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ISGAN
INTERNATIONAL SMART GRID
ACTION NETWORK

Smart Grid Case Studies

SPOTLIGHT ON
Energy Storage Systems

Casebook

Austria, Canada , France, India, Korea, the Netherlands, Sweden

ISGAN Annex 2 Smart Grid Case Studies

March 2019

iea Energy Technology Network

CLEAN ENERGY MINISTERIAL

About ISGAN Casebooks

ISGAN casebooks are meant as compendium documents to the global trends and discussion about smart grids. Each is factful information by the author(s) regarding a topic of international interest. They reflect works in progress in the development of smart grids in the different regions of the world. Their aim is not to communicate a final outcome or to advise decision-makers, but rather to lay the ground work for further research and analysis.

Disclaimer

Acknowledgement

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Nomenclature or List of Acronyms

AGC	Automatic Generation Control
ASP	Ancillary Service Provider
BESS	Battery Energy Storage Systems
CHP	Combined Heat and Power
DR	Demand Response
DSO	Distribution system operator
ESS	Energy Storage Systems
FEMS	Factory Energy Management System
FIT	Feed-in Tariff
HEMS	Home Energy Management System
IOT	Internet of things
PCS	Power Conditioning System
REC	Renewable Energy Certificate
RPS	Renewable Portfolio Standard
SGSH	Standard Grids Smart Homes
SLA	Service Level Agreement
SOC	State Of Charge
TSO	Transmission System Operator
USEF	Universal Smart Energy Framework

Preface

The objective of Annex 2 is to assess outstanding examples of current case studies, develop and validate a common case study template and methodological framework, and then develop in-depth case studies using this framework. The template is currently the "casebook" to contain descriptive information. The common frame work for case studies will allow comparison and contrast of policies and technologies adopted in different regulatory, legislative, network (grid), and natural environments. The overarching aim is to collect sufficient information from the case studies around the world to extract lessons learned and best practices as well as foster future collaboration among participating countries.

ISGAN Annex 2 participating coutnries have volunteered to offer information about on-going cases with an aim to share knowledge and strengthen cooperation between different stakeholders in terms of on smart grid project planning, implementation and management. Depending on the progress of the projects, some of the cases may only present outcomes or lessons learned of the projects partially. Therefore, some of the cases are anticipated to be updated on a regular basis as the projects progress to the next steps.

This casebook reflects one way that ISGAN gather experts and stakeholders globally to increase the awareness of the energy storage system in the field of smart grid. In this stage, the casebook includes fourteen cases from seven different countries including Austria, Canada, France, India, Korea, Netherlands, and Sweden. It specifically focuses more on actual operation of ESS rather than looking at the test pilots in order to show its feasibility and usability in the real sites. Each case is meant to introduce the role of ESS in each system and to analyze with a special focus on economic benefits of ESS.

Abstract to Introduction

Additional power system flexibility allows countries to reliably use more variable renewable energy in coordination with other clean energy sources, increase power system reliability and resilience to disruptions, improve system efficiency and performance, and reduce the investment needed for new and existing assets.

The energy storage systems (ESS) is becoming more important in a smart grid because of its ability to provide reliability and flexibility to a smart grid. The variability of renewable energies and loads may negatively impact the stability and reliability of a smart grid, and ESS is one of the key solutions to address these challenges. ESS could store energy produced at one time for use at later and also provide stable voltage and frequency for a smart grid. It can be used as a core element of the demand side management by providing peak cut and peak shifting functionalities, too. In addition, ESS is utilized in wide areas including demand response, power generation business based on renewable energies, smart factory, smart city, and EV charge station.

Increasingly, digital technologies are being employed to better track and dynamically manage electricity production, transmission, distribution and use – a small part of the broader societal trend toward “digitalization.” Energy storage systems are another emerging and potential source of power system flexibility and will likely play a pivotal role in next generation electric grids, acting as a flexible bridge between the needs of utilities (and other energy service providers) and their customers.

Although energy storage systems, digital sensors and controls, and other smart grid-relevant technologies that improve power system flexibility are already being deployed globally, considerable research and development (R&D) is still needed for them to reach their full potential.

Also, energy storage-as-a-service (ESaaS) is becoming a key service model. ESaaS simply refers to a combination of an advanced energy storage system, an energy management system, and a service contract which can deliver value to a business by providing reliable power more economically. The business model was initially developed by Constant Power, and it is being replicated elsewhere to generate steady returns for investors upon completion of an ESS project. With energy storage deals previously avoided by investors due to the complexity surrounding cash flow, new business models like ESaaS is a promising development to attract financing and further grow the industry.

Table of Content

1. Austria: District heating storage Linz Mitte + possible extension with a seasonal storage for waste heat recovery

<table>
<tr><th colspan="3">Project Information</th></tr>
<tr><td>Project Title</td><td colspan="2">District heating storage Linz Mitte (short term, existing) + possible extension with a seasonal storage for waste heat recovery (feasibility study)</td></tr>
<tr><td>Location</td><td colspan="2">Linz, Austria</td></tr>
<tr><td>Time Period of Project</td><td colspan="2">• Short term storage: Construction: April 2003 – April 2004; Operation: since 2004
• Seasonal storage: feasibility study: 2016-2017</td></tr>
<tr><td>Funding</td><td>(Government) National funding by the Austrian Klima und Energiefonds - Seasonal storage feasibility study</td><td>(Private Sector) Linz AG - Short term storage</td></tr>
<tr><td>Participating organizations</td><td colspan="2">Short term storage:
• Construction by Bilfinger VAM Anlagentechnik GmbH;
• engineering: VA Tech Hydro;
• final user: Linz AG
Seasonal storage feasibility study:
• Energieinstitut an der Johannes Kepler Universität (lead)
• AIT Austrian Institute of Technology GmbH
• Linz AG</td></tr>
<tr><td>Link to Project Website</td><td colspan="2">Short term storage
• https://www.linzag.at/portal/de/ueber_die_linzag/konzern/gesellschaften/linz_strom_gas_waerme_gmbh/energieerzeugung/fernheizkraftwerk_linz_mitte
• http://www.vam.bilfinger.com/referenzen/apparate-behaelter-tankbau/referenzen-waermespeicher/#gallery862
Seasonal storage feasibility study
• https://oesterreichsenergie.at/ueber-uns/oesterreichs-energie-forschung-innovation/forschungsbericht-2017/forschungsprojekte-der-mitgliedsunternehmen/waermespe.html
• www.4dh.eu/images/1_20170913_Presentation_-_FDHS_Linz.pdf
• www.ait.ac.at/fileadmin/mc/energy/downloads/News_and_Events/2016-2017/2016_11_15_2.Praxis_und_Wissensforum_FWK/B3_Pauli__Future_DH_System_AIT_15_Nov_16_Pauli_V3.pdf
• www.ait.ac.at/fileadmin/mc/energy/downloads/News_and_Events/2016-2017/2016_11_15_2.Praxis_und_Wissensforum_FWK/B4_Muser_GWS_Linz_-_Muser.pdf
• www.sciencedirect.com/science/article/pii/S036054421831257X
• www.sciencedirect.com/science/article/pii/S0360544218313549</td></tr>
<tr><td>Key Word (3-4)</td><td colspan="2">District heating network; thermal short term storage; combined heat and power; waste heat integration, multi-use seasonal storage</td></tr>
</table>

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1.1. Project Summary

The city of Linz has about 192,000 inhabitants, it is characterized particularly by its large industry, were 72 % of final energy consumption is attributed to. The district heating (DH) network of Linz AG spans most of the city, around 59% of all apartments in the city are connected to the network. A total of around 1130 GWh/a heat is generated by all plants of Linz AG. The base load is covered by a waste incineration plant, supplying ≈ 32 % of the heat. About 14 % is from a biomass CHP and approximately 47 % is generated by fossil CHP plants (combined-cycle plant using natural gas). The fossil peak load boilers generate about 7% of the total heat demand. The peak load heat demand in winter is about 500 MW and the summer minimum is around 30 MW.

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For optimization of the DH network, especially with regards to CHP operation, a short term storage was installed in 2004, which one was at this time one of the largest in the world. Further on, significant potentials of industrial waste heat from a stell mill are available but cannot supplied to the Linz DH network during summer times due to the must-run condition of the waste incineration. As a consequence, 2016/2017 a feasibility study was done for integrating a large scale, i.e. a seasonal storage for shifting the summer excess heat to winter times.

1.2. Objectives of the project

Short term storage: The main objectives of installing the short term heat storage in the Linz DH network in 2004 were:

- Supporting the operation of the gas fired CHP plants for optimizing their participation on the electricity market
- Reducing peak loads in the DH network and thus reduce the use of fossil fired peak load boilers
- Supporting a more stable operation of the waste incinerator (especially in summer times, were the heat demand can be lower than the heat supply.

Figure 1: short term thermal storage in the Linz DH network

Source: https://www.linzag.at//media/dokumente/linzag/folder-kw-linzmitte.pdf

Seasonal storage: the main objectives of the feasibility study for the seasonal storage are:

- Analysing the feasibility of integrating the existing waste heat potentials from a local stell mill via a seasonal heat storage

- Optimization of the seasonal storage operation by integration with the CHP plant schedule (dispatching) and thus supporting the operation of the short term storage
- Assessment of financing concepts and micro- and macroeconomic studies.

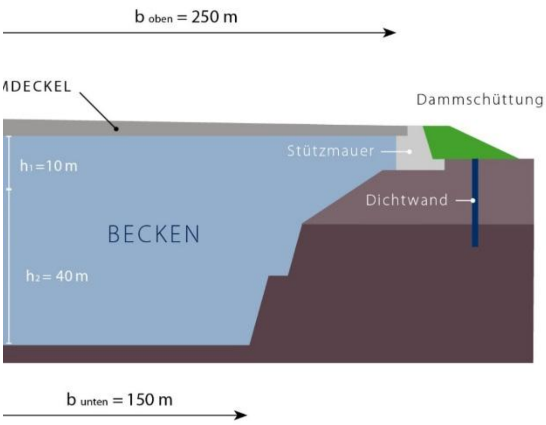

Figure 2: possible construction principle for the seasonal thermal storage
Source: https://www.ait.ac.at/fileadmin/mc/energy/downloads/News_and_Events/2016-2017/2016_11_15_2.Praxis_und_Wissensforum_FWK/B4_Muser_GWS_Linz_-_Muser.pdf

1.3. Current status & results (outcomes)

Short term storage: The storage has been installed in 2004, its technical data: Capacity: 1,300 MWh (Tmin = 55°C, Tmax = 97°C), height: 65 m; volume: 35.000 m³; diameter: 26 m; overall weight: 900 t. The operation is ongoing since. About 10% of the heat supply for the DH networks can be attributed to discharging the storage. The positive effects of the short term storage can be seen in Figure 3.

