ReFlex Guidebook for the replication of use-cases tackling the flexibility challenge in smart energy systems

ReFlex Guidebook for the replication of use-cases tackling the flexibility challenge in smart energy systems

The ReFlex project

The ReFlex project aimed to develop a replicability guideline for the deployment of technologically feasible, market-based and user-friendly solutions for smart grids with a high level of flexibility. The focus was put on grids with an expectedly high level of renewable energy production which is effectively and efficiently used locally through mixes of measures from voltage regulation, demand response, energy management and storage.

ReFlex is based on evolving smart grid pilots in eight demo sites in Austria (AT), Germany (DE), Sweden (SE) and Switzerland (CH). Four of them – Salzburg-Köstendorf (AT), Island of Gotland (SE) and Malmö-Hyllie (SE), Lausanne-Rolle (CH) – involved demo sites situated in larger areas with a distribution system operator (DSO) as the main project partner. The other four of them – Biel-Benken (CH), Güssing (AT), Hartberg (AT) and Wüstenrot (DE) – are situated in smaller areas with less than 15,000 inhabitants involving private and public owned energy utilities, which did not have to unbundle grid operation from energy supply.
To extract as much practical knowledge for this ReFlex Guidebook, the project provided a balanced mix of partners, practitioners and experts from larger and smaller energy companies and municipalities as well as regulatory and other socio-technical context factors in different countries.

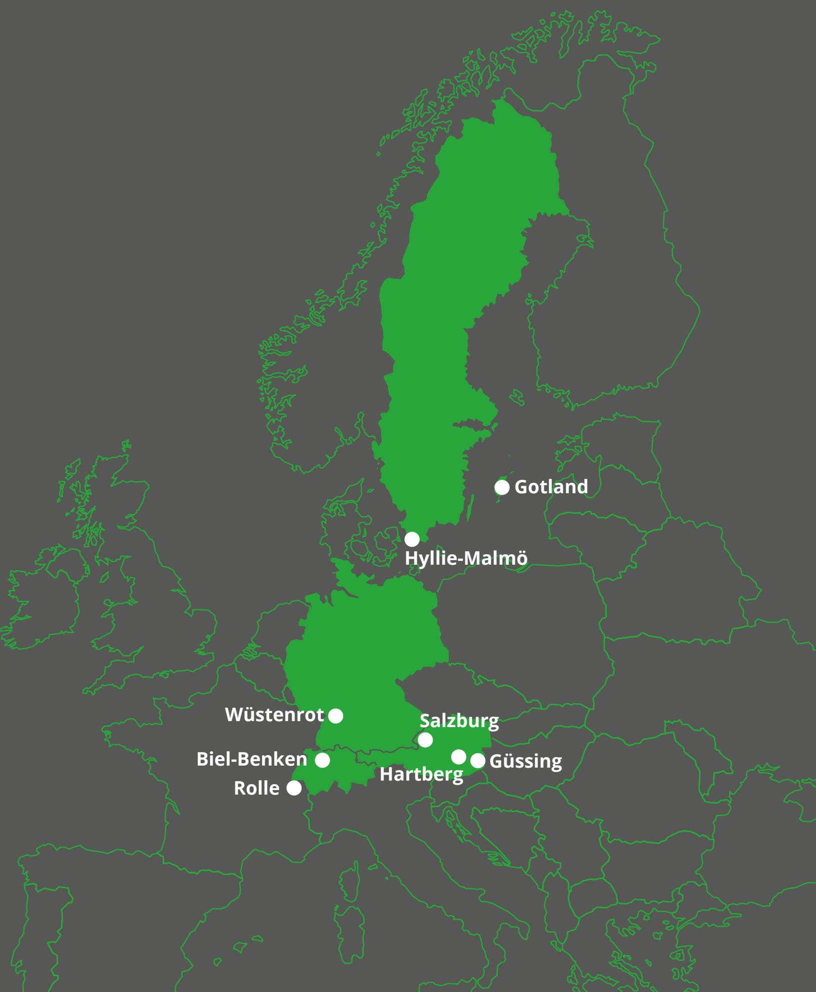
Drawing on the learning experience among ReFlex partners, replicability-guidelines were elaborated, to support the demo regions and the broader group of European smart grid stakeholders in deploying and advancing their smart grid initiatives and replication projects.

01.04.2016 – 31.03.2019

Acknowledgements

The Reflex-team of authors is indebted and thankful to the many active participants in the workshops and demo site visits of the ReFlex Community of Practice (CoP) during 2016-2018. Those practitioners, experts, municipal representatives and researchers have provided in-depth knowledge on successes and failures through their open and intensive discussions, thus providing the basis for this Guidebook. Without their contributions and the hospitality of the hosting organisation, this publication would not have been possible.

The project team is also thankful to ERA-Net Smart Grid Plus and the national funders from Austria, Germany, Sweden and Switzerland and the European Union’s Horizon 2020 research and innovation programme of this trans-national research project. Without the possibility to coordinate a meta-study and a Community of Practice across four countries, many insights and tools would not have been possible to make available through this publication.



1 Use Case #1 in Flexible Smart Grids: Short term voltage-stabilization in local electricity grid

2 Use Case #2 in Flexible Smart grids: Energy Management for business parks

3 Use Case #3 in Flexible Smart Grids: District Heating load management

4 Use Case #4 in Flexible Smart Grids: Shared use of local low temperature resources

5 ReFlex Toolbox

6 Final Recommendations

7 Annex

Technologies review

Smart Grids and distributed energy systems have been identified as crucial elements of the energy transition. Many innovative solutions have been developed to deal with the flexibility challenge going along with the integration of renewable energy into local energy grids. Engineers widely agree that technologies are at hand and many use cases are technically feasible, which has been demonstrated in many research and demonstration projects across Europe under optimised framework conditions. Now the question is:

How can technically feasible, innovative use cases, tackling the flexibility challenge, be replicated and deployed in other locations and contexts?

This ***ReFlex-Guidebook*** shall help those interested in implementing innovative solutions for flexible smart energy systems and smart electricity and thermal energy grids smart grids, which are technologically feasible, economically viable and user-friendly.

The guidebook shall help private and public actors and stakeholders, such as

- municipalities,
- local grid operators (e.g. distribution system operators and municipal energy utilities) and
- energy suppliers

in their endeavour to replicate or transfer smart solutions to their local contexts.

As any practitioner can tell, merely copying solutions, which have been promoted through conferences and site visits, does not work. Therefore, this guidebook will provide knowledge about the context factors to be considered when ***replicating*** innovative solutions ***in other locations***, particularly when transferring them to ***other countries***.

The recent developments in European Electricity Directive and Regulation aim at more active involvement of citizens in the energy system. It mainly allows for "citizens energy communities" and other measures to ***involve citizens***, "***active consumers***" and ***end-users*** in shaping the future energy system. Hence, replicating the use cases, described in this ReFlex guidebook, might become easier, which makes it timely to ***learn from the experiences of practitioners in eight demo-sites in Austria, Germany, Sweden and Switzerland*** made available through this publication.

Overview of Content

The ***first part*** of the guidebook will ***outline four typical Use Cases***, based on examples from the eight demo-sites in the ReFlex project. It includes aims, technical functionalities, assumed business and mission models, stakeholder-network constellations as well as the geographical context, the legal and regulatory context, the economic context and other social context factors to be considered for replication and adoption. ***Target groups***, both already established and new actors in the energy system, as well as municipalities, ***can focus on the use-case they are interested in***.
The use cases are addressing the ***flexibility challenges*** which either primarily deal with (a) availability and quality of ***power at any instant of time*** or (b) providing ***flexibility in balancing renewable energy production and use*** over a specific period-of-time. Two of the use cases are related to grid management involving ***grid operators and "active consumers" (B2C); the other two are related to business to business (B2B) energy services***.

The ***second part*** provides a ***checklist and toolbox*** for guidance in how to plan, develop and implement use-cases in replication projects. The ***target groups*** will be provided with general information as well as with specific tools relevant for local grid operators, as well as for municipalities.
Tools are related to learning processes, development of (cooperative) business models and mission model, technological replicability and upscaling, planning and decision making, end-user and stakeholder involvement, governance of transition process.
The second part includes information on Community of Practice, ReFlex Simulation model and other planning tools, Collaborative Business Models, Mission Models, citizen engagement and regulatory sandboxes.

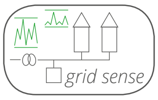
The motto of the Guidebook: Don't Copy – Co-create

After visiting Güssing – one of our demo-sites – Arnold Schwarzenegger proclaimed that "The whole world shall become like Güssing" ["Die ganze Welt soll Güssing werden"] as he was impressed by the many activities carried out in the frame of Güssing' renewable-energy-based local energy system. Transferring the many interesting solutions to other locations, i.e. replicating them in other contexts, does not mean copying or duplicating a blueprint.

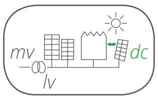
As experienced in the many discussions and interactions in workshops and sites visits throughout the ReFlex Community of Practice, intense cooperation and collaboration is required in the innovation process, as we are dealing with complex challenges and highly integrated solutions.
Thus, *Co-creation is the way forward* to replicate the *four ReFlex Use-Cases* in this book.

The four ReFlex Use-Cases

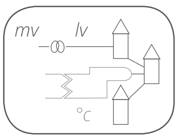
The following use cases are presented in part 1 based on experiences from eight demo-sites:



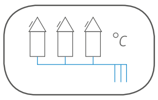
#1. ***Short term voltage-stabilisation in local electricity grid:*** this is based on empirical evidence from Biel-Benken (CH) focusing on load shifting and load management at the household level and from Salzburg-Köstendorf (AT) dealing with short term local low voltage grid stabilisation. Furthermore, the demo sites of Island of Gotland (SE) and Lausanne-Rolle (CH) provided valuable evidence
(Target groups: local grid operators, local grid owners)



#2. ***Energy Management for business parks:*** this is based on empirical evidence from Hartberg (AT) focusing on optimised use of locally generated renewable energy in a business park
(Target group: business park owners and operators, local grid operators)



#3. ***District heating load management:*** this is based on the implementation of a smart district heating system in Malmö-Hyllie (SE) to use the building stock for load management purposes, as well as examples from Güssing (AT)
(Target groups: municipalities, district heating system operators – public or private utilities, property owners / facility managers)



#4. ***Shared use of local low-temperature resources:*** this is based on empirical evidence from Wüstenrot (DE), a community-owned low-temperature agrothermal collector combined with heat pumps supplying heat to of a newly built neighbourhood
(Target groups: municipalities, house owners / facility manager)

What we understand by Flexibility – challenge, services, aims, purpose

The *flexibility challenge* as understood in this Guidebook goes along with the integration of distributed renewable energy sources into local energy grids. Most discussions on flexibility are focussing on the issue of grid stabilisation for which local grid operators are searching for economically feasible solutions. Other actors in the energy system are also facing flexibility challenges of some sort or can provide flexibility services to grid operators or other actors in the energy system.

Those smart solutions, we are looking at, focus on providing flexibility of two different *purposes and aims*:

(a) *Flexibility for Power* enables to *match generation and loads on time*, across seconds and minutes in the power-grid. These energy system services aim to maintain
(i) quality of power,
(ii) local grid stability as well as
(iii) availability of power supply for congestion management and operating reserve under changing conditions due to increasingly volatile energy generation.
(b) *Flexibility in Energy-logistics / Flexibility for Energy* enables the overall balancing of the energy system (including the electricity and heat system) by energy generation and use across a period: minutes, hours, days and seasons. The aim of these energy system services is to manage variability and uncertainty in the energy systems, to
(i) manage the just-in-time feed-in and withdrawal of energy, to
(ii) make locally produced renewable (access) energy available for optimal local energy-use and to
(iii) optimize decarbonization of the energy system across weeks up to months.

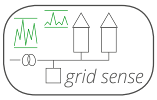
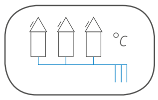
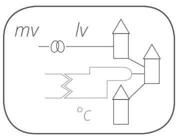
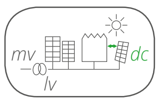
Analysing the four ReFlex Use-Cases, we have identified solutions for the following ***flexibility services***:

- ***end-user's services*** such as incentivised active demand response via heat pumps, through temperature control of heated rooms,
- ***generation/supply side services*** such as shifting of heat production for electricity grid stability purposes in CHPs, control of PV production that is either fed into the grid or stored in a battery depending on grid conditions (voltage and frequency) ***infrastructure modifications*** to improve flexibility capacity and grid stability such as variable transformers for neighbourhoods, low-temperature earth collectors for neighbourhoods and direct DC lines from PV to large scale heating units.

- ***direct energy storage*** such as thermal storage in building mass and electricity storage through second-life batteries for short term frequency reserve.

The ReFlex Use-Cases, as many other flexibility solutions cannot, and need not, be aiming at one or the other flexibility service. All our use cases can be supportive for grid stability, but not all focus on optimising local energy use.

Table 1: Main Flexibility Services provided by use-cases

	Flexibility for Power	**Flexibility in Energy-Logistics**
Grid Management B2C with actively engaged energy end-user	Short-term voltage-stabilization in local electricity grid 	Shared use of local low temperature resources 
Load & Energy Management Services B2B without active engagement energy end-user	Load shifting for load-management of energy-utilities 	Energy Management for business parks 

What we understand by Replication

In this guidebook, the focus is on the replication and transfer of smart grid solutions to new locations and contexts. Replications of smart grid solutions are targeted, problem-solving attempts of learning from one experiment or innovation project and transferring the (successful) elements of this demonstration project to another site.

Our concept of replication is broad and comprises the different distinctions made in the current literature regarding the deployment of feasible socio-technical solutions. Often a main distinction is made between

(A) different forms of transfer of functionalities (accumulation) or scaling-up ***within given socio-technical contexts*** and
(B) more far-reaching transfer of functionalities and/or up-scaling strategies ***in other socio-technical contexts.***

Transfer of functionalities in the former case is considered here as ***replication in the narrow sense of this guidebook*** or, when different forms of system transformation and institutional change are involved, upscaled replication or transformation.

