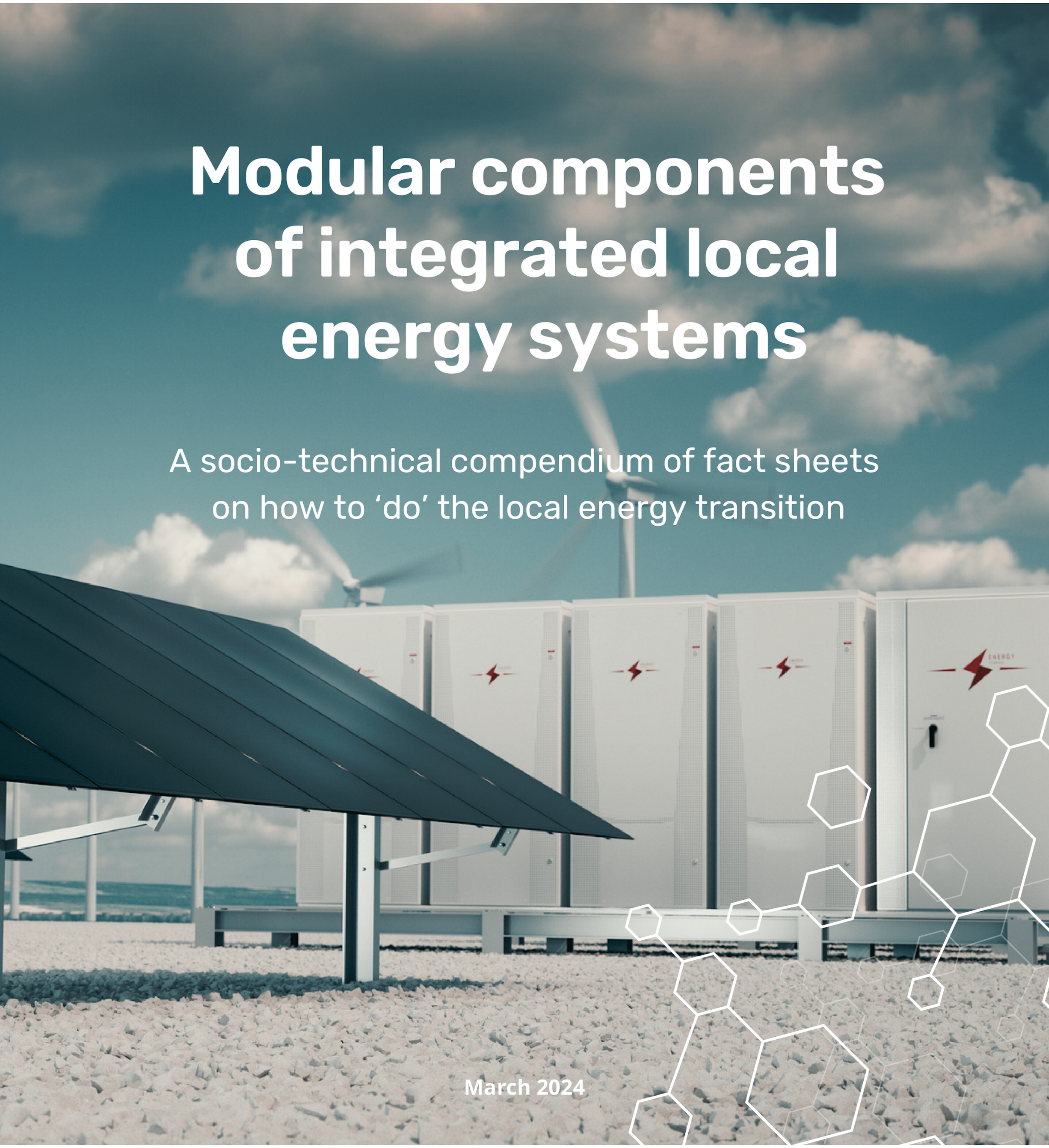
SERENE

SUSTAINABLE AND INTEGRATED ENERGY SYSTEMS IN LOCAL COMMUNITIES



Modular components of integrated local energy systems

A socio-technical compendium of fact sheets on how to 'do' the local energy transition

March 2024

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#H2020SERENE

www.h2020serene.eu
contact@h2020serene.eu

enlit.world/projects/SERENE

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Project partners:

Editorial Team
Birgitte Bak-Jensen, Aalborg University
Ewert Aukes, Uniwersity of Twente
Katherine Brooke Quinteros, Aalborg University
Katarzyna Bogucka-Bykuć, Institute of Fluid-Flow Machinery Polish Academy of Sciences

Introduction

Ewert Aukes, University of Twente
(e.j.aukes@utwente.nl)

To achieve a more sustainable energy system as soon as possible, citizens need to know how they can contribute. The energy sector has the largest contribution to greenhouse gas emissions of all sectors. As we need energy for many things we do in life, we must reduce the emissions from that sector drastically, if not to zero. This requires action on all levels and in all sectors of society. Governments, companies, and citizens need to contribute. One way for citizens to contribute to this cause, is by organising themselves with others to scrutinise their local energy system and effect changes within their sphere of influence.

More and more digital technologies are available to support citizens in making these changes in their local energy system. With digital technologies added this is also called an 'integrated local energy system'. In other words, such digital technologies make the energy system 'smart'. Among others, the European Union (EU) is stimulating research into these possibilities. As the EU-funded SERENE project, we want to share our knowledge and findings about possibilities for citizens to use smart technologies to gain more insight in their local energy systems.

The H2020 SERENE project aims to accelerate the energy transition. The project's objective is to demonstrate cost-effective and customer-centric solutions for the effective integration of different energy system carriers to enable the sustainable development of regional communities via meeting their energy needs from local sources of renewable energy. How are we going to achieve these goals?

- By activating locally available distributed generation, demand response resources, energy flexibility and energy storage technologies in various energy domains e.g. electricity, heat, water treatment and transport, and focusing on attractive citizen-centred business models and local economies.

- By demonstrating smart technological, socio-economic, institutional, and environmental solutions to enable the local management of integrated energy systems and networks; which in turn utilise, utilisation of higher shares of local renewable energy and incorporate active consumer engagement in real neighbourhoods across 3 different EU countries.
- By introducing leading to the market introduction replicable and replicability of the innovations for in other energy communities across Europe and beyond.

The specific goal is to establish locally integrated "energy islands" in the different villages of Skanderborg (Denmark), Olst (the Netherlands) and Przywidz (Poland). Such "energy islands" will contribute to the decarbonisation of local energy systems via the optimal integration of multi-energy carriers through smart control and the balancing of systems and grids at the local level.

As a result of the experiences gained at the demonstration sites, before you lies a compendium of technical, social and organizational components for local energy systems as we researched and applied them in our project. The purpose of this compendium is for you, interested and engaged citizens, to see possibilities and discuss among each other how a sustainable local energy system could look in your place. The compendium is not meant as a one-size-fits-all solution to make local energy systems sustainable. You are always tied to the current legal, political, social, and economic situation. So, not all components might make sense in your case. Furthermore, the components should be seen as exemplary. Some of them are already operable, others are still under development. They are supposed to trigger your imagination about what the starting points are in your concrete situation. The authors are always happy to interact and discuss.

The compendium contains fact sheets about the following topics:

Technical

Social / organisational

Business model

Stakeholder engagement

Technical

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Community Energy Management System

Morten Veis Donnerup, NEOGRID
(mvd@NEOGRID.dk)

Strengths & weaknesses

Strengths	Weaknesses
Optimized utilisation of energy	Added initial cost
Decreased load on local electricity grid	Lack of consumer awareness
Scalable infrastructure	Increased technical complexity
Reduced energy consumption	
Reduced energy costs	

Purpose

Heating systems in buildings are becoming increasingly dependent on electricity, as well as more complex with the addition of elements such as electric vehicle charging and the intelligent planning of electricity consumption becoming involved. A "Community Energy Management System" (CEMS) can help by optimising the interaction between the connected electricity system components to better match the requirements of the building and its inhabitants.

Short description

The Community Energy Management System (CEMS) is a cloud service offered by NEOGRID that enables the intelligent control of all the connected electricity system components. It does so by constantly monitoring the local production and electricity prices and selecting the optimal moments to buy from or sell to the grid. The CEMS, thereby, decreases the cost of imported electricity, increases self-consumption and reduces the peak load on the local electricity grid.

Requirements

- Controllable system components need to be able to connect with the NEOGRID CEMS via a programme interface from API, HW or MODEL: API: the integration is done from the manufacturer's cloud to NEOGRID's cloud.
- HW: the asset connects to a local NEOGRID IoT gateway by MODBUS, mBus or other.

MODEL: we combine the physical characteristics of i.e. a PV system and the local weather forecast to predict the performance of the asset. Legal considerations

The NEOGRID CEMS software and infrastructure is owned and operated by NEOGRID and can be licensed to end users and/or 3rd party.

