no responses indicating disagreement or strong disagreement post-system use.

This data suggests that the application not only improved respondents' knowledge about photovoltaic technology, as previously discussed, but also increased their confidence in expressing their opinions on the subject.

The increase in opinion confidence has meaningful implications for the broader goal of enhancing citizen engagement. The willingness to express one's opinion is a crucial aspect of civic participation. The confidence to share opinions can encourage active involvement, foster a sense of ownership over the process, and contribute to a more inclusive and democratic engagement initiative.

However, it is also noteworthy that a small group moved into the "neutral" category after using the system. This could suggest that while they no longer disagree, they may still need further support or encouragement to fully gain confidence in expressing their opinions.

Overall, the increase in confidence in sharing opinions indicates the potential of the ICT-supported system to not only disseminate knowledge but also foster active, confident participation in discussions about photovoltaic technology.

8.2.3 Change in Opinion on Photovoltaic Technology in general

The survey responses demonstrate a small but positive shift in respondents' attitude towards photovoltaic technology after using the application. Prior to using the system, the majority of the respondents already agreed (70%) or strongly agreed (30%) that they had a positive attitude towards photovoltaic technology.

After using the system, the general positive trend remained consistent, with the majority of respondents either agreeing (60%) or strongly agreeing (40%) with the statement. This result indicates a slight shift from "agree" to "strongly agree" after the interaction with the ICT system.

It is important to note that the lack of neutrality or disagreement in the responses, both pre and post-system use, might also suggest a selection bias. The respondents who participated in this survey might have been those already interested or positive about photovoltaic technology. Therefore, caution should be exercised when extrapolating these results to the broader population.

8.2.4 Change in Attitude to Photovoltaic Technology on Heritage Buildings

The survey results indicate a substantial shift in respondents' attitudes towards the installation of photovoltaic technology on heritage buildings after using the application. Before using the system, there was a mixed distribution of attitudes: 50% of respondents agreed or strongly agreed that they were positive towards the application of photovoltaic technology on heritage buildings, while the other 50% were neutral.

After engaging with the system, there was a marked increase in positive attitudes. A majority of respondents either agreed (60%) or strongly agreed (30%) that they were positive towards the application of photovoltaic technology on heritage buildings. Only a small proportion (10%) maintained a neutral stance, and importantly, there were still no negative responses.

This data suggests that the application positively influenced respondents' attitudes towards the use of photovoltaic technology specifically on heritage buildings. The ability of the system to inform and shape positive attitudes in this regard underlines its potential as an educational tool and a platform for dialogue about nuanced civic issues.

The change in attitudes suggests that the system has been effective in positively influencing views on this complex issue. Note that in this case a result where the citizen's opinions went from positive to negative would also be considered an effective system.

8.3 System Usability Scores

The SUS-scores of the previous evaluations were ≈ 84 and ≈ 91 for iteration one and two respectively. As previously discussed, the number of users participating in the concept evaluation and usability test were too low to give a reliable score, as the variance with so few data points is relatively high[46].

As documented the data collection method differed in the final evaluation from the first and second iteration. In the first two iterations the questions and answers were given verbally. Such a setting may have made the participants susceptible to response bias. One such type of response bias is social desirability bias. This refers to the tendency of respondents to answer questions in a way that will be viewed favorably by others[39]. For this thesis, the occurrence of social desirability bias could have made the participants rate the system more highly than they would in an anonymous setting, leading to a higher SUS-score in the first two evaluation iterations. Such bias were less likely to occur during the final evaluation, as the participants participating in an interview setting were given anonymity and privacy when answering the survey.

As presented in the theory, the average SUS score is around 68[46]. The final evaluation producing a mean SUS-score of 75.8 indicates that the developed application has a high degree of usability. This shows that the user-centric approach and integration of citizens in the development process has lead to an application where most users feel comfortable.

8.4 Data Correlation and Framework Evaluation

We can utilize the correlation-table to evaluate the initial evaluation framework. These values are between -1 and 1, where 0 means that the values have no linear relationship, -1 means that they have an inverse linear correlation (if one goes up the other goes down), and 1 means that they have a perfect linear correlation (if one goes up the other one follows by a factor). We can also use the correlation table to test our assumptions.

For instance the perceived confidence and perceived knowledge have a high correlation (0,76), which suggests that rising the perceived knowledge of a citizen also increases their confidence.