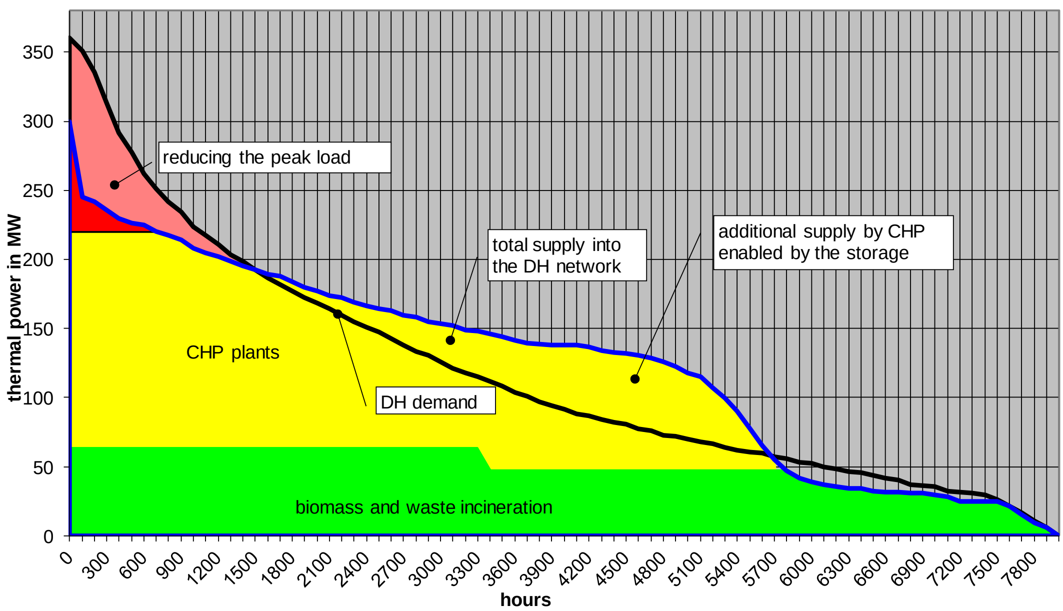

Figure 3: sorted load duration curve of the Linz DH network, positive effect of the short term storage
Source: https://www.ait.ac.at/fileadmin/mc/energy/downloads/News_and_Events/2016-2017/2016_11_15_2.Praxis_und_Wissensforum_FWK/B3_Pauli__Future_DH_System_AIT_15_Nov_16_Pauli_V3.pdf
(translated)

Seasonal storage*:* Within a pre-feasibility study, the following technical data of the storage have been identified: volume: 2,000,000 m³, capacity: 80 GWh; investment costs: about 100 mil. €.

Within the current feasibility study, different scenarios for the integration of the seasonal storage into the Linz DH network have been analysed. Since, the number of cycles is crucial for economic feasibility, two different charging/ discharging strategies has been investigated: The “simple” charging strategy, where the storage is mainly charged in summer times using industrial waste heat and discharged in autumn/winter is resulting in utilization a 1.8-fold storage capacity. Revenues purely from the shift of summer heat to winter or transitional period, i.e. achieving a number of one or even two cycles is always economically inefficient. For the “strategic” operation strategy, fostering a much higher degree of short term charging/discharging and as a consequence enhancing the operation of the existing CHP plants and reducing the use of the peak load boiler, this value is increased to 4.4. As a result, a payback period for the seasonal storage of about 20 years[1] can be achieved. On the ecological side, about ¼ of the energy in the Linz DH network can by supplied by waste heat if integrating a seasonal storage, substituting especially fossil fired CHP and peak boilers, resulting in up to 44% reduction of CO2 emissions, see Figure 4.

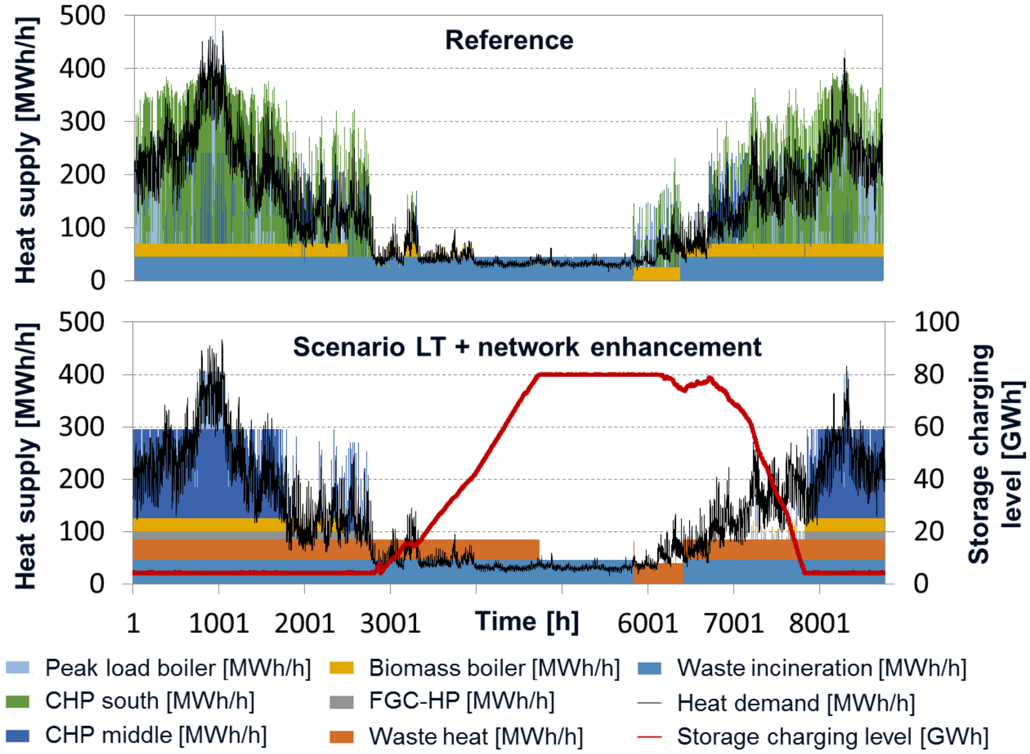

Figure 4: load duration curve of the Linz DH network, top: status-quo, bottom: positive effect of the seasonal storage, FGC-HP = flue gas condensation heat pump; CHP: combined heat and power

1.4. Barriers & obstacles

Short term storage: No major barriers or obstacles. Short term heat storages in district heating networks are state-of-the-art and their utilization for supporting the participation of the CHP plants on the electricity market (CHP dispatch optimization) is widely done.

[1] The calculation does not include any subsidies from the European Union, federal, regional or local governments

Seasonal storage: for boosting its economic efficiency, using the seasonal storage for CHP dispatch optimization is crucial. However, various uncertainties apply, especially electricity prices, long term availability of the waste heat and CO2 market conditions. Together with the high investment costs of about 100 mil. Euro, the investment risk for the storage is very high in the particular case. However, smaller DH networks with lower network temperatures and lower investment costs have already proven to be realizable.

1.5. Lessons learned & best practices

Short term storage: The short term storage Linz Mitte is operated successfully since 2004 and the operators are very satisfied. Especially with

- Stabilizing the overall operation of the DH network, including some hydraulic balancing
- Higher profits of the CHP plants on the electricity markets
- Reducing the fossil fired peak load boiler

Seasonal storage: Until now, no seasonal storage has been integrated in urban DH networks, thus no best practice can be described.

1.6. Key regulations, legislations & guidelines

Short term storage: The integration of thermal storages into district heating networks is not regulated in Austria. Linz AG is the heat supplier and network operator of the district heating network in Linz. So any new storage or heat supply option needs to consider only technical and economic conditions of the Linz AG (besides the usual building permissions and (if applicable) environmental compatibility test).

Seasonal storage: The same aspects like above apply. However, for such large scale infrastructures as a seasonal storage, regulations with regards to ground water might limit the land use or make it more expensive. Also social acceptance could be an issue.

2. Austria: Power-to-Heat plants, Salzburg AG

Project Information		
Project Title	Power-to-Heat plants, Salzburg AG	
Location	Salzburg, Austria	
Time Period of Project	Currently: two (Power-to-Heat) p-t-h plants (each 15 MWel) are in operation at two location within Salzburg: • HKW-Mitte (since 2015) • HKW Nord (since 2016)	
Funding	**(Government)** N/A	**(Private Sector)** Salzburg AG
Participating organizations	• Salzburg AG (operator) • Construction company or technology provider is unknown	
Link to Project Website	• https://eventmaker.at/uploads/4261/downloads/SCHULLER_Power2Heat_-_Erste_Betriebs-_und_Einsatzerfahrungen.pdf? • https://eventmaker.at/uploads/10216/downloads/rainer.pdf?	
Key Word (3-4)	District heating network; network as storage; power-to-heat	

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2.1. Project Summary

The city of Salzburg is located next to the Prealps and has about 146,560 inhabitants. The district heating network of Salzburg (operated by Salzburg AG) supplies about 800 GWh, the installed capacity is about 400 MW based on CHP, heat only boilers and waste heat.

The two power-to-heat plants in Salzburg converts excess electricity into heat. Each plant can take up power of up to 15 MWel and convert it into heat with virtually no loss. The resulting heat is fed into the Salzburg district heating network in the form of hot water.

