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Smart Meter Assistant using Real Time Use information

SmartU

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2 Introduction

2.1 Background

Since 2015 Smart Meters are being enrolled in Austria. These devices offer a hardware-customer interface to receive meter data in near real time for private use or third-party applications. However, providers developed various proprietary data formats and protocols concerning the data transmission from and to the Smart Meter. Burgenland, for example, is using Smart Meters from Landis & Gyr , which offer two hardware interfaces (i.e., an infrared adapter and an M-bus interface). Due to these numerous different solutions and various further aspects (e.g., low cost plug and play hardware) no widely used near real time data visualisation is available (see Figure 1). Hence, additional (third-party) services based on near real time Smart Meter data cannot be offered and, even more critically, end users (e.g., households) are not aware of the potential benefits of such services.

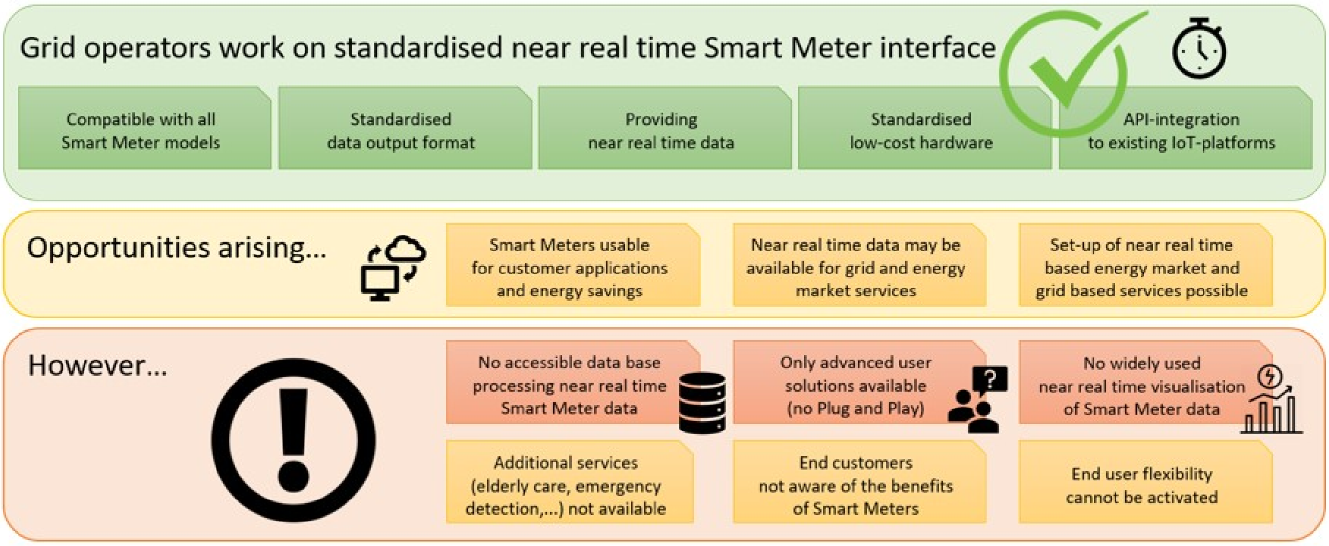

Figure 1: Components of the test application

In order to tackle the challenge of developing standardised data formats and protocols "Österreichs Energy" created a working group to devise a standardised hardware solution. This solution should (1) be compatible with all Smart Meter models used in Austria, (2) deliver a standardised data output format, (3) provide near real time data, (4) follow a low-cost approach and (5) allow API integration into existing IoT-platforms.

Prior to these efforts, the Netz-Burgenland GmbH and the FH Burgenland GmbH developed the end user application SMEKS. SMEKS is a hard- and software solution connected to one of the Smart Meter interfaces, providing near real time metering data via a webserver. Various use cases can be implemented on the basis of this near real time data of electricity consumption/production and their disaggregation. It is also assumed that a suitable visualisation of the data (together with corresponding incentives) for households leads to beneficial demand response effects. Hence, in the following the state of the art of these aspects is discussed.

2.2 Problem Definition

The full exploitation of the broad potential of Smart Meters remains elusive. Despite the identification of numerous use cases where meter data needs to reach end-users, distribution system operators (DSOs), or retailers almost in real-time, effective solutions are lacking. A key challenge lies in the absence of a standardized data interface and a unified software solution. This results in the underutilization of Smart Meters for end-user applications, with the lack of real-time visualization solutions leading to limited flexibility for end-users and a general lack of awareness regarding the benefits of Smart Meters.

However, efforts by distribution system operators to establish a standardized, near real-time interface for Smart Meters are opening up new possibilities. Through this standardized interface, Smart Meters will, for the first time, be fully usable for customer applications and energy savings. Near real-time data will then be available for network and energy market services, laying the foundation for innovative solutions in the energy market and network-related services.

This development highlights numerous research needs, as depicted at the end of Figure 2.

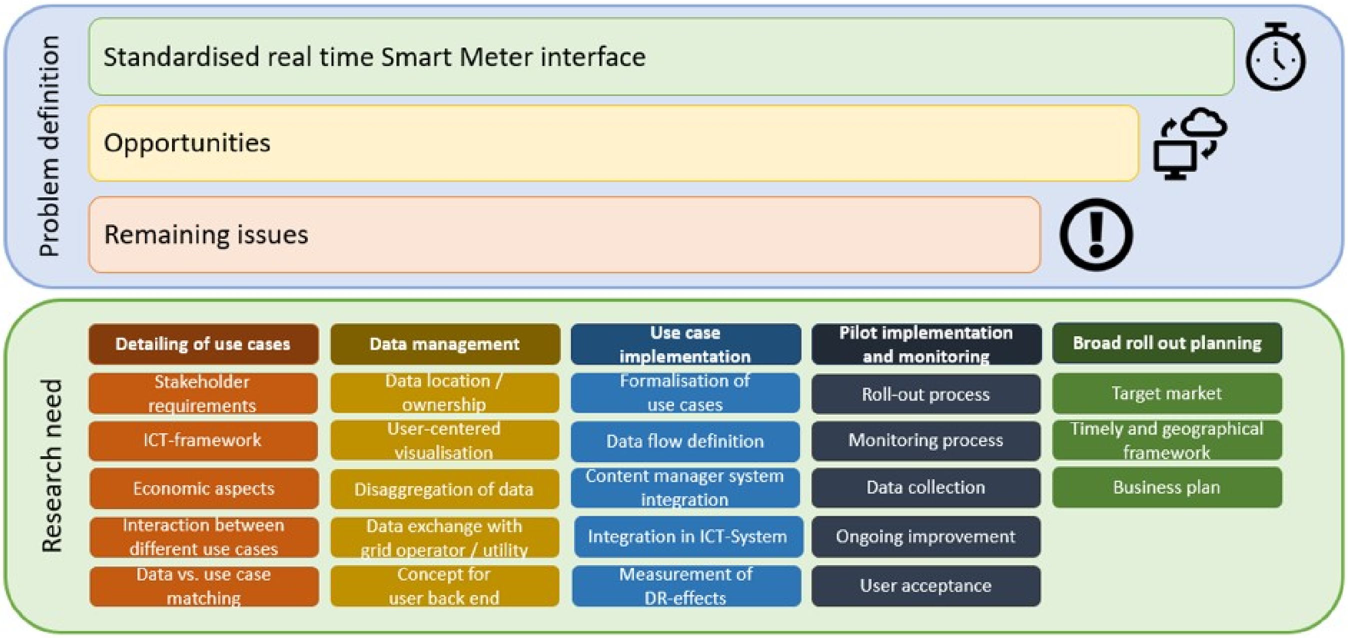

Figure 2: Need of research

<u>Detailing Use Cases</u>
Participatory development of use case concepts best addresses stakeholders' needs and is transformed into a defined set of stakeholder requirements. A key task is to analyze the ICT framework, as each use case requires different resolution or latency. It is crucial to determine the required data resolution for each use case.