We must still keep in mind that the number of responses on the survey is relatively low (n=10), so we cannot make a definite judgement, but test our assumptions. We can calculate the P-value to test the validity of our findings, this will tell us whether we have enough data to make a statistical basis to make a conclusion.

In the case of P-values, lower is better, as it tells us the change of the correlation happening by chance. By identifying the occurrences of low P-values we can see if any of the assumptions made in the evaluation framework can be discarded or confirmed, and which assumptions we need more data to confirm or deny.

P1 (Previous CE attitude and participation affect the outcome): Our correlation table does not suggest that there is any relevant correlation between previous engagement and outcome. However all the correlations related to previous participation have a P-value of 0.37 or higher. This means that we cannot make any definite statistical conclusion on whether or not this has any effect on the outcome.

During the evaluation interviews we collected thoughts and feedback from citizens who had no experience with civic participation, and citizens who had lots of experience with civic participation. Both groups were interested in using digital technologies to engage in local issues.

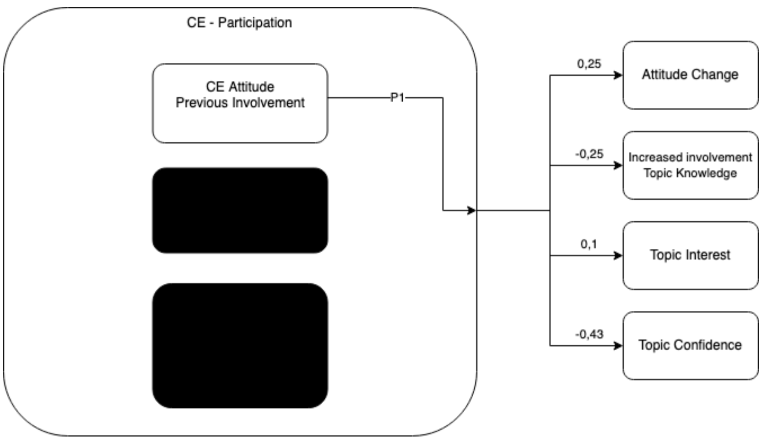

Figure 8.1: Isolation of P1 correlation to Effects

P2 (System Usability and Perceived Usefulness affect the outcome): We did not collect enough data to make a statistical definite conclusion on the impact of system usability on the outcomes of citizen engagement.

The results of the system usability scale does however show that this application and approach to civic engagement is accepted as valuable with a low standard deviation and high score. Although the technical information presented on photovoltaic technology is relatively complex the participants did not find the application itself unnecessarily complex, showcasing the value of interactive digital technology in an education setting.

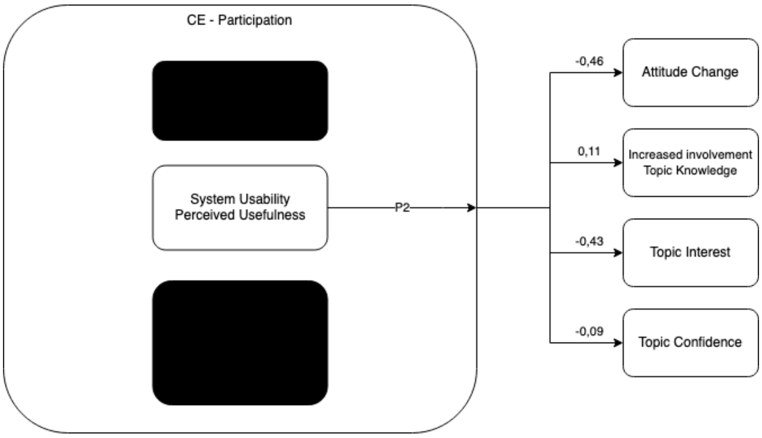

Figure 8.2: Isolation of P2 correlation to Effects

P3 (The system's ability to capture the user's attention and make them engage with the system affects the outcome): Our correlation table finds a couple strong correlations between UES constructs and citizen engagement outcomes. The strongest correlation is with Novelty and general attitude (0.62), which is also backed up with a low P-value (0.04). This supports the assumption that user engagement constructs have a positive impact on citizen engagement outcomes. We need more data to confirm or discard the inclusion of the remaining constructs of focused attention, aesthetic appeal and endurability.

During the interviews multiple users noted that the home page of the application was boring and not very inviting. This feedback and the results of the evaluation hints that digital technologies and high usability by itself does not guarantee intention to use and increased involvement. In the development of the application the core interactive features and information pages received more focus in terms of aesthetic appeal, and the home page did not get a lot of attention outside of the simple A/B test. Applications that aim to increase engagement should strive to make the entire user experience from first application launch to feedback as inviting and engaging as possible.