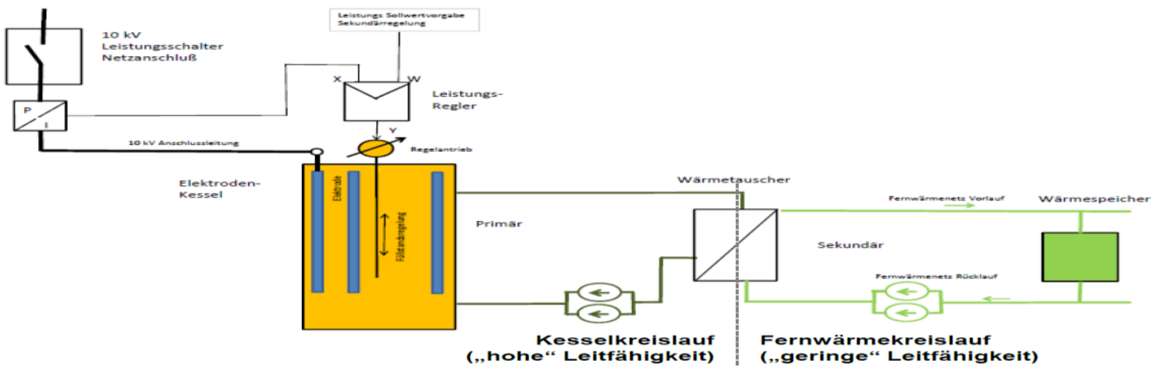


Figure 5: simplified diagram of the power-to-heat plant in Salzburg

Source: https://eventmaker.at/uploads/4261/downloads/SCHULLER_Power2Heat_-_Erste_Betriebs-_und_Einsatzerfahrungen.pdf**?**

2.2. Objectives of the project

The main targets for installing the p-t-h plants were:

- Supply of CO2-free heat for the district heating network (decarbonization)
- Participation at the balancing market
- Utilization of negative electricity prices due to oversupply on the short term markets
- Security of supply (n-1) in the district heating network

2.3. Current status & results (outcomes)

Table 1: basic data of the power-to-heat plants in Salzburg

	Power2Heat Mitte	**Power2Heat Nord**
In operation	since 2015	since 2016
Capacity	0-15 MW	0-15 MW
Power supply	10 kV (NE4)	6 kV (NE5)
project (of wich planning)	13 month (6 month)	10 month (4 month)
commissioning	Jan. 2015	Jan. 2016
Overall efficiency	rd. 98%	rd. 99%

Technology installed:

- electrode boiler with 15 MWel capacity
- Compact Installation
- High efficiency, almost no losses
- High load change velocity (>3MW/min)
- No minimum load, infinitely variable

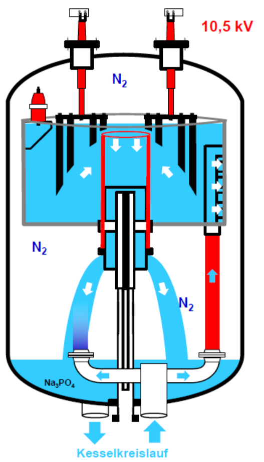


Figure 6. electrode boiler (source: VA Elektrokessel GmbH)

Operational experience:

- Small variable costs at the balancing markets (same conditions for tertiary and secondary)
- Spot-market: until now, very low hours with low or negative electricity prices
- Operation on the spot market is not competitive to CHP plants with district heating network

➔ Result: main operation on the negative, secondary balancing market

➔ Alternative: operation on the negative tertiary balancing market, if the bits to the secondary market are not accepted

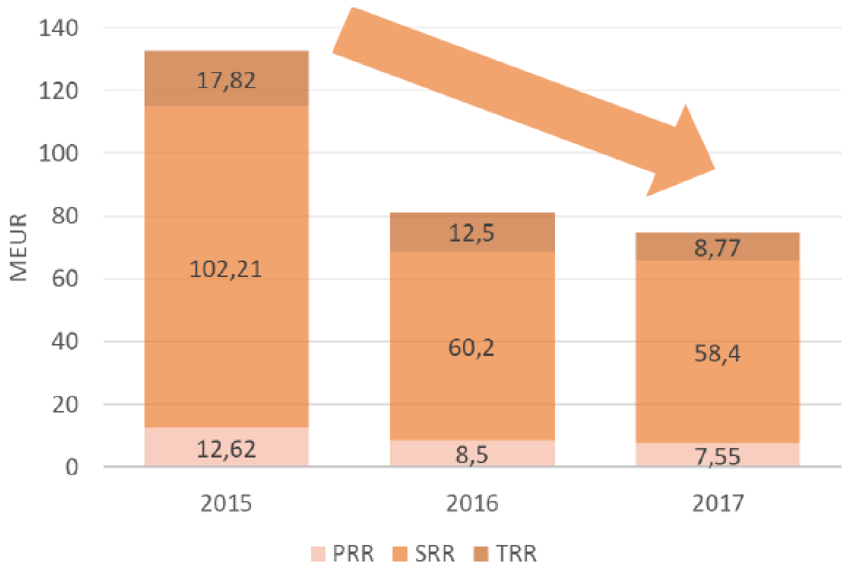
➔ Further option: operation on the positive secondary balancing market in combination with CHP plants in times of high District heating demand

2.4. Barriers & obstacles

- Power2Heat is treated as final customer, resulting in high fees and taxes and thus reduces its economic feasibility
- Electricity price per kilowatt is very low (except some peaks at holidays and special events)

- One of the main barriers is the price development at the Austrian secondary balancing market. Due to the further developments on the demand and supply side, the overall costs of the balancing markets were decreasing significantly in the last years
- Significantly increasing number of p-t-h pants and increased capacity due to more flexibile conditions for pre-qualification

➔ These factors are a major risk for existing and new power-to-heat plants in Austria!



Quelle: APG

Figure 7: Development of the overall costs of the balancing markets

2.5. Lessons learned & best practices

Installation: simple and established technology, challenges for integration into the district heating network:

- prognosis of heat production of the p2h units required for overall supply planning - consider the operation of CHP plants for optimizing the network fees
- Maximum heat supply needs to be stored in the DH network at any time. Helpful is a DH storage for covering peaks (heat load flow to the storage needs to be hydraulically feasible)
- Suitable dimensioning of the district heating networks for transporting the heat required

Operation: stable operation on the secondary balancing market, especially considering some backup capacities in the Salzburg AG own balancing pool

- Minimum reaction time and minimum capacity gradient.
- Automated calls via the process computer

Market: volatile, challenging

- By trend decreasing revenues in the overall market
- It is still possible to cover the marginal return

2.6. Key regulations, legislations & guidelines

The integration of the p-t-h plants and the supply of heat to the district heating network is not regulated (Salzburg AG is the heat supplier, owner and operator of the district heating network in Salzburg) – so any heat supply option needs to consider only technical and economic conditions of the Salzburg AG.

For the participation in the balancing markets and the connection to the electricity grid, the relevant regulations apply. Special permission for the p-t-h plant were required (due to the generation of hydrogen and electrolytic gas during the electrolysis initiated as a side effect of the p-t-h process).

3. Canada: Markham Energy Storage Facility

Project Information		
Project Title	Markham Energy Storage Facility	
Location	Markham, Ontario, Canada	
Time Period of Project	• Designing and Commissioning: January 2015 – May 2018 • Operational: May 2018 - Present	
Funding	(Government) N/A	(Private Sector) Hydrogenics and Enbridge Gas Distribution
Participating organizations	• Hydrogenics • Enbridge Gas Distribution • Independent Electricity System Operator	
Link to Project Website	https://www.hydrogenics.com/2018/07/16/north-americas-first-multi-megawatt-power-to-gas-facility-begins-operations/	
Key Word (3-4)	Power-to-Gas, Renewable Hydrogen, Regulation Services	

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3.1. Project Summary

The Markham Energy Storage Facility is located in the Province of Ontario in the City of Markham at Enbridge Gas Distribution's Technology and Operations Centre, and is the first multi-MW Power-to-Gas reference site in North America. The facility is jointly owned and operated by Enbridge, a multinational company who focuses on the transportation, distribution and generation of energy primarily in North America, and Hydrogenics, a developer and manufacturer of industrial and commercial hydrogen generation, hydrogen fuel cells and MW-scale energy storage solutions. This facility is under contract to provide regulation services with the Independent Electricity System Operator (IESO), a crown corporation which operates the electricity market and ensures the reliable operation of the grid in Ontario. The energy storage system (ESS) is connected to a 27.6 kV feeder with a total capacity of 2.1 MW, and is controlled remotely adjusting its output every 2 seconds under dispatch by the IESO. It has been in service since May 2018.

Excess clean energy can be used by a water electrolyser to split oxygen, and hydrogen (also known as renewable hydrogen). Power-to-Gas is a unique solution to produce renewable hydrogen while providing ancillary services for the grid operator as shown in Figure 8. Power-to-Gas does not fit the conventional battery energy storage system paradigm. Power-to-Gas is an ESS that acts like a load but converts excess energy into a fuel to be used for the various applications described by Figure 88.[2] It is the only energy storage solution that can bridge the electricity sector with either the transportation sector or natural gas sector. The renewable hydrogen can be used to fuel zero-emission fuel cell electric vehicle fleets including commuter trains, buses and heavy mobility trucks, and can also produce renewable natural gas (either by direct injection into the natural gas grid or methanation).

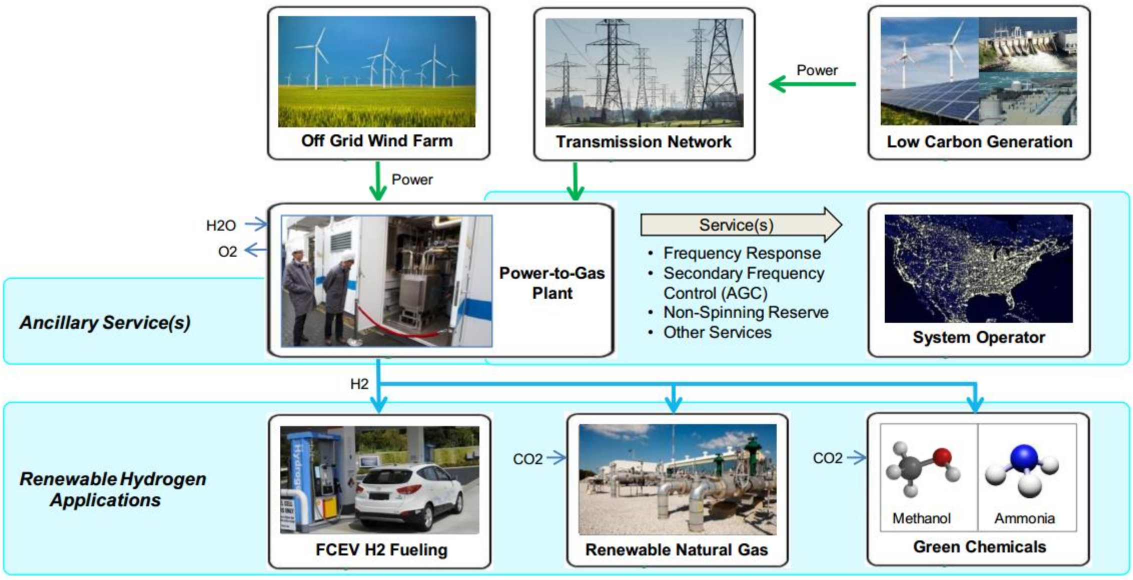

Figure 8: System overview

3.2. Objectives of the project

The IESO is responsible for managing a reliable power system for Ontario including planning for future energy needs. Beginning in 2014, the IESO opened a competitive procurement process with two consecutive phases to secure a total energy storage capacity of 34 MW for regulation services and voltage support.[3] One of the objectives of this procurement was to learn firsthand about the capabilities of different energy storage technologies to deliver ancillary services for grid operations. The Markham Energy Storage Facility was awarded a contract for 2.1 MW of regulation service and was the only hydrogen Power-to-Gas technology contract awarded.