Link to other components

The NEOGRID CEMS can connect to and steer a broad range of assets. In the SERENE project it will be demonstrated to interface with the following assets:

- Heatpumps controlled via HW and API interface.
- Thermal batteries via HW.
- The building's heating system via HW and MODEL.
- PV systems interfaced via HW and MODEL.
- Electrical batteries via HW and API.
- EV chargers via HW and API.
- EV's via API and MODEL.

DANISH DEMO

Public meeting to engage citizens from local villages in the energy transition

Susanne Skårup, Skanderborg Municipality
(susanne.skaarup@skanderborg.dk)

Strengths & weaknesses

Strengths	Weaknesses
Efficient tool to inform and engage local villages (in collective heating)	Costs of screening heating possibilities
Enables sharing of knowledge and experiences	High costs in terms of time and resources to hold such meetings and perform adequate follow-up
Identification of interested people for further engagement	Increased technical complexity
Creates networks of interested people within the community and in each village	

The purpose is to help citizens convert from conventional heating (i.e. using oil and gas) to more climate-friendly, preferably collective heating systems (i.e. district heating and community heat-pumps) to increase the drive towards the energy transition. Community based heat pump, reduces noise pollution and supports households without the financial capacity to invest in individual heating systems. When the municipality does not have a public district heating company, the locals have to establish a company themselves or cooperate with a company that will help them.

Short description

A typical agenda for the public citizen meeting about alternatives to conventional heating systems or if they are unable to connect to district heating could look like this:

1. Presentations on:
    - Plans for district heating in the municipality.
    - The individual heating solutions (i.e. different types of heat pumps) and the associated benefits, specifically energy savings from increased efficiency and noise reduction.
    - Termonet (i.e. a common ground heat pump solution. See more on www.termonet.dk)
    - Results for screening of heating possibilities for each village
    - Examples from already active local villages on common heat solutions.
2. Stimulate a dialogue between the citizens from the same village, seat villagers at the same table.
3. Summary in plenum.
4. Offer possibilities to seek funding for the process for each village and provide a contact person at the municipality to help the villages with any questions on regulations and permits etc.

Fig. 1 Meeting of citizens in the Municipality of Skanderborg in Denmark, (Susanne Skaarup, 2023).

As a result of these meetings, the villages became active in working for a common heating solution in their village. Skanderborg Municipality helped them to successfully apply for external funds to support their project. Now the Municipality also established a fund that the villages can use to support the process.

The village must:

- Establish a group of active citizens.
- Create a support group: hold meetings, via Facebook-groups, in the local news.
- Provide information on the possibilities (here paid by the municipality).
- Hold ongoing citizen meetings to provide new knowledge and probe levels of support as things progress.
- Gather knowledge via for e.g. a questionnaire to determine the levels of local support and/or results of consultant report on economy.
- Establish a company or find an existing district heating company to perform the establishment and operation of a collective heating system.

Requirements

- People who actively want heating alternatives, and who live in villages without district heating. These people must be able to activate their local community.
- Financial resources to hire an energy consultant for assessing the heating situation and identifying the possibilities within each larger village (e.g. >100 houses). Preferably also, the financial resources required to conduct a deeper calculation of the economic costs of the collective heating system.
- Access to facilities with AV-equipment for presentations and the capacity to host lots of people at round tables.
- Detailed recording of the the meeting, including a registration form which documents each village where the participants live. Preferentially with e-mails so follow up contact can be made afterwards.
- A subsidy scheme for active villages to apply to, if they form a group of active citizens with a committed interest to establish a common heating system.

Legal considerations

In Denmark you are not legally permitted to make a profit on heating. So, the heating company must be economically self-sufficient.

DANISH DEMO

Flexible EV charging management system

Rakesh Sinha, Birgitte Bak-Jensen, Sanjay Chaudhary, Aalborg University
({rsi, bbj, skc}@energy.aau.dk)

Strengths & weaknesses

Strengths	Weaknesses
Adaptive Control based on electric grid requirement and EV battery status.	Risk of cyber-attack and data theft potential.
Supports grid voltage regulation and alleviates congestion.	Limited consumer participation due to "range anxiety" and battery degradation issues.
Possibility of remote control of charging as well as autonomous charging modes.	Need for the charging infrastructure in the residential sector.
Low price for customer.	Limited public car charging infrastructure available with flexible rates based on market and electric grid status. (Mostly available with fixed price).

Purpose

Distributed electricity generation (e.g., through household-level solar panels) and shifting energy service demands (e.g., more and more EV charging stations in addition to other flexible loads, both public and private) create new challenges for the electrical grid. Furthermore, it is desirable to minimise the cost of electricity for charging electric vehicles. Flexible EV charging management systems can support the operation of the electricity grid and simultaneously reduce the overall cost of charging EVs.

Short description

The flexible EV charging management system is installed at the charging station. The system adjusts the car charging according to the current energy price and electricity grid voltage. Users can set their individual charging or V2G preferences through a mobile app or via manual entry, where they can switch the system on or off, or adjust settings. The in-built flexibility reduces the necessity of grid reinforcement through the assumption that users will choose to charge their vehicle when prices are low, if possible. Thus, the system creates the prerequisites for users to participate in the electricity grid market and to take advantage of variable electricity prices according to their own priorities and preferences. The EV charging controller responds to the local grid conditions to avoid low voltage and grid congestion, while promoting grid balancing, renewable energy generation, electrification and sector coupling.

Requirements

- Electric vehicle.
- Charging station with the integrated control system installed.
- Communication medium (e.g., internet) for information exchange in real-time or preloading the information before charging starts.
- User consent and contract for operation flexibility and data handling.

Legal considerations

- User consent for data handling and remote operation of EV charging.
- User contract with the aggregator or energy retailer (balancing responsible) for EV charging.
- Obey the electricity standard for electricity chargers, e.g. in DK: https://www.retsinformation.dk/eli/lta/2016/1082

Link to other components

Fact sheet on Distribution grid flexibility: it reflects the technology adapted for flexibility in energy generation, consumption and storage.

Additional comments

Figure 1 shows the architecture of V2G (vehicle to grid) when the EV is connected to the charging station. The charging station is shown as the red dotted line. When the EV is connected for charging, the controller within the charging station monitors the status of the EV battery and accepts the user input such as estimated time of departure, and minimum charge level of EV required before departing time, along with options to participate in grid flexibility for voltage and frequency control and grid support. Based on the information provided by the user, the priority for charging the EV is set along with the charging schedule generated online through cloud computing or designated apps.

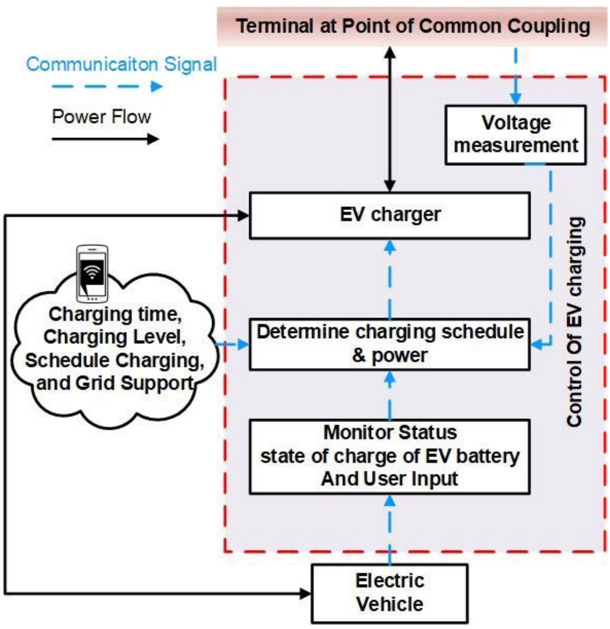

Fig. 1 The architecture of V2G (vehicle to grid).

DANISH DEMO

Enabling more flexible energy service demand by consumers

Rakesh Sinha, Birgitte Bak-Jensen, Sanjay Chaudhary, Aalborg University
({rsi, bbj, skc}@energy.aau.dk)

Strengths & weaknesses

Strengths	Weaknesses
Flexible and independent.	Cyber security threat and data protection issues.
Accommodate a large share of renewable energy sources.	Limited consumer awareness and participation.
Ability to feed in other energy sources.	Coordination and control of complexity.
Low loss and cost-effective.	

Purpose

The production of renewable electricity and changing energy service demands in the distribution grid may create bottlenecks in the form of congestion and poor voltage regulation due to overloading of the feeders. The problem arises as the intermittent nature of renewable electricity generation and electrification of transportation and district heating systems. In addition, the production and consumption of electricity need to be balanced instantaneously. Therefore, technical solutions are required to impart flexibility to the demands for electrical energy. Some of the ways in which this can be achieved is through power system flexibility and 'sector coupling', which refers to the integration of various energy sub-systems (i.e. electricity, heat, and transportation), with the objective to gain mutual benefits to support their stable and secure operation.