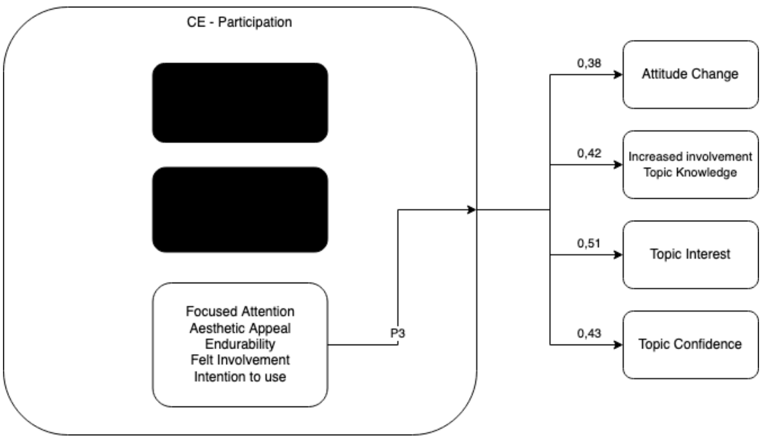

Figure 8.3: Isolation of P3 correlation to Effects

8.5 Application Technologies and Complexity

The developed application uses 3D models to provide an interactive and engaging user experience. During the exploration phase before start of the study, Augmented Reality (AR) and Virtual Reality (VR) technologies were considered as interactive technologies. Ultimately 3D modeling was chosen due to lower development requirements, as well as lower requirements for technical prowess and hardware limitation.

Finding the right balance between application complexity and user engagement is a crucial consideration in the design and development of any software application, especially for civic participation. While adding more features and complex functionalities may seem like a way to improve the application, it can sometimes lead to usage complexity that negatively affects user engagement, accessibility and learnability.

The evaluation results show that the applications had achieved a high usability and engagement score. This shows that engaging experiences can be developed and created with simpler forms of 3D model usage, and its accessible and intuitive potential. The focus of a knowledge building application has to balance between keeping its users engaged and retained, with presentation and information sharing regarding complex issues.

Chapter 9

Conclusion

9.1 Main Contributions

In this thesis, the potential of digital technology to enhance Citizen Engagement has been explored. From performing a literature review of the social science aspects, to investigating modern research applications through the lens of ICT, a broad initial research gap with research questions were discovered. After diving deeper into the theoretical processes of Citizen Engagement, the initial research questions were refined. These refined research questions have motivated an iterative user centered research process with multiple evaluation result, each with different focus and expected outcomes. The result of this research is an application which can be further iterated upon and serve future value for Helios in engaging citizens of Møllenberg. In this chapter the refined research questions will be discussed based on the findings in the research process, and the future potential for the application will briefly be discussed.

> **Refined Research Question 1:** How can digital technologies be used to facilitate citizen engagement?
>
> > **Refined Research Question 1.1:** What is citizen engagement?
> >
> > **Refined Research Question 1.2:** How can digital learning technologies be used to facilitate and support the learning process of citizen engagement?

By performing literature review, citizen engagement has been identified as a type of civic participation process. Citizen engagement is a process where project owners educate the public with the aim of increasing their knowledge and collect their feedback.

ICT and digital technologies has the potential of increasing the accessibility of citizen engagement processes, as citizens can participate, learn and give their voice on their own accord in line with their own schedule and whereabouts.

In this study numerous citizens who have no experience with civic participation programs have been exposed to and participated in the knowledge building step of citizen engagement. Digital technologies enables interactive experiences such as interactive 3D models, radiation maps and other interactive experiences.

> **Refined Research Question 2:** How does the use of specialized digital interactive learning technologies impact the attitudes of the citizens in regards to citizen engagement?

In this study we have created a digital application that enables citizens to interactively learn about photovoltaic technology and its potential in heritage areas. They have also been presented with challenges related to the technology and challenges specific to heritage areas. Citizens have been included in an iterative user-centered design process from concept evaluation to usability testing and a final evaluation including engagement, usability and citizen-engagement outcomes.

We have engaged both citizens who are regularly engaged, as well as citizens who have never participated in local engagement projects. During the concept and usability evaluations, all participants claimed they would be more likely to engage in local democratic processes if they could do so with a digital application. The final evaluation found no difference in measurable outcomes related to perceived knowledge, nor perceived knowledge confidence, suggesting that digital tools can indeed effectively raise awareness and knowledge of citizens, regardless of previous engagement levels. However our conclusions are based on a rather low sample size, and more research targeting a larger number of users should be conducted before definitive conclusions can be drawn.