Deployment in the same context (A) includes different accumulation and scaling-strategies such as the roll-out of new products and services, or the expansion of pilot projects. Deployment in different contexts (B) includes different transfer and scaling strategies such as the replication of smart grid solutions in new contexts and locations or shaping of institutional and rule sets. A fundamental tenet in the current literature (e.g. Sigrist et al. (2016),[1] Naber et al. (2017),[2]), which has been empirically confirmed and specified in the ReFlex project is the importance of socio-technical context dimensions such as socio-cultural, institutional, political, spatial and economic contexts as pre-conditions, incentive and shaping factor of deployment processes.
Moreover, the replication and up-scaling of solutions from pilot projects needs to be integrated into a broader perspective of systemic change to live up to the longer-term aim of transforming the existing electricity grid, also beyond the replication and economic success of specific smart grid pilot solutions. An attempt to define separate mechanisms at play in such a transition towards a more sustainable energy system is e.g. undertaken in the following table.

Table 2: Deployment strategies for socio-technical solutions

Concerning smart grid pilot projects it is crucial to ask: Which elements and solutions of the pilot project can be replicated somewhere else? Which context dimensions are critical for the replicability of these solutions? If these critical context conditions are not matched at the new place where a smart grid solution should be implemented, the solution in question is either not applicable, or in some cases, framework conditions might need to be changed to accommodate the smart grid.

Against this background, we suggest an analytical framework for replication which is sensitive to the specific institutional, economic, technological, geographical and stakeholder contexts of the smart grid pilot projects on the one hand and the different contexts at those places where outcomes of the experiments are supposed to be taken over on the other side.

The first question to be asked is: ***Which elements of the smart grid pilot project are expected to be transferred to another location?*** In principle, the range stretches from highly standardised technical products (e.g. a new monitoring or visualisation device) to the whole set-up and system configuration of a pilot project, which can be implemented in a similar way somewhere else.

		Deployment Strategies	
		Transfer	(Up-)scaling
Socio-technical context: spatial, socio-cultural, institutional, political and economic	Same context	**Accumulation** roll-out and diffusion of new products and services	**Growth** expansion of pilot projects
	Other context	**Replication** replication of smart grid solutions in new socio-technical contexts	**Upscaled replication** standardisation of technological components, otherwise context-independent, and **Transformative replication** shaping institutional change

Analytical framework

Replication rarely means implementing an identical smart grid project or solution at a different place. Instead, individual elements or innovations developed within a smart grid pilot project are transferred to new contexts. This transfer often requires some level of translation or adaptation of these solutions.

While the first case mainly requires some technical preconditions to ensure the operability of a technical device in a new context, the much more complex set-up and system configuration are transferrable only under particular circumstances.

1 Sigrist, L.; May, K.; Morch, A.; Verboven, P.; Vingerhoets, P.; Rouco, L. (2016): On Scalability and Replicability of Smart Grid Projects—A Case Study. Energies 9 (2016), 195. https://www.mdpi.com/1996-1073/9/3/195

2 Naber, R., Raven, R., Kouw, M., Dassen, T. (2017): Scaling up sustainable energy innovations. Energy Policy, 110 (2017) 342–354

We suggest '***use cases***' to describe the socio-technical transfer of smart grid solutions at an intermediate and sufficiently concrete level.[3] Such use cases comprise the detailed descriptions of functionalities and actions related to specific solutions (e.g. the type of actors involved, their behaviour and action[4]). For replication to other locations, it is also necessary that the analysis of use cases also comprises different context conditions such as business models, regulatory situation and more.

Therefore, in our replicability approach, when analysing a use case as socio-technical configuration we take the dimensions into account, which are outlined in the following table.

Table 3: Socio-technical Components & Context Factors

	ReFlex Use-case components	Socio-technical context factors of use-case
Technical functionality and technology	• Functionalities in energy system • Key technological components and configurations, as well as digitalisation, ICT and artificial intelligence applications	• Relevant system boundaries • Energy grid configuration • Interoperability • Availability of know-how
Context dimensions		
Space and Geography	• Physical Infrastructure • Potential for local energy generation	• Size of replication site, • Climate conditions
Institutions and Regulatory	• Organisations and actors groups involved	• EU and national legislation on competition and energy market regulation • Energy market institutions • Standardisation
Social and political practices, networks and culture	• Mission model (beyond economic benefits) • Actor and stakeholder constellation	• Cultural Norms, • Social practices of end-users • Citizens' acceptance and trust in institutions
Economic	• Business Model of private and public actors • Collaborative business model	• Culture of cooperation and costs of coordination • Macro-economic benefits

[3] This approach build on existing methodologies to describe use cases as part of IT systems for software developers and system architects (see ISO/IEC 19505-2: 2012) and further adapted to the design of smart grid systems (Gottschalk et al., 2017).

[4] Gottschalk, M., Uslar, M., Delfs, Ch. (2017): The Use Case and Smart Grid Architecture Model Approach: The IEC 62559-2 Use Case Template and the SGAM applied in various domains. Springer Briefs in Energy Springer.

1 Use Case #1 in Flexible Smart Grids: Short term voltage-stabilization in local electricity grid

The use case describes how an operator of a local electricity grid (often a distribution system operator (DSO) or municipal energy utility) could mitigate local grid instabilities at low voltage level caused by decentralised generation. Power injection into the low voltage grid endpoints, typically by photovoltaic systems, has the potential to raise the local voltage significantly, thus causing power quality issues (e.g. harmonic distortions). In this use case, the local electricity grid operator leverages the flexibility potential offered by loads with shifting characteristics (heat pumps, electrical heaters, electric car (EV) chargers) and storage units (thermal and electric storage).

Keywords
local grid operation, DSO, load shifting, storage, flexibility, demand side management, low voltage grid

Reference – Demo Site Biel-Benken

The overall goal of the Biel-Benken demo site was to demonstrate the technical feasibility of a fully decentralised residential demand side management system. The Swiss University of Applied Science and Arts of Southern Switzerland (SUPSI) developed a decision algorithm which uses the local voltage levels to estimate the power at the transformer. The voltage profile is used in combination with the tariff profile to drive a multi-objective optimisation system. After the completion of the research project, the technology is now further developed in an industrialisation project, under the name GridSense, in cooperation with Alpiq, a leading Swiss electricity and energy services provider. The industrial prototype is installed at the Biel-Benken demo-site.

Image 1
Demo-site Biel-Benken
(Source: ReFlex website)

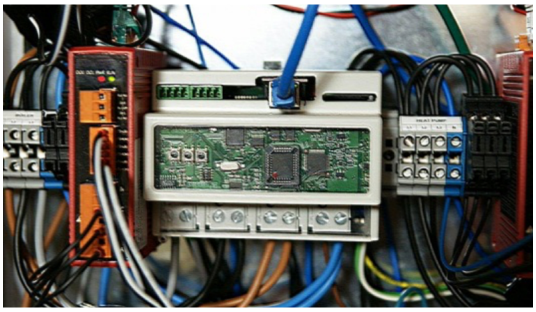


Image 2
Prototype of energy controller in Biel-Benken
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case may be applied to areas with a high penetration of decentralised generation in the low voltage grid. The higher the penetration, the higher the effect on low-voltage stability, thus increasing the need for mitigation actions. The objective of this use case is to utilise the existing flexibility potential to mitigate grid instabilities and to allow a more significant share of generation from local renewable energy sources.

Narrative of the use case
In Europe, solar generation is reaching significant levels of penetration, which is expected to rise further thanks to a wide range of environmental, social, technical and economic drivers. From this growth, a range of issues related to the operation and economic impacts of photovoltaic (PV) generation on the power grid arises. From a technical point of view, the stochastic nature of solar production causes operational challenges. Among them, the unbalance between production and consumption, overvoltage and overload of grid components are the most common ones.

The increase in self-generation tends to reduce the income from grid-fee for local grid operators, considering that the grid component of the electricity tariff is usually a function of the consumed energy. On the other hand, due to the above-mentioned technical challenges, the investments in the network infrastructure are expected to increase.

Among the technical measures for mastering this challenge, the intelligent management of the flexibility available at the demand side is recognised as a promising approach to relieving the network stress. In Europe, most of the grid issues related to PV penetration are located in the low voltage levels of distribution grids, close to the demand side. To avoid creating unbalances in the distribution grid and to improve the grid energy efficiency, demand side management, alongside with local storage, could be used to realign consumption and production.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Clarify regulatory aspects
- Clarify the necessity for voltage control
- Clarify the value of these voltage control mechanisms

What to do as actor in the Energy Sector?
- Clarify regulatory aspects
- Develop innovative business models

What can be replicated from Demo Site Biel-Benken? (GridSense)

The Biel-Benken demonstration project has already been replicated and upscaled in SoloGrid, a joint flagship project of Alpiq, AEK, Adaptricity and Landis+Gyr in the municipality of Riedholz in the Swiss canton of Solothurn. The goal of the project, which was supported by the Swiss Federal Office of Energy (SFOE) and received funding from the canton of Solothurn, was similar to Biel-Benken project: to analyse the energy flow within an electricity distribution grid and to optimise it using artificial intelligence, in order to minimise the need for grid development measures. In SoloGrid Alpiq trialled a fully industrialised control unit, ready for mass production.

Context conditions

Assumptions

The low voltage grid has voltage magnitude variations that justify the need for grid management intervention (actions by the grid operator). Use case conditions are also met when forecasted penetration of distributed electricity generation and loads justifies a preventive action to avoid voltage magnitude variations.

Geographic and Environmental Conditions

As this use case is based on an existing grid structure, climatic conditions are less relevant. However, in rural areas with long distances between grid-connected buildings, the electricity grid might be weaker than in urban areas. The weaker the grid, the more distributed energy resources (DER) and loads may lead to voltage magnitude variations. Therefore, this use case may be applied in rural areas and in regions where power grids experience congestion issues due to the high penetration of renewable energy sources.

Prerequisites

A new regulatory framework needs to be defined that specifies how the provision of flexibility is remunerated and allows to set up innovative electricity and network tariff schemes. Grid users must accept to install a remotely controllable or independently controlling system behind the meter. Incentives or marked based mechanisms for the grid users to provide flexibility to the local grid operator needs to be deployed. In the case of grid users with a local energy generation, such as photovoltaics (PV), the flexibility mechanisms should not conflict with the optimisation of the self-consumption rate.

Legal and Ethical Considerations

All relevant legal guidelines of the country must be considered, as well as all contracts between local grid operators and the grid users must be legally completed, for this, a lawyer for contract law must examine the documents and confirm the legal correctness of the contracts to avoid any further complications.

Key Performance Indicators (KPI)

In this use case, several KPIs are used to represent the low voltage grid and the performance of a voltage stabilisation system, such as ***Voltage Magnitude Variations*** and ***Voltage Stabilization Performance***. The primary criterion for short term voltage stabilisation is to comply with the allowed voltage band.

Context conditions – Demo Site Biel-Benken

The pilot project PowerGrid has been set up explicitly to test the GridSense solution in the field and to allow developing it further. In the EBM operated grid of Biel-Benken, Switzerland, a low voltage (LV) feeder with a high PV penetration that leads to considerably high voltage fluctuation was selected. In spring 2015, four houses equipped with rooftop PV plants and heat pumps were equipped with control and monitoring system. Additionally, EBM also provided monitoring of the low voltage end of the transformer. The pilot system became fully operative in the summer of 2015. Since then, several versions of the developed hardware and software have been tested using this testing platform. The installation and commissioning of photovoltaic, house battery, charging station for electric vehicles, electric boilers and heat pump as well as the validation and calibration of the physical models of these GridSense components were successfully tested in the PowerGrid pilot project. The PowerGrid pilot system proved itself very useful for the development and the testing of Demand Side Management (DSM) solutions.

Local energy system and stakeholders

Local grid infrastructure
No further components.

Generation and storage
No additional components are required for this use case. Pre-existing generation, loads and storage components flexibility can be utilised. However, the more generation, load and storage components are installed, the higher the optimisation potential for demand side management. Tariffs designing incentivising local flexibility could also lead to the installation of additional generation and storage components at grid users' premises.

End-user components "behind the meter"
A load monitoring and control equipment is installed in the grid users' premises, behind the meter. The equipment will monitor and control local loads and storage systems, by sending control commands with priority order. Depending on the deployed local control algorithm, a central intelligence may also be needed. If many grid users along one power line use the control equipment, they could optionally interact with each other improve the flexibility performance.

Actor-groups and Stakeholders-groups (third parties, ownership)
The key partners to operate a low-voltage stabilisation system are:
- operator of the local electricity grid (DSO or municipal electricity utility)
- service provider/manufactures
- grid users (e.g. businesses, house owners, private households)

Key partners – Demo Site Biel-Benken

The key partners in the Demo Site Biel-Benken are the local electricity utility (EBM AG), the service provider and manufacturer of the system (Alpiq InTec AG) and the grid users (single-family households). The GridSense system developed by Alpiq is a business-2-business product offered to EBM. EBM then provide the product to the end-users, negotiating with them. In this specific project demonstrator, the hardware was provided on a free basis to the customer by the electric utility and the manufacturer. The goal was to demonstrate the technical feasibility of a decentralised load management solution.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs
The reductions of voltage instabilities enable higher penetration of distributed local renewable generation, increasing the community autarky and self-consumption and reducing the carbon footprint.

Beneficiaries / Stakeholder
- Local Grid Operator
- Grid users
- Service provider/manufacturer
- Energy supplier: not involved in this use case

Value Propositions
- Local Grid Operator: increased voltage stability, cost saving due to the reduction of infrastructure improvements needs
- Grid users: cost saving thanks to innovative tariffs schemes and the increase of own self-consumption (for end-user with PV generation)
- Service provider/manufacturer: profit from sold devices and licenses.

Collaborative / Cooperative Business Model(s) along the value chain Local Grid Operator: operate the low voltage grid efficiently, avoid unnecessary grid investment
Manufacturer: production of new control devices covering new business cases
Grid users: active role in the low voltage grid

Biel-Benken

The use case allow a higher penetration of local renewable energy generation in the low voltage grid. The solution is a step toward a decarbonised society. Moreover, the usage of local green energy empowers the community members.