From the perspective of the project developers, there are three core objectives for this project: design and build a multi-MW Power-to-Gas reference site in North America using Hydrogenics' large scale PEM electrolyser stacks, gain valuable operating experience for the provision of regulation services to the IESO as a contracted Ancillary Service Provider (ASP) in Ontario, and design the architecture for a 5 MW module to be the platform for future large-scale commercial projects.

[2] IESO, "IESO Report: Energy Storage," 2016.
[3] IESO, "Energy Storage Procurement at the IESO," 17 January 2019. [Online]. Available: http://www.ieso.ca/en/Sector-Participants/Energy-Procurement-Programs-and-Contracts/Energy-Storage. [Accessed 18 February 2019].

3.3. Current status & results (outcomes)

The Markham Energy Storage Facility has been designed, built, certified and commissioned. It has performed well in providing regulation services to the IESO. It has met and exceeded expectations as a reference site. Images of the facility and components are shown in **오류! 참조 원본을 찾을 수 없습니다.**9.

Figure 9: Facility images

Frequency Regulation is a service that acts to match total system generation to total system load (including transmission losses) and helps correct short-term variations in power system frequency that affect the stability of the power system. A Power-to-Gas facility provides frequency regulation by modulating the dynamic load of the electrolyser—the power consumption is adjusted every 2 seconds over its entire operating range in response to an operator signal. Unlike a battery energy storage system which may at times be constrained by its state-of-charge, an electrolyser does not have any chemical operating restrictions and can be “set” at full load or minimum load or any other point within its operating range as long as is required.

Figure shows a sample of an actual IESO dispatch signal (also called an Automatic Generation Control (AGC) signal) from July 11, 2018 in blue and the Power-to-Gas facility’s response in green. This graph shows how accurately the facility was able to support the regulation services.

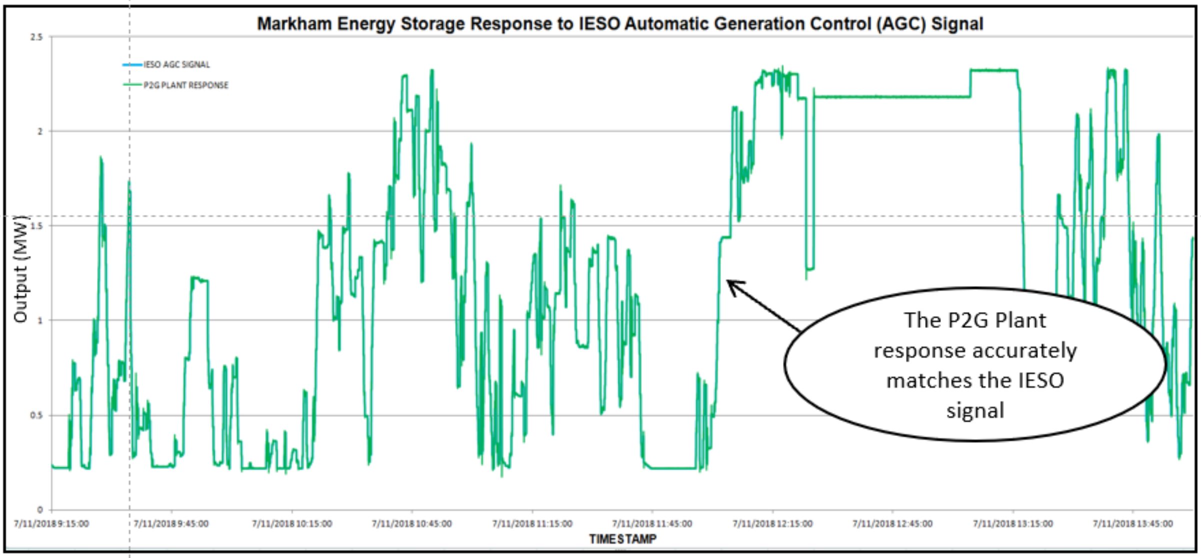

Figure 10: The Power-to-Gas facility output matching the IESO AGC signal exactly on July 11, 2018

3.4. Barriers & obstacles

One of the biggest barriers for this project was finding a suitable site. Prior to getting all of the requisite approvals of a site at Enbridge's Technology and Operations Centre, due diligence and a review process was carried out for two other prospective sites in succession. While all of the sites met the basic site criteria for access to power, water and the natural gas grid needed for the Power-to-Gas project, the review process to finalize the site took a lot longer than expected.

Other obstacles faced are typical of those in a demonstration project. For example, the availability of engineering resources at Enbridge was limited at the start of the project because Enbridge was undertaking another large infrastructure project in Ontario. New suppliers were required for balance of plant components such as custom stainless steel piping for hydrogen gas which took much longer for delivery than anticipated. Delays in the project schedule pushed the commissioning stage into the winter months with harsher weather conditions which also complicated the commissioning process.

3.5. Lessons learned & best practices

Engaging earlier with all stakeholders involved in the review process to finalize a site location including the local distribution company and municipal zoning, would have sped up the process. In addition, engaging with these stakeholders earlier would also have reduced or eliminated the amount of engineering re-work that was required.

The installation of interconnections (in terms of piping and electrical) between components, and certifications from the Electrical Safety Authority, Canadian Standards Association and Technical Standards and Safety Authority (TSSA) for equipment in a building, were both an order of magnitude more complex and time consuming than other smaller scale projects. For smaller scale projects, the electrolyser stack(s) and balance of plant is a containerized solution where the equipment is built, installed and shipped in an ISO 40 foot container. The verification and certification of the equipment is done at the factory before it is shipped. In contrast with larger scale projects such as the Markham Energy Storage Facility, the equipment is shipped in skids and then interconnected, tested, commissioned and certified in a building on-site. In future projects, it will be possible to standardize the equipment skids and speed up the certification process because of the experience with the Markham Energy Storage Facility building space constraints. A precedent is also set for future multi-MW scale projects to better inform certification of future commercial scale plants.

This Power-to-Gas facility along with the other ESS providing regulation services to the IESO are registered ASPs in the province and must follow the same market rules and day ahead reporting requirements required by other large scale hydro and gas generation plants. This has given Hydrogenics excellent insights into how plants need to be operated to accurately and effectively provide grid services.

Prior to the commissioning of the IESO Phase 1 energy storage facilities, the IESO released a technical report on the potential capabilities of energy storage: http://www.ieso.ca/-/media/Files/IESO/Document-Library/energy-storage/IESO-Energy-Storage-Report_March-2016.pdf?la=en.

3.6. Key regulations, legislations & guidelines

The Technical Standards and Safety Authority (TSSA) promotes and enforces public safety on behalf of the government of Ontario. TSSA is the chief regulatory body for hydrogen in the province and worked closely with Hydrogenics for the certification of hydrogen equipment and pressure vessels for the Markham Energy Storage Facility. Since this was the first-of-a-kind multi-MW Power-to-Gas project in North America, TSSA broke new ground in the certification of this facility.

Hydrogen safety is enforced via verification of compliance against the Canadian Hydrogen Installation Code (CHIC) that is approved by the Standards Council of Canada. CHIC was adopted by TSSA in August 2007. The Canadian Hydrogen Installation Code sets the installation requirements for hydrogen generating equipment, hydrogen-powered equipment, hydrogen dispensing equipment, hydrogen storage containers, hydrogen piping systems and their related accessories.[4]

The 2nd edition of the CHIC (expected in 2020) will have a revised and expanded scope to take into lessons learned from both the use of the CHIC and global experience in the field with hydrogen technologies.

[4] Bureau de normalisation du Québec, " Canadian Hydrogen Installation Code," [Online]. Available: https://www.bnq.qc.ca/en/standardization/hydrogen/canadian-hydrogen-installation-code.html. [Accessed March 2019].[4]

4. France: InterFlex

Project Information		
Project Title	InterFlex	
Location	Europe (Demonstration projects are conducted in 5 EU Member States (Czech Republic, France, Germany, The Netherlands and Sweden).	
Time Period of Project	2017 - 2019 (3 years)	
Funding	(Government) European Commission: 17 M€	(Private Sector) 5,8 M€
Participating organizations	• 5 major European electric power DSOs (Avacon, CEZ Distribuce, Enexis, E.ON, Enedis) and one gas DSO (GrDF) • 2 large-scale European retailers (EDF, ENGIE), • 2 major IT solution providers (GE Grid Solutions and Siemens) • 4 manufacturers of smart inverters and solutions for smart grids (Schneider Electric, Siemens, Fronius, Socomec) • 3 research centres (AIT, TNO, RWTH Aachen University) • A knowledge and innovation centre (ElaadNL) • A consulting company (Accenture) • SME (Trialog)	
Link to Project Website	https://interflex-h2020.com/	
Key Word (3-4)	Flexibilities, DER, Storage, Electric vehicle	

Author Information	
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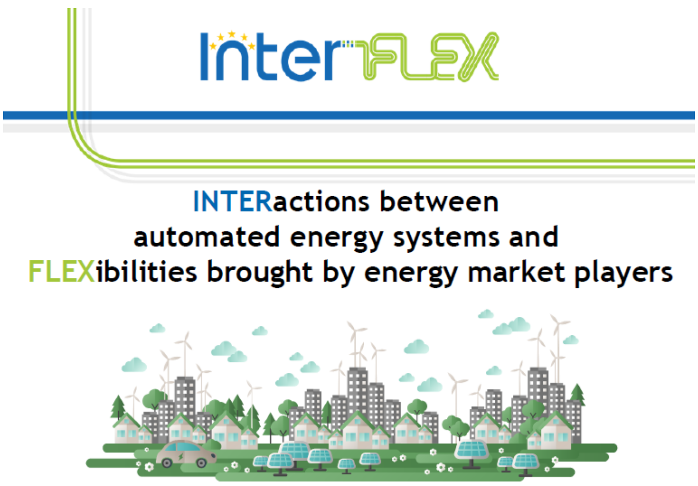
4.1. Project Summary



In the framework of the biggest EU Research and Innovation programme, Horizon 2020, the smart grid project InterFlex has officially been launched on January 1st, 2017. During three years, 20 project partners will explore new ways to use various forms of flexibilities in the aim of optimizing the electric power system on a local scale. InterFlex investigates the INTERactions between FLEXibilities provided by energy market players and the distribution grid, with a particular focus on energy storage, smart charging of electric vehicles, demand response, islanding, grid automation and the integration of different energy carriers (gas, heat, electricity).