Additionally, economic analysis aids in selecting use cases that bring societal benefits.

Data Management
Analyzing data location and ownership is an essential component in creating a user interface capable of providing the necessary data. At its core is a visualization that users can easily understand and utilize. For some use cases, detailed data breakdown is required. Energy data disaggregation or Non-Intrusive Load Monitoring (NILM) aim to estimate the power demand of individual devices from a household's total power consumption.

Implementation of Use Cases
This topic involves formalizing the use cases, leading to the specification of interactions involving the user interface and all possible external actors in the system. Bidirectional and task-specific interaction must be implemented to involve the customer in communication. Furthermore, developing logic integrated into the data backend is necessary for automated processing of these interactions. Designing the data flow and integrating it into existing ICT systems are essential.

Pilot Implementation and Monitoring

Subsequent to formalizing and implementing the use cases, the pilot implementation phase commences. This phase involves deploying the developed solutions in a controlled setting to assess their functionality and effectiveness in real-world scenarios. Key tasks include planning deployment, installing and configuring hardware and software components, conducting thorough testing, providing user training, and continuously monitoring and evaluating the pilot implementations. Feedback gathered during this phase informs iterative improvements to the solutions, ensuring their readiness for broader deployment and maximizing their impact on energy management and efficiency.

Broad Rollout Planning
Following a successful testing phase, a planning phase for a widespread rollout of the new standardized system ensues. Determining the timetable, geographical scope, and identifying the target market are crucial steps in developing the business plan.

2.3 Focal points of the project

The SmartU project's focus was delineated into four primary categories: 1) Use Cases, 2) Stakeholders, 3) Success Factors, and 4) Testing Phase. Category 1 encompassed various use cases based on the project's standardized hardware solution. These included raising end-users' awareness of their energy consumption and enabling better predictions, facilitating more efficient utilization of energy storage systems, for instance. Moreover, Smart Meter data empowered energy providers to identify faulty network components promptly and react swiftly without disrupting their service. An essential aspect of the proposed project was investigating the connections and interferences among the different use cases to evaluate potential synergies.

Integral to the proposed project was the involvement of all stakeholders listed in Category 2 (e.g., prosumers, distribution system operators, and energy providers) in the development phase of specific use cases. This occurred within a co-creation process ensuring high acceptance of the developed use case from the earliest project stages. This fulfilled the project's goal of ensuring stakeholder involvement in every development phase of a use case, as described in Category 3.

Another success factor for the successful implementation of developed use cases was their functionality, providing additional benefits for end-users (cost reduction, AAL) and/or energy providers. Lastly, an essential aspect of any use case developed within the proposed project was data security. This was particularly crucial as high-resolution data from the Smart Meter enabled personalized analysis of energy consumption data, allowing for additional insights into individual behavior (e.g., daily routines like bedtime). Another success factor was the strong customer engagement between the energy provider and the customer. An enhanced interface created the opportunity to establish closer contact with customers, better understanding them and their needs.

Ultimately, the success of the proposed project was assessed based on the qualitative objectives outlined in Category 4.

To achieve the qualitative objectives depicted in Figure 2, the project aimed to fulfill the quantitative objectives formulated below:
- 15 use case concepts developed in the participatory process
- 10 selected use cases for the co-creative development phase
- 6 selected use cases for demonstration
- 1 bidirectional user interface with content management
- 225 end customers
- 2 improved forecasting models (1 for production, 1 for consumption)
- 3 rollout plans for widespread implementation

Unfortunately, the project came to an unexpected standstill, halting progress towards its objectives. Despite this setback, significant strides were made in certain areas:

Implemented:

15 distinct use case concepts were meticulously developed through an inclusive participatory process.
Subsequently, 10 exemplary use cases were selected for further co-creative development.
Efforts were made to implement the majority of the 6 selected use cases within the project framework.

Not Implemented:

Regrettably, due to the project's interruption, the planned demonstrations for the 6 selected use cases did not occur as intended. So, the implementation phase for 225 end customers was rendered unattainable due to the project's interruption.
Consequently, planned enhancements to forecasting models and the formulation of rollout plans for widespread adoption were similarly affected by the project's untimely conclusion.

2.4 Placement in the Programme

The research project SmartU was submitted under the RTI Initiative 3rd Call - Energy Model Region. SmartU was conceptualized and executed as an Experimental Development, aiming to innovate and test novel solutions within the energy domain.

The project contributed to the following program objectives, listed in descending order of importance:

Objective 1: Involvement and active participation of users.
SmartU prioritized user involvement by incorporating user feedback, preferences, and needs into its design and testing phases. Active participation ensured that the solutions were user-centric and addressed real-world challenges effectively.

Objective 2: Development and model use of local energy and energy-related transport technologies for the large-scale field testing of intelligent system solutions in live operation.
SmartU contributed to this objective by introducing innovative solutions, such as smart metering and data analytics, to optimize energy usage and management at the local level. By conducting field tests and live operations, the project evaluated the performance and scalability of these solutions in diverse environments.

Objective 3: Strengthening and developing Austria as a lead market for innovative energy and energy-related transport technologies and services.
SmartU played a crucial role in achieving this objective by introducing novel approaches to energy management and consumption. By fostering collaboration between stakeholders, including researchers, industry partners, and policymakers, the project contributed to the development of a vibrant ecosystem for energy innovation in Austria.

Overall, SmartU's alignment with these program objectives underscored its significance in driving forward the goals of the RTI Initiative, fostering innovation, and promoting sustainable energy practices in the region.

2.5 Methods used

Within the framework of the project, various methods were combined to enable a comprehensive analysis and development of the SmartU solution. The applied methods included:

• Literature and Market Research: A comprehensive analysis of existing literature and the market was conducted to gain a thorough understanding of existing solutions and challenges.
• Internal Workshops: Workshops were conducted internally to generate ideas, identify problems, and discuss solution approaches.
• Requirements Analysis: Expert interviews and stakeholder workshops were utilized to identify the requirements and needs of the target audiences and to define the use cases.
• Simulations: Simulations were employed to assess different scenarios and predict potential impacts of the SmartU solution.
• Co-Creation Workshops: Co-creation workshops were conducted jointly with stakeholders to define and optimize the use cases.
• Laboratory and Field Tests: Prototypes were evaluated and optimized through laboratory and field tests to ensure their functionality and performance.
• Quantitative and Qualitative Empirical Social Research Methods: Methods such as surveys and focus groups were used to assess user acceptance and gain insights into user behavior.
• Development and Optimization of Business Models: The development and optimization of business models complemented the approach to ensure that the solution can be successful in the long term.

By combining these methods, a solid foundation was established for the development and implementation of the SmartU solution, meeting the needs of users and stakeholders while also adhering to scientific standards.

2.6 Structure of the work

The project was structured into several work packages, each encompassing specific objectives, contents, methods, and milestones.

The first work package, **Project Management (Work Package 1)**, aimed to efficiently lead the project according to defined goals and resources. Standard processes following the guidelines of the IPMA (International Project Management Association) were applied, covering project initiation, coordination, monitoring, and closure. Essential subprocesses included project management tools and collaboration software to support project initiation, coordination, monitoring, and closure processes.

Work Package 2, Requirements Analysis, focused on the procurement and analysis of test hardware, as well as the evaluation of requirements and deployment scenarios. This involved conducting literature and market studies, holding internal workshops, and conducting expert interviews. The outcome included detailed documentation of stakeholder requirements and a description of hardware functionalities.

The definition of use cases took place in Work Package 3. Here, detailed use cases were developed and examined for their interactions using design thinking and co-creation processes. Design thinking workshops, co-creation processes, and surveys were the main methods to achieve this goal. The end result included developed use cases with high acceptance and a concept for the user interface.

During the **Co-Creative Development Phase (Work Package 4)**, the use cases were implemented in hardware and software, the user interface was optimized, and prototypes were tested and refined. This was done through programming, the use of web mapping technologies, and the conduct of co-creation workshops and laboratory tests.