Collaborative Business Model – Demo Site Biel-Benken

As the control equipment stabilises the local power grid and prevents grid issues through load shifting, a reduction of the network charge is achieved that benefits to all customers of EBM; thus, not only the involved households equipped with control boxes but also people located in the test area take advantage of this investment. The local grid users also profit from cost-saving thanks to increased self-consumption and attractive tariffs. Data collected that give detailed information about the status of the power grid is of value for the local grid operator and/ or a local service provider. This information allows to develop further innovative solutions for grid stabilisation tailored to users' needs.

Framework conditions for adoption and replication

Market regulations
The main actor for adoption and replication is the local grid operator. The role of the local grid operator is strongly regulated, and therefore innovation regarding regulation is crucial. In Switzerland, for instance, the new 2018 Energy Law allows the local grid operator to install load management control boxes behind the meter and offer alternative power-based tariff schemes to customers to provide incentives to reduce peak loads. This new legal framework increases the likelihood of replication and adoption significantly.

Financing
Financing aspects are not critical for this use case per se. They are dependent however on favourable market regulation. The hardware itself is in general not cost intensive. However, installation costs must not be underestimated. In particular, individual electrical installations at the grid users' properties might become too high.

Social acceptance
In order to have a high social acceptance, there is a need for a voltage stabilisation system, which is fully automated and does not have any impact on end-user comfort. This condition is guaranteed by the fact that no equipment or services involve action by or continuous permission from the grid-users. The risk is also reduced by the fact that previously affected appliances in households such as dishwashers and laundry machines are so efficient today that they are not considered for demand response measures.

Identified barriers to replication and scalability

Technology Level
No technology breakthrough is necessary to implement this use case. However, there are high barriers: the control of household devices is not standardised, and it is still very fragmented. These barriers slow down the replicability and upscaling. Another constraint is about components cost. The control unit manufacturers market is highly competitive with low margin on hardware costs. Manufacturers are very cautious about adding additional technology to their product line. The lack of a standard for the control interface/management of demand control solutions is one of the leading technological obstacles to the uptake of demand response technologies.

Market level
The major challenge is coming from regulation. It can be very tough for the local grid operator to justify an investment in behind-the-meter control boxes because the national authority does not support this type of investment since it's not the most efficient and cost-effective solutions compared to other existing technologies. Another challenge is to develop innovative tariff schemes that benefit to the grid operator and the grid users. Deployment of a new type of tariffs scheme, for instance, power-based tariffs, can be blocked by existing market regulation.

Stakeholder Adoption level
A potential barrier is a lack of public acceptance from end-users. The cost saving for the grid users may not be significant enough to offset the costs of installing the additional control box and so achieve economic profitability.

Technology Level – Demo Site Biel-Benken

GridSense is a Demande Side Management solution of the Alpiq InTec Group, which has been developed at SUPSI, the University of Southern Switzerland. It allows for autonomous decentralised control of dispatchable loads such as boilers, charging stations for electric vehicles (EV), battery to grid systems (B2G) and heat pumps. The GridSense solution enables new emerging energy services such as energy monitoring and automatic demand side management for distribution grid operators and power companies, as well as optimised self-consumption services for end users. The sensing and actuation parts are performed through the GridSense unit, a smart meter running with intelligent algorithms in a decentralized way.

The developed algorithms can operate in different optimisation modes:
- Grid support: Based on local voltage measurements, the algorithm shifts the power consumption from periods in which the voltage is low to periods in which the voltage is high.
- Cost reduction: Based on energy tariffs, the algorithm shifts power consumption to periods in which the electricity cost is low.
- Self-consumption: By monitoring the electricity flow and the house load and the production of the PV plant, the algorithm optimises the self-consumption of the end user, and therefore its energy costs.

2 Use Case #2 in Flexible Smart Grids: Energy Management for Business Parks

The use case deals with an optimized energy management of a business park or similar site with multiple purpose buildings and other infrastructures such as parking space, event halls etc, including renewable energy power and heat generation. Energy can be distributed through a local heating network, the low-voltage electricity grid and direct DC connection between PV and local end-users. The business park can be manged in an optimised way based on the availability of on-site renewable energy production, energy storage capacities, and the local consumption with a broad range of end-use services. In addition, there is sector coupling by E mobility charging stations and peer-to-peer solution (direct line) for the surplus of power generated by renewables within the business park.

Keywords
Building Energy Management, Load Shifting, local flexibility, optimisation

Abstract – Demo Site Hartberg

The demo site in Hartberg is a business park labeled as "Ökopark Hartberg" with office buildings, a cinema and museum. It is situated in Styria, a state of Austria, which has significant forest resources. Stadtwerke Hartberg and its different affiliated organizations are 100% owned by the City of Hartberg. The Stadtwerke operates the grid and acts as the local (almost monopolistic) provider of electric energy. One of the particularities of the demo site is that the business park itself is run by the Stadtwerke which allows them to maintain close relationships with end-users such as companies renting offices, operators of the aquarium, cinema and museum in the leisure complex, owners of electric cars who regularly charge their cars.

Image 1
Electric storage (left) and power inverter (Source: ReFlex website)

Image 2
Solar carport at ÖKOpark Hartberg for local power generation and EV charging (Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
The use case can be applied to business parks or similar sites with multiple purpose buildings and other infrastructures such as parking space, event halls etc, including renewable energy power and heat generation. The objective is to optimize energy consumption, storage and consumption to reach the goal of low-, zero- or even positive energy business-parks on the one side and on the other side to provide flexibility of power and energy-logistics to energy infrastructure operators and energy suppliers. The scaling of such a use-case is limited to the maximum size of a business park or similar site with the potential to optimize energy flows as if being a single user to the electricity grid and other energy infrastructures outside the premises

Narrative of the use case
The climate and energy policy of European countries aims at significantly reducing CO2 emissions by 2030 in all areas including industry and businesses. Hence, National Energy and Climate Plans will likely include also measures for increasing energy efficiency, incentivising on-site production of renewable energy and reducing fossil-fuel-based energy consumption of industry and businesses in heating, cooling of buildings, transport etc. Future-proof business-parks should therefore develop business models for energy management and energy services, which allow their customers to contribute to those societal goals and at the same time save in energy bills.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Actively develop a mission model together with the actors and stakeholders of the business park including environmental and regional development vision and medium- and long-term goals
- Actively communicate with stakeholders and actors, such as owners and managers of business parks and interested businesses to present the use case and its benefits, sharing the vision and medium- and long-term goals developed in the mission model

What to do as actor in the Energy Sector?
- Clarify regulatory aspects together with the national energy regulator and, if needed, apply for the creation of a regulation innovation zone (regulatory sandbox), which allows to explore and test various technological solutions and business models.
- Enter into collaboration with local companies (e.g as flexibility service provider with demand response) and other actors in the energy system (e.g. local grid operator, distributed energy producers ...) to develop cost-efficient and flexible solutions that will support the use case implementation.

Context conditions

Assumptions

The use case assumes that industrial and commercial companies increasingly want to cluster at sites with favourable conditions for optimizing their energy consumption towards local generation and consumption as well as reducing their CO_2 emissions. If the energy management should provide flexibility services, the renters (tenants) need to be willing to participate in the concept even if small disadvantages occur compared to other alternative options, as long as they are compensated by other services or savings.

Prerequisites / Framework Conditions

A prerequisite for the replication of the use-case in our demo-site is the existence of a business case for providing energy services to the enterprises renting the office space and other infrastructures. Furthermore, unlike in the case of a fully integrated municipal energy utility, in cases of an unbundled actor constellation a collaborative business case would be needed that is favourable for the owners of the on-site energy infrastructure, the energy infrastructure operator as well as the energy suppliers.
In case of ownership of the local energy generation and grid operation being separated, e.g. the local PV is owned by the business park and grid operation is manged by a local grid operator (DSO), the latter would either have to tolerate a direct line for peer-to-peer exchange of electricity within the business park, or allow for the use of its grid. Otherwise peer-to-peer exchange might not be profitable.

Geographic and Environmental Conditions

The use case will find favourable conditions in regions with availability of local renewable energy sources (e.g. biomass), space for PV as well as space for storage of access energy. Thus, geographic conditions like nearby forests or favourable geothermal conditions are favourable. Furthermore, large business parks with favourable topographic conditions and space for PV on buildings increase the profitability of such use case.

Legal and Ethical Considerations

European directives, national laws and Energy market regulation must provide the room which allows or facilitates contractual arrangements between business park owners/operators, local energy infrastructure operators and tenants. In the case of direct DC connections attention need to be drawn on grid codes, which might be hindering its implementation.

Key Performance Indicators (KPI)

In this use case, KPIs are mainly related to the optimised energy-logistics, e.g. use of locally generated renewable energy, the degree of net autonomy (percentage of kWh of heat and electricity consumed from external sources) With respect to serving the flexibility demand of local grid operators indicators could include kW*minutes of demand response and kW*minutes of electricity from storage provided. The reduction of fossil fuel consumption in kWh is another KPI for reducing CO_2 emissions, in cases where this is part of the mission model benefits.

Example: Framework conditions – Demo Site Hartberg

The business park, Ökopark Hartberg is a local micro-grid due to its neighbourhood with a biomass-based CHP on the business park's premises. The energy infrastructure includes the biomass based CHP, low-energy buildings, PV for E-mobility charging and a direct power line from the PV plant to the aquarium. Thermal heat comes from the CHP and additionally required electricity is made available through the local grid of the Stadtwerke Hartberg.
The management board of Stadtwerke Hartberg had a strong leadership role and assumed responsibility over several years, particularly linking municipal policy making with the local business sector and the various actors at the business park. This role as care-taker to coordinate the complex network of stakeholders and actor groups of the business park from medium to long term was identified as one of the key success factors in this case.
Another aspect which needs to be considered in replication is that, on the demo site, the business park is also run by the municipal utilities. Thus, not only do they have to have a close relationship with end-users as grid operators and customers in an energy supply contract (electricity, heat and electric cars charging) but also as landlord to tenant (firms renting the offices, operating of the entertainment complex (cinema/museum), renting space in a car park). Hence, the basic assumption is that there is an atmosphere of cooperation among the different actors and stakeholders.

Local energy system and stakeholders

Local grid infrastructure
The mix of local energy infrastructure consists of local heating network, low-voltage electricity grid, and direct DC-connections. It can be replicated in any business park, assuming collaboration between key actors. The limits to upscaling can be extended to the medium-voltage level if the size of business park requires more than one substation and local heating grid could be linked up with a larger district heating grid. However, the consequences for a profitable collaborative business case need to be considered.

Generation and storage
The use case could include serval renewable energy sources to generate power and or heat. In addition, sector coupling is possible. Therefore, PV and wind plants, biomass combined heat and power plants (CHPs), thermal and electrical storages and heat pumps as well as charging station for electric vehicle could be integrated into this use case. Thus E-charging, thermal storage and batteries can also be part of local energy-logistics, thus increasing the potential for flexibility services.

End-user components "behind the meter"
End-users can also be integrated into this use case. It is crucial to check that the device standards are compatible with the overall energy management platform.

Actor-groups and Stakeholders-groups (third parties, ownership)
Operator of the system can be either the municipality together with the municipal utilities, the business park operator, a private service provider or a cooperation.
The most important key partners to operate an overall energy management system of an business park are:
- Landowner / business park operator
- municipality
- energy suppliers (DSOs) (e.g. municipal utilities, private energy suppliers)
- end-users (e.g. business end-user, house owner)
- engineering and construction companies
- service providers

Example: Key partners – Demo Site Hartberg

The most important key partner at the demo-site is the municipal utilities of Hartberg, which acts not only as energy provider and distribution grid provider, but also as owner and renters of the business park. Furthermore, serval tenants in the business park are businesses and companies controlled by the municipal utilities of Hartberg. Hence coordinating local energy generate and sharing it on a peer-to-peer level requires less transaction costs. The public relations are provided by the municipality and its utilities while construction and maintenance are coordinated by a engineering and planning company also under control of the utility. Thus, the municipal utility, as a kind of one-stop shop, also provides the overall energy management concept and services.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs

- Independent, cost-effective and sustainable delivery of heat and electricity
- Promotion of sustainability and regional attractiveness

Beneficiaries / Stakeholder

- Property owner
- DSO / District heat provider
- End-users
- Facility manager, Municipality,
- Engineering company, Construction company, Service company, Service staff

Value Propositions

- Business model
- Reliable and economic heating and cooling supply
- End-users loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain ***Local Grid Operator:*** operate the low voltage grid efficient
Municipality: provision of land and resources, compensation through tax revenues and possibly rental fees
Engineering and construction company: design and construction of the system
DSO: operate and maintain grid, deliver energy to the costumers
Service company: maintenance of the energy system, carrying out repairs
Service staff / Municipal utilities: "care-taker" role as well as energy provider of the end-users. Gain knowledge about load shifting potential, opportunities to set up variable tariffs schemes and demand for innovative business models

Tenants and End-user: Independent cost-effective and sustainable delivery of heat and electricity by using load shifting potential for demand side management purposes.

Example: Economic, social and environmental needs – Demo Site Hartberg

As the city of Hartberg has realized the danger of the regional and local effects from global warming it promotes sustainable settings such as at the demo-site. That's why the local companies at the business park could do peer-to-peer energy trading supported by the local utilities even if that's against their own business. The municipality also promoted renewable energy plants for power and heat generation and charging stations for electric vehicles powered by PV plants. The solution simultaneously fit the objective to a low environmental impact and enrich the community socially due to more sustainable companies and serval events to let people participate at the plans of the municipality.

Example: Collaborative Business Model – Demo Site Hartberg

The municipality needs to have a vision and commitment to protect the climate including the reduction of CO2-emissions. The development of the business park is related directly to the management of municipal utilities and the related city strategy. By hosting research and firms dealing with environmental-technologies such as greening of economy could also improve the awareness to be part of regional and environmental strategy.