Furthermore, aspects related to the interoperability of systems, replicability of solutions and the identification of relevant business models constitute major objectives. In the project electricity retailers, power component manufacturers and smart grid experts are working together with 5 European distribution companies (DSOs) ČEZ Distribuce (Czech Republic), Enedis (France), E.ON (Sweden), Enexis (The Netherlands) and Avacon (Germany).

Figure 11: Project overview

With Enedis as the global coordinator and ČEZ Distribuce as the technical director, InterFlex relies on a set of innovative use cases. Six industry-scale demonstrators are being set up in the participating European countries:

- The French demonstrator of Enedis, located in the metropolitan area of Nice and its surroundings, investigates flexibility mechanisms to support the grid, storage systems and islanding operation
- The Czech demonstrator led by ČEZ Distribuce uses grid automation and energy storage to integrate decentralized renewable energy within the distribution grid and smart functions of charging stations for electric vehicles as a source of flexibility, in different areas of the country
- The German demonstrator of Avacon, located in the region of Lüneburg (northern Germany), manages a centralized platform of flexibilities and distributed energy resources to use energy where it is generated in order to relieve constraints on the distribution grid
- A 1st Swedish demonstrator of E.ON, located in Malmö investigates synergies between different energy carriers using heat inertia of buildings as a flexibility measure in order to attain a more optimized and environmental friendly production in a distributed energy system
- A 2nd Swedish demonstrator of E.ON, located in the Skåne region (Southern Sweden), is exploring means to island a portion of the distribution grid, supported by the customers through a local market approach, while assessing the benefit of advanced control of Local Energy Systems for the DSO
- Enexis’ demonstrator in Eindhoven in the Netherlands proposes a multi-service and market approach to unleash all available local flexibilities such as stationary storage and electric vehicle batteries, by using interactions between the distribution system operators, balance responsible parties and the charge point operators for electric vehicles

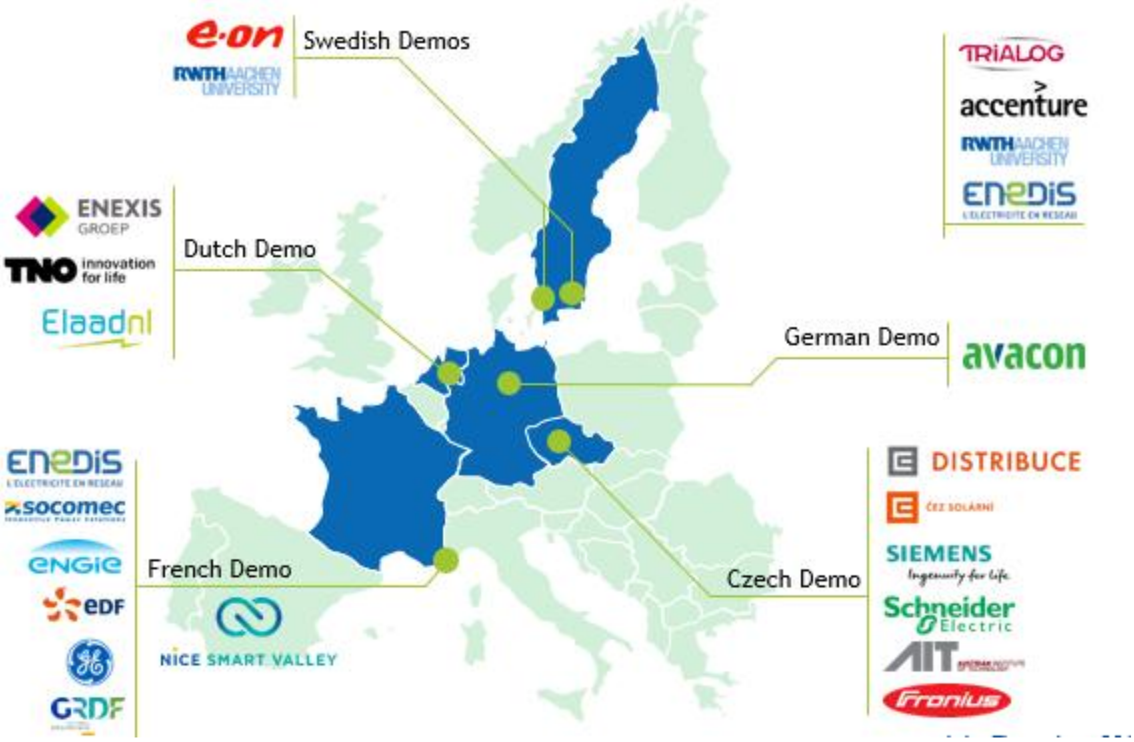


Figure 12: Six industry-scale demonstrators

4.2. Objectives of the project

InterFlex aims at improving the global performance of electricity distribution networks at a local or regional scale, while dealing with new challenges, such as the steadily increasing complexity of power flows and growing interactions between the market players. The InterFlex project translates the aim of its consortium members to explore the local optimization potential that can be addressed through grid automation and the use of flexibilities for the electricity system. InterFlex designs the way towards future energy systems dealing with multiple interactions between distributed power generation (renewables), multi-energy consumers (electricity, heat, gas) taking into account newly appearing customer needs (e-mobility) and behaviours. The DSO, as an enabler, may emit market signals to power producers, consumers, prosumers (or their aggregators), or even to third parties such as municipalities which will in return stimulate the market players to offer generation and/or consumption flexibilities.

InterFlex is a real scale smart grid demonstrator exploring storage and system integration technologies in the perspective of strongly increasing shares of renewables. Its main objectives are:

- Demonstrate a set of technologies and solutions in a real-scale environment, while considering a strongly increasing share of renewable energy sources (e.g. 50% by 2030)
- Use of mature and proven technologies (high level of maturity: TRLs 5-8)

Demonstration and validation of new business models involving different players (aggregators, private and commercial customers, municipalities, DSOs) integrating:

- Distributed energy resources (wind, solar)
- Flexibilities on a local scale (energy storage, smart EV carging, optimized utilization of the respective distribution networks of different energy carriers such as electricity, gas or heat)

Energy storage capacities are involved in all InterFlex demonstrators. They are operated at the district or multi-user level as well as on the private household level to serve various purposes.

Home storage systems
(Czech, German Demos)

Shared large-scale batteries
(French, Swedish, Dutch Demos)

Cross-energy-carrier synergies
(French, Swedish Demos)

Figure 13: Energy storage capacities

InterFlex intends to demonstrate through various use cases the added value of storage at different scales (single/multiple users) and different systems (electrical/cross-energy-carrier storage).

- Residential storage
  - Small distributed batteries' contribution to increase the hosting capacity of distributed generation units in Low Voltage networks
- Centralized storage
  - Shared large-scale batteries to enhance collective self-consumption
  - Flexibility lever to relieve grid constraints for the local network (with significant electric vehicles and renewable energy development in the future)
  - Increasing resilience or improving the reliability of power supply (islanding, incident or work management)
- Cross-energy-carrier integration as a flexibility
  - Use of additional means of storage at both individual (thermal or gas) and collective levels (heat or cold network)

4.3. Current status & results (outcomes)

The project is currently at its final phase:

- Use cases have been defined
- Equipments have been nstalled and demonstrators are all up and running
- First lessons are learned from experiment

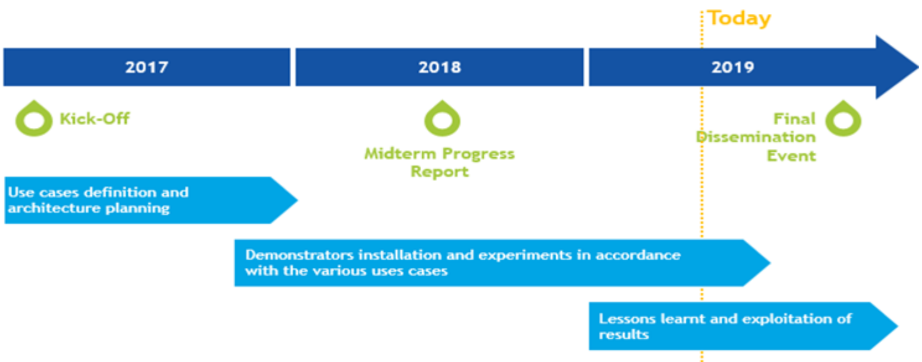


Figure 14: Current status of the project

Use cases are presented hereinafter.

Table 2: Storage-related use cases in the InterFlex project

Storage-related Use Cases in the InterFlex project		
German Demo	UC2	Demand Side Management including residential storage to relief grid constraints
Czech Demo	UC4	Usability of residential smart energy storage to increase the DER hosting capacity on the grid
Dutch Demo	UC1	Improve grid flexibility using a central Smart Storage Unit
Dutch Demo	UC3	Usability of an integrated flex market
Swedish Demo	UC2	Using heat inertia of buildings and the energy exchange with the district heating grid as a means of thermal storage
Swedish Demo	UC3	Technical management of a Local Energy System that can run in an islanded mode with 100% renewable generation
French Demo	UC1	Automatic Islanding based on a multi-battery scheme (grid-forming and grid-supporting battery systems)
French Demo	UC2	Multiservice approach for centralized storage systems

Increase the DER hosting capacity

Within the Czech Demo's (CEZ Distribuce) Use Case 4, smart functions of home-energy storage systems help to increase the hosting capacity of distributed generation units in LV networks with mitigation of negative impacts on customers. Batteries are located at customer premises and help to shave PV feed in peeks and thus provide flexibility.

The German Demo's (Avacon) Smart Grid Hub will control distributed storage devices to increase the hosting capacity. The Use Case 2 shall show how the inherent flexibility of local loads could be leveraged to improve system stability and power quality and relieve local grid congestion.

Improve Grid Management

In the Netherlands (Enexis), the demonstrator in Eindhoven will integrate a central neighbourhood battery (Smart Storage Unit). In the Use Case 1, this SSU will improve grid flexibility enabling ancillary services, congestion management, temporary voltage and power quality support, promoting batteries.