Work Package 5, Rollout and Monitoring, involved the installation of hardware and software, continuous monitoring of use cases, and data collection to improve algorithms. On-site installation, monitoring/reporting, empirical social research, and simulation were the main methods for executing this work package.

The final work package, **Accompanying Research Activities and Dissemination (Work Package 6)**, aimed to develop a dissemination plan, publish project results, and establish the project in Austria. This was achieved through planning and conducting accompanying research activities, developing a dissemination plan, and summarizing and evaluating project results.

Overall, this structure reflected the organized execution of the project, with each work package pursuing specific tasks and objectives that ultimately contributed to achieving the project's overall goals.

However, it's important to note that **Work Packages 2, 3, and 4 were effectively executed** during the project. Nevertheless, **Work Package 5 could not be implemented** due to the premature termination of the project. Therefore, the intended pilot phase involving end customers could not be carried out as originally planned.

3 Content presentation

The development of the use cases within this project was grounded in a comprehensive process that integrated stakeholder input, prototype testing, and design thinking methodologies. Initially, meticulous efforts were made to gather stakeholder requirements regarding the transmission technology of smart meter real-time data. This step aimed to ensure alignment with stakeholder expectations and to define parameters for subsequent development phases.

Concurrently, rigorous testing was conducted on a prototype of the hardware solution provided by "Österreichs Energy." This testing phase served to assess the functionalities of the prototype and to identify any potential areas for improvement or refinement. Through testing, the project team gained valuable insights into the practical implementation of the smart meter adapter and its compatibility with the envisioned use cases.

Furthermore, a parallel Design Thinking process was initiated to collaboratively identify and develop the use cases. This iterative and user-centered approach involved engaging stakeholders in workshops and brainstorming sessions to explore potential scenarios, challenges, and opportunities. Detailed use cases were defined, refined, and prioritized based on stakeholder input and feasibility considerations.

Central to this entire process was the Smart Meter Adapter, which served as a crucial interface between the smart meter and the end customer. This adapter facilitated the transmission of highly granular real-time data, essential for informing the development of the use cases. Figure 3 Figure 1illustrated the architecture of data transmission, depicting the flow of information from the smart meter through the adapter to the Beenera App, serving as the user interface for the customer.

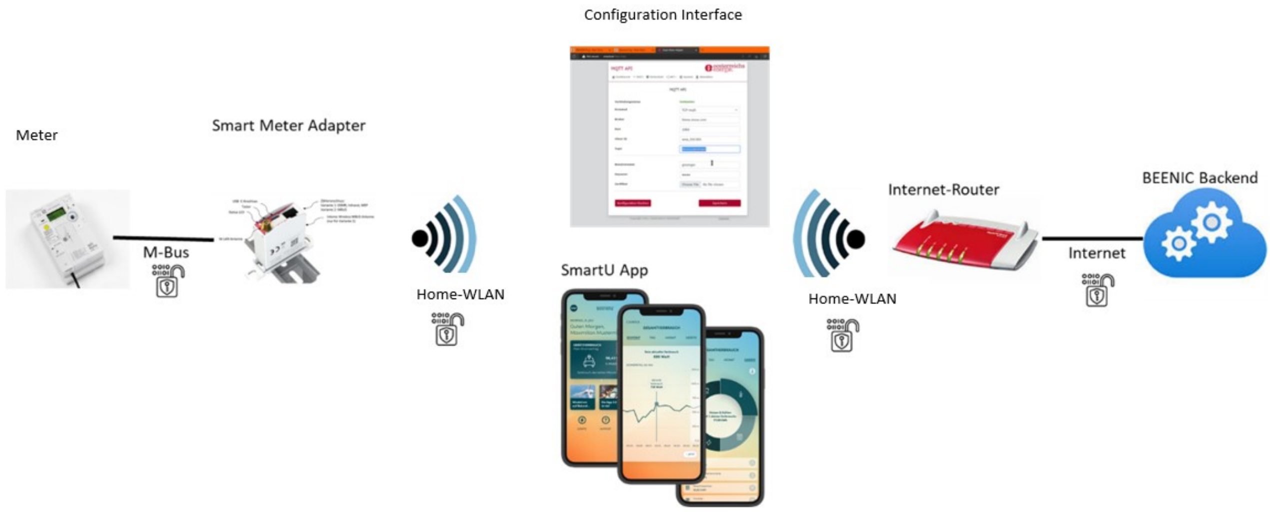

Figure 3: Architecture of Data Transmission

To initiate the process, the requirements of stakeholders for the transmission technology of smart meter real-time data were identified. Following the definition of stakeholder requirements, the hardware solution provided by "Österreichs Energy" was validated.

3.1 Stakeholder Requirements

To begin with, the stakeholders' requirements for the transmission technology of smart meter real-time data were determined. The focus here was on various aspects, including ensuring error-free data transmission and the use of LED signals for the WLAN connection and meter communication. Another focus was on the uniform use of the term "sensor" and the requirements for the device ID in accordance with DIN 43863-5. In addition, the process for registering with the Azure IoT DPS endpoint was defined.

These requirements were collected through intensive analysis and discussions with the stakeholders in order to understand their needs and priorities.

Summary of stakeholder requirements for the transmission technology of smart meter real-time data:

- **Transmission technologies:**
    - Ensuring error-free data transmission.
    - Use of LED signals for WLAN connection and meter communication.
- **Device-ID and processes:**
    - Consistent use of the term "sensor".
    - Requirements for device ID in accordance with DIN 43863-5.
    - Process for logging on to the Azure IoT DPS endpoint.
- **API and configuration:**
    - Updating properties via local API.
    - Functions for data transmission and configuration of the meter.
- **Documentation and operating instructions:**
    - Structured documentation
    - Operating instructions for end users with technical data, safety instructions and disposal instructions.

3.2 Prototype Testing

After defining the stakeholder requirements, “Österreichs Energy” hardware solution was validated. During this process, the hardware functionalities of the Smart Meter Adapter were tested in a test setup, and the following functions were identified:

- Meter data is **encrypted** and transmitted to the adapter via an **M-Bus interface**. The adapter then sends the data, also encrypted, via home Wi-Fi and the internet router to the backend, where it can be processed, analyzed, and visualized in an app.
- The adapter is available in **two variants**: a "UART" variant supporting DSMR, infrared, and MEP interfaces, and an MBUS variant supporting MBUS and Wireless MBUS interfaces. The device variants are distinguished by the type plate.

Additionally, recommendations for improvements were provided, such as implementing MQTTS for secure connection, expanding the dataset to include metadata like Wi-Fi signal strength, and enhancing encryption to 1024 bits. Suggestions were also made to conduct the onboarding process directly within the app rather than on a separate page.

Regarding data transmission, challenges were identified, including **unencrypted connections and difficulties with the handshake between the adapter and the MQTT broker**.

Overall, the technical feasibility of the adapter is established, but improvements are recommended to enhance usability and security.

3.3 Design Thinking

To develop and define the use cases in the project at hand, a Design-Thinking and Co-Creation process was formulated, shown in Figure 4. An essential focus during the conception of this process was the inclusion of all stakeholders. The process comprises several phases, some of which interconnect. The objective of the Design-Thinking process is to observe and identify the needs of all stakeholders. Subsequently, detailed use cases are defined in a Co-Creation process with all stakeholders. Modeling and testing of the models occur at a later stage.