Framework conditions for adoption and replication

Market regulations

The energy regulator plays a major role in this use case by setting rules for the operation of the power grid and defining rights and obligations of the grid operator. Today, most players in the energy market are in a competitive situation, which can jeopardize some business models like peer-to-peer exchange of electricity. Thus, in unbundled settings exceptional contractual arrangements between different businesses are needed, if the use case is to be replicated. The creation of regulation innovation zones (regulatory sandboxes) is seen as a good opportunity to speeding-up market uptake, while enabling regulatory bodies to allow for the testing of various temporary schemes and mechanisms.

Financing

This use case builds on existing power grids and energy assets. The most significant investment to be made are the energy management platform and adaptations to make device flexible to price and control signals. Cost savings can be achieved by fostering collaboration between local technology providers and energy utilities. Investment in new and additional infrastructures, e.g. DC direct lines between PV and specific end-user appliances would require stable legal conditions and long-term contractual arrangements.

Social acceptance

Social acceptance of a broader public is of less importance, as main relations are set between businesses. However, active collaboration between the municipality, the energy utility, end-users and local technology providers to develop innovative solutions to the benefit of the local economy. A transparent and clear public communication that provides feedback on a regular basis and helps attracting new customers.

For tenants, it is important to implement cost-effective technology with proven technology. To attract tenants, the system must be simple and operate by itself.

An effective optimisation of energy management might require a "care-taker", with high social competences, who coordinates the complex network of stakeholders and actor groups around the use case. He/she should play a key role in developing a shared vision between stakeholders and helps to identify win-win situations.

Identified barriers to replication and scalability

Technology Level
Technologically the use case is feasible with market ready solutions. Energy management systems developed for industrial companies can be extended and applied to a district or a business park. However, national and local regulations must be carefully examined as they may hinder the provision of certain services to end users.

Market level
For replication and upscaling, one of the critical conditions seems to be the "bundled" context as Hartberg's local grid is operated by its own energy utility, Stadtwerke Hartberg, which is also the energy supplier at the same time.
Energy regulator have to set the rules for the monopolistic grid operator's rights on the one side and on the other side, its obligations. An example from the business park is set up of a direct line for peer-to-peer exchange of electricity. Depending on the country the monopolistic distribution system operator could have the right to forbid two grid-users to exchange energy through the electricity grid or to build a direct line. Thus, many aspects of the pilot project, need exceptional contractual arrangements between different businesses in unbundled structures. Otherwise, the transaction costs often increase and business model of the use case is less attractive or at all impossible.

Stakeholder Adoption level
If the solutions deployed are too complex and expensive and effective maintenance is not ensured, this can lead to a loss of customer confidence and damage the reputation of companies involved in the use case. Data security and protection is also an important aspect to be considered.

Example: Replication – Demo Site Hartberg

Not all components of the use case implemented in Hartberg may be replicable to other business parks. However, some standard technologies such as car charging stations, the energy management platform and demand response technologies implemented on site can be easily replicated in other sites without much modification. Other services like peer-to-peer exchange of electricity may not be applicable in all countries depending on local regulation.
The local context and resources of the area, city or region where the use case is to be replicated must be considered. This has a major impact on the technologies and flexibility services that will be provided to the end-users and the local grid operator.

3 Use Case #3 in Flexible Smart Grids: District Heating load management

This use case describes how smart grid technologies can be used by district heating utilities to shave peak loads in a district heating network. Such load management can be achieved by using the heat storage capacity of building structures to slightly overheat the building in advance of an expected peak. What is required is the thermal capacity of the buildings to predict district heating peak loads in advance, smart building gateways which interact with the building energy management system and a smart grid IT platform which can also be integrated with smart electricity grid functions.

Keywords
District Heating Network, Building Energy Management Systems, Load Shifting

Abstract – Demo Site Hyllie MALMÖ

In the new urban district Hyllie in the city of Malmö, Sweden, a smart grid platform has been implemented which in the longer term will integrate both, the electricity and the district heating network. Currently, the system is mainly applied to manage heat loads of the district heating system by using building structures for heat storage.
Hyllie is Malmö's largest development area and will in the final phase comprise around 9000 new homes and an almost equal number of office spaces. Hyllie is seen to be a 'lighthouse' for Malmö's target to become 100% renewable by the year 2030 as laid out in a climate-contract between the city of Malmö and the companies VA Syd and EON.

Image 1
Control unit used in Demo Site Hyllie
(Source: ReFlex website)

Image 2
Focus areas of the Demo Site Hyllie
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case may be applied in all district heating networks with a need to shave peak loads. Such load management reduces the need for heat generation with back-up units, which are in many cases fossil fuel based, e.g. natural gas or oil burners. Load management reduces the level of back-up capacity required and the hours of use of such units and thereby helps reduce the climate gas emissions of district heating as much as it is improving its economic viability. What is required for this use case is a working interface with building energy management systems and the cooperation of property owners or facility managers.

The objective of this use case is to supply as many households and businesses as possible with affordable and sustainable heat in winter and/or cooling in summer.

Narrative of the use case
The main precondition of this use case is the existence of a municipal or local district heating network – which can be both publicly or privately owned and operated. Moreover, an integrated heat supply system is required, where the network owner/operator and the heat supplier are identical or can cooperate closely. Currently, most district heating systems are not unbundled which means there is no strict separation of a monopoly network operator and competitive heat suppliers as is known from deregulated electricity systems.

Moreover, close cooperation with property owners or facility managers is necessary. They need to accept the interaction of the district heat supplier with their building energy management system which has to be externally controlled to intercept a peak in the DH system. Large property owners and operators, such as municipal housing companies, are advantageous. It reduces financial and administrative burdens compared to multiple contracting parties and increases the chance for similar energy management systems to reduce installation and maintenance costs. The heat provider must install a smart communication interface in each building which can interact with the specific characteristics of the energy management system applied in the building.

Sometimes in advance of a district heating supply peak the district heating operator sends a signal to the building energy management systems to raise the temperature level of the buildings beyond the current target. Temperature rises within a small range, around 0.5 – 1 degree, are barely felt by the building users. At the time of the district heating peak, i.e. high demand for district heating from users, the supply of the 'over-heated' buildings can be reduced and shifted to other customers, bringing the originally over-heated buildings back to their original level or even slightly below. If the overall heat demand goes back to a normal range, all buildings are heated at their target level.

In the smart district heating system applied in several places by e.on Sweden, the business model currently builds on the participation of building owners without financial compensation. However, small fees for the use of the building energy management for district heat management purposes are possibly viable.

What can be replicated? How could this be achieved?

What to do as Municipality?

- Develop sustainable heating and cooling strategy for the municipalities in cooperation with relevant stakeholders; include options for better DH load management and thus more efficient operation of the DH system in the municipal strategy.
- Help to motivate building owners to participate and create a favourable environment for the use case.

What to do as actor in the Energy Sector?

- Attract building owners who are willing to participate in the heat load management system
- Cooperate with the municipalities and environmental initiatives to create a favourable environment for a more sustainable smart district heating system
- Provide examples of working cases of the management system to create trust and show that building energy management systems are not negatively affected by the external intervention.

What can be replicated from Demo Site Hyllie MALMÖ?

The use case which can be replicated from the example in Hyllie is a smart grid platform for the load management of district heating with an IT infrastructure for control and prediction of heat loads and special devices interacting with the building energy system to store heat in the building structure in advance of peak load of the district heating system.

Despite some technical limitations (control infrastructure needs to be built up; interfaces with building energy management systems and their technical specifications need to be developed and are currently not commercially available), only a few pre-conditions appear to be critical for replication or upscaling of this smart grid solution. Such solutions are only relevant for cities with district heating systems (and preferably in situations where a reduction of peak loads is useful, e.g. by reducing the need to increase the capacity of heat pipes despite the expansion of the DH system) and only buildings with an energy management system can be integrated.

Integration of network ownership and supply are a precondition, but this is usually the case with district heating systems. Public ownership is not a requirement, but a cooperative relationship with building owners is essential because they have to voluntarily accept the installation of such a system in their building without financial benefits (otherwise the business case for this solution might be in jeopardy). It is thus also of advantage to have only a limited number of building owners as contract partners in the supply area. As has already been tested by e.on the system is scalable and can also be applied to the existing building stock and replicated in other cities.

Context conditions

Assumptions
It is assumed that a reduction of district heating peak loads improves both, the environmental and economic performance of the district heating system. Moreover, the agglomeration of buildings in question, whether in an urban or more rural context, needs to be supplied by a district heating grid and needs (in a sufficient share) to be equipped with building energy management systems. As there are no off-the-shelf solutions available, the heat supplier needs to be sufficiently competent in developing interfaces with the building energy management systems and integrating these in a joint IT platform (e.g. smart grid platform).

Geographic and Environmental Conditions
The system is easily scalable and can be implemented in both, new buildings and the existing building stock. The dimensioning depends mainly on the dimensions of the district heating system with its requirements of heat supply densities. Constant maintenance and proper operation of the system are obviously of crucial importance and might otherwise result in reduced comfort levels of building users. Beyond this, environmental damage from operation problems cannot be expected.

Prerequisites
Framework conditions and prerequisite which make the implementation of such systems easier are favorable municipal planning contexts, e.g. a municipal energy or climate plan, which request sustainable heat supply solutions and provide a sufficient motivation for actors, such as property owners, to cooperate in this effort to reduce heating network peak loads even without monetary compensation. Moreover, an ownership structure of buildings connected to the DH system with a small number of building owners and preferably with a limited number of types of building energy management systems significantly reduces transaction costs for building up a smart district heating grid.

Legal and Ethical Considerations
All relevant legal guidelines of the country must be observed, as well as all contracts with property owners must be legally completed; for this, a lawyer for contract law must examine the documents and release to the legal correctness of the contracts and to avoid complications.

Key Performance Indicators (KPI)
Relevant KPIs for the optimization of district heating systems also apply in this use case (see Cortés, 2015: D 2.1. of Horizon2020 project Optimisation of District Heating & Cooling systems). Such KPIs include 'reduced energy consumption', 'reduced peak load' (aggregated peak load, discrete peak load or singular peak load), 'user thermal comfort flexibility' (referring to the thermal comfort zones of users in buildings) as well as 'economic benefit'. Appropriate algorithms to specify and calculate these performance indicators need to be developed in concrete cases.

Context conditions – Demo Site Hyllie MALMÖ

The model is embedded in a broad partnership of the municipality, e.on as the owner of the district heating system and heat provider, and municipal or private building developers and owners. A foundation for these collaborative relationships is the Climate Contract and Hyllie Environmental Programme as well as a long tradition of collaborative public-private partnerships for the provision of different types of infrastructure services in Malmö municipality.

Local energy system and stakeholders

Local grid infrastructure
The local grid infrastructure consists of a local/municipal district heating network supplied by a sustainable energy source. The district heating grid is connected to a sufficient number of buildings with building energy management systems. In addition to the district heating grid, the buildings have to be integrated with a smart grid IT platform which interacts with their building energy management system through a smart gateway and allows the heat supplier to take influence on the building temperature level controlled by the BEM system.

Generation and storage
Generation is not specific to the 'smart' district heating system which builds on a traditional district heating system and its heat generation. However, in the best case, the need for peak heat generation capacity, e.g. through gas boilers can be reduced. Heat storage is provided through the existing building structures and does not need separate storage provisions.

End-user components "behind the meter"
No additional installations are required at the user side / behind the meter as the user does not need to intervene in the system actively and should not feel a difference in heat supply with or without peak load mana-gement, in terms of thermal comfort.

Actor-groups and Stakeholders-groups (third parties, ownership)
Important key actors are:

- district heating system operator – public or private utility
- property owner / facility manager
- Users of buildings, e.g. households or offices, do not need to actively participate in the system.

Local Energy System – Demo Site Hyllie MALMÖ

The system is applied to manage heat loads of the district heating system by using building structures for heat storage. In the longer run, the aim is to develop a smart grid platform operating across the heating network and electricity grid. The main feature of the smart district heating system is a smart residential gateway (control box with mini-computer) connected to the building management system in district heat supplied buildings and allowing to use the building structure as heat storage by slightly overheating the building in advance of expected peak demand. In the longer run, the residential gateways can be used to provide other types of smart grid functionalities to the buildings and households.

Key partners – Demo Site Hyllie MALMÖ

The key partners in the demo site Hyllie, a new-built urban district in the Swedish city of Malmö, are the international energy utility E.on, which in Malmö operates the district heating network and supplies heat to a large share of properties in the city, as well as property owners, in the first place the municipally owned housing company, but also private property owners. The municipality is essential to provide an appropriate context, e.g. through the municipal environmental program in Malmö, which creates (non-financial) incentives for property owners to cooperate with the municipality or district heating system operator.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs
More cost-effective and sustainable delivery of heat in winter, or cooling in summer through the reduction of peak load costs (additional peak load boilers and generation; avoided costs for the capacity increase of pipes).

Beneficiaries / Stakeholder
- Local electricity grid operator / District heat provider
- Grid users / heating network users
- Property owner
- Facility manager, Municipality, District heat provider

Value Propositions
- Business model
- Reliable and economical heating and cooling supply
- End-users' loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain
- Property owner: provision of building as heat storage, providing access to building energy management system
- District heat provider or IT company: design and construction of the system
- Local electricity grid operator / District heat provider: operate the district heating network and smart management system, deliver heat
- Service staff / District heat provider: contact to end-users, service delivery
- end-users: customer of the services offered, cheaper and more reliable heat supply

Economic, social and environmental needs – Demo Site Hyllie MALMÖ

Sustainable development and the mitigation of climate change are crucial elements of the vision of an integrated energy system in Hyllie, and the smart grid development is regarded as a part of that aim. The macro-economic effects are based on the reduction of peak production – thus reducing costs due to climate emission taxes and fuel prices. A broader installation of load management would have further potential and is currently implemented also in existing residential areas in Malmö and other Swedish cities.