Figure 15: Smart storage unit

In Swedish Malmö demonstrator (E.On), Use Case 2 is exploring the optimal use of a commercial heat pump and cooling pump asset providing energy efficiency and electricity flexibility for grid management purposes. By optimizing its production of heat and consumption of electricity based on the current most profitable energy source such heat and cooling pumps connected to thermal reservoirs (i.e. low temperature grids) can act as an important flexibility source for both the thermal system and the electrical grid.

Enhance islanding capacities

- Within the French Demo 'Nice Smart Valley' (Enedis) and its Use Case 1, storage capacities designed for different purposes (islanding, renewable self-consumption) are mutualized with other uses. There are two communicating and complementary storages systems:
  - A main grid-forming storage system operated by the DSO for local grid optimization purposes (controls and maintains the frequency and the voltage of the local system in case of islanding).
  - Secondary grid-supporting storage systems operated by an electricity provider to deliver a commercial service to local customers as well as a complementary grid support service upon the DSO's request.
  - Aggregators become services provider for the DSO to increase the islanding duration.

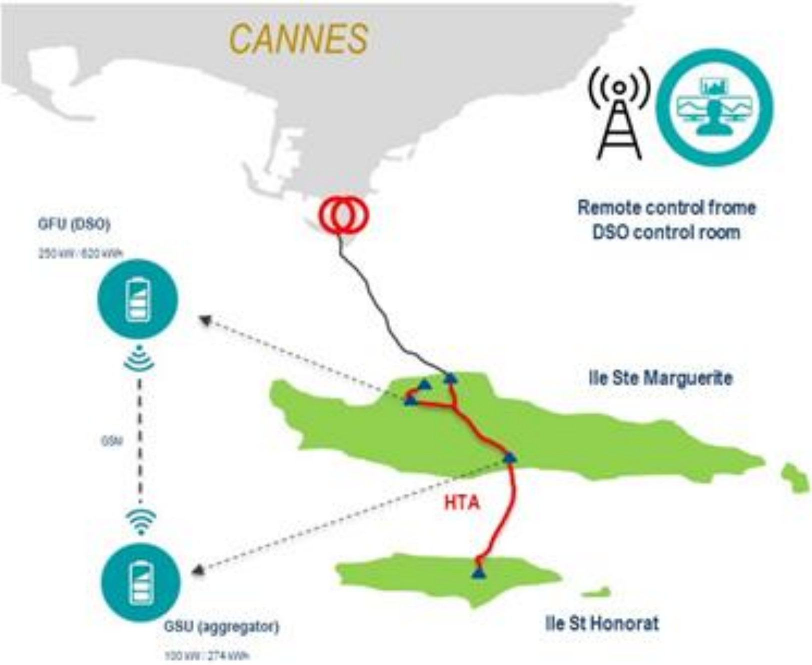


Figure 16: French demo, Nice Smart Valley

- At Simris, in the second Swedish Demonstrator, battery systems are tested in the Use Case 3 to maintain frequency and voltage of a Local Energy System. The demonstrator allows fora seamless transition between grid-connected and islanding mode by opening a conventional circuit breaker. Two modes are being tested:
  - Island mode: maintain frequency, voltage and power quality in a zero-inertia power system with local renewable energy production, curtailing generation and operating the backup generator when required.
  - Connected to the main grid: ancillary services including constraint management, peak lopping and voltage control.

Figure 17: Batter systesm at Simris

Provide multiservice (including cloud storage)

The French demonstrator (Enedis) analyses in its Use Case 2 a multiservice approach for a central storage system. The idea is to use a storage unit upon the DSO’s request to relieve local grid constraints and to offer a complementary share of the battery to market players depending on their needs. This use case shall foster a mutualization of storage assets and a coordinated use for local (constraint allieviation and cloud storage) and national needs (balancing market).

Usability of an integrated flexibility market

In the Dutch demonstrator (Enexis), the Use Case 3 is validating technically, economically and contractually the usability of an integrated flex market based on a combination of stationary neighbourhood batteries and electric vehicle charging stations.

Figure 18: Electric vehicle charging stations

4.4. Barriers & obstacles

InterFlex demonstrators and use cases aim to overcome obstacles such as:

- Storage business model uncertainty:
  - Solve the issue of multiservice storage value assessment between regulated services and services for market players
  - Benefits from shared storage systems for different users (e.g. multi aggregators): self-consumption, electric vehicle fleet managers, DSO or other actors like (renewable) energy producers

  - Market design for flexibilities provided by storage assets
- Technical aspects:
  - Islanding capabilities, automatic islanding transition and related electric protection issues
  - Micro-grid system operation
  - Battery communication within multi-stakeholders systems
  - Battery system implementation constraints

4.5. Lessons learned & best practices

InterFlex is currently collecting first feedback from the various demonstrators.

Among the first learnings are the following:

- A minimum market size is required to have multiple Aggregators offer flexibility from different flexible sources (SSU, EV chargers) in a flex market. In this way, the DSO can procure flexibility (e.g. congestion management).
- All agreements between the parties about availability of energy flexibility services need to be described in a service level agreement (SLA).
- Technical replicability needs to be guaranteed using open interfaces, open protocol and open systems
- Variable capacity mechanism should be defined on a contractual basis for a POC, limiting the available capacity for a limited period of the day. Variable capacity can provide to the DSO an alternative to the local flexibility market.
- Regulatory or contractual constraints among the different stakeholders constitute major barriers to overcome
- Local needs for flexibility undergo rapid fluctuations and so does the value assessment of the corresponding flexibility offers. The definition of the market design of the tradable offers constitutes a major challenge

4.6. Key regulations, legislations & guidelines

InterFlex strives to contribute to policy framework and replicability. Conclusions will enclose recommendations for micro grid operation, regulatory framework proposition for storage solutions and more globally to foster the efficient utilization of flexibilities. Results will also outline the consumer behaviour thanks to analyses of electric vehicle user profiles or demand response of domestic devices.

InterFlex conducts studies which aim at contributing to discussions about storage and flexibility markets. The various demonstrators explore the interest and limits for the DSO to own or operate storage assets, in relation with the Clean Energy Package discussions. The DSOs handle experimentations with variable power contracts and investigate the contract rules with the different stakeholders. Finally, the value buckets of flexibility markets are highlighted as well as the associated rules to procure flexibilities for the DSO’s needs.

5. India: Battery Energy Storage System Pilot Project at Puducherry

Project Information		
Project Title	Battery Energy Storage System Pilot Project at Puducherry	
Location	Puducherry, India	
Time Period of Project	October 2015- April 2017	
Funding	(Government) POWERGRID	(Private Sector) N/A
Participating organizations	Power Grid Corporation of India Limited	
Key Word (3-4)	Battery Energy Storage System (BESS), Frequency Regulation, Energy Time Shift, Advanced lead Acid, Lithium Iron Phosphate.	

Author Information	
Country	INDIA
Contributor	Power Grid Corporation of India Limited
Organization	Power Grid Corporation of India Limited
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5.1. Project Summary

Variability and Intermittency associated with Renewable Energy can make load-generation balancing of the Grid a challenge. Grid connected Battery Storage System (BESS) is one of the option to address renewable variability. With fast response and high ramp rate they can offer vital support to the Grid. Battery Energy Storage technologies along with battery management systems as a whole are evolving.

To examine the efficacy of Battery Energy Storage System in India, POWERGRID has taken lead initiative for pilot project with capacity of 1MW, 500 kWh on different battery technologies (Advanced Lead Acid and Lithium Iron Phosphate) including associated Battery Management System. BESS are being used for Frequency regulation and Energy Time shift applications.

5.2. Objectives of the project

POWERGRID has implemented the Battery Energy Storage System (BESS) project with the following objectives:

- Proof of concept for application of BESS towards frequency regulation & energy time shift applications – Ancillary Services
- First-hand experience of different battery technologies & it's battery management system before large scale deployment prospects in future
- Policy / Regulatory advocacy for deployment of such technologies for grid stability

5.3. Current status & results (outcomes)

POWERGRID has completed commissioning of BESS (for both Advanced Lead Acid and Lithium Ion) in April 2017. Since, then the BESS system is in operation in grid connected mode. The application mode i.e. Frequency Regulation/ Energy Time Shift is changed as and when required. Technical analysis has been carried out on several aspects of the storage system and experience in operation of BESS is regularly published by POWERGRID in technical conferences and meetings.

Some of the key results are as follows:

- 10% of peak load shaving was possible through Energy Time Shift application of BESS
- Average Daily exchange during frequency regulation application is about 3 cycles
- AC to AC efficiency of Lithium Iron Phosphate and Advanced Lead Acid BESS is about 80-85% and 70-75% respectively.
- Normalised Root Mean Square (NRMSE) error between PCS command and Power output of BESS is 14% and 18% for Lithium Iron Phosphate and Advanced Lead Acid respectively.

The detailed results/analysis that are published by POWERGRID can be found in the following links:

- https://ieeexplore.ieee.org/document/7858894/
- https://ieeexplore.ieee.org/document/7115796/
- http://www.cea.nic.in/reports/others/planning/rd/allpapers.pdf

5.4. Barriers & obstacles

Every battery technology has different rated Depth of Discharge for specified cycles. To bring all the technology on single platform during tendering, useful capacity was defined.

During operation, each cycle depth is different hence evaluating batteries for cycle life is found difficult. Equivalent energy transaction for specified cycles are considered base for the same.

In Frequency Regulation application of BESS it was observed that, around 50Hz frequency, the BESS fluctuates between charging and discharging mode. To counteract the problem, in the control algorithm of the BESS a dead band was introduced. This reduced the frequent charge-discharge of the battery considerably.

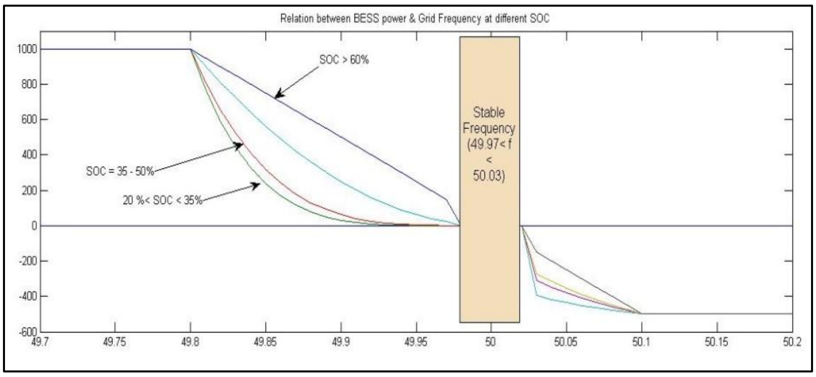

Figure 19: Relation between BESS power & grid frequency at different SOC

The distribution of frequency of Indian grid, is not symmetrical in either side of 50 Hz. Due to this it was observed that the BESS remains idle for a considerable amount of time. Control algorithm of BESS was changed appropriately to reduce the idle time of BESS.