Short description

The consumer can become actively engaged in demand side management. Incentives and motivation can be provided to consumers for their contribution to increasing their flexible energy service demands, so that the peak demand in the distribution grid is reduced and moved to off-peak periods, where demand is low, or during periods of surplus generation. Such peak shaving of energy demand better enables the utilisation of the generation of renewable energy and the power distribution system. At the same time, the intelligent management of the demand should impart negligible or minimum discomfort to the consumers. The users are therefore incentivised to increase their flexible demand of electric energy e.g. from their EVs, heat pumps etc. Likewise, they can become interested in installing energy storage devices like battery units and rooftop generation from photovoltaic panels.

Requirements

A legal contract between the user and the responsible party is required to handle the flexible load and generation based on the electricity market and grid requirements. User consent is also required to handle data on energy usage and requirements. Appropriate devices may be required to be installed for the control of flexible loads, including storage possibilities and generation sources remotely. Such devices may be controlled by an app on a mobile or a computer.

Legal considerations

- User consent for data handling and flexible operation of devices.
- Anonymisation and encryption of the user data collected by the system operators/ aggregators or retailers.
- Contract with aggregators or retailers to be able to provide the flexibility service to the grid and act on the electricity market.

Link to other components

Fact Sheet on PCM Storage and Electric Vehicle flexibility which describes the actual method for provision of flexibility from these devices.

Additional comments

The electricity system needs to keep the balance between power consumption and production at all times. This is ensured via bidding on the electricity market (Fig. 1).

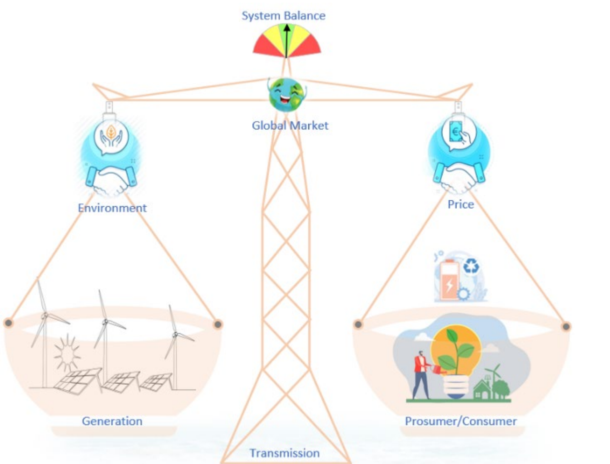

Fig. 1 Synergies between generation technologies, market structure, transmission system, and loads (Power System Flexibility).

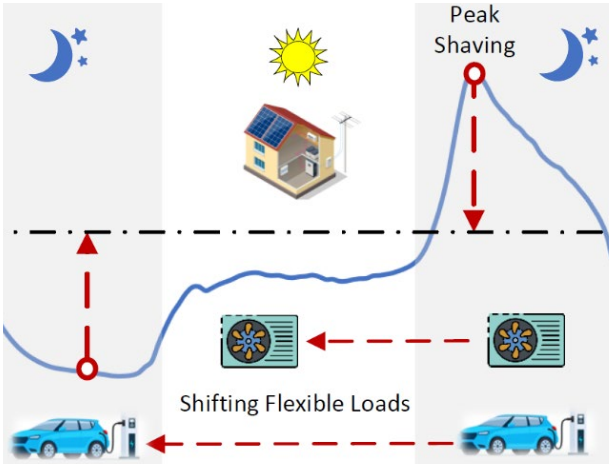

Fig. 2 Demand Side Flexibility.

With more renewable energy and the variable power production that comes with it, we need to make electricity consumption more flexible to ensure the balance. This cannot be done without the active participation of consumers. Normally, aggregators or retailers, who are bidding on the market on behalf of their customers, aggregate how much electricity their customers need, and procure the necessary power at market price. When there is an abundant supply of electricity, the market price drops (low price periods). The cost of electricity can be minimized if shares of consumption can be shifted to the periods when there is excess production of renewable energy. This, in turn, reduces electricity consumption in periods with low supply and high prices. However, increasing the market share of local electricity production and consumption of new energy services (e.g., heating with heat pumps or EV charging) can lead to congestion of the electricity grid due to too much electricity supplied by local sources. This congestion can be partially tackled with "peak-shaving", which is the activity of moving electricity consumption from high-demand periods to low-demand periods (Figure 2).

DANISH DEMO

Thermal energy storage based on Phase-Change Materials (PCM)

Rakesh Sinha, Birgitte Bak-Jensen, Sanjay Chaudhary, Aalborg University
({rsi, bbj, skc}@energy.aau.dk)

Strengths & weaknesses

Strengths	Weaknesses
High Energy Density reduces the size of the storage unit.	Lifetime unknown.
Non-flammable, safe handling.	Limitation in the rate of energy exchange.
Nontoxic and biodegradable.	Expensive.

Purpose

The large sizes required by thermal energy storage systems is still a barrier to their widespread application. So, storage systems requiring a smaller area/volume per unit of energy are preferred over larger ones. This is the case for PCM storage. It stores more energy compared to the same size of the popular hot water thermal storage tanks.

Short description

Thermal energy storage systems based on hot water have poor energy density and so their volume is large. Phase Change Materials (PCM) have a large latent heat capacity. Hence, they exchange a large amount of heat energy at a constant temperature as they change their phase (e.g. melting or freezing). PCM material is integrated with a hot water storage tank to increase its thermal storage capacity, thereby reducing its size. Combined with other heating devices, such a storage system can apply power-to-heat to optimize power consumption based on energy prices/availability. Integrating such a thermal storage system with heat pumps or electric boilers makes it suitable for the flexible operation of distribution grids by increasing their hosting capacity, or for balancing the electricity market.

Requirements

Adequate space is required for the installation of PCM storage tanks (300-1000 litre for xx kWh energy), heat pump, and control device. The number of storage tanks and heat pumps varies based on daily energy requirements and flexibility needs. Electrical power capacity can vary depending upon the requirement and can be between the range of 2-6 kW for the larger installations (normally 3-phase systems), and for smaller heat-pumps up to around 3 kW (single-phase connections) based on EU standard electricity supply.

Legal considerations

- User consent for data handling and operation of devices.
- In Denmark you can apply for economic subsidies for installations of heat-pumps (https://www.vp-ordning.dk/boligejer/sadan-far-du-tilskud-til-din-varmepumpe)
- There are several standards and rules to obey when installing a heat-pump (eg., in Denmark https://www.vp-ordning.dk/installator/love-og-regler

Link to other components

Factsheet on distribution grid flexibility, which deals with the technological aspects of attaining flexibility.

Key references

R. Sinha, P. Ponnaganti, B. Bak-Jensen, J. R. Pillai, and C. Bojesen, “Modelling and Validation of Latent Heat Storage Systems for Demand Response Applications”, CIRED 2023 International Conference & Exhibition on Electricity Distribution, Rome, 12-15 June 2023.

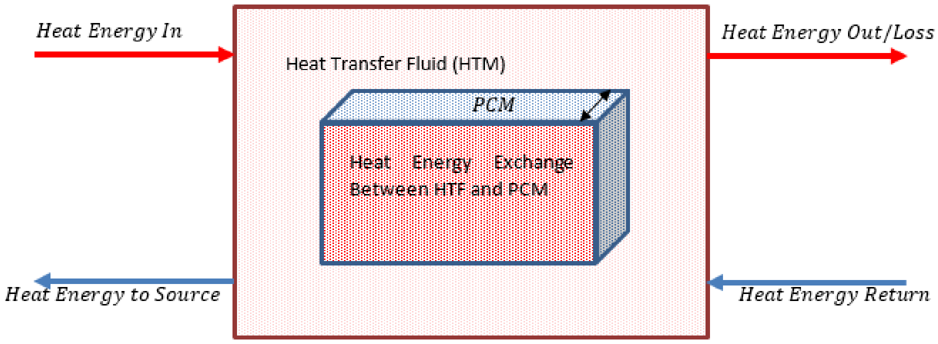

Fig. 1: Schematic of PCM storage tank with energy flow

Additional comments

Figure 1 shows the schematic of PCM storage with energy flow. PCM material is arranged inside the thermal storage tank. The heat energy is transported from the heat source (heat pump) to the thermal storage tank and to the customer using water as a heat transfer fluid (HTF). When the incoming heat energy is more than the heat energy out and losses, the extra energy is stored in the PCM (phase change material) which can store more energy compared to the same volume of water. Thus, when no heat is required and the energy price is low, heat energy is stored in the PCM tank, whose size is comparatively smaller than a traditional hot water storage tank.

DUCH DEMO

A holistic socio-technical local energy systems approach

Frans Coenen, University of Twente
(f.h.j.m.coenen@utwente.nl)

Strengths & weaknesses

Strengths	Weaknesses
Explicitly considers the suitability of technical solutions for a given system.	A holistic socio-tech system approach makes system change more complex.
The holistic perspective shows that a change in one system component, no matter if technical or social, affects other components directly or indirectly.	A holistic system approach needs both specific and broader knowledge about the system.