Collaborative Business Model – Demo Site Hyllie MALMÖ

The energy infrastructure has been privatised since 1991 and is now owned by the German company e.on. The municipality and energy company are however cooperating closely on many issues, and especially in the Hyllie project – e.on as the owner of the district heating system and heat provider, and municipal or private building developers and owners.

Framework conditions for adoption and replication

Market regulations

District heating networks are only lightly regulated in most European countries. Some countries e.g. have regulated heat energy prices. So far, DH systems are fully integrated, i.e. there is no regulatory and ownership separation between the heating network and the supply of heat. However, EU's Heating and Cooling Strategy (COM (2016) 51 final) and the so-called winter package (clean energy package) include provisions for third-party access to the DH network for renewable heat producers. These strategies have not yet been transposed into national laws and moreover include provisions for certain exemptions to third-party access. Thus, the use case for smart district heating networks with load management which builds on the integration of network operation and heat supply should be applicable in most European Union member states.

Financing

The use case builds on existing heating networks which also do not need upgrading to comply with the smart load management strategy. For the time being the primary funding barrier appears to be the development and programming of smart gateways as interface of the smart grid platform and the building energy management system as well as the IT platform for smart grid load management. Currently, there is no commercial product available. E.on Sweden has developed such systems for their use and start to roll them out in municipalities where they operate the district heating network.

Social acceptance

In the applications of the use case so far, social acceptance of tenants in buildings has not been a discernible issue, as people living in the respective buildings or working in offices there should not feel a difference with or without the load management system. Also, the installation of the smart interface with the building management system is limited to the control system of the building and does not require any construction work. Acceptance is however required from the property owner or facility manager which so far has not been a severe problem. Acceptance can be further facilitated by a municipal setting where the cooperation of district heating providers and building owners is encouraged and part of municipal energy and climate strategy. Information material and events to the building occupants will further increase their support for the load management systems, particularly if embedded in a strategy for increased energy efficiency and low-carbon heat supply.

Identified barriers to replication and scalability

Technology Level

As pointed out above, a significant technological barrier is that no such interfaces between the district heat provider and the building energy management system (smart gateways), nor an IT system for smart district heating networks is commercially available at the moment and has to be custom made in case of replication. A further barrier is that these interfaces need to be made compatible with the particular building energy management systems implemented in the buildings which should become part of the load management system.

Market level

In the case of smart grid applications in Malmö, Sweden, the smart district heating load management system was the only part where a viable business case could be developed under current conditions. Installation and operation costs of the system are outweighed by the savings achieved through load management. This situation may change if building owners request fees for their participation in the load management effort.

Stakeholder Adoption level

A challenge is undoubtly to install the heating network load management in a sufficiently large number of buildings connected to the district heating network. Benefits of delayed (or avoided) network capacity extensions of the provision of back-up heat generation capacity require a certain level of storage capacity in the buildings which are part of the system (depending on the specific situation in the network in question, such as number and height of peaks, network capacity limits). Recruitment and motivation of building owners to participate in load management is thus an essential part of the use case. A further precondition for the adoption level is the availability of an interface for the technical specifications of the building energy management systems of DH users. If only part of the buildings can be connected for technical reasons, the adoption level remains proportionally lower.

4 Use Case #4 in Flexible Smart Grids: Shared use of local low temperature resources

The use case describes how a municipality could enhance its attractiveness to new citizens and promote development areas by using a sustainable heating concept. A medium sized decentralised thermal energy source feeds a local heating network, which distributes heat to individual end-users. Each end-user utilises a heat exchanger, mostly a heat pump, for cooling and heating its building. With only one energy source a large area can be supplied. Also, the network acts as a thermal storage system.

Keywords
Municipality, Low Temperature, Heating Network

Reference – Demo Site Güssing

In Güssing, a biomass plant supplies heat to a district heating network with a length of about 35 km and more than 85 end-users connections. Customers are private households as well as industrial end-users. Biomass is provided by regional farmers, foresters and the local parquet industry (sawdust and waste-wood). In total, three large heating plants are connected to the heating network, of which two are currently in operation. These primarily supply the city of Güssing and the region around the power plants with thermal energy. Outside Güssing there are some other small district heating networks for local heat supply. This system configuration allows minimising distances between heat production and supply, thus keeping heat losses as low as possible.

Reference – Demo Site Wüstenrot

An agrothermal heat collector serves as a thermal energy source to supply heat to a low-temperature district heating network. The heating network is connected to a development area in Wüstenrot nearby an agricultural area. The end-users are single-family houses equipped with heat pumps. The heat pumps extract energy from the low-temperature network and transfer it into the buildings. They are powered by the electricity grid and local PV power plants. The key partners in Wüstenrot are the municipality and its utilities (energy supplier). Both are responsible for public relations, primarily to promote the solution and its benefits to the end-users. Furthermore, the municipal utility has to acquire customers and negotiate with landowners. The technical construction and services are performed by subcontracted engineering and constructing companies.

Image 1
Planned heating network Wüstenrot
(Source: ReFlex website)

Image 2
Plus-energy residential area ‚Vordere Viehweide'
(Source: ReFlex website)

Use case outline
The Flexibility Challenge

Scope and objectives of the use case
This use case is suitable for areas with an available decentralised low-temperature heat resource nearby. The advantage of a shared local low temperature resource is the use of (process) heat at low-temperature to feed the thermal network, which otherwise remains unused. Thermal energy is often available, e.g. from the environment (ground/air) or generated as an unused by-product in many industrial processes. Any source of thermal energy with enough power to heat the transfer medium to a specified temperature level can be used.

The objective of this use case is to supply as many end-users as possible with cheap and sustainable heat in winter and/or cooling in summer.

Narrative of the use case
In rural areas and districts with a low population density, the heat demand is much lower than in urban districts. Distribution losses and high investment costs for the network infrastructure impeding the profitable operation of a traditional heating network based on a large-scale heat generation unit. Instead of using individual heat generation units, local low-temperature resources may be shared. A medium-sized heat generation unit distributes thermal energy through a local heating network to connected households. Each household operates a decentralised heat pump to increase the temperature level to meet the individual demand. Assuming a coefficient of performance (CoP) of up to 4.0 for the heat pumps a significantly reduced energy demand may be achieved compared to individual central gas or oil heating.

What can be replicated? How could this be achieved?

What to do as Municipality?
- Identify potentially usable low-temperature heat resources (e.g. agrothermal, geothermal, waste heat)
- Clarify legal requirements for the implementation and operation of a local heating network
- For (new) development areas, consider the implementation of a heating network at an early stage of planning
- Raise the attention of potential customers by informing and involving them from an early stage onwards

What to do as actor in the Energy Sector?
- Attract a critical mass of end-users to connect them to the heating network
- Provide a sufficiently large sustainable heat source that can supply enough heat to connect (additional) end-users
- Provide service to customers (e.g. long-term contracts, maintenance)

What can be replicated from Demo Site Wüstenrot?

To replicate this use case like it is applied in Wüstenrot similar boundary conditions are substantial. An agrothermal collector can only be installed if there is appropriate space close-by and the municipality or property developers can acquire the right to use it in the long term. Having the opportunity to install an agrothermal collector, sufficient load has to be connected to operate a profitable local heating network.

Context conditions

Assumptions
It is assumed that the residential area already has a heating network, or it can be installed. It is essential to be aware that a subsequently installed heating network generates excessively higher project costs. Depending on heat generation and installation costs there are a minimum number of end-users for a profitable heating network. The higher the connection rate of households the more profitable is the system. In new development areas, a general obligation to connect to the heating network may be considered.

Geographic and Environmental Conditions
From an environmental point of view, the heating network does not present any danger to the environment during normal operation. However, in the event of a leak, an environmental impairment must be considered, and an emergency plan is obligatory.

Prerequisites
The prerequisite for optimal planning and operation of the heating network is that the designated area, which has to be supplied with heat, is located close to the heat generation unit to minimise heat losses and costs. To achieve high availability of the heating network, operation and maintenance of the system play a key role but can be performed by the manufacturer himself or an external service company.

Legal and Ethical Considerations
All relevant legal regulations of the country must be observed, and all contracts must be legally concluded. A lawyer or legal expert must examine carefully each contract to avoid any further complications between the involved parties.

Key Performance Indicators (KPI)
In this use case, several KPIs are used to represent the performance of the low-temperature heating network, such as Seasonal Performance Factor (SPF) and the return in terms of profit in relation to the capital, also called ROI (Return on Investment).

Key partners – Demo Site Wüstenrot

The outskirts of Wüstenrot are close to agricultural land. The municipality as the landowner was willing to provide its nearby field for heat exchange purpose. Thus, an installed agrothermal collector feeds heat to a new development neighbourhood utilising a low-temperature heating network. As the municipality and its utilities made a significant effort on engaging people, all private household are connected. Electric heat pumps use the low-temperature source for cooling and heating the building and for hot service water. Thermal storages and roof-top photovoltaics complement the system.

Local energy system and stakeholders

Local grid infrastructure
The local energy infrastructure consists of a local heating network for heating and cooling, connected to a sustainable energy source as well as the local electricity grid. Each house has its connection to the district heating network with an electric heat pump to transfer energy from the network to the building or to release thermal energy it into the network for cooling.

Generation and storage
Due to the thermal mass of the heat transfer liquid of the heating network, it can act as thermal buffer storage. By increasing the liquid's temperature within safe boundaries, generation peaks can be buffered in the network. Therefore, excessive thermal energy from the generation unit can be stored in the network itself or additionally in thermal buffer storage systems in the buildings.

End-user components "behind the meter"
An electric heat pump transfers the heat from the heat transfer liquid of the heating network to the internal circuit of the building while also adding more energy and heat to it. This circuit distributes the heat to the space heating units and / or to the air conditioning system. Depending on the installation, the circuit could also feed service water.

Actor-groups and Stakeholders-groups (third parties, ownership)
The operator of the system can be the municipality with the municipal utilities or a private provider. Cooperation is also possible so that for example the municipality operates the heating network but draws thermal energy from a private provider.
The most important key partners to operate a shared local low-temperature network are:

- Municipality
- Energy suppliers (e.g. municipal utilities, private energy suppliers)
- Landowner (agrothermal) / processing company (heat as by-product)
- Grid and heating network users (e.g. businesses, house owner)
- Engineering and construction companies
- Service providers

The task of the operator of a district heating network is not only to supply energy but also includes preventive maintenance and emergency service in case of defects. The operator can be municipal utilities, private service companies or the energy supplier itself. Also, experience has shown that direct communication with the customers is essential at every stage of the project. The communication may be performed by telephone, postal, in person (service staff) or digitally via the internet (online portal, e-mail) and must not be underestimated. Furthermore, sales, dealing with repair services, complains and administration of end-users' data has to be considered to operate a local heating network properly. Energy supply as well as service and maintenance base on contracts between the key partners. This includes long-term contracts between the heating network operator and owner, the landowners, house-owners and engineering and construction companies.

Key partners – Demo Site Wüstenrot

The key partners in the Demo Site Wüstenrot are the municipality as the owner of the land used for agrothermal collectors and its municipal utilities (in charge of electricity grid operation, energy supplier). Both do public relations to promote the solution to interested parties living in new development areas. The municipal utilities are in charge of acquiring customers and negotiating with landowners. Subcontracted engineering and construction companies perform technical construction and services.

Mission model

What are the needs? How is value created?

Economic, social and environmental needs
Independent cost-effective and sustainable delivery of heat in winter and cooling in summer.

Beneficiaries / Stakeholder

- Energy infrastructure operators: energy utility / local heat provider
- Grid and heating network users
- Property owner
- Facility manager, Municipality, District heat provider
- Engineering company, Construction company, Service company, Service staff

Value Propositions

- Business model
- Reliable and economical heating and cooling supply
- End-users' loyalty
- Increased attractiveness for the beneficiaries

Collaborative / Cooperative Business Model(s) along the value chain

- *Municipality*: provision of land and resources, compensation through tax revenues and possibly rental fees
- *Engineering and construction company*: design and construction of the system
- *Energy infrastructure operators*: operate the plant, deliver energy to the households connected to the local heating network
- *Service company*: maintenance of the energy system, carrying out repairs
- *Service staff / Municipal utilities*: first level contact with end-users
- *End-users*: household connected to the local heating network

Economic, social and environmental needs – Demo Site Wüstenrot

As the community of Wüstenrot is a rural area with no nearby jobs, it suffers from migration into urban agglomerations. Attract people by new development areas with prospective low incidental expenses especially for heat due to a district heating network and obligating power generation by PV plants was shown to be a good solution for Wüstenrot. Also, the solution simultaneously fit the objective to a low environmental impact and enrich the community socially due to new young families and serval events to let people participate in the plans of the municipality.

Collaborative Business Model – Demo Site Wüstenrot

While the municipality and its utility have to spend money on service staff for public relation and to interact with the end-users, they also earn money directly by property tax and indirectly by enriching the village with new citizens spending money on local businesses. Besides, municipality, its utilities and the service company are now frequently requested to show the Demo-site to experts from all over the world. The municipal utilities and especially the service company could use their gained expertise for other comparable projects. After the successful realisation of the heating network, other end-users are more willing to participate in new heating networks. This is why another heating network will be realized in the centre of the village with existing buildings and a school centre.