5.5. Lessons learned & best practices

Installation

Lithium Iron Phosphate is more energy dense than advanced Lead Acid Battery. For same sizing Advanced lead Acid has 1.5 times footprint than Lithium Iron Phosphate BESS.

Operation

BESS provides a very quick response rate to changing grid frequency signals.

There is no limitation in terms of Ramp rate for providing grid support through both Advanced Lead Acid and Lithium Iron Phosphate BESS.

Being a tropical country, air-conditioning requirements are high. Overall efficiency is affected due to auxiliary power consumption (mainly for air-conditioning) by about 5%.

AC to AC efficiency of Lithium Iron Phosphate and Advanced Lead Acid BESS is about 80-85% and 70-75% respectively

5.6. Key regulations, legislations & guidelines

In India there is no existing framework for BESS projects. However, in 2017 Central Electricity Regulatory Commission has released a draft paper where following are covered in detail:

- Grid level application of ESS
- Potential Owners of Electricity Storage Applications
- Operational Framework
- Recovery of Electricity Storage Services
- Regulatory Jurisdiction

The detailed staff paper is available in the public domain.
(http://www.cercind.gov.in/2017/draft_reg /SP.pdf)

6. Korea : Application of ESS for Wind Power Connection to Youngheung Wind Farm

Project Information	
Project Title	Application of ESS for Wind Power Connection to Youngheung Wind Farm
Location	Yeongheung-myeon, Ongjin-gun, Incheon, Republic of Korea
Time Period of Project	March 2015- September 2015.
Participating organizations	• KOREA SOUTH-EAST POWER COMPANY • Hyosung Corporation
Link to Project Website	
Key Word (3-4)	ESS (Energy Storage System), RPS (Renewable Portfolio Standard), REC (Renewable Energy Certificate)

Author Information	
Country	South Korea
Contributor	Young-Jin Kwon,
Organization	Hyosung Corporation
E-mail	Kwon@hyosung.com

6.1. Project Summary

To promote the use of renewable energy, many governments around the world have adopted various types of subsidy regulations such as FIT (Feed-in Tariff), RPS (Renewable Portfolio Standard) and so on. Korea government proposed RPS regulation in 2012. This directly affected to Korean companies to produce a specific restricted proportion of their electricity supply with renewable energy sources to comply the regulation. Basically 1 REC (Renewable Energy Certificate) corresponds to 1MWh of renewable energy generation, but it can be weighted according to the installation type and criteria of renewable energy sources. The RPS regulation was revised to provide additional RECs for ESS connected to wind power generation since 2015. And it became enables to acquire 4.5 to 5.5 RECs from discharging 1MWh which increased the weight by 4.5 to 5.5 times. The revised weight provides good incentives enabling many generation companies and wind power companies to start installing ESS connected to their wind power generators.

The Youngheung thermal power station has installed a large wind farm with a 46MW capacity in their station to meet their mandatory RECs. The entire wind farm is composed of two farms. One of them has 9 wind turbines, total capacity of 22 MW, and the other has 8 wind turbines, total capacity of 24 MW. Here, for the first time in Korea, lithium-ion battery based ESS (Energy Storage System) was installed to maximize the REC acquisition. The historical data of the wind farm and generation capacity are analyzed to optimize the capacity of the grid-connected PCS (Power Conditioning System) and the battery. Following the results of the analysis, 2MW / 8MWh ESS was installed at each farm. Operation functions of ESS with the wind power which are introduced here are divided into REC maximizing operation and ramp rate operation. The REC maximizing operation is based on scheduled operation which its charging / discharging time vary according to the off-peak / peak time. The ramp rate operation ensures to meet a specified ramp rate limit of wind power output, which has not been established by any Korean regulations. As ESS becomes more economical, it is expected to have more widespread penetration of ESS may result in additional regulations with respect to the power system such as ramp rate limit and participation in the existing power trading market as dispatchable generators.

6.2. Objectives of the project

As part of the ESS promotion policy, Korean government introduced a scheme to grant REC (Renewable Energy Certificate) weights to ESS connected to wind or photovoltaic power generation. As a result, the economic feasibility of ESS connected to them has greatly improved.

To meet the REC obligation to comply with RPS regulations, the Youngheung thermal power station, the largest power station in the Seoul metropolitan area, has set up a project, which is the first commercial operation of ESS connected to wind power in Korea, to install an ESS at their 46MW wind farm located inside their territory.

6.3. Current status & results (outcomes)

The ESS capacity (4MW/16MWh) was determined to be of 4 hours instead of 3 hours since the use of ESS for 3 hours with additional usable energy capacity is needed and when the battery life is taken into consideration, the capacity must still be retained after 12 years.

After studying a power system analysis and consulting with the power station members with respect to the ESS connection points in the existing wind farm grid, the ESS was installed in two farms as shown in the Figures below.

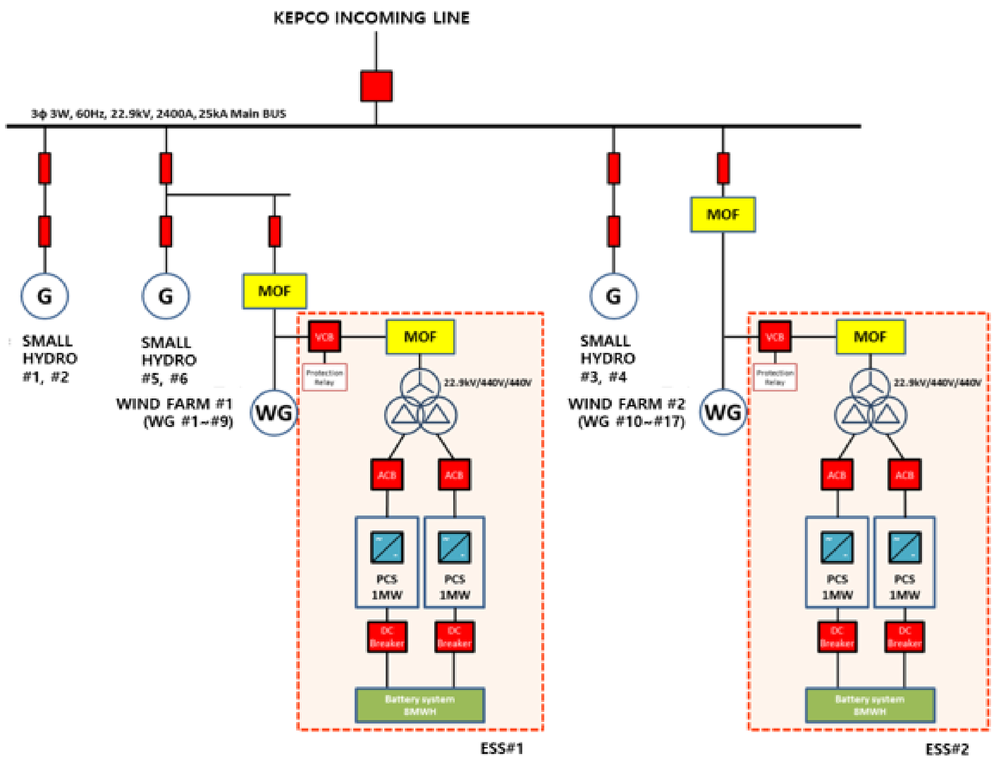

Figure 20: A single line diagram of installed ESS

Operation modes

When there are no faults or maintenance issues, the automatic mode operation is normally performed based on the setpoint that can be set by the operators. In manual mode, the operators can control each component of the ESS including the PCS, the battery, and the circuit breakers in order to identify fault issues and maintain their assets.

REC maximizing operation

The REC maximizing operation strategy is based on a scheduled operation that discharges during the peak time and charges during the other times. Charging operation is recommended to start right after the peak time because when the weather condition is not good enough for wind turbines to generate for a long time, SOC (State Of Charge) of the battery may not sufficiently ensure full discharging during next day's peak time.

In the graph on the left, it is expected to have no problem until next day's peak time discharging so that the maximum RECs from the ESS are acquired.

The graph on the right shows a case in which sufficient SOC cannot be secured before the peak time. The peak time of 3 hours was over without completely discharging. The peak-time discharge may be difficult if the wind power generation is insufficient the next day as well.

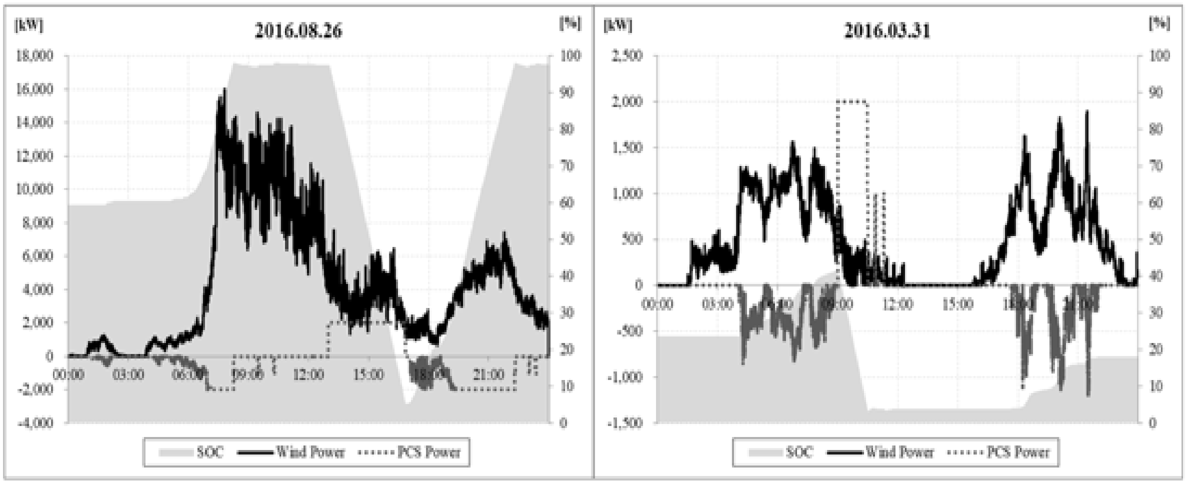

Figure 21: Sampled graphs of daily operation results

Ramp rate operation

A ramp rate is defined as the power difference from minute to minute based on rated power of a generator. It must be met even when a wind power generator stops right after its rated power for any reasons, or the wind power goes from zero to its rated power in an instant. Thus the algorithm we developed is based on comparing the energy remaining in the battery with total output power reference of wind power plus ESS power. it was tested in an ESS testbed located in Jeju Island. In the test-bed, a 3MW wind turbine and 4MW / 8MWh ESS was used for the algorithm operation test.

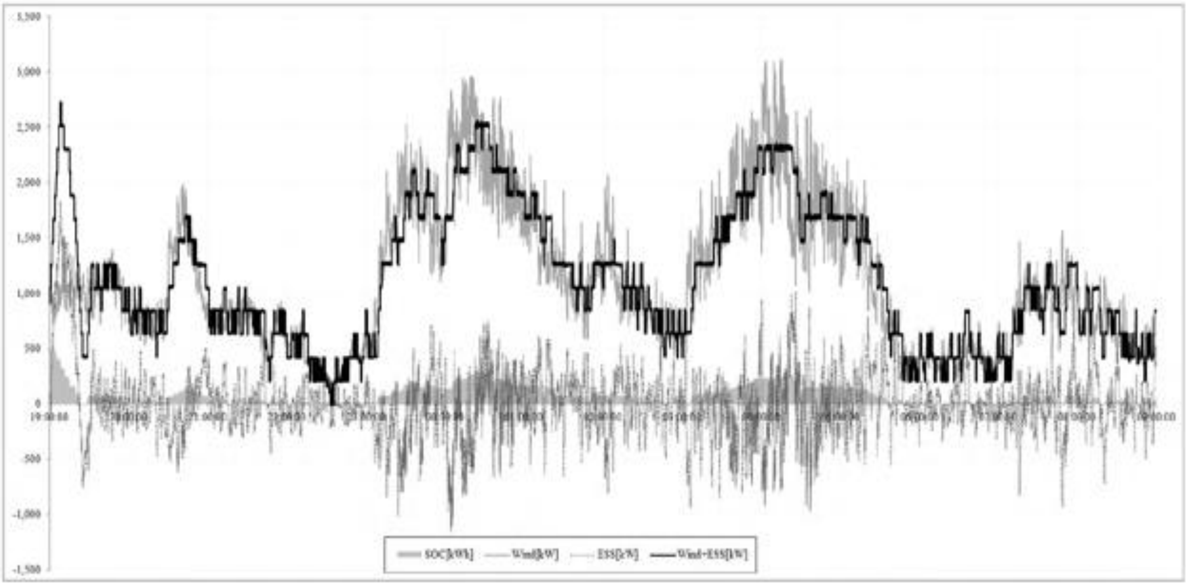

Figure 22: A ramp rate operation result

6.4. Lessons learned & best practices

As the REC weights are revised, the ESS can store the energy of the wind power during the off-peak time and discharge for 3 to 4 hours with different peak times by season to obtain the maximum REC. However, from the point of view of the entire power system, simply discharging the rated output only at peak time without reducing the fluctuation of the wind power output is not the best solution since the ESS connected to the wind power can contribute more to the power system due to the fact that the ESS penetration promotion policy should be considered a priority because the price of batteries remain high and incentives and subsidies related to reducing wind power’s variability are not easy to quantify.

As ESS itself becomes more economical, it is expected that a more widespread penetration of ESS may result in additional regulations with respect to the power system such as renewable energy output smoothing, ramp rate limit, voltage regulation and participation in the existing power trading market as dispatchable generators.

6.5. Key regulations, legislations & guidelines

REC weights are applied depending on the kind and installation type of the renewable energy source.

Table 3: REC weights for energy source and criteria

category	REC weighting	Energy source and criteria	
		Facility type	Criteria
Solar PV	1.2	Facility installed on general site	< 100kW
	1.0		≥100kW
	0.7		> 3,000kW
	1.5	Facility installed on existing buildings	≤ 3,000kW
	1.0		> 3,000kW
	1.5	Facilities floating on the water	
	5.0	ESS (connected to solar pv)	'16~'19
	4.0		'20~
Others	0.3	IGCC, Byproduct gas	
	0.5	Waste, Landfill gas	
	1.0	Hydro, Onshore wind, Bioenergy, RDF, Waste gasification, Tidal power (with embankment)	
	1.5	Wood biomass, offshore wind (grid connection less than 5km)	
	2.0	Fuel cell, Tidal power	
	2.0	Offshore wind (grid connection longer than 5km), Geothermal, Tidal power (no embankment)	Fixed
	1.0~2.5		Variable
	5.5	ESS (connected to wind power)	'15
	5.0		'16
	4.5		'17~'19
	4.0		'20

The REC weights are not provided undiscriminatingly. It is possible to discharge only during different peak times by season according to the regulation. The energy discharged during peak time must be the energy charged from the wind power generation during the off-peak time.

Table 4: Peak time for seasons

Season	Period	Peak time	Duration
Spring	3/17 ~ 6/6	09 ~ 12 o'clock	3 hours
Summer	6/7 ~ 9/20	13 ~ 17 o'clock	4 hours
Autumn	9/21 ~ 11/14	18 ~ 21 o'clock	3 hours
Winter	11/15 ~ 3/16	09 ~ 12 o'clock	3 hours

7. Korea: Demand Side Management with ESS

Project Information	
Project Title	Demand Side Management with ESS
Location	Changwon, South Korea
Time Period of Project	2014 - Present
Participating organizations	KERI
Key Word (3-4)	ESS, demand side management, incentive policy

Author Information	
Country	South Korea
Contributor	Wanbin Son
Organization	KERI
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7.1. Project Summary

KERI (Korea Electrotechnology Research Institute) installed three energy storage systems (ESSs) in the institute at 2014: two 1.2MWh Lead Acid battery ESSs and a 405kWh Lithium battery ESS. The ESSs are used for demand side management of the institute. Financial benefit of the three ESSs of KERI increases 2-3 times from 2016 by the effect of the new policy of the South Korea government. The Korea government has a strong promotion policy on the energy storage industry from 2016. Under the new policy, almost 80% of the financial benefit by operating ESSs in KERI from the incentive of the new policy. The ESS payback period under the new policy is now less than 10 years, it gives an attention to several companies to install their own ESSs in South Korea. The lesson learned from this case is the powerful support of the government (or the grid operator) is the key to disseminate ESSs extensively.

7.2. Objectives of the project

KERI has operated the three ESSs for active demand side management of electronic load of the institute. The objectives of the project are as follows:

- Financial aspects: demand side management has the potential to reduce electricity costs.
- Research aspects: for demand side management, several functionalities are required for EMS including charge/discharge scheduling and forecasting electronic load. KERI has tried several algorithms to implement the functionalities.

7.3. Current status & results (outcomes)

KERI installed three ESSs in the institute at 2014: two 1.2MWh Lead Acid battery ESSs and a 405kWh Lithium battery ESS. They are used for demand side management of the institute.

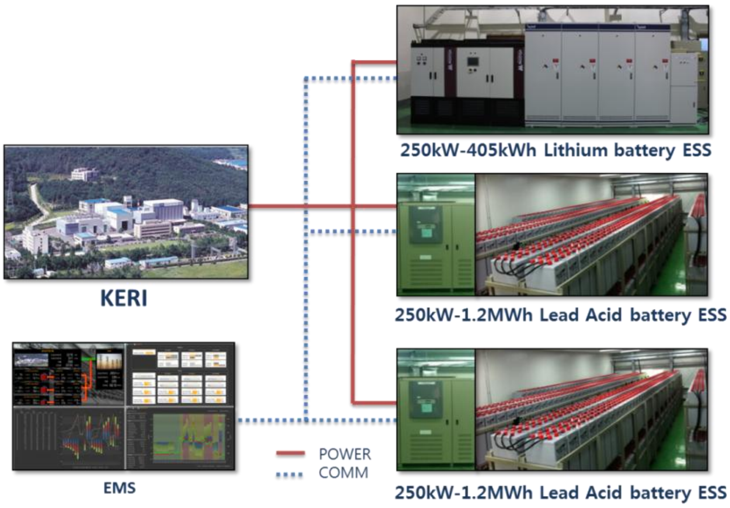

Figure 23: KERI ESS overview

Charging and discharging scheduling for three ESSs for a day is done by the EMS at midnight. For the scheduling, the EMS forecasts electronic power load of the next day first. By considering constraints including the forecasted load, power prices and the government promotion policies, hourly charging/discharging amounts of electronic power for each ESS is scheduled. The object function of the scheduling is maximizing the financial benefit.

The following table shows monthly average financial benefit of ESSs from Nov 2016 to OCT 2017. Monthly average revenue of ESSs is $25,370 and almost 80% of the revenue is from the ESS incentive of the grid operator.

Table 5: Monthly averaging revenue of ESS

Monthly Averaging (Nov 16-Oct 17)	Peak (kW)		Benefit ($)			
	Original	Managed	Peak reduce	Load shift	ESS incentive	Total
	9,040	8,778	2,256	2,918	20,196	25,370

Table 6: Monthly benefit of ESS

	Peak (kW)		Benefit ($)			
	Original	Managed	Peak reduce	Load shift	ESS incentive	Total
11, 2016	8,603	7,869	6313	3479	7513	17305
12	8,491	7,891	5158	3935	8217	17311
1,2017	9,023	8,306	6167	3932	30678	40777
2	9,152	9,030	1048	3825	30752	35625
3	9,152	9,030	1048	1585	21642	24275
4	9,152	9,030	1048	1236	21905	24189
5	9,152.	9,030	1048	1172	16664	18884

6	9,152	9,030	1048	4209	20128	25385
7	9,152	9,030	1048	4765	23345	29158
8	9,152	9,030	1048	4615	21617	27281
9	9,152.	9,030	1048	1367	22791	25206
10	9,152	9,030	1048	902	17109	19059

The cost and revenue of ESSs are estimated as follows.

Table 7: ESS costs

	Lead Acid Bat 1	Lead Acid Bat 2	Lithium Bat	Total ($)
ESS Cost	500,000	500,000	576,360	1,576,360

Table 8: ESS benefits

Year	Benefit ($)	Benefit Sum ($)
2014	41,369	41,369
2015	80,330	121,699
2016	143,416	265,115
2017	323,810	588,926
2018	316,921	905,846
2019	303,435	1,209,281
2020	131,009	1,340,290
2021	128,032	1,468,322
2022	122,212	1,590,534
2023	113,880	1,704,414

In 2022, the total revenue will be greater than the initial cost. The pay-back period is 8.9 years, and benefit-cost ratio