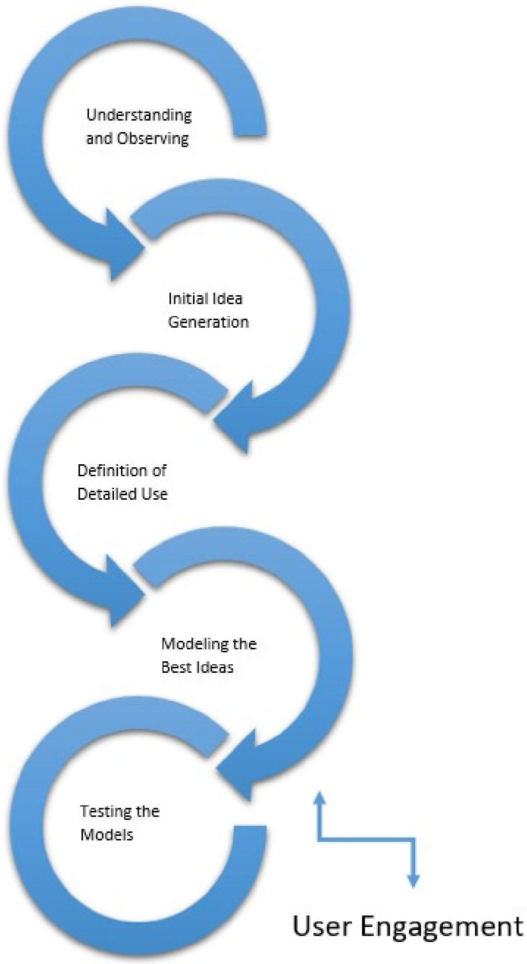

Figure 4: Design-Thinking- und Co-Creation Prozess

The Co-Creation process for defining the use cases commenced with online workshops involving representatives from energy supply companies and network operators. The aim was to understand the challenges and expectations of these stakeholders.

<u>Understanding and Observing - Gathering Challenges and Expectations</u>

Through brainstorming sessions with representatives from energy supply companies and network operators, expectations and challenges concerning future energy demand were elicited.

Initial Idea Generation

Based on the collected hypotheses, initial ideas for use cases were developed. These were visualized on a web-based tool, distinguishing between system-level challenges and challenges for end-users. The list of use cases was compared with literature-based use cases and classified in a 2x2 matrix based on effort and benefit. This served to refine and prioritize the ideas.

The 28 developed use cases were described in an Excel matrix and evaluated by the project partners. The 15 highest-prioritized use cases were divided into small groups to develop concepts.

Definition of Detailed Use Cases

The small groups developed concepts for each set of 5 use cases and presented them in online meetings. Through discussions and presentations, a common understanding was achieved. Finally, 7 use cases were selected for further elaboration, including a new use case called "Childcare." "Patrons" from the project consortium were appointed to develop detailed concepts

Modeling the Best Ideas

After gathering and refining the initial ideas through brainstorming sessions and workshops, the next step in the Design-Thinking process is to model the best ideas. This involves taking the prioritized use cases and transforming them into tangible concepts.

The modeling phase begins by breaking down the selected use cases into detailed components and functionalities. Each component is analyzed to determine its requirements, feasibility, and potential impact. This analysis helps ensure that the final concept aligns with the project objectives and stakeholder expectations.

Once the components are defined, they are synthesized into a cohesive concept or prototype. This may involve creating wireframes, mockups, or simulations to visualize how the use case will work in practice. Feedback from stakeholders is gathered iteratively throughout this process to refine and improve the concept.

Testing the Models

After the concepts have been developed, the next crucial phase in the Design-Thinking process is testing the models. Testing serves to validate the concepts, identify potential flaws or weaknesses, and gather feedback for further improvements.

During the testing phase, the developed use cases are evaluated in real-world scenarios with 225 end-users to assess their performance and usability. These tests allow for the identification of usability issues, technical challenges, or design flaws that may arise during actual implementation.

Feedback from stakeholders, including end-users, is collected. This can be done through surveys, interviews, or observation sessions to measure user satisfaction and identify areas for improvement. Throughout the testing phase, an iterative approach is applied to incorporate feedback and make necessary adjustments to the models. This iterative process continues until the models achieve the desired level of quality, functionality, and user-friendliness.

User engagement is ensured throughout all phases, particularly to ensure that the final product meets the needs and expectations of its intended users.

4 Results and conclusions

4.1 Rough concepts

In Table 1, the individual high-level concepts are presented, outlining their description, objectives, and potential impacts briefly.

Table 1: List of use cases selected for rough concepts

Concept	Description
Monitoring of Capacity Price	Continuous monitoring of non-consumption-related costs in electricity, especially capacity prices, to identify potential savings.
Show Potential	Analysis and presentation of consumption values to identify potential savings and raise awareness of energy consumption.
Detecting Energy Guzzlers	Identification of standby devices and energy guzzlers in the household to optimize energy consumption and reduce costs.
CO_2 Optimization in the Household	Aim to reduce CO_2 emissions in the household by analyzing consumption times and patterns to make more environmentally friendly decisions.
Social Comparisons	Comparison of one's own energy consumption with other users to create incentives for savings and raise awareness of one's own consumption.
Elderly Care	Care for older people through visualization and warning of potential risks to ensure their safety and well-being.
Detecting Device Failures	Early detection of device failures such as refrigerators to take timely measures to remedy them and minimize downtime.
Child Care	Care for children by monitoring and ensuring their needs to provide parents and caregivers with more security.
Market-Driven Demand Response	Responding to market signals to optimize energy consumption to reduce costs and increase efficiency.
Insights from Live Data	Obtaining insights into energy consumption through the analysis of real-time data to make informed decisions and identify efficiency potentials.
Self-Consumption Optimization with Live Data	Optimization of energy self-consumption through the analysis of live data to maximize the use of renewable energies and reduce costs.

Community Energy Optimization	Optimization of energy consumption in a community to efficiently use resources and reduce costs.
Provider Flexibility Verification	Verification of a provider's flexibility to respond to market requirements and support the integration of renewable energies.
Capacity Price Optimization	Optimization of non-consumption-related costs in electricity, especially capacity prices, to reduce costs and improve profitability.

4.1 Detailed concepts

In the following section, the detailed concepts for the selected use cases, slated for implementation in Work Package 4, are presented. Each concept includes a description, objective, and potential impact, providing a comprehensive overview of the planned initiatives.

4.1.1 Self-consumption optimization with live data

The concept, shown in Table 2, focuses on optimizing self-consumption of energy through the continuous analysis of real-time data. By evaluating live data, consumption patterns can be identified, consumption peaks minimized and the use of renewable energy maximized. The aim is to reduce dependence on external energy sources, cut costs and increase energy efficiency.

Table 2: Key data of the concept “Self-consumption optimization with live data (without control)”

Feature Title	**Self-consumption optimization with live data (without control)**
Epic Description	For end-users with self-generation facilities, particularly photovoltaic systems, who seek to optimize their self-consumption, the feature provides insights into optimal time-shifting of consumption based on real-time consumption data and PV production forecasts, aiming to increase self-sufficiency, save costs, and reduce carbon footprint.
Business Outcome Hypothesis	The end-user will be empowered to: - Act neutrally towards the grid - Act in an environmentally friendly manner (if the energy mix is not already bilaterally 100% renewable) - Reduce costs by reducing grid consumption: € = Costs for grid consumption (working price)
Leading Indicators	- PV self-consumption rate in % - How much percent of my electricity from the PV system have I consumed myself? - Economic efficiency and payback period
Stakeholders / Shareholders	User: Users with a PV system Customers / Client: Energy supply companies (EVUs)

	Partner / Cooperation or other stakeholders: The service WITHOUT control is ideal for selling a paid automated self-optimization service. However, a controllable consumer is required for this. Therefore, bundle products from the EVU, such as an e-car electricity tariff including a controllable wall box, are suitable.
User Needs / Benefits	- Easy readability of data - High user-friendliness - Enjoyment in usage - Simple graphics for precise data reading
Trigger (Rational or Trigger)	Need for energy savings / efficient use of energy generated by the PV system.
Use Case (User Perspective)	Optimization of own power consumption through efficient use of energy produced by the PV system.
Use Case Details	- Information is delivered through an application in real-time. - Detailed information on energy consumption and production can be viewed.
Preconditions	The end-user must own a photovoltaic system.
Postconditions	- Best-practice examples of how to represent energy production through the PV system. - Best-practice examples for simple representation forms - Graphics that appeal to users' emotions and thus bring joy.
User-generated Data	- Size of the home - Number of people in the household - Hours at home / at work
Data Link	- Information is delivered through an application in real-time. - Detailed information on energy consumption and production can be viewed.
Platform Needs / Benefits	- Known thematic areas (features) related to this system / service.
Design Requirements (User Experience (UX) / User Interface (UI))	- Positive feelings during usage - Few negative emotions during usage
Minimum Viable Product (MVP) Definition	The first minimal functional iteration includes: - Graphics / data for energy production / consumption

4.1.2 Detecting device failures

The concept, shown in Table 3, focuses on the early detection of failures in key appliances such as cooling units and photovoltaic systems. By analyzing live data, potential problems such as drops in performance or defects can be detected so that remedial measures can be initiated in good time. This minimizes downtimes and maximizes the efficiency of the appliances.

Table 3: Key data of the concept "Detecting device failures"

Title of the Feature	**Device Failure Detection Functionality**
Epic Description	The SmartU App offers a feature to detect faults or failures in refrigeration devices and PV systems, promptly notifying users. Currently, no solutions are available that detect anomalies in refrigeration devices and provide timely warnings. This solution aims to warn users of increased power consumption and potential disruptions in the cold chain. It also provides the advantage of applicability to older PV systems without communication modules and eliminates the need for data exchange with hardware manufacturers through feed-in and consumption data analysis, providing scalability benefits.
Business Outcome Hypothesis	The utility company acts as a caretaker of the household, warning against potential damages such as cold chain interruptions or revenue loss. This use case is expected to be of interest to a significant portion of users due to the widespread usage of refrigeration devices and PV systems. The benefit for end-users lies in emotional reassurance (peace of mind) and potential cost savings. Detection of a PV system fault can prevent loss of earnings until detection, which can be significant. Additional services can be derived from PV anomaly detection, offering a full-service package to end-users. There is great potential for market differentiation through smart interaction with end-users.
Nonfunctional Requirements	- Good portability of the algorithm across different households - Querying necessary PV system parameters through a transferable and scalable in-app survey mechanism - Persistence of survey results in master data, preferably via general key-value pairs.

The "Anomaly detection of refrigerator failures" and the "Anomaly Detection of PV System", which are parts of the use case "Detecting device failures" are described in Table 4 and Table 5.

Table 4: Key data of the concept "Anomaly detection of refrigerator failures"

Feature Title	**Anomaly detection of refrigerator failures**
User Requirements	End-users require timely detection of refrigerator failures, such as decreased cooling performance, to prevent spoilage of food and excessive electricity consumption. Additionally, they seek early detection of human errors, like leaving the door open, to avoid high electricity costs and food spoilage.

Trigger	Anomalies in the consumption pattern trigger the algorithm, indicating potential refrigerator malfunctions.
Use Case	This feature aims to enable cost control by warning users of abnormal refrigerator consumption patterns, thereby facilitating prompt action to prevent food spoilage and reduce electricity costs.
Use Case Description	The algorithm identifies existing refrigerators and informs users about its functionality upon successful learning. Users can activate the service (OptIn), allowing the algorithm to detect abnormal refrigerator behavior. Users receive notifications at different escalation levels—Information, Warning, and Alarm—delivered through various channels such as messages, push notifications, and widgets. Additionally, the app may include a detailed page to inform users about the type and occurrence of anomalies detected, allowing users to respond accordingly. Users can confirm/deactivate notifications to prevent constant alerts and report false alarms to improve algorithm accuracy. Furthermore, the app may provide monthly reports, highlighting normal operations to reinforce user confidence.
Preconditions	To utilize this feature, users must have a functioning refrigerator equipped with a smart meter and any additional required hardware. The system must have access to at least 1-2 months of consumption data, and the refrigerator should be in optimal working condition during the learning phase. Additionally, the algorithm must be trained and capable of recognizing refrigerators, and the data must have a resolution of at least seconds.
Postconditions	Upon detection of anomalies, users receive individualized information enabling them to rectify misuse or address any device defects promptly.
User-generated Data	Users provide data on electricity consumption via smart meters and additional hardware. Optionally, users may input information regarding the number of refrigerators and other cyclic devices (e.g., well pumps) to improve analysis quality. Additional data points such as device manufacturer, type, and age may be collected via surveys to enhance classification accuracy.
Data Link	The feature utilizes data from additional hardware and incorporates in-app surveys to gather necessary information.
Platform Needs/Benefits	This feature requires a workflow for Customer Journey, campaign management for content delivery, an anomaly

	recognizer/classifier, and customer interaction/surveys with master data persistence. The necessity and utility of a widget and detail page are yet to be determined.
Design Requirements (User Experience/User Interface)	The app should deliver push messages in a simple and user-friendly design. Further evaluation is needed to determine if a widget and detail page are essential for optimal user experience.
Minimum Viable Product (MVP) Definition	The initial version of this feature focuses on recognizing defects without the need for a widget or detail page.
References & Synergies	This feature aligns with other functionalities aimed at providing timely information to users. Synergies exist with all features that send relevant notifications to users

Table 5: Key data of the concept “Anomaly Detection of PV System”

Feature Title	Anomaly Detection of PV System
User Requirements	Users require timely notification of anomalies in their PV systems to ensure safety and security. Additionally, users seek assurance that their PV systems operate efficiently and effectively.
Trigger	Anomalies in the PV system, such as decreased power generation or equipment failures, trigger the detection process.
Use Case	The use case involves detecting anomalies in users' PV systems and promptly notifying them to take necessary action.
Use Case Description	The app identifies anomalies in the user's PV system and notifies them accordingly. Users can activate the service through opt-in. The app delivers alerts at different levels—Information, Warning, Alarm—through channels like Messages, Push Notifications, and Widgets. Detailed information about the detected anomaly is provided to empower users to respond effectively.
Preconditions	Users must have monitoring equipment installed on their PV systems, and sufficient historical performance data must be available for anomaly detection.
Postconditions	Users receive timely information about anomalies in their PV systems, allowing them to address any issues promptly.
User-generated Data	Data related to PV system performance and anomalies is generated by users.
Data Link	Data is sourced from the PV system's monitoring equipment.

Platform Needs/Benefits	The platform requires a workflow for customer journey and integration with monitoring equipment and data sources to ensure effective anomaly detection.
Design Requirements (User Experience/User Interface)	User-friendly push notifications in the app's design enhance user experience and interface.
Minimum Viable Product (MVP) Definition	The initial version focuses on detecting and notifying anomalies without additional widgets or detail pages.
References & Synergies	Synergies exist with all features aimed at sending relevant information to users.

4.1.3 Home Care/ Elderly Care

The concept, shown in
Table 6, focuses on caring for older people by ensuring their safety and well-being through visualization and warning of potential risks. By monitoring behavioral patterns and health data, early warnings can be issued and support measures initiated to enable older people to lead a self-determined life.

Table 6: Key data of the concept "Elderly Care/Home Care"

Feature Title	Elderly Care
Epic Description	For a trusted person (Household 1 – VP) who wants to be alerted in case of inactivity of a resident (Household 2 – B), providing real-time insight into the resident's electricity consumption (resolution 15min/1h) through algorithmic activity detection from smart meter data, with inactivity alert via in-app message, providing peace of mind for the trusted person. Since equivalent low-invasive products are not known, this solution offers innovative added value as a unique selling proposition (USP) from smart meter data, going beyond the usual energy-related services. When alerted (VP) about inactivity in another household (B), it is referred to as "Elderly Care". If the VP's own electricity consumption is the basis for activity detection, focused on specific times of the day, it is referred to as "Child Care".
Business Outcome Hypothesis	The offering meets a user need and can potentially be monetized. Low-invasive activity detection from smart meter data is an "entry-level product" that can meet the demand for safety and staying in one's own home for the "Silver Surfers". Comprehensive home emergency call systems (with IoT devices) are sold for between €50-100/month. There is therefore a willingness to pay. It is the entry into a product portfolio around home assistance systems and care. The next

	development step could be the integration of a home emergency call system with corresponding upselling potential.
Leading Indicators	-% of users who want to use the feature -Churn Rate when fees for activity detection are called - Qualitative feedback
Nonfunctional Requirements	- Maintenance: Possibilities for algo-monitoring must be created by rollout. How reliable is activity detection? - Marketing and pricing strategies need to be developed.
Involved Actors	User / User: Trusted person and resident
Feature Title	*Activity Detection for Inactivity Alerting with Data Consent (DSE)*
Initial Specification Feature & Use Case(s)	- DSE with Data Release by Invitation of B to VP - In-App Alerting and Contact with B
Feature Title	*Absence & Focus Times*
Initial Specification Feature & Use Case(s)	- Absence: Input of absence and consideration in alerting - Focus Times: Input of periods for focus times and consideration in alerting
Feature Title	*Child Care – VP Observes Themselves*
Initial Specification Feature & Use Case(s)	- Child Care (VP without B): Trusted person is alerted in case of inactivity in their own household
First Steps Towards Implementation	
Minimum Viable Product (MVP) Definition	Minimal implementation: Implementation of the above-mentioned features

4.1.4 Potential Awareness Functionality

The detailed concept, shown in Table 7, aims to highlight the potential for saving electricity and offers a variety of functions within the SmartU app. The aim is to provide interactive assistance for end customers who want to reduce their electricity costs. This includes detecting standby devices, identifying power guzzlers, and comparing their own consumption with that of other households.

Therefore, the features and use cases are divided into three main categories. The first feature "Find your standby monsters with the base load speedometer" (see Table 8) enables users to identify hidden standby devices. The second feature, "Uncovering Power Guzzlers"(see Table 9), measures the power consumption of individual devices to identify power guzzlers. The third feature offers an "intra-household comparison based on historical data" to visualize consumption trends and highlight potential for behavioural change (see Table 10).

Table 7: Key data of the concept "Potential Awareness Functionality"

Feature Title	**Potential Awareness Functionality**
Epic Description	For end-users seeking opportunities for electricity savings, the SmartU App offers an interactive tool that simplifies the identification of energy hogs, recognizes standby device consumption, displays consumption comparisons with similar households, and provides historical consumption data. Unlike non-existent solutions, our solution offers high-resolution measurement to identify individual consumers.
Business Outcome Hypothesis	Customer retention, especially among energy-conscious households
Leading Indicators	– Preliminary Indicators – Measurably increased customer satisfaction (Method: Survey) – App usage rate (Pageviews per week/month)

Table 8: Key data of the concept "Baseload Tachometer"

Feature Title	**"Find your Standby Monsters with the Baseload Tachometer" - playful interaction to reduce the base load to 0**
User Needs / Benefits	- Cost explosion for energy, and unknown cost drivers in the household - Cost control and savings
Description	The user selects the use case in the app, after which they are first introduced to the functionality with an info text. A tachometer appears, displaying the current consumption. Users are then prompted by the app to turn off all electrical devices in their household and see if they can bring their meter to rest. This way, they can identify hidden standby devices, as well as previously unknown energy guzzlers.
How often (per minute/hour/day) are the use cases executed?	As needed
Postconditions	Ideally, the power consumption is reduced to 0.
Platform Needs/Benefits	The attractiveness of the platform is increased by more targeted guidance on action through saving tips.
User Interface (UI)	Quick-reacting tachometer with colors indicating very high consumption in red and low consumption in green.

Table 9: Key data of the concept "Uncovering Power Guzzlers"

Feature Title	**Uncovering Power Guzzlers**

User Needs / Benefits	- Address energy cost explosion and identify cost drivers - Enable cost control and savings
Description	User opens SmartU App with "Electricity Stopwatch" widget. Function sets current baseline to 0 and prompts user to turn on device to be measured. Upon starting, current power consumption is measured, minus baseline. User prompted to stop timer after desired operating time of device. By switching on individual devices, power consumption of device under test is measured in kilowatt hours (kWh), allowing identification of power hogs.
How often (per minute/hour/day) are the use cases executed?	Initiated by user as needed
User Interaction	Start and stop power meter
Preconditions	Smart meter must be available; Current power consumption before switching on corresponding device must be measured to subtract this baseline;
Postconditions	Power consumption of corresponding device in kWh
User-generated Data	- User indicates when device was turned on by starting stopwatch - For benchmark, user could select device name from dropdown menu
Data Link	No external data needed
Platform Requirements/ Benefits	- Clear start-stop timer - Platform attractiveness increased by providing typical power consumption of comparison device, as many users are unaware Additionally, app could identify device as power hog

Table 10: Key data of the concept “Intra-Household Comparison based on Historical Data”

Feature Specification	**Intra-Household Comparison based on Historical Data**
User Needs / Benefits	- Address energy cost explosion and identify unknown cost drivers in the household - Enable cost control and savings - Provide assistance to end customers in energy crisis and thereby retain customers (EVU)
Description	Primary interaction occurs by opening SmartU App by the user. User is informed via widget about current consumption as well as daily, weekly, and monthly summaries. Current consumption is categorized as low, medium, or high based on historical values and displayed within a color scale.
Use Case Frequency	Initiated by user as needed
Preconditions	Historical data must be available

Data Link	No external data required
Platform Requirements/Benefits	Clear presentation of current consum
Design Requirements	Current consumption value/daily value/monthly value within a color scale Or dashboard with overall overview, similar to a speedometer

4.1.5 Optimization of Energy Communities

The concept, shown in Table 11, aims to present the energy balance of an energy community and to identify options for action to adjust current consumption within the community. By regularly analyzing data from the customer interface, measures can be taken to adjust consumption (sum of metering points) in order to improve the efficiency and sustainability of the energy community.

Table 11: Key data of the concept "Optimization of Energy Communities"

Feature Title	**Optimization of Energy Communities**
Epic Description	Our platform aims to support participants of Energy Communities (EEGs) and their sponsoring organizations in maximizing the self-consumption and autonomy level of their EEG. Through real-time data from individual metering points, they gain insights into the current energy and power balance to activate flexibilities effectively. In contrast to conventional EEGs, which receive data with a one-day delay, we offer an improved data situation for more efficient utilization within the EEG.
Business Outcome Hypothese / Business Case	Our platform enables EEGs and their participants to: - Increase their self-supply with locally generated electricity - Act sustainably and reduce costs by minimizing energy supplier consumption - Safeguard against rising energy prices by increasing autonomy within the EEG. EEGs offer a new way to trade energy locally and increase independence from international energy markets. The business model behind the service provision of EEGs involves charging fees for the services provided, with various fee structures possible. The introduction of a real-time data structure offers additional potential that can be financed through improved energy balance and cost savings for the EEG and its participants.
Leading Indicators	The key KPIs are the self-consumption rate and the autonomy level of the EEG in percent, as well as the profitability and amortization time of the additional real-time data option. It is essential to ensure that all metering points continuously provide data or that missing data points can be estimated accurately.

Nonfunctional Requirements	The platform must be scalable, easy to maintain, and performant. Continuous data transmission from all metering points is crucial for the platform's utility.
Stakeholders / Shareholder	- User : Participants and sponsoring organizations of EEGs - Customers / Client: Service providers for energy communities, established EEGs, potential partners such as sector coupling plant operators and aggregators
Features & Use Cases	Feature: Visualization of Energy or Power Balance and Notification of Surpluses User Needs / Benefits: - Users require real-time data to optimize the energy balance of their EEG. - The ability to be notified about surpluses or deficits enables proactive action. Use Case: Display of current energy balance and push notifications - Description: Users can view the current energy balance and receive push notifications about expected surpluses or deficits. - Detailed information: The energy balance is continuously updated, and users can acknowledge the notifications. - Preconditions: Data transmission from the metering points must occur, and users must have the ability to activate flexibilities. - Postconditions: Evaluating the effectiveness of the notifications and checking the actions of the users.
Platform Needs / Benefits	The platform needs features for workflow control, campaign management, and customer interaction via push notifications. This expands the potential for interactions and increases the platform's attractiveness by generating additional data.
Design Requirements	The user interface should convey a sense of energy independence and sustainability and convince users through intuitive usability. Push notifications must be designed not to be intrusive and contribute to a positive user experience.
Minimum Viable Product (MVP) Definition	The MVP includes the visualization of the energy balance and push notifications about expected surpluses or deficits. It aims to quickly gather feedback from users and provide an initial functional version of the product.
Timeline	The implementation follows the timelines of the funding and project plans, as well as the technological requirements and customer needs.
References & Synergies	The platform should be compatible with other systems related to self-consumption optimization to leverage synergies and enable seamless integration.

First Steps Towards Implementation	The initial steps involve mapping metering data to EEGs, collecting data, and displaying the energy and power balance in the app. This forms the basis for additional features and the iterative development of the product.

4.1.6 Market-Driven Demand Response

The concept, shown in Table 12, involves adapting energy consumption to current market signals in order to reduce costs and increase efficiency. By reacting to market requirements, consumers can benefit from cheaper tariffs and at the same time reduce the burden on the energy system. The flexible adjustment of consumption behavior enables the efficient use of energy resources.

Table 12: Key data of the concept "Market-Driven Demand Response"

Feature Title	**Market-Driven Demand Response**
Epic Description	For energy providers researching end-user acceptance of dynamic tariffs (15-minute price), allowing the implementation of Demand Response Management in the SmartU App based on BEENERA, deriving an indicator quantifying the use of a hint for favorable energy consumption. Unlike market-standard tariffs, our solution provides previously unavailable insights into customer behavior and the potential savings compared to a standard tariff (to be defined). Furthermore, simulated dynamic tariffs can also be used to examine customer acceptance and behavior, or determine which information presentation or combinations of time and price achieve high acceptance/application.
Business Outcome Hypothesis | Business Case	Potential Business Model: The energy provider receives an analysis of how end customers respond to dynamic pricing through specific information presentation. The end customer gains a "sense" of "market- & grid-friendly" behavior and is motivated by cost savings representation. With rollout, the distribution network could be relieved through high utilization by end customers. Energy providers can change their procurement strategy with equally high penetration by altering the load profiles of end customers through their adaptive behavior using price-forward curves.
User Needs / Benefits	Due to the current rise in energy prices, customers are looking for ways to save costs. With standard market tariffs on a monthly or

	annual basis, neither monetary effects nor user acceptance of recommendations for action can be quantified.
Leading Indicators	Savings of the customer and switching actions confirmed by the customer and, if possible, statistically validated. Change in customer usage behavior compared to the reference period. (Adaptive behavior) Utilization rate of certain targeted price indications. (Market- or grid-friendly behavior)
Actors	Users: Feature for all end customers with live data. Customers: SmartU Use Case. Partners: Gain insights for energy providers.
Trigger	A price indication from the energy supplier suggests a call to action to the user via the app.
Preconditions	User / smart meter / adapter / legal basis accepted SM adapter installed and functional Permanent data transmission Data storage Data pre-period for learning consumption behavior (machine learning:ML) Individual consumption forecast learned from ML Continuous price indication for a selected period App with corresponding data preparation for end users in terms of the feature Notifications from consumption forecast and price indication in terms of the feature

4.1.7 Childcare

The "Childcare" concept focuses on providing security for relatives of key children by drawing conclusions about the child's presence based on electricity consumption. By measuring the load within a defined focus time, it is possible to determine whether the child has arrived home safely. This serves to provide parents and carers with certainty and minimize potential risks.

Table 6 includes the concept´s key data.

4.2 Optimization of the user interface

The user interface of the SmartU project is realized through the Beenera app (see Figure 5), which has been optimized in another co-creation phase. Sequential usability tests are conducted to actively involve users in the development of the concept. The evaluation focused on the Beenera app and an Elderly Care function.

Figure 5: Home Screen Beenera app

The study was divided into two parts.

In the first phase, a comprehensive analysis of the BEENERA app was conducted using both qualitative and quantitative methods. Qualitative methods included eye-tracking and emotion measurements to understand user behavior during app interaction. Eye-tracking tracked participants' gaze movements to determine which areas of the user interface attracted their attention the most. Emotion measurement was used to capture participants' emotional responses while using the app.

Simultaneously, participants were asked to perform specific tasks related to the BEENERA app. This allowed researchers to assess usability, user intention, and other relevant aspects of the app firsthand. After completing the tasks, participants filled out an online questionnaire to capture their experiences and opinions about the app.

The insights from the study were diverse. Through eye-tracking and emotion measurements, researchers could precisely determine which areas of the BEENERA app's user interface attracted users' attention the most and the emotions they experienced during interaction. Analysis of user activities during task performance provided valuable insights into app usability and identified potential weaknesses or areas for improvement.

Furthermore, evaluation of the online questionnaires provided additional information about user experience and participant satisfaction with the app.

In the second phase of the study, participants were exposed to various scenarios related to a potential Elderly Care function. This aspect of the study focused on addressing the growing challenge of an aging society and the importance of supporting older adults in their familiar homes while ensuring their safety. Technological solutions were explored to meet this need, particularly "Human Activity Recognition" (HAR), which can monitor the daily behavior of older adults to detect potential hazards such as falls early. Such a solution is based on Smart Meter data that monitors electricity consumption and can detect deviations in behavior.

The BEENERA app was used as an example of such a technological solution. This app allows caregivers to be notified via push notifications or alerts when a care recipient may be in danger. However, there have been no studies on how to effectively design these alerts.

The study conducted an experiment with 50 participants to test different versions of alerts and evaluate their effectiveness. Various scenarios were presented indicating different periods of inactivity of the care recipient. The alerts were displayed in green, yellow, and red colors, each intended to evoke different emotional reactions.

The results showed that red alerts were the most effective as they were perceived by participants as an immediate threat. In contrast, yellow and green alerts were confusing. The participants' physiological reactions supported these results, with red alerts showing higher levels of emotional responses such as fear.

In summary, the design of alerts for Elderly Care applications is crucial, and color choice has a significant impact on emotional effect. The study provides important insights for the future development of Elderly Care technologies and emphasizes the importance of user-centered design of alerts.

4.3 Developed Use Cases

This section describes the use cases developed in detail and sets out their objectives, methods and expected results.

4.3.1 Use Case – PV self-consumption optimization with live data

The PV self-consumption optimization use case comprises two main elements: the **PV generation model** (backend) and the detail page for the app user (frontend). Its aim is to provide the end-user with all pertinent information to maximize their consumption of self-generated electricity, particularly during sunny periods. **The feature relies exclusively on data from a bidirectional meter with a sensor**.

PV Generation Model:

- A bidirectional meter is employed to capture both grid consumption and electricity fed back into the grid.

- A sensor on the bidirectional meter provides data on grid consumption (+) and grid feed-in (-).
- In addition to this, the user requires information on consumption and generation, as all four values are necessary to comprehend optimization possibilities.
- The PV model utilizes a "Dichotomizer" to determine household consumption based on measured feed-in, consumption, and modeled PV generation.
- The modeled PV generation values are estimated based on PV parameters and local weather data.
- The determined consumption pattern serves as the basis for Algorithmic Appliance Detection (NILM) and the visualization of self-consumption and self-generation ratios.
- The backend design of the feature allows for the future interoperable exchange of all data sources, potentially replacing modeled generation values with actual readings from the inverter.

Detail Page in the App:

- The user interface and detail page consist of three elements:

(1) In PV onboarding, the user inputs the specifications of their PV system to feed the generation estimator.

(2) The detail page visualizes grid feed-in, consumption, (estimated) generation, and (derived) consumption in a time-series view.

(3) Widgets enable the user to customize their app. For the PV case, the first option provides an estimation of future generation and highlights favorable or unfavorable time periods, while the second option displays a stylized energy flow diagram.

4.3.2 Use Case – Device Failure Detection

Use Case 3 "Device Failure Detection" encompasses a detailed technical approach to identifying defects in devices based on electricity consumption data. Advanced algorithms and data processing steps are employed to detect deviations in power consumption and diagnose potential failures early.

A key element of this Use Case is the "Cooling Check", which is specifically designed to detect defects in refrigeration devices using high-frequency consumption measurements from the Smart Meter, without the need for separate plugs. A specialized algorithm continuously monitors the power consumption of the cooling device and predicts potential failures based on patterns and deviations. **This algorithm is based on machine learning and trained with historical data to recognize failure patterns and notify the user of any detected defects.**

Ensuring the accuracy of the algorithm requires extensive **ground truth data** serving as a reference for the normal operation of the cooling device. These data are used to train the model and ensure it can reliably distinguish between normal operation and a potential failure.

A challenge arises from the fact that many households own more than one cooling device, such as a refrigerator and a freezer. The reliability of failure detection decreases with the number of devices, making it challenging to provide the feature to end customers and requiring ongoing development.

Additionally, an algorithm detects the failure of electricity generation in a PV system solely from the analysis of the **bidirectional meter** with (Ginzinger) sensor. **A PV model calculates a target PV production based on parameters and current weather conditions. A comparison with current measurements determines whether the PV system is generating electricity**. The user receives a corresponding notification in case of detected failure.

4.3.3 Use Case – Home Care / Elderly Care

The use case "Elderly Care" is aimed at providing older individuals and their caregivers with enhanced security by leveraging real-time or near-real-time electricity consumption data coupled with artificial intelligence. The primary objective of this feature is to swiftly identify potential anomalies, particularly inactivity, and to pinpoint potential emergencies based on these observations. At the heart of this use case lies the implementation of the "Inactivity Alert" feature, which targets residents and their trusted individuals. This feature comprises a **two-part algorithm and a state machine that delivers pertinent information within the app**. The first part, the "Activity Recognition," conducts a **minute-by-minute analysis of electricity consumption** to discern human activities. The second part, the "Inactivity Alert," assesses the system's current state based on residents' recent activity and issues warnings to trusted individuals within the app in case of prolonged inactivity. Offering significant value to both user groups, this feature establishes a direct link between residents and their trusted individuals, providing the latter with added peace of mind and security through insights into hourly consumption patterns and notifications of inactivity.

Furthermore, building upon this "Home Care - Inactivity Alert" use case, another use case named "Child Care" has been derived. In this scenario, a user monitors their own electricity consumption and receives notifications regarding activities and inactivities within the app. This use case is particularly relevant for parents expecting a "latchkey child" after school and wishing to track their arrival and activities. The "Child Care" use case represents a straightforward derivation of the inactivity alert and can be easily expanded upon once a proven market demand exists.

4.3.4 Use Case – Potential Awareness Functionality

The present use case aims to uncover energy-saving potentials by precisely and in real-time measuring electricity consumption and to assist users through the app in reducing their energy consumption. Both standby power demand and the individual energy consumption of devices are taken into account to raise awareness of their electricity usage.

A central objective of this use case is to improve the CO2 balance of households. Customers are provided with information on the availability of green energy at specific times to adjust their consumption accordingly. Additionally, incentives are created to promote behavioral changes and optimize energy consumption.

The "Social Comparison" feature allows users to compare their own electricity consumption with that of similar households. This fosters awareness of individual energy consumption and motivates users to change habits to save energy and money.

The implementation of this use case involves the implementation of algorithms and data processing steps that enable real-time analysis and comparison of energy consumption. Data from smart meters are collected and analyzed using **AI methods and device recognition algorithms** to provide accurate information about the electricity consumption of individual devices.

A crucial step is the calculation of comparison values for users' energy consumption. **Statistical analyses** are conducted to compare the consumption of individual devices with a benchmark. By visualizing these comparison values in the app, users can compare their own consumption with the average and identify potential energy-saving opportunities.

4.3.5 Use Case – Optimization of Energy Communities

The implementation of this use case is pending. The project was terminated before reaching the development phase of this use case.

4.3.6 Use Case – Market-Driven Demand Response

To address fluctuations in energy supply, the method of consumer-side load management, known as Demand Response, has been developed. Demand Response aims to regulate consumer loads in response to renewable energy fluctuations. Market-driven Demand Response involves load management through price signals. Its purpose is to elicit a demand-side response, i.e., consumer behavior, to price signals. When prices are high, the goal is to encourage consumers to shut off devices like heat pumps or pause electric vehicle charging, while conversely, loads should be activated when prices are low.

End Customer - Visualize Market Prices: The results of auctions for the next calendar day are retrieved daily around noon from an **API interface to the wholesale market (EPEX electricity exchange**). End-users can choose to view price visualization in the app.

End Customer - Calculate Hypothetical Costs with Market Prices: Another button allows the end-user to **calculate their current consumption (via sensor) against hourly prices to estimate hypothetical cost trends**. This enables customers to compare their actual costs based on real consumption with the potential costs that would have been incurred with a dynamic tariff.

Supplier - Offer Dynamic Tariffs for Billing: The supplier can effectively offer dynamic tariffs to end customers if the necessary data quality and reliability from smart meters are available for billing purposes. Additional processes may be required, as consumption values captured and transmitted by a digital household meter with a sensor may not be sufficiently tamper-proof for effective billing.

The widget is based on an algorithm with a state machine that formulates an interpretation of price changes based on the price trend in the following hours, for example, "Prices will be cheaper tomorrow."

5 Outlook and recommendations

Regrettably, the SmartU project was terminated prematurely before all planned use cases could be fully implemented and tested with end customers. EVUs encountered a shifting landscape due to the energy crisis, characterized by evolving frameworks. These changes introduced complexities and uncertainties, requiring EVUs to reassess their priorities and strategies.

This premature termination resulted in some critical steps towards final implementation and validation with end customers being missed. This circumstance raises questions and leaves open ends regarding the final realization and benefits of the project.

Potential of the Use Cases

Despite the premature conclusion of the SmartU project, it is noteworthy that the identified use cases within the SmartU project have the potential to bring about significant improvements in the field of smart energy systems. This potential is attributed to the fact that the use cases were not developed in isolation; rather, they emerged from a comprehensive co-creation process involving stakeholders. Electricity utilities (EVUs), grid operators, and end customers actively participated in the development of these concepts, contributing their needs and requirements. This close collaboration resulted in practical solutions that were based on the actual needs and challenges of the industry.

One promising use case is "market-driven Demand Response," also known as "Dynamic Tariffs." This innovation, based on real-time data, was intended to enable a direct response from consumers to price signals. By integrating real-time price visualizations and calculating hypothetical costs based on market prices, end customers would have been able to better understand and control their energy costs. This would have not only meant financial benefits for consumers but also facilitated more efficient electricity usage and enhanced integration of renewable energies into the overall system.

Another promising use case is the "Optimization of Energy Communities" using real-time smart meter data. This concept aimed to improve the integration of local energy communities into the overall system. By utilizing live data from individual metering points, participants would have been able to maximize their self-consumption and increase the self-sufficiency of energy communities. This would have contributed not only to increasing energy efficiency but also to strengthening the resilience of the energy system as a whole.

Implementation and Testing with End Customers

It is regrettable that the implementation and testing of the use cases with end customers could not be realized. The experience of actual application in practice would have provided valuable feedback and enabled the identification of weaknesses and opportunities for improvement.

However, the developed use cases serve as a solid foundation for future projects in the field of smart energy systems. Although the SmartU project was prematurely terminated and the planned implementation did not fully materialize, the concepts developed can serve as a guide for further initiatives grappling with similar challenges.

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