Framework conditions for adoption and replication

Market regulations

District heating networks are not subject to regulation in Germany. The topic of district heating is not part of the statutory scope of the Federal Network Agency. There is also no regulation of district heating suppliers. The Federal Cartel Office is responsible for the protection of competition in the supplier market as an independent competition authority. In 2009, the Federal Cartel Office initiated an investigation of the district heating sector, providing a final report "Sektoruntersuchung Fernwärme" in 2012.[2]

Financing

In terms of financing, first of all, investment costs have to be considered. For a district heating network, these are the costs for engineering and construction companies as well as for technical components and the entire construction material. Secondly, running costs must be taken into account: these costs build up during the entire service lifetime of the system. Some costs such as the routine service are incurred on a regular basis, other, such as spare parts for defect subsystems, are irregular.
HFT Stuttgart, the leader of the accompanying research project "envisage" in Wüstenrot, set up a procedure to develop an appropriate financing concept for low-temperature district heating networks. The main steps are:

1. Energetic-technical analysis to check the basic requirements: survey energetic potential and fields of action, analyses of technical feasibility, definition of measures as well as alternatives and variants, identification of relevant stakeholder groups.
2. Economic efficiency analysis and sustainability analysis as a basis for initial investment decisions: calculation and evaluation of the respective investment volumes and operating costs lead to first conclusions regarding the cost-effectiveness and their compatibility with the objectives of the region.
3. Development of Appropriate Financing Concepts based on the identification of target groups, collection of funding and resources, identification of funding needs and constraints, exploration of funding opportunities and innovative financing instruments.[3]

2 https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Verbraucher/Energielexikon/energielexikon-node.html
3 Vision 2020 Die Plusenergiegemeinde Wüstenrot Fraunhofer IRB Verlag ISBN (Print): 978-3-8167-9629-9

Social acceptance
Due to the higher construction and installation costs at the beginning, the initial investment costs might be an obstacle for interested households. Although a connection to the heating network is attractive on a long-term perspective. It has to be proven to the customer that the low-temperature heating technology is cost-effective (robust investment plan including investment and operating costs) compared to alternative heating systems. The new, not yet pervasive coupling technologies such as photovoltaic based heat generation can also be a reason for a somewhat cautious attitude of people towards solutions based on local heating networks. Therefore, it is necessary to promote the concept of low-temperature heating networks and actively involve interested users, e.g. through information events and site visits.

Identified barriers to replication and scalability

Technology Level
There are many solutions for low-temperature heating networks on the market. However, every solution has its specific framework conditions which makes it difficult for replication and upscaling. However, using an agrothermal collector and a low temperature is successful for regions with seasonal temperature variation as it deals with heating and cooling the buildings. Furthermore, it could shift the resaved heat from the buildings in the summertime to the autumn due to the inertia of the soil.

Market level
The major challenge is to find the best solution and suitable area for the energy resource, which should be preferably close to the end-users' premises to minimize heat losses and costs for the heat network. For maintenance, the service staff need to be trained on the individual heat generation unit, the heating network and the heat exchangers of the end-user. It can be assumed that every local heating network differs in its structure, scope and technology. Furthermore, it is crucial to demonstrate the added value and prospects of low-temperature resources to (new) customers. This includes the supply of energy around the clock at a reasonable price and fulltime service. The added value for the municipality is an increase of attractiveness of the development area as the local heating network provides thermal energy with a simple, low-maintenance and sustainable solution to the households.

Stakeholder Adoption level
Another challenge is to convince as many households as possible to connect to the heating network and give up their old heating system. After finding a suitable heat source, one of the main obstacles for the energy supplier is to acquire enough customers. Therefore, it is important to have service staff trained to advise and recruit. Based on experience a good communication concept is essential for good user acceptance. Especially good communication between customers / households on the one side and service provider(s), heat supplier, municipality and municipal utilities on the other side is important to make the service smooth, effective and sustainable.

Technology Level – Demo Site Wüstenrot

Currently the agrothermal technology is still at the level of an early commercial deployment, there are a few agrothermal collectors in operation. There are still many research topics to be observed. On example are the effects on plants growing on the fields above the collector. Also, there is a lack of information about long term operation as the technology is relatively new.

5 ReFlex Toolbox

Replicability tools for target groups

Introduction

The successful replication of smart grid projects can be supported by specific tools in order to facilitate the implementation of solutions within new settings and in new areas. However, different target groups, different socio-economic or spatial settings and the various project phases may require different tools for upscaling and replication. ReFlex differentiates between 5 phases within the replication process (see figure "Overview ReFlex Tools" below) that cover the whole process starting with the search for ideas; the planning and analysis of the replication project; the actual implementation phase as well as lessons learnt from own and other Smart Grids projects. The ReFlex Guidebook presents some major methods and tool to support replication within those different phases (for example, the ReFlex CoP can support the finding of initial ideas, provide lessons learnt as well as reducing barriers and opposition for implementation of the replicated solution; whileas the ReFlex-Box is mainly addressing the planning and analysis phase of a replication process).

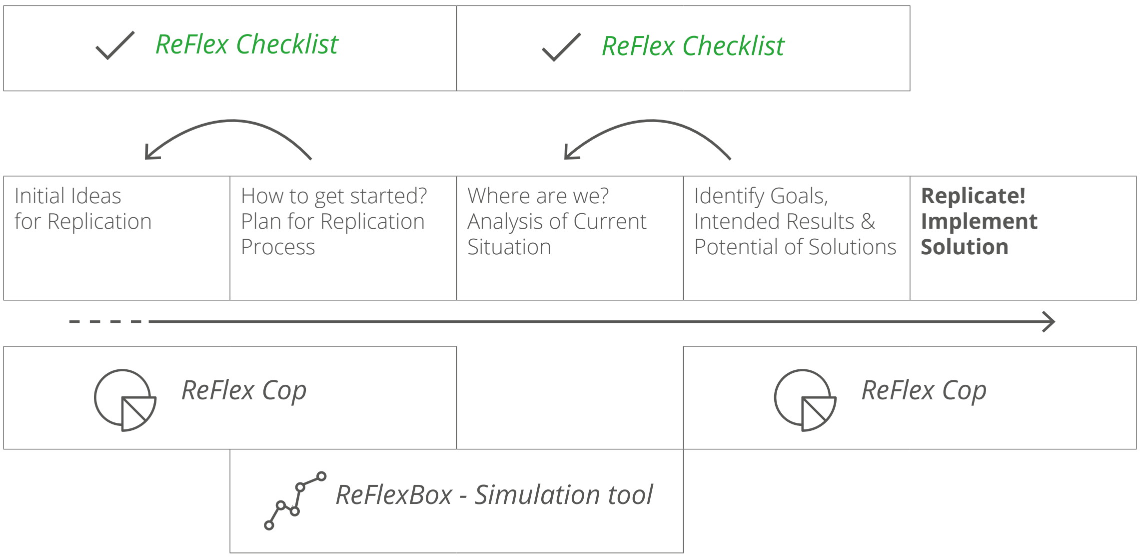


Figure 1
Phases within a Replication Process and the ReFlex Toolbox

Checklist for the evaluation of context factors for successful replication

Introduction
If you intend to transfer one of the use-cases to a replication site, the following checklist helps to identify the critical context factors to be considered. Not being able to answer all questions with yes must be expected. If answered with NO, you might have to reconsidered to replicate the use-case at all. Other questions, if not answered with YES, leads to further investigations how context conditions can be changed, and which measures could be taken to replicate the use-case.

Please consider that the list is not encompassing all factors which might be encountered in replication. However, it provides a systematic overview of the most relevant dimensions and context factors identified by practitioners in the ReFlex project.

Table 1: Checklist

	Questions
Space and Geography	Are relevant geographical and climate conditions similar? Are the spatial scales and dimensions applicable to the replication site?
Technical functionality and technology	Can the same technological components be implemented? Can the same digital control, information and communication hardware and software applications be implemented? Is the relevant technological know-how available among the partners in the replication project, or can it be acquired?
Economics and Sustainability	Is there a profitable business case for all private and public economic actors involved? Are the right economic actors involved? (public and private investors, energy infrastructure owners, energy system businesses, end-users as consumers and producers) If end-users are involved, are their economic benefits clear and transparently communicated? Is there a clear analysis of risks and uncertainties and how the consequences are shared among the partners in the replication project? (e.g. consequences of hacking, sharing of losses) Can the replication be financed by the actors involved, and/or is it bankable? (public and private investors, energy infrastructure owners, energy system businesses, end-users as consumers and producers …) Does the use-case make sense from the economic perspective for the municipalities and/or regions affected by it? (e.g. local value added, local employment, tax revenues) Does the use-case, once transferred to other sites in the same country and beyond, have the potential to provide benefits for the whole economy, in terms of value added and employment? Does the use-case, once transferred to other sites in the same country and beyond, have the potential to provide benefits for the decarbonisation of the energy system at large?

Institutions and Regulations	Do the same national legal frameworks and standardisation rules apply? a) requirements for unbundling of energy supply and grid operation and energy market regulation (not all the same under EU regulation) b) tariff models for end-users c) grid codes (e.g. allowing for DC grids or direct lines) d) rules for licencing of distribution system operation e) data protection and privacy regulations Are the energy market institutions comparable? a) room for local energy utilities (e.g. Stadtwerke) to act as grid operator, energy supplier, energy producer, storage provider b) room for local energy exchange in "citizens energy communities" or business-to-business cooperation Does the state provide (soft) measures to foster the integration of renewable energy sources and flexibility services? a) regulatory-body's legal space for allowing replication projects (e.g. regulatory sandboxes) b) requirements for climate and energy strategies and implementation plans c) regulators' possibilities for accepting Capex and Opex for grid tariffs
Social and political visions, practices, networks and culture	Do actor and stakeholders share a vision on how to achieve shared goals by the intended replication, be it explicit in the form of a formal political agreement or an implicit or explicit strategy? Are the benefits of the use-case for third parties (neighbours, citizens, competing businesses) explicitly or implicitly considered in a mission model? Are the actors and stakeholders convinced of the values and benefits of the use case in terms of economic, ecological and social sustainability? Is the network of actors involved in the replication project robust for long term commitment? (joint investments of businesses, households, public-private partnerships) Do establishes practices and behaviours of end-users exist, on which to build on? (e.g. demand response tariff-schemes) How developed is the trust between actors and stakeholders? (e.g. trust in state institutions regarding private data, ICT security) Would the use-case also work if this trust is shattered?

ReFlex - COP Community of practice as learning tool

Why repeating mistakes others already paid for?
Many projects dealing with flexible and integrated Smart Energy solutions share similar challenges when in the phases of (a) Identifying initial ideas for the right solutions, (b) Selecting and deciding how to get started, and (c) Final decision-making how to implement the replication project. At the same time, many obstacles and opportunities are similar, although most likely there are differences in technological components used, as well as in how the solutions are embedded in a socio-economic environment. Therefore, exchanging experiences with other practitioners helps to enlarge the knowledge on success factors and – foremost – how to avoid costly mistakes, for which others already had to pay for. One of the most appropriate Learning Tool, which considers those aspects, is a Community of Practice:

What is a Community of Practice?
A Community of Practice is a group of practitioners, who share the same interest and challenges in a specific area. Through a moderated process of sharing information, expertise and experiences, members learn from each other for tackling their challenges and can develop personally and professionally.
To get communities going and to sustain them over time, it is crucial that participants regularly meet and discuss shared challenges and try to find practical solutions.

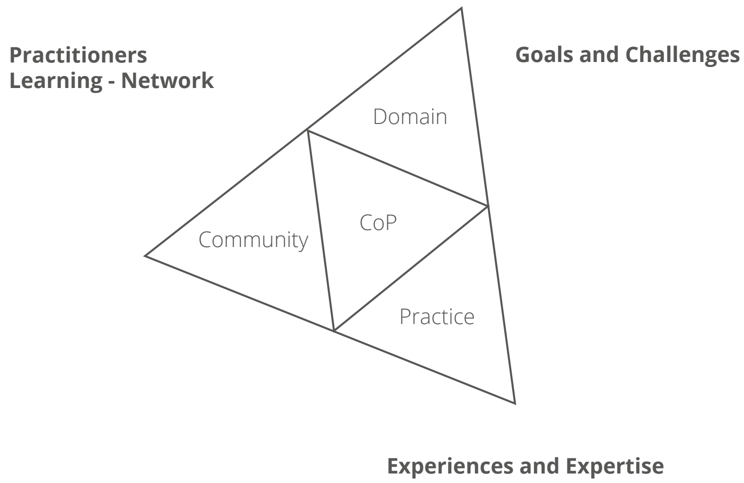


Figure 2
Key Element of a CoP

The Community of Practice in ReFlex

In the framework of the ReFlex project, the main purpose of the CoP was to foster knowledge exchange, learn from the experience in the Smart Grid demo regions and discuss issues encountered during the project implementation phase and challenges related to the transfer and/or replication of the tested solutions to other sites.

Resources – The CoP included 7 site-visits, three of them back-to-back with the CoP workshops, which were held in Austria, Switzerland, Germany and Sweden in a period of 2 years. The events were organised by the local project partner and had up to 30 participants.

Main activities – CoP workshops were prepared based on practitioners' questions regarding ongoing and emerging challenges. These were collected in interviews and sessions of previous CoP workshops. Thus, working groups with dedicated subjects were prepared with inputs from the project team's experts and designed for exchange and discussions among practitioners. Pressing topics included the profitability of flexibility services, cooperative business model development and changes in markets structures. Also emerging topics such as the role of distributed ledger (blockchain) technologies and expected regulatory changes trough the energy policy framework "Clean energy for all Europeans" (winter package) were discussed.

Main outcomes – Practitioners' mutual learning on the trustful atmospheres was highlighted as main benefit. This included learning from successful and failed projects and from trying to understand the reasons behind it considering the various context conditions (e.g. what difference it makes when you compare innovation potential for grid operators in unbundled and vertically integrated market structure). The intensive workshops also provide legitimacy to the recommendations out of the ReFlex project such as the need for experimental space in sandboxes or regulatory innovation zones.

CoPs are not yet commonly recognised as highly effective for replication and rarely financed with public support. Hence, those in need of such learning experiences, should consider it as a tool of choice and should request from the funders of replication projects to provide this opportunity and to search for a critical mass of practitioners to establish such learning-networks.
Peculiar aspects of a ReFlex CoPs as learning tools between demo site- and replication practitioners – Deep-diving into demo site experiences are valuable sources for replication processes. They help to learn about the technological and functional aspects off use cases as well as the collaborative aspects of innovation process and business models and allow to investigate the similarities and differences in the context conditions of each use case. CoPs as interactive tools help to learn from good practice as well as from the failures. In the trusted atmosphere of CoP workshops individual and group knowledge can be generated and applied in the planning, decision making for replication projects as well as during the co-creative implementation process.