Purpose

The purpose of the holistic socio-technical local energy system approach is to connect technical change with social and organisational factors. And to draw attention to social dynamics in local energy system change.

Short description

Creating or initiating integrated local energy systems which are truly ‚socio-technical', means striking a balance between changing the technical components of a local energy system and its social and organisational components. It may also mean a change to those social and organisational system components. Perspectives prioritising technical change in local energy systems see social factors as obstacles to be overcome to successfully implement technical innovations. For instance, policies, regulations and costs are seen as conditions that need to be changed to make technical changes possible. However, local energy systems do not only consist of concrete or physical entities in the real world. Changing a local energy system also faces social and cultural barriers.

Requirements

To develop a local energy system as a combination of a physical-technical system and the complex social system around it, we need to apply a holistic perspective that considers the co-evolution of different system elements. From a holistic perspective, a change in one system component, no matter if technical or social, affects other components directly or indirectly. It is essential to understand each component to get a holistic perspective. A holistic perspective means that technical innovations consider the suitability of the technical solution for a given system, for instance, how different usage patterns or market coordination mechanisms affect system processes. We need to consider the non-technological dynamics of energy transitions which might play a role in the implementation of the technical innovations. A list of general socioeconomic, governance and regulatory factors that influence changes in the local energy system is a starting point for incorporating components into their integrated local energy system (Figure 1).

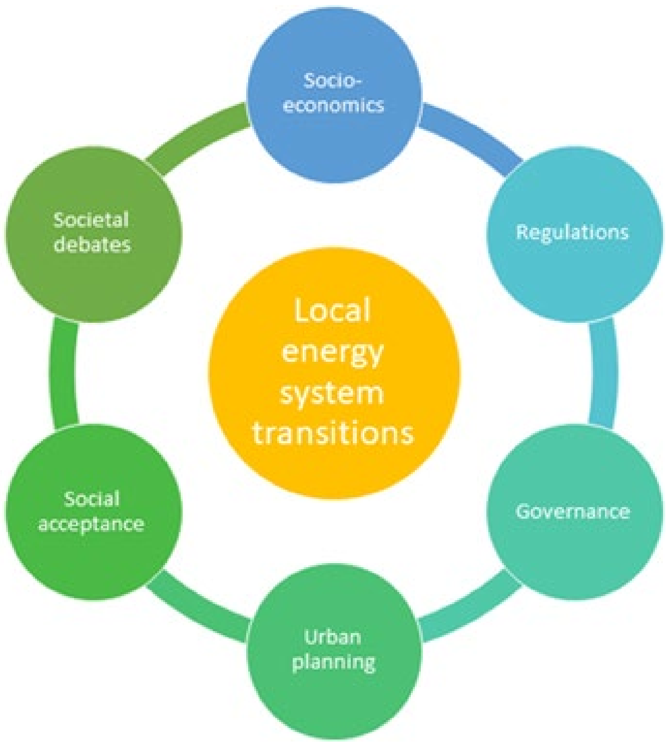

Fig. 1 The social science perspectives to assess social factors that affect the local energy system change.

Legal considerations

The new integrated local energy systems in the energy transition ask for low-carbon, decentralized, digitalized and citizen-centred solutions. These new integrated energy systems do not fit neatly into today's policies, regulations or rules, which were designed for more centralized energy systems characterized by large-scale energy providers. These often broader regulations and policies cannot be changed at the local level. Interventions on the national or EU level are needed to address a wide range of regulatory issues related to their specific technological or social innovations.

Link to other components

A holistic system approach is relevant for all technical and social components. From a holistic perspective, a change in one system component, no matter if technical or social, affects other components directly or indirectly. The factors identified below can present obstacles to the implementation of specific technical or social innovations or to the overall local energy transition, as well as lead to unintended side effects of innovations, e.g., the marginalization of vulnerable groups.

Additional comments

Socio-economic factors, including the personal circumstances and motives of individual citizens and the interactions between technology and the energy market, influence energy consumption patterns and can create incentives for investments in the local energy system.

Regulatory factors are predominantly related to the mismatch between the existing regulations, which were originally designed for fossil fuel-based energy systems, and the regulations needed to facilitate local energy systems based on renewable energy sources, including corresponding market regulations.

Governance factors cover a range of factors related to the polycentric nature of energy governance, with transition processes including various institutions and actors across different levels, each of which may influence the local energy system transition. It is, therefore, crucial to account for the role of different actors and institutions in the energy transition processes and to ensure opportunities for the active participation of local residents, and to account for emerging self-organization structures and the heterogeneous energy visions and preferences of the local community and actors.

Urban planning factors revolve around the decentralized local energy system as a new contender for urban land use, and the need to integrate energy and urban planning in multi-sectoral and multi-objective considerations.

Social acceptance factors relate to people's perceptions, attitudes, and thoughts towards a social transformation of energy, which determine likely positive or negative community reactions to the local energy system transformation.

Societal debate factors reflect on the changing role of citizens in the local energy system transition and cover issues related to notions of discourse, socio-technical imaginary and citizen empowerment.

Key references

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DUCH DEMO

Empowering communities by collaborating on energy solutions

Ferdi Hummelink, VAON, Javier Ferreira Gonzalez, Saxion UAS, Katherine Brooke Quinteros, Aalborg University, Bart Homan, Saxion UAS
(ferdi.hummelink@aardehuis.nl, j.ferreiragonzalez@saxion.nl, kbq@adm.aau.dk, b.homan@saxion.nl)

Strengths & weaknesses

Strengths	Weaknesses
Strong commitment to energy experiments within the Aardehuizen demonstrator.	The decision to stop committing to the project is also possible (even if it is unlikely in this case).
Feedback on and cooperation with the project demonstrator.	The unique circumstances surrounding this demonstrator could prove difficult to replicate elsewhere.
Project partner that is also inhabitant of the demonstrator-project (high commitment).	

Purpose

A demonstrator (in our case the Aardehuizen community residents), as envisioned in the SERENE project, is completely dependent on the participation and cooperation of the inhabitants, so collaboration, co-creating and engagement activities with the inhabitants is crucial for the success of the demonstrator and the efficacy of the provided solutions. The purpose of collaboration and co-creation in this way is engaging the residents to improve the research and invite criticisms as opportunities for improvement.

Fig. 1 The Aardehuizen Community (VAON).

Short description

The residents of the Aardehuizen community have quite a unique outlook on life and it is their distinctive participation and engagement that makes the Aardehuizen demonstrator possible. As a community, the Aardehuizen residents strive in general towards being self-sufficient and sustainable, in an energy-sense this means that they strive to avoid using any energy from the Dutch national grid, and even want to share their excess energy with others via the existing grid, but as locally as possible. To achieve their goal, the Aardehuizen residents accept a higher than average “level of discomfort”, for instance, if there is insufficient hot water available, this is no reason for complaint, one can take a hot shower later or settle for a cold shower. Their unique outlook, characterized by resilience and a shared commitment to sustainable living, not only defines their lifestyle but underpins the very essence of the co-creation process to develop solutions for the energy transition. The Aardehuizen residents actively engage in shaping and refining the very solutions that will empower them and others. Together, they are not merely developing a dashboard or mobile application; they are collaboratively crafting a future where sustainable energy is not merely a vision but a tangible reality.

By their very nature, the experimental technology, concepts and solutions developed in the SERENE project are perfect for use in the Aardehuizen demonstrator. When, technical issues and unexpected consequences of the control behaviour occur, which can for e.g. cause shortages of hot water with a negative impact for the users’ comfort, the way in which the Aardehuizen users respond has a large impact on the research and researchers. Their acceptance and reporting of an issue is far more constructive and helpful for the research than dissatisfaction and discontinuation of the experiment.

The Aardehuizen user’s ability to accept and aptly report such issues is profoundly insightful, providing invaluable data for the iterative refinement process of the technical solutions. In this intricate synergy between technology and user interaction, for example the co-creation of dashboards and mobile applications with the inhabitants assumes a central user-centric role.

Through this collaborative endeavour, complexities are navigated and the user perspectives are incorporated into the design and implementation throughout the iterative cycles. This symbiotic relationship not only enhances the technical robustness of the solutions but also enriches the understanding of user behaviour and preferences (personalized solutions). The resulting dialogue cultivates a nuanced comprehension, ensuring that the solutions are not merely technically sophisticated but also incorporate the results from the communities successfully lived experiences. In essence, the co-creation research transcends the realms of mere technological innovation, evolving into a holistic exploration. Here, the confluence of state-of-the-art technology and nuanced user insights paves the trajectory for the development of innovative, user-centric solutions.

Another important part is the role of the Aardehuizen project coordinator who is an inhabitant of the Aardehuizen community. He is therefore able to interact with the other residents on a level that e.g. members of the research institutes can't. He can both discuss the project and ease tensions about it with his fellow residents, as well as voice concerns or praise about the project to his fellow SERENE project members.

An unforeseen benefit is that some of the (more tech-savvy) residents have offered their help in the installation of the boiler-control, energy storage and EMS systems. And, as the residents know the setup of the energy systems in their homes very well, and in some cases have installed these themselves, who would be more suitable for helping make the necessary changes?