> **Refined Research Question 3:** How does usage of digital learning technologies impact perceived knowledge confidence in citizen engagement?

In the final evaluation results we evaluated the perceived knowledge confidence and performed a correlation analysis with multiple evaluation models identified in the literature. The results found perceived knowledge having a high correlation with the system's UES-endurability-score.

Our findings do not make a conclusive judgement on the correlation between knowledge confidence and system usability nor the UES constructs aesthetic appeal, novelty and felt involvement. This is due to the limited number of study participants, making the findings have too low confidence. These p-values show that we need more data to accurately determine the degree in which these construct correlate to perceived knowledge confidence in citizen engagement.

9.2 Limitations

As discussed the clear limitation of this study is the number of respondents in the final evaluation. An evaluation framework has been proposed based on a literature review, but the evaluation did not produce results with a satisfactory confidence. Future studies should aim to address this by recruiting more participants for evaluation.

The study recruited participants for the study, which means that we can not make any judgement on how digital technologies can help in organically engaging citizens for civic participation.

None of the evaluations included citizens over the age of 68. In this study a stated goal of incorporating digital technologies is to increase accessibility of citizen engagement projects. Citizens of this age group has to be included before a definite conclusion on whether or not digital technologies increases accessibility in civic participation programs can be made.

9.3 Future Work

Helios have already expressed interest for further work with the application developed in this thesis, proving the value for stakeholders to have a platform to engage citizens. By developing a backend-API the application can be expanded to allow for aesthetic visualization, radiation analysis and efficiency estimation of more houses. Furthermore the app can be developed to fill a larger scope of the entire citizen engagement process. As the application at its current state only supports knowledge building, further work can add support for direct communication between citizens and stakeholders. It is also possible to develop the application to present information targeting different stakeholders.

The experiences and findings are planned to be used in a full paper, the abstract of which has been accepted for the REALCORP 2023 conference[5]. This abstract can be found in the appendix.

The data presented in the discussion strongly suggest that the proposed evaluation framework and application needs more evaluation data to be conclusive. The participants and interviews conducted as a part of this study were all positive towards the idea of using ICT and digital technologies to enhance civic participation.

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Appendix

Appplication Code

You can get the code at https://github.com/hkgranli/flutter-engagement. The commit used for the evaluations are:

- Evaluation 2: d775743
- Evaluation 3: 2270039

To check the different commits, clone the main branch and rollback using git checkout ¡commit¿.

Development guide and user setup guide can be found in the README.md-file.

🏆 *reviewed paper*

Engaging Stakeholders and the Community in Sustainable Energy Transitions of Heritage Buildings using Digital Technologies

1. ABSTRACT

A huge percetage of the building stock in Europe and in the world are energy inefficient. The transition to a decarbonised building stock by 2050 requires the engagement of all stakeholders. One of the challenges in this process is to raise the awareness and the knowledge level of citizens about new energy sources and how they could affect the building's fasade or the economic implications of the transition. Furthermore, a few housing areas are declared heritage areas in an effort to preserve the culture and history of a country. Many such heritage buildings are highly energy inefficient and costly to maintain. They are often in need of renovations in many aspects. The owners of such buildings are faced with a number of dilemmas in transitioning to a more energy efficient future. In this paper, we consider a small neighbourhood in our city that has numerous buildings that are declared as heritage buildings. These buildings have strict regulations about any changes, in particular, their facades. Plans are made to transition to solar panels for energy. However, given the restrictions imposed by the heritage council as well as the financial burdens to the owners, it has been challenging to make any progress. In a survey where several of the households in the neighbourhood participated, they indicated their willingness to the transition to solar panels for energy. They also indicated their limited level of knowledge about the new energy source, such as the physical area of the roof or the walls that would be taken by the solar panels, to obtain adequate energy. The participants of the survey also indicated their interest in using new and emerging technologies such as Augmented and Virtual Reality. In this paper, we will present our experience in using a mobile app to engage the stakeholders in a cultural heritage neighbourhood, to transition from fossil fuel to solar energy. Our main research question is to understand how digital visualisation technologies could engage citizens and other stakeholders in energy transitions, through increased awareness and knowledge. This work has been conducted within a research project who focus is to accelerate the adoption of solar panels for energy efficiency.