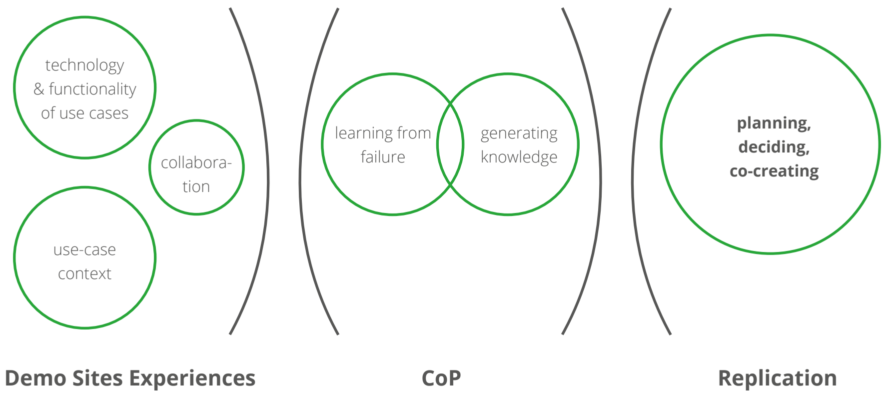


Figure 3
ReFlex CoPs as Learning Tools between Demo Sites and Replication

RefleBox simulation tool

The Flexibility Assessment

The ReFlexBox Tool

The ReFlexBox tool simulates the operation of energy systems, consisting of single buildings located in the same grid area. The tool assesses the flexibility potential of the designated area to optimize and scale up best practice technologies. The replicability potential is based on experiences obtained in various smart grid demonstration projects of the ReFlex Project.

The ReFlex tool can assist cities and districts in planning their local smart grid infrastructure by replicating smart grid solutions from existing demo-sites and scaling them up to the desired size. Each building in the model has a heat pump with thermal buffer storage for space heating and a boiler with a hot water tank to supply domestic hot water. Furthermore, a PV plant with a battery storage system supplies power to electrical loads. The energy system operation is simulated on both, building and district level.

Flexibility potential of the energy system is defined as a power adjustment kept for a period without influencing the comfort level in the buildings. The flexibility potential of the replicated and scaled-up system is quantified in the simulation. For comprehensibility, the results are translated into the number of additional electric vehicles that can be implemented on the site using statistics but without the need to enhance the energy system.

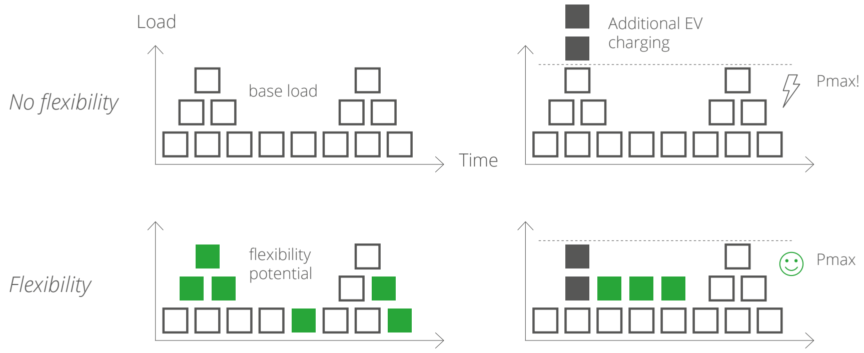


Figure 4

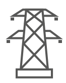
Plus-energy residential area ‚Vordere Viehweide'
(Source: ReFlex website)

Target Groups

ReFlexBox supports multiple stakeholders involved in smart grid projects:

Decision Makers

Decision makers to understand better energy systems and the benefits of flexibility provided by controllable loads and decentralised generation units. During the simulation, users can observe the operation of the onsite energy system over time. Yearly energy system performance and overall flexibility potential are assessed and visualised.



Local electricity grid operator (DSOs, local energy utilities)

Local electricity grid operator, e.g. Distribution System Operators (DSOs) or local energy utilities, interested in solutions of demand-response-related questions, such as, to which extent load management can be reasonably done, by quantifying the amount of flexibility offered from the energy system.

Local authorities
Local authorities can assess the feasibility of replicating or scaling-up a demonstration smart grid project by modifying inputs such as weather conditions, number of households.

Simulation Framework and Input Data

Current replication and upscaling are based on measured input data of the Biel-Benken demo-site in Switzerland. A demo version of the ReFlexBox is available online, which allows running two preset cases, at following link:
https://bit.ly/2GcMXZJ
A full version of the ReFlexBox allows the user to customize the setup and replicate to other locations. Please click on the following link to access this full version:
https://bit.ly/2Ht7YyJ

User interface and results

The User Interface

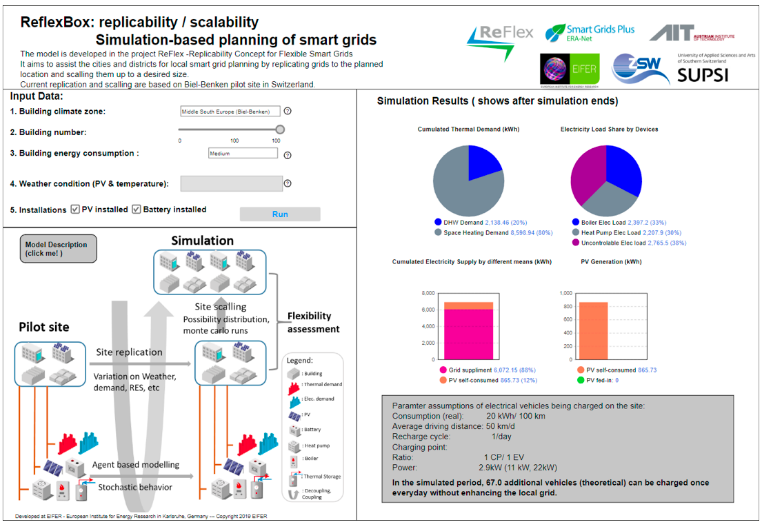


Figure 5
Illustration of the Impact of Electric Vehicles on flexible and unflexible Energy Systems

On the graphical interface of the ReFlexBox, the input parameters can be changed by the user. The user can select among 4 zones of central Europe that are implemented in the tool. The weather conditions refer respectively to those of the cities of Biel-Benken, Berlin, Warsaw and Malmö.

Input Data
The figures above show the graphical interface of the ReFlexBox and the input parameters that can be changed by the user. The user can select among 4 zones of central Europe that are implemented in the tool. The weather conditions refer respectively to those of the cities of Biel-Benken, Berlin, Warsaw and Malmö.
If the "User Defined Location" is selected, the user shall upload a customised weather file in format TMY (.tm2) in the corresponding "Weather condition" row. Data for other locations can be obtained from the Meteonorm database https://meteonorm.com/.

The user can choose the number of buildings and their energy consumption. The thermal energy consumption bases on a neighborhood of 100 houses in Biel-Benken, with an assumed average of 6470 kWh/year/house. Given this information as reference, the user decides whether the consumption is
"Very high" (20% higher consumption than reference),
"High" (10% higher),
"Medium" (equal to reference),
"Low" (10% lower consumption than reference) or
"Very Low" (20% lower)
Furthermore, PV and battery installations could be activated or deactivated by using the checkboxes.

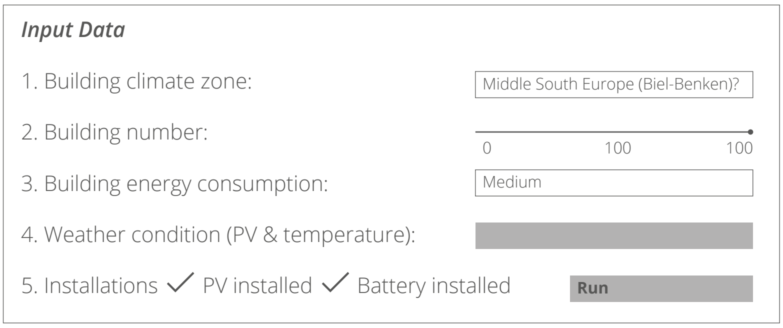


Figure 6
Model Input for Simulation

Simulation Results

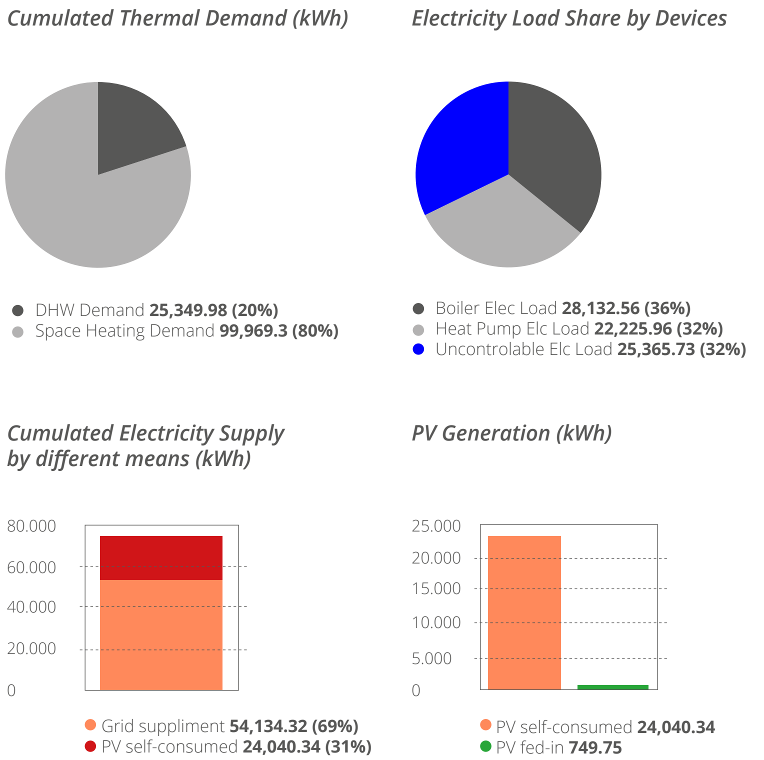


Figure 7
Visualized Energy System Performance

During the simulation, the user can observe the operation of the onsite energy devices over time including daily and seasonal change of thermal and electrical demand, PV generation, thermal and electrical storage state of charge, as well as the flexibility potential of the distributed energy resources. At the end of the simulation, yearly key performance indicators (KPIs) such as thermal and electrical demand, electricity supply from PV generation and the utility grid, overall flexibility from which the grid can benefit are assessed and visualised.
The flexibility potential of the simulated neighbourhood is quantified for each simulation time step, and the tool indicates at the end of the simulation how many additional electric vehicles can be implemented onsite without the need to reinforce the local grid. Model assumptions for electric vehicles base on German statistics and are listed in the below box.

Paramter assumptions of electrical vehicles being charged on the site:
Consumption (real): 20kWh/100 km
Average driving distance: 50 km/d
Recharge cycle: 1/day
Charging point:
Ratio: 1CP/1EV
Power: 2.9kW (11kW,22kW)

In the simulated period, 8 vehicles (guaranteed) can be charged once everyday without enhancing the local grid.

Figure 8
Parameter assumption for electrical vehicles adding to the local grid and its permissible number not influencing the grid impact

Several simulations were carried out to measure and compare the flexibility potential of different sites and system configurations. The scenarios and results are summarised in the table below.

Interesting scenarios by replicating a grid from Biel-Benken to Malmö show the deduction of flexibility potential by less 10%, which is caused by higher thermal consumption in Malmö. While replicating the smart grid solution to two different meteorological areas, we can still see a relevant flexibility potential in both, making the deployment of smart grid solutions interesting throughout the different countries. Two use cases of a grid consisting of 100 single-family houses located in Biel-Benken, with and without battery and PV installation are compared. The result shows that the battery and PV system doubles the grid's flexibility potential. In term of implementable electric vehicles, the grid without battery and PV allows 31 additional vehicles while the one with battery and PV allows 64 additional vehicles.

Table 2: Examples of Simulation Results

Scenarios			**Results**
Location	**Number of households**	**System configuration**	Permissible number of EVs that can be charged simultaneously without impact on grid stability
Biel-Benken	100	With PV and battery systems	64
Malmö	100	With PV and battery systems	60
Biel-Benken	100	Without PV and battery systems	31

6 Final Recommendations

Final Recommendations

Replication of flexibility solutions is an economically feasible and efficient way towards future-proof energy solutions. Building on innovations that already have been shown promising in pilots and demonstration projects in one site, helps to avoid repeating mistakes others already paid for. The following spotlights summarise some of the learnings, which practitioners in municipalities, energy system actors, technology providers and supportive researcher should take up when setting up a replication projects.

Spotlight #1: Demonstration and pilot projects cannot be copied! – How to compensate?

Demo Sites are based on specific context-conditions. Find out how you can compensate for peculiarities in context conditions on which pilots' successes depend!

Financing:

As piloted use-cases are by definition not yet profitable, they depend on public funding. Find out how you can compensate for R&D funding, e.g. by other forms of risk finance!

Unconventional organisational and personal constellations:

Overlaps of economic and political key actors can make innovation processes easier and faster in the first place. Find out how you can create similar conditions, e.g. by creating trust between replication partners and do not underestimate the value of cooperative climate!

Incentive structure:

Financial incentives, e.g. to end-users, for creating laboratory conditions in demo sites can make perfect sense for testing solutions, but not for replicating them under real world conditions!

Medium- and Long-term orchestration:

For systemic solutions, key-actors' shared visions on long-term transformation of the local energy-system are crucial. Find out how to build those visions and/or otherwise orchestrate actors in replication projects! Pioneering spirit: Involved staff and end-users with pioneering spirit is highly motivated, interested and often higher educated than will be the average user of a solution will be when deployed. Find out how to mobilise other resources, when developing a sustainable solution!

Spotlight #2: Compatible & Adaptable Context-Dimensions – What to look at?