Requirements

The Aardehuizen inhabitants have embraced the concept communal tasks should be managed by residents who consider themselves as the "problem-owner". In order to facilitate effective coordination, specific roles are appointed to specific inhabitants. Thus, among the residents, there is a SERENE-coordinator overseeing general responsibilities, a technical person for the installation and maintenance of the battery system and a treasurer for handling the financial transactions related to the overall SERENE project, with a specific focus on the EV-loading stations.

Additionally, a dedicated working group known as the Electricity team, takes on the comprehensive management of electrical systems at Aardehuizen. This group convenes on an as-needed basis, preparing agenda-items for the general assembly of inhabitants covering various aspects such as energy-use, monitoring and investments or maintenance of the electrical infrastructure.

Integral to their approach are co-creation workshops (Figure 2), conducted periodically between Aardehuizen residents and members of the SERENE project research institutes. Rather than merely seeking feedback, they actively foster collaboration, striving to create a shared vision—a digital ecosystem that accurately reflects the unique perspectives, aspirations, concerns, and values of Aardehuizen inhabitants. These workshops play a crucial role in tailoring technical solutions, such a mobile apps or dashboards, to the individual needs of community members. Personalization is not just a feature; it's our commitment. Each dashboard and app, is a bespoke solution, designed to optimize energy consumption and promote sustainable energy consumption habits unique to each user. Actively involving communities in the creation process ensures that they take ownership of the solutions, generating a sense of belonging and transforming passive users into proactive advocates for sustainable living.

Fig. 2 Co-creation workshop Aardehuizen inhabitants.

Achieving a high level of energy self-sufficiency, peak shaving of energy-use and –production are key objectives for Aardehuizen. The success of peak shaving goes beyond technical measures such as automated control of household appliances; it relies heavily on behavioural aspects, including the acceptance and practical use of complicated and invasive energy management systems (EMS). To ensure continued engagement, each household is equipped with an easy to understand and flexible EMS dashboard. In the event of questions or concerns they need not resort to a remote helpdesk; instead, they can directly contact a resident expert from the user group of inhabitants that has an affinity with the EMS-system. This approach fosters a sense of community involvement and ensures that residents can navigate the systems with confidence and convenience.

Legal considerations

There is a standard agreement between the Aardehuizen residents and SERENE members on which data can be used, and how it can be published. However, two important aspects play a role, first there is a long-standing relationship between the Aardehuizen residents and some members of the research institutes, where a mutual trust has been developed over the course of several previous (EU) projects. Second, the Aardehuizen project coordinator was able to ease the concerns voiced by some reluctant residents.

Link to other components

In the Aardehuizen demonstrator, the heat production from e-boilers in the residences is controlled using the boiler controller and the optimization algorithms in DEMKit to (ultimately) optimize the energy usage of each residence. In the case of the boiler controller, the residents have invited us to their homes to modify their existing boiler setups. In the case of the optimization algorithms, the residents allow us to control their boilers, accepting possible negative side-effects.

Key references

Vereniging Aardehuis - https://www.aardehuis.nl/

DEMKit - https://www.utwente.nl/en/eemcs/energy/demkit/

Social / organisational
Stakeholder engagement

DUCH DEMO

Open Dynamic Electricity Composition Tracker (ODECT)

Bas J. Jansen, Edmund W. Schaefer, Gerwin Hoogsteen, University of Twente (g.hoogsteen@utwente.nl)

Strengths & weaknesses

Strengths	Weaknesses
Provides better insight into CO2 emissions from the national electricity grid.	No real-time insight due to delay in data from sources.
The model is based solely on publicly available data.	No ground truth as it cannot be measured.
Open source available.	Currently lacks predictions to act upon.

Purpose

The Open Dynamic Electricity Composition Tracker provides insight and awareness to customers, businesses and energy communities into the CO2 footprint of their imported electricity. In the future, it will not be enough to perform a bookkeeping of annual energy production and consumption. Due to daily fluctuations, and seasonal and weather variance, it becomes necessary to match our consumption in time with renewable generation (see Figure 1). It has been shown that dynamic electricity prices from the day-ahead markets correlate weakly with the emissions from the electricity mix [3]. Open access to such information is of utmost importance to our society, as the information can lead to concrete actions by stakeholders to reduce our greenhouse gas emissions. That is also why the tool is made open source.

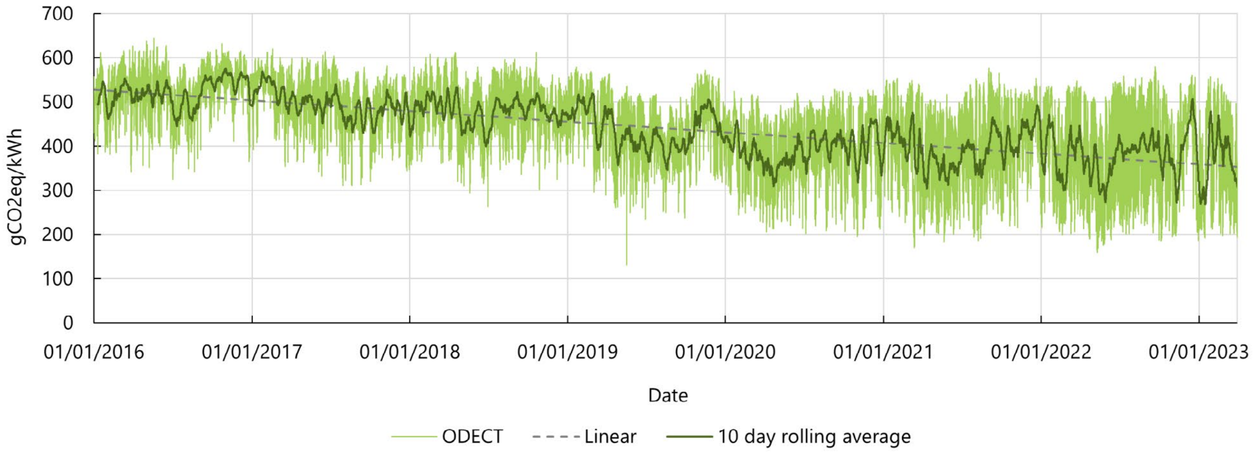

Fig. 1 Description.

Short description

Electricity needs to be imported from the national electricity grid when local renewable production is not sufficient. Depending on the time of the day and season, this electricity may be generated using high CO2 emission power plants such as those that use coal, lignite, and natural gas. The Open Dynamic Electricity Composition Tracker (ODECT) [1,2] uses the known electricity generation mix to calculate the equivalent CO2 emissions for each kilowatt-hour of electricity imported from the Dutch main grid. ODECT also provides insights into the different energy sources and fluctuations, both daily and seasonally.

Requirements

The tool requires appropriate licenses from the data sources it depends on. Technical skills from software engineers are needed for the deployment and potential integration of the tool. A more user-friendly dashboard is envisioned in the future.

Legal considerations

In principle there are no legal considerations applicable for the model and tools themselves. The Apache Version 2.0 License applies to the code. In some applications, the data sources on which the tool depends may require a (non-free) license, depending on the application and business model used.

Link to other components

The provided output of the tool may be used in business case calculations, stakeholder engagement, and social/organisational discussions on how the behaviour of people in an energy community can be changed. In the latter, it serves as input for discussion and thoughts on what is possible. Also, for some business cases, end-users value a reduced carbon footprint, for which this tool can provide the calculations.

From a technical perspective, the tool can be used as input for energy management, e.g., to optimize run-times of heat pumps and smart charging of electric vehicles. This has the potential to directly tap into business cases that target a different audience than is often considered, one that that is more environmentally motivated. The resulting data may also be used in novel displays that aid users in their conscious use of electricity, e.g., through delaying a washing machine after consulting a display indicating the CO2 emissions (Figure 2). For many applications it is advised to create CO2 emission forecasts, e.g., using machine learning models, to be able to steer consumer behaviour proactively.

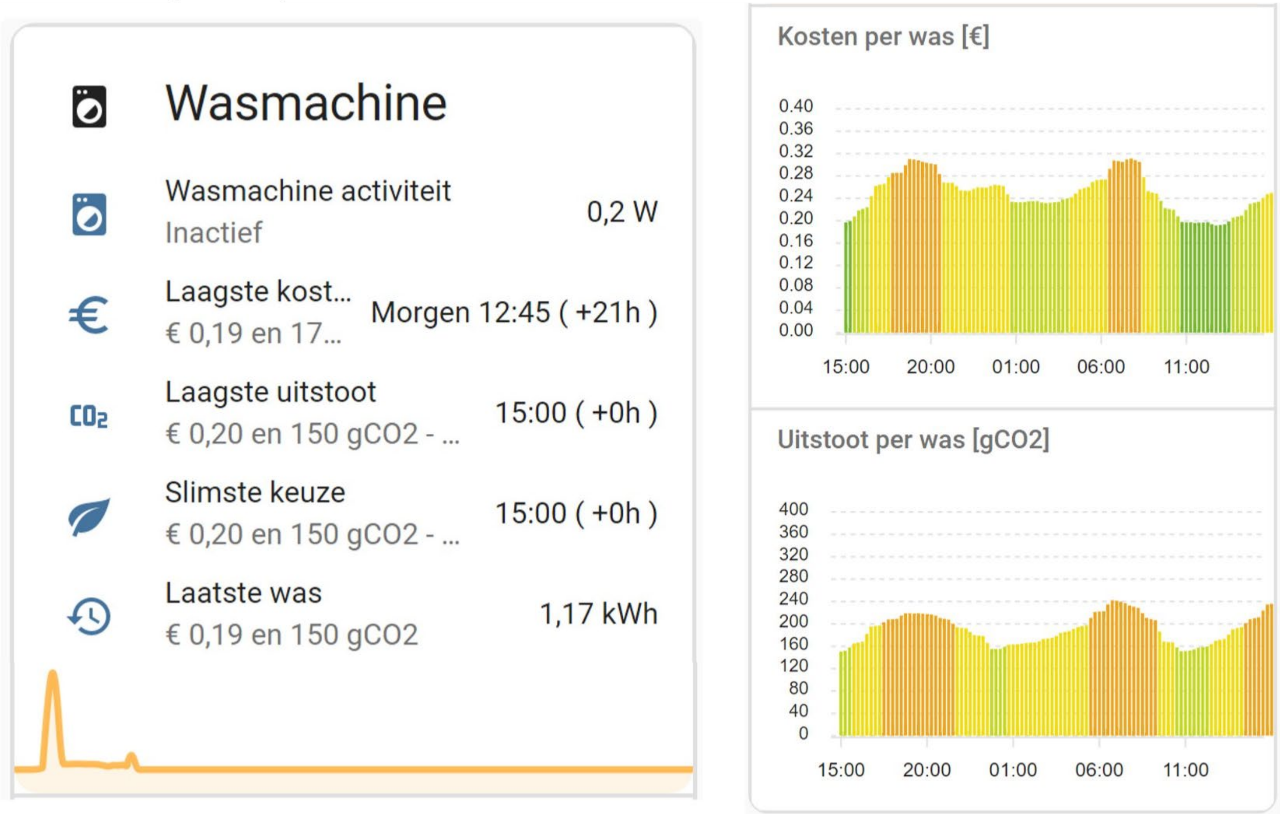

Fig. 2 Example how the data can be used in a home automation platform to schedule a washing machine according to electricity prices or emission minimization, directly quantifying the effect of the action.

Key references

[1] B.J. Jansen, "Modelling the dynamic greenhouse gas emission intensity of the Dutch electricity grid," Master's Thesis, University of Twente, 2023. - Available: https://essay.utwente.nl/96154/

[2] ODECT source code, https://github.com/utwente-energy/odect

[3] G. Hoogsteen, A. Pappu, B. Ahmadi, J. L. Hurink, E. W. Schaefer, C. Gercek, and R. P. van Leeuwen, „On the Effects of Active Energy Community Participation in the Energy System," in 2022 IEEE PES Innovative Smart Grid Technologies Conference Europe, Novi Sad, 5 pages, October 2022. - doi: 10.1109/ISGT-Europe54678.2022.9960552

Technical
Social / organisational

DUCH DEMO

E-boiler Control System

Viktor Nikolayev, Rita Garcia Peran, Bart Homan and Richard van Leeuwen, Saxion UAS, ({v.nikolayev, r.garciaperan, b.homan, r.p.vanleeuwen}@saxion.nl)

Strengths & weaknesses

Strengths	Weaknesses
By incorporating smart controls into the e-boiler, it can be transformed into a flexible asset, capable of serving purposes beyond just heating water as needed, e.g. heating water when electricity is abundant as directed by a home energy management system.	E-boiler is fully automated and the inhabitants should not make manual adjustments, as this will lead to disruptions and unexpected results of the experiments.
Potentially reducing the electrical costs (needs to be studied).	There needs to be installation work to access the water pipe system.
Utilizing the PV production to supply the e-boiler.	

Purpose

The control system measures the temperature of the water that enters the tank and the tempera-ture of the water that leaves the tank. It also measures the water flow (volume of water per unit of time) that enters or leaves the tank. It controls and measures the duration that the boiler is be-ing charged. The measured information is translated into energy flows and the latter is handed over to the EMS. The EMS keeps track of the total amounts of energy flowing in (during charging) or out (during discharging) and keeps track of the State of Charge (SoC). The EMS makes “smart” decisions as to when the e-boiler should be turned on. In this case, smart may mean, for instance, to utilize as much renewable energy as possible or for peak shaving, hence the tank connected to the boiler can be used as a "heat-battery". The boiler control system receives control information from the EMS through wireless internet and turns the e-boiler on or off according to this communi-cation.

Introduction

Electric boilers, also known as e-boilers, consume electricity to produce hot water. They also store the hot water in its water tank. E-boilers normally work with preset internal settings to guarantee that they provide hot water whenever the user opens the tap. It would be beneficial if the e-boiler could automatically turn on when there is an abundance of solar energy production and heat the water in its tank for future use, prioritizing this goal over normal operation. To achieve this, Saxion's Sustainable Energy Systems (SES) research group designed and developed an e-boiler control sys-tem in the form of a measurement, communication and power switching device that is connected to an energy management system (EMS).

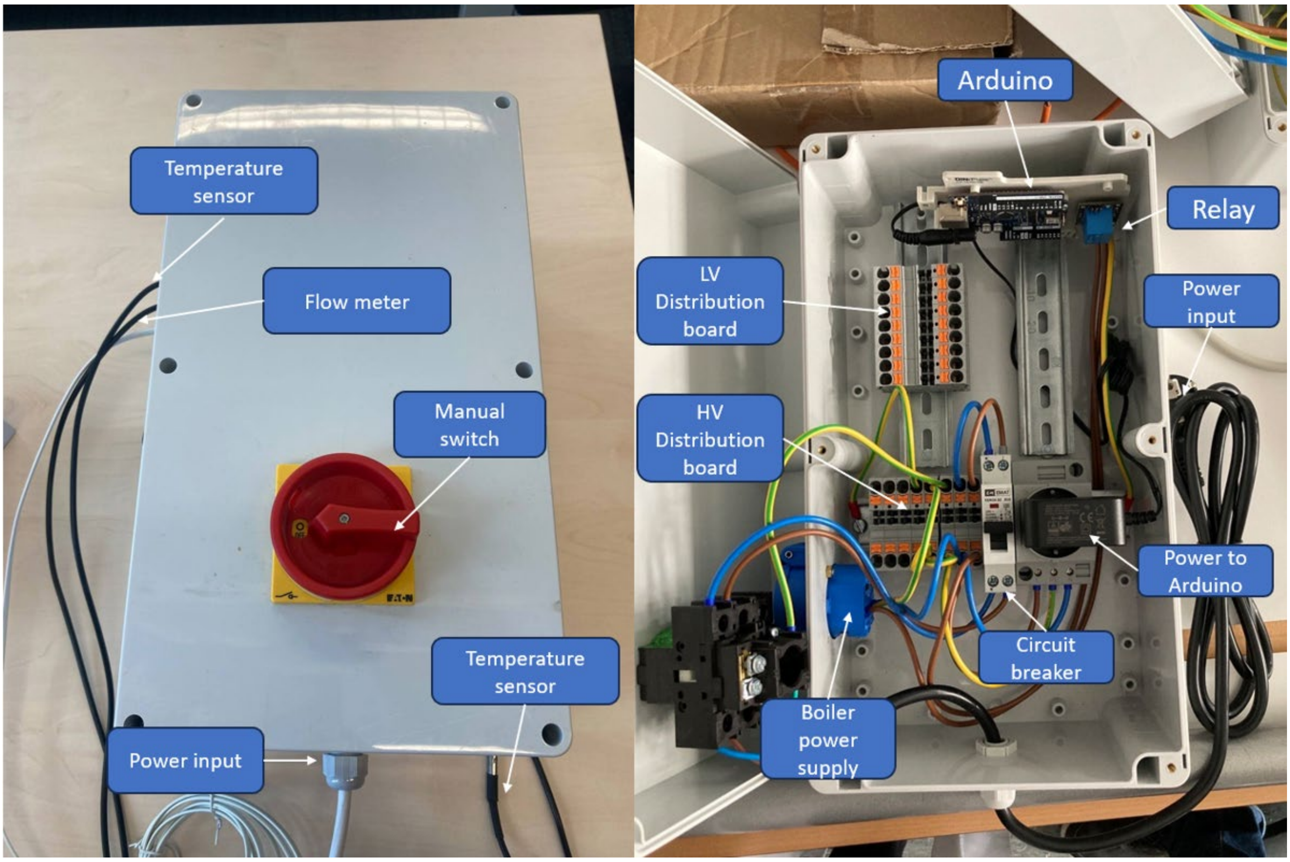

Fig. 1 E-boiler control system.

- Temperature sensors are located on the exterior of both the inlet pipe supplying cold water to the e-boiler and the outlet pipe carrying the hot water from the e-boiler.
- The flow meter measures the amount of water that enters the e-boiler.
- For disconnecting the controller, a manual switch has been incorporated.
- The Arduino board is in charge of receiving signals from the sensors, sending them to IECON infrastructure, and receiving commands from DEMKit.
- The relay turns on and off the e-boiler according to the received Arduino's commands.
- The circuit breaker protects the system from overcurrent, as it breaks the flow if the system exceeds more than 10A.
- The e-boiler requires connection to the boiler power supply to function, and the controller

to work, in turn, it must be powered through the power input.

- The High Voltage (HV) distribution board allocates power to the Arduino and the e-boiler, the power supply to the e-boiler is controlled by the relay, while the Low Voltage (LV) distribution board distributes low-level power to the temperature sensors and the flowmeter.

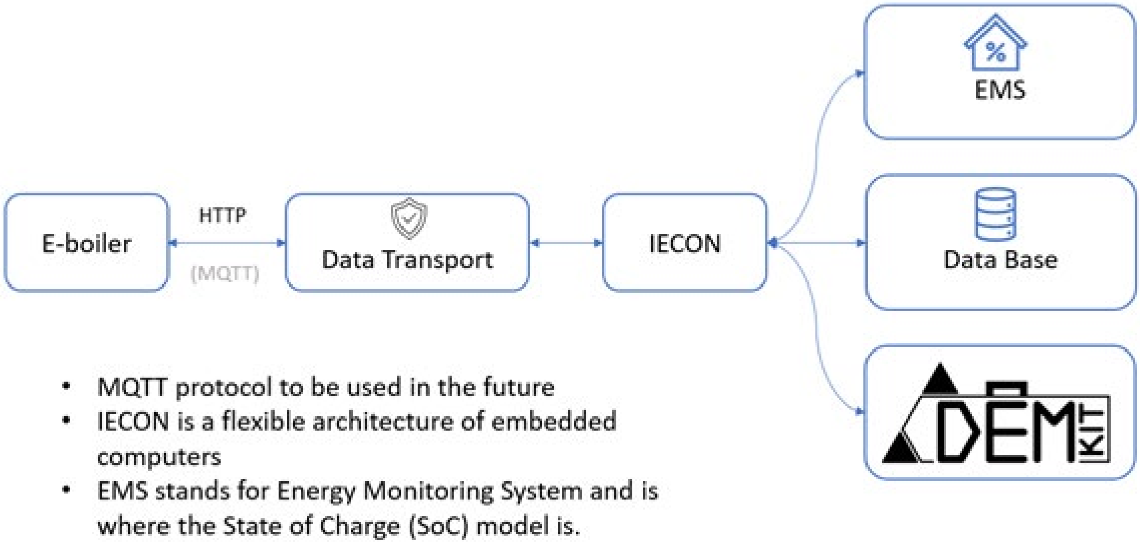

Fig. 2 E-boiler control system software schematic:

- Access to the water pipeline system to install the flow meter sensor, preferably within the inlet pipe.
- Access to a power socket is needed, which can be the socket to which the e-boiler is connected.
- Wi-Fi credentials: the system requires Wi-Fi connection in order to enable smart control (A prototype requiring an ethernet connection is under development).
- Energy management system (EMS): the control system needs to be connected to an energy management system (over Wi-Fi or Ethernet). The software within the control system needs to be adjusted to the energy management system protocol.

Legal considerations

Data is encrypted and protected. The data recorded will only be used within the EMS. The data will not be accessible for outsiders beyond the inhabitants and people involved in maintaining the EMS, without the consent of the inhabitants.

Identity and Contact

The identity of participants and their private information is not publicly available. Only the person installing the control system will know this.

Device Safety

The control system is electrically protected and for user safety a grounded and protected OFF switch is installed on the device. All components comply with CE regulations. The system itself is to be considered as a prototype. To use the system outside the project SERENE, the system itself should also obtain a CE certificate.

Additional comments

- As previously mentioned, the aim of the control system is to provide an interface between an existing, off-the-shelf e-boiler and an energy management system (EMS) in order to make an electric energy system more flexible. The degree of flexibility that is used and the resulting outcome, however, depends on the control objectives.
- The user can always override the EMS (by switching off the interface) and use the local boiler controls to apply the desired settings.
- If the control system loses contact with the EMS (e.g., due to Wi-Fi failure) the control system will revert the boiler to its default (user defined) settings.

Technical
Social / organisational
Business model

POLISH DEMO

Demand side response services

Weronika Radziszewska, The Institute of Fluid-Flow Machinery Polish Academy of Sciences (IMP PAN)
(wradziszewska@imp.gda.pl)

Strengths & weaknesses

Strengths	Weaknesses
Income for the participant.	Disturbance in normal operation.
Improvement of grid situation.	There might be a necessity to add additional automation hardware/software to the participant's installation.

Purpose

Demand-side response (DSR) or demand-side management (DSM) is a method of influencing (lowering) the users' consumption of energy (using mostly financial incentives) in a way to improve the stability of the energy system.

Short description

The national energy system constantly balances the production and usage of energy, but in the case of an unexpected event, e.g. high temperatures, malfunction of a power plant, damage to the energy lines, the power grid is at risk of losing the stability, which may cause blackouts. To prevent that, a dedicated DSR operator contracts companies to act as grid balancers. These companies agree to reduce their energy use upon request. In urgent situations, the DSR operator then sends a reduction request, warning the participants that they have to reduce their energy usage in a few hours for the duration of a certain time. If enough consumers reduce, the power grid can continue functioning as if nothing happened.

Requirements

Until 2022 such services could only be provided by bigger consumers, e.g. companies whose usage was contracted to at least 300kW and with a minimum energy usage of 2 GWh per year. However, recently some DSR companies have agreed to connect smaller users to the system. It is motivated by the need to extend the flexibility of the national energy system to protect the grid even better. The consumers that sign the contract have to be able to reduce a certain amount for a couple of hours on demand, for their service the consumers get: a) a fixed compensation for participating, b) a compensation for forced change in their energy usage. The consumer can be removed from the DSR service for not complying with the reduction request.

Legal considerations

DSR is nationally controlled, there are designated DSR operators that can sign the contracts. The need for reduction is decided on the level of national power grid.

Additional comments

The waste-water treatment plant in the Polish demonstrator in Przywidz is, from November 2023, in the DSR service. The local DSR operator – Enspirion sp. z o.o. agreed to connect the waste-water treatment plant even though it has a lower energy usage that typically required for DSR services. Enspirion sp. z o.o. aims to research and develop the schema to connect smaller facilities belonging to municipalities to increase their total reduction possibilities.

Technical
Social / organisational
Business model
Stakeholder engagement

POLISH DEMO

Electric public transport in a rural community

Weronika Radziszewska, The Institute of Fluid-Flow Machinery Polish Academy of Sciences (IMP PAN) (wradziszewska@imp.gda.pl)

Strengths & weaknesses

Strengths	Weaknesses
Reduced emissions.	Need for charging points.
Increased usage of power from RES.	Need for more frequent charging.
No noise pollution.	Heavier than conventional vehicle with impact on road usage.
Improves the sustainability image of the municipality.	More expensive.

Purpose

Electrifying public transport vehicles will lower the emissions of the transport sector as well as emissions in general. Furthermore, an electric bus allows the use of locally produced energy for transport. An energy management system steering the charging system and the batteries (which store excess of locally-produced electricity) has knowledge of the bus schedule. This enables the energy management system to reserve the electricity for the bus and discharge the battery once the bus is connected again and there is insufficient solar energy production.

Short description

Rural public transport can also be electrified: whilst already widely used in cities, electric busses can also be deployed in rural areas. Such a bus has many advantages: it is less polluting, is more silent and can use the electricity from the local renewable energy sources, if the infrastructure allows for it. The route of the bus is planned in advance, so it is considered a load of very fixed time and amount for which the energy management system can anticipate. The electric transport also improves the green credentials and image of the municipality (Figure 1). To realize such a type of transport, changes to the infrastructure are required – there has to be more charging points, the route of the bus should consider the range of the bus and the bus stops have to be prepared for heavier vehicles.

Fig. 1 Electric public transport in the Municipality of Przywidz in Poland (W.Radziszewska, 2023).

Requirements

The implementation of the electric transport requires well-positioned electric vehicle chargers and route planning that would allow the bus to drive the whole trajectory safely. The EV charger's charging speed should be aligned with the bus's battery capacity to ensure fast charging between rounds. The electric bus itself is more expensive than the diesel one and will, thus, require more upfront financial resources. However, they are widely available with a number of companies producing them. Driving electric vehicles does not require any additional licences, so licensed bus drivers can easily change to the electric vehicles. Although the energy management system is not required for the operation of the electric bus line, it is very beneficial from the energy point of view to pair it with one.

Legal considerations

The municipality is legally obliged to provide transport for young children to and from school. The bus can be part of this service or part of the regular bus transport grid. The financing is provided mainly from the budget of the municipality, the national Bus Transport Development Fund and partly from the SERENE project.

Link to other components

Electric bus charging can be steered by an energy management system to increase its efficiency and profitability. The system can schedule the charging to avoid taking power in high price peak or, on the contrary, take the energy produced by PV modules to help balance the grid.

Technical
Social / organisational

POLISH DEMO

Energy Management System (EMS)

Weronika Radziszewska, The Institute of Fluid-Flow Machinery Polish Academy of Sciences (IMP PAN)
Krzysztof Rafał, Stay-ON
(wradziszewska@imp.gda.pl, krzysztof.rafal@stay-on.pl)

Strengths & weaknesses

Strengths	Weaknesses
Provides knowledge on the operation of the local energy system.	Requires installation of measuring infrastructure.
Allows increases in the consumption of energy from self-produced energy sources.	Additional cost and energy usage of the system.
Allows reductions to peak power usage.	Effectiveness differs depending on the setup.
Increases control over devices.	

Purpose

Energy management systems (EMS) can have multiple goals. They can be used to optimize the cost of operation, decrease emissions, increase system independence, prolong the life of the components, and increase safety/security. The goal might also be a combination of the above. The system functionality is always limited by the abilities of the components. An EMS enables individuals or communities to provide auxiliary services for system operators. Typically, a time-of-use strategy is applied to minimize the cost of energy drawn from the grid and maximize profit from selling surplus energy from PV installation. This is done by controlling flexible devices having the characteristics of an energy buffer (energy storage systems, EV battery charging, heat pump with its storage tank). Furthermore, clear visualization of energy usage, generation and price profiles allows users to adjust their behaviour to optimize energy costs.

Short description

An Energy Management System (EMS) consists of hardware and software which is designed, installed and programmed to:

- gather data from the devices in the system (e.g. power grid, energy storage system, heat pumps, PV installation, EV charging stations),
- manage the operation of devices in the energy system, and to
- communicate with other external systems (e.g. the power operator, grid services aggregator).

The designated overarching goal can differ, but is, usually, to optimize the operational costs of the energy system or to decrease its environmental impact.

The EMS developed within SERENE and which is also being implemented at the 'Arena' sport and culture building in the Polish village of Przywidz, serves as a behind-the-meter controller for the assets installed in the municipality building. It provides monitoring of the power flows between energy system components, controls the energy storage system and adjusts charging strategies for electric vehicles. It includes the option to operate in an off-grid mode, i.e. to operate independently from the central energy grid (Figure 1).

Fig. 1 Energy management system – monitoring of the power flows.

Requirements

The EMS system requires the additional installation of a number of sensors and interfaces to existing energy system devices. For many popular brands of devices, interfacing might be limited or even sometimes not permitted. This problem also emerges with 'smart home' systems and can be avoided by (a) integrating an EMS in the energy storage system, (b) selecting compatible electric vehicle chargers, and/or (c) adjusting the temperature setpoint of a heat pump. Some of the optimization strategies might directly affect the quality of life for the system owner/user. For example, depending on how much the EMS is automated, it might refuse to switch on, because the outside temperature is too high (e.g., 18 degrees), while the inside temperature is uncomfortable (e.g., 17 degrees). This limits the users' ability to decide for themselves when to switch the heating system on or off. The system usually needs adjusting to a changing environment (e.g., pricing schemes) or to changes in the infrastructure, so there is the need for constant support or a service contract.

Legal considerations

Utilization of EMS is not limited legally.

Monitoring of energy data raises privacy issues - the system should not violate the privacy of the users or reveal any personal or sensitive information.

Interfacing with systems of other producers might require getting a license or permission from their manufacturer.

Link to other components

Links to every possible energy system component through possible communication channel (i.e. serial port, Ethernet, WiFi). Possible integrations:

- Energy meters/power analyzers,
- PV inverters,
- Energy storage systems,
- EV charging stations,
- HVAC systems (heat pumps, buffers).

Key references

[1] What is an Energy Management System? How an EMS Works? (codibly.com)

POLISH DEMO

Battery Energy Storage System

Krzysztof Rafał, Stay-ON, Weronika Radziszewska, The Institute of Fluid-Flow Machinery Polish Academy of Sciences (IMP PAN)
(krzysztof.rafal@stay-on.pl, wradziszewska@imp.gda.pl)

Strengths & weaknesses

Strengths	Weaknesses
Increases self-consumption of renewable energy.	High upfront cost.
Uninterruptible power supply.	Limited number of charging cycles.
Reduces energy cost.	Potential fire safety issues.
Solves power quality issues.	

Purpose

An Energy Storage System (ESS) allows the increase of the local self-consumption of renewable energy and, thus, increases the share of renewables in individual households, businesses, municipal buildings [1] and local communities [2]. Furthermore, an ESS governed by an energy management system aims to minimize energy cost by applying time-of-use strategies. In cases of power outages or when grid voltage parameters are invalid, an ESS can ensure the seamless transfer to the off-grid mode and protect users against power quality issues. ESS enables prosumers to become 'flexumers' and take part in power system balancing i.e. through local or grid-scale flexibility schemes – this can be an additional revenue stream for the owner.

Short description

An ESS is essentially an energy-buffering device that draws energy from the grid when required, for example, in situations when there is a renewable energy surplus or if the energy price is very

Fig. 1 Energy storage unit (Stay-ON, 2023)

low. By charging the battery, the surplus or cheap energy is stored and the battery can be discharged when needed (e.g., no renewable energy generated locally, a high energy price or power outage). The all-in-one design developed by the SERENE project (Figure 1) includes a hybrid inverter, battery packs, an energy management system, electrical protections and housing. The ESS includes lithium-iron-phosphate batteries that has a typical design life of around 10-15 years and 5000 cycles. Even though they are considered to be hazardous in terms of fire safety, proper usage and safety mechanisms eliminate this risk.

Requirements

An all-in-one design requires minimum site preparation at the customer site and minimum effort from the installer. A total space of approximately 1m² is required in a technical building (i.e., a garage) with access to electrical network.

Legal considerations

In Poland, where the SERENE ESS was constructed, there are currently special funding schemes for residential ESS, which reduce investment costs [3]. This might be different at other locations. There are no special requirements for small-scale ESS.

Link to other components

ESS is typically paired with the public grid and PV installation through a hybrid inverter that physically manages power flow in the system. The whole installation is governed by Energy Management System that decides about operational strategy with aim to minimize energy cost. ESS can also pair with a diesel genset to form an off-grid system.

Key references

[1] How to Make Good Use of Residential Energy Storage System | Gresgying
[2] Neighbourhood batteries (energy.vic.gov.au)
[3] Strona główna - Mój Prąd (mojprad.gov.pl)

Technical

POLISH DEMO

Heat pumps in rural schools

Michał Gliński, Weronika Radziszewska, The Institute of Fluid-Flow Machinery Polish Academy of Sciences (IMP PAN)
({mglinski, wradziszewska}@imp.gda.pl)

Strengths & weaknesses

Strengths	Weaknesses
More energy efficient than other types of heat sources in certain conditions.	Changes to the infrastructure mean installation costs.
Can be used for heating and cooling.	Use electricity.
Reduces CO2 production, almost no pollutants.	Limited temperature operation range and heat production capacity.
Safe and easy to use.	Working conditions determine the efficiency of the heat production.

Purpose
Heat pumps generate much less air pollution than any other heat source, if they are powered with renewable energy sources. They are used as a way to heat buildings as primary or supporting heat source.

Short description
Heat pumps are devices that produce heat by transferring heat from a lower heat source such as from the outside air to an upper heat source (e.g., a building heating system) using an electrically powered compressor. Heat pumps are scalable from small ones for single flats to big ones that can heat communal buildings like schools. They come in different types: air-source, ground-source, etc. Their effectiveness depends on the temperature differences and working conditions.

Fig.1 Heat pumps installed on the school building in the Municipality of Przywidz, in Poland (W. Radziszewska, 2023)

Requirements

The required capacity and type of heat pump depends on the heat demand of each building and its location. Basic measurements and data about heat consumption are necessary. The installation of air-source heat pump requires additional space around the building. Such a unit can be noisy, so special efforts should be invested to minimise disturbance of peoples activities near the installation. The installation of the heat pump must be provided by experts with appropriate knowledge and experience.

Legal considerations

In case of air-source heat pumps the installation does not require any special permissions. The important thing to remember is the noise pollution and its effect on any neighbours. Other types of heat-pumps, such as the ground-source type, do require permission due to a more complicated installation process relating to the requirement to drill deep holes.

Link to other components

Energy management systems – the heat pumps can be steered by the system, but special technical requirements of the devices must be taken into account. Such characteristics include, among others, the minimal/maximal operation time; the minimal time between switching the pump off and on; taking care of the defreezing system; allowing the pump for the dehumidifying cycle.

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