Context conditions for replication projects need to be compatible & adaptable in the dimensions outlined in this guidebook:

Geography and Space – Climatic and topographic conditions as well as adequate spatial dimension; Technology – Energy infrastructure configurations, interoperability of components and the technological know-how; Policies of Actors – Governance processes, citizens' acceptance, trust in institutions;

Economic:

Costs of coordination, culture and willingness for co-creation, micro- and macroeconomic profitability, distribution of macro-economic benefits; Institutional Structures – EU and national legislation on competition and energy market regulation, energy market institutions, standardisation;

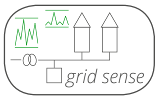
Actors and Stakeholders:

Actor-constellations, actor- & stakeholder network; People: entrepreneurial practice, cultural norms and peculiarities, social practices and behaviour of end-users and prosumers.

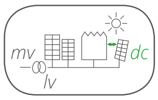
Spotlight #3: Role of Flexibility in Use Cases – Which kind of flexibilities?

A differentiation of two kinds of flexibilities can be provided by the use-cases. Flexibility for Power enables to match generation and loads on time, across seconds and minutes in the power-grid. Flexibility in Energy-logistics / Flexibility for Energy enables the overall balancing of the energy system (including the electricity and heat system) by energy generation and use across a period: minutes, hours, days and seasons.

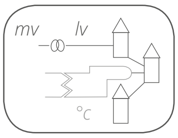
The aim of these energy system services is to manage variability and uncertainty in the energy systems:



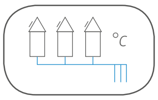
#1. ***Short term voltage-stabilization in local electricity grid:*** Aiming at stabilising the grid it serves as use-case for flexibility for power, mainly by managing the grid with actively engaging end-users by demand-response, which may effect social practices of household members.



#2. ***Energy management for business parks:*** Aiming at load and energy management b2b-services the use case provides flexibility for energy-logistics without having to actively engage end-users on a day-to-day basis.



#3. ***District heating load management:*** Aiming at load and energy management b2b-services the use case provides mainly flexibility for power in an integrated heat and electricity system, while it can also provide flexibility services for energy-logistics. The use case is based on using building structure as intermittent heat storage without bothering the end-users' comfort.



#4. ***Shared use of local low temperature resources:*** Mainly aiming at the use of a cheap energy source and potential heat- and cold storage, the use case can provide flexibility for energy-logistics with active engagement of the end-user. However, heat-pumps could potentially also be used for flexibility of power.

Spotlight #4: Success-factors for Flexibility-Solutions – How to Co-Create?

As flexibility solutions, for a foreseeable time, will not become available from the shelf, they will require tailoring to the needs of those who want to replicate existing solutions. It also requires reconsidering the roles of new and incumbent actors, which increasingly overlap (e.g. prosumers) and change. Thus, the question is to be answered how new coalitions are built, how they collaborate and compete. In the ReFlex demo-site this always involved co-creative innovation processes. Success will be based on a co-creative innovation process between involving those actors and other key stakeholders in multiple dimensions: Shared Visions & Missions-Models – Shared visioning and road-mapping processes involving all actors can help orchestrating energy system improvements in a sustainable way. A mission-model canvas, which outlines the monetary and social benefits, instead of considering the end-user merely as customer as ultimate source of profits.

Learning from & with Practitioners in Communities of Practice (CoP) – CoPs structure peer-to-peer learning among practitioners in a trustful face-to-face atmosphere. It is the key to learn from failures other already made, it is crucial for understanding of the importance of context factors and is a source for new innovative ideas. This cannot be replaced by reading guidebooks, expert advice or ICT-supported exchange platforms.

Co-Creation & unconventional co-operation – Innovation activities can build on a broad range of technological solutions on the one side but with the emerging new use-cases on the other side and new actors involved, establishes models of how innovations are developed changes. Particularly, as in some of the use cases there is a potential to provide flexibility services of different kinds, unconventional cooperation might be beneficial and co-creation becomes more likely.

Overlapping Networks (Policy, Economy, Research, ...) – As the energy system is in transition, so are the networks of actors and stakeholders providing the innovation-ecosystem. This involves networks in policy making, industry, energy sector and research. Although many actors are involved, those who are able to link between those regionally, sectorial or disciplinary constituted networks play an important role in adapting the context-conditions for replication.

Collaborative Business Models – Demonstration and Pilot projects for the use-cases do not yet constitute feasible business-models. However, they show that collaboration and cooperation are key to create new value propositions and societal benefits. Therefore replication processes should consider developing collaborative business models with fair distribution of benefits between all actors. This includes co-operation between municipalities and energy sector actors as well as end-users or prosumers when providing flexibility services for others.

Room for Experimenting – As context conditions are critical for the replication of flexibility solutions, more and more policy makers recognise the need new instruments to create room for experimenting. This includes funded Experimental Sandbox programs (like in UK and Singapore) and laws for regulatory exemptions (like in the Netherlands and Germany). When planning replication projects, those possibilities should be identified and evaluated.

7 Annex: Technologies Review

The Replication of Technologies

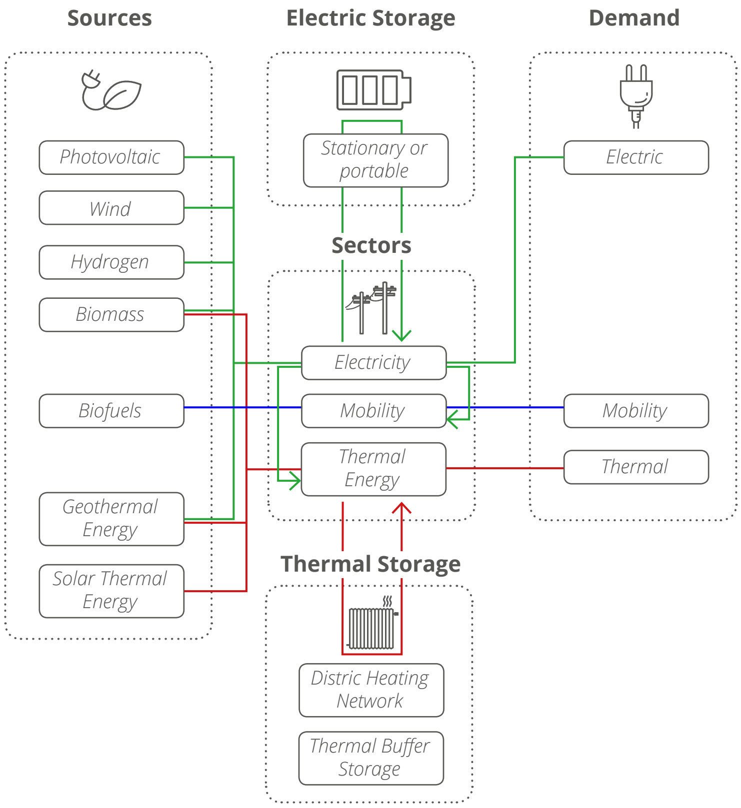


Figure 1
Sector coupling within the demo sites showing also the used energy sources, sectors and covered demands.

Photovoltaic

To estimate the potential of PV systems, run a performance analysis to identify the best locations for solar installations. Seasonal fluctuations are substantial due to the different hours of sunshine from summer to winter. Regional differences lead to fluctuations in the performance of PV systems, as the hours of sunshine depend on both, weather and geographic location.
For PV systems, areas with high solar irradiance are preferred. Therefore, residential or industrial buildings with suitable rooftops or open space areas need to be exploited.
The profitability of a PV system depends on the installation costs, energy yield and electricity price. At most demo sites, residential or car-park PV systems focused on the optimisation of self-consumption.

Hydro

There are two types of power plants using hydropower to generate electricity. Firstly, run-of-river hydroelectricity with small or no water storage and secondly, pumped-storage hydroelectricity. Hydroelectricity power plant could also be used for sector coupling such as power-to-gas especially for seasonal storage of energy. Nevertheless, hydroelectricity is not used within the demo-sites and therefore could not further be evaluated.

Demo Site Examples Photovoltaic:

Open Space
Güssing: Currently the region's largest PV plant with a rated power of up to 2,5MW
Hartberg: Carport with integrated PV station for re-fueling electric vehicles
Köstendorf: High density of PV systems, should be installed on every second roof
Gotland: PV system was designed to resemble a typical micro production, to determine if modern smart meters can be used to identify and correct power quality variances

Roof top
Biel-Benken: Using PV systems for self-consumption with and without energy storage in batteries and electric vehicles
Hyllie: "A significant share of the energy production will be locally produced in the form of such solutions as solar photovoltaics on the properties"
Wüstenrot: Roof top PV-installations with battery storage systems

Solar Thermal Energy
All demo sites only use small-scale solar thermal collectors for domestic heat supply. Seasonal fluctuations are substantial due to the varying hours of sunshine from summer to winter. Regional differences lead to fluctuations in the performance of solar thermal collectors, as the hours of sunshine depend on both, weather and geographic location.
For solar thermal collectors, areas with high solar irradiance are preferred. Therefore, residential or industrial buildings with suitable rooftops or open space areas need to be exploited.
The profitability of solar collectors depends on the installation costs, energy yield and costs for heating.

Demo Site Examples Solar-thermal

Güssing: Solar thermal system with 40m² collector area and 3000m³ hot water tank as hot water used in a gym and space heating.
Hartberg: Desiccative Evaporative Cooling system (DEC) with 12m² flat plate collectors.
Hyllie: Apartment blocks equipped with solar thermal collectors.
Wüstenrot: Injecting solar thermal energy into a heating grid.

Biofuel and Biogas
If renewable energy sources are used to provide fuels, e.g. for mobility, they are called biofuels.
Biofuels could be produced out of electricity by sector coupling such as power-to-gas and power-to-liquid, but also directly from biomass using thermochemical processes. The needed carbon dioxide (CO2) source could be supplied by efficiently by a nearby biogas plant.
The efficiency of the biofuel production mainly depends on the used technology, the CO2 source and steady energy supply. That's why it could be beneficial to buffer the fluctuating renewable energy sources by battery storage and/or locate the plant in a rural area with enough accessible biomass nearby. As the efficiency is rather small compared to direct energy use for movement, heat or electricity, an overlap of installed renewable energy plants is recommended. Because handling and storing gas and fuels are well known and therefore are suitable solu-

tions for seasonal energy shift. Biofuel and Biogas production could also be a showcase for good regional cooperation of nearby municipalities.

Biofuel and Biogas
If renewable energy sources are used to provide fuels, e.g. for mobility, they are called biofuels.
Biofuels could be produced out of electricity by sector coupling such as power-to-gas and power-to-liquid, but also directly from biomass using thermochemical processes. The needed carbon dioxide (CO2) source could be supplied by efficiently by a nearby biogas plant.
The efficiency of the biofuel production mainly depends on the used technology, the CO2 source and steady energy supply. That's why it could be beneficial to buffer the fluctuating renewable energy sources by battery storage and/or locate the plant in a rural area with enough accessible biomass nearby. As the efficiency is rather small compared to direct energy use for movement, heat or electricity, an overlap of installed renewable energy plants is recommended. Because handling and storing gas and fuels are well known and therefore are suitable solutions for seasonal energy shift. Biofuel and Biogas production could also be a showcase for good regional cooperation of nearby municipalities.

Biomass
The supply of biomass is the biggest obstacle for replication. The different types of biomass are subject to seasonal variations such as e.g. agricultural products (corn) and therefore not permanently available. Other biomass products such as e.g. fuel alcohol from agricultural products can be stored over a long period and are thus seasonally independent. However, the endeavour to supply enough food to the steadily growing world population means that the availability of biomass from agricultural products is becoming increasingly scarce.
Limits of biomass exist only in the procurement of raw material and energy distribution; the power plants can be built almost arbitrarily large. Biomass can be burned directly or converted to liquid biofuels or biogas. The most efficient way to use biomass as an energy source is a combined heat and power plant (CHP) with a heating grid.
The costs of biomass as an energy source are mainly dependent on raw material prices of the used type biomass (e.g. wood chips, grass). Independence of energy supply, regional jobs and sustainable development of a region cannot be measured by financial aspects only.

Demo Site Examples Biomass:

Güssing: Thermochemical biofuel production supplied by local biomass (mostly grass) and biogas plant.

Local Geothermal Energy

Local Geothermal energy systems use heat in the ground. In general, there are two types of local geothermal energy systems. On the one hand, to provide heat to individual users and on the other hand to provide heat to several users connected to one source. The replication of the first type is based on individual requirements. However, the connection of a local geothermal source to multiple premises only makes sense in combination with a local heating network. Geothermal energy sources could be near the surface (e.g. an agrothermal collector) or deep down whereby the temperature increases with depth. Hence, near-surface geothermal collectors provide a low but constant temperature ideal for electric heat pumps heating the buildings in winter or cooling down in summer. The heat provided from deep geothermal sources can often be used directly without the need for heat pumps. If available, groundwater is used as heat transfer fluid but also closed loop systems are common, especially in nature conservation areas.

As the efficiency of geothermal energy systems is based on the used technology and its geographical location, a potential analysis is recommendable. The underground limits the size and number of energy systems at one location. From an environmental point of view, a heating network does not present any danger to the environment during normal operation. However, in the event of a leak, environmental impairment such as landslides and impacts on groundwater could occur. An emergency plan is obligatory. All relevant legal regulations of the country must be observed, and all contracts must be legally concluded.

As geothermal energy systems have to meet high safety standards and also needs excavation work- Excavation costs increase with the depth and soil quality. Depending on heat generation and installation costs a minimum number of end-users for a profitable heating network is required.

Demo Site Examples Local Geothermal Energy:

Wüstenrot: A near surface geothermal energy system with an agrothermal collector as shared low temperature source provides heating/ cooling for private households using heat pumps and a district heating network.

ReFlex Project Partners

ReFlex Project Authors

Xiubei Ge
Paul Haering
Gudrun Haindlmaier
Simon Hummel
Enrique Kremers
Klaus Kubeczko
Norbert Lewald
Dick Magnusson
Davide Rivola
Harald Rohracher
Joanna Skok
Joel Wenske
Doris Wilhelmer

contact@reflex-smartgrid.eu

ISBN 9788875951061

Swedish Energy Agency

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Federal Ministry Republic of Austria
Transport, Innovation and Technology

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE
Swiss Federal Office of Energy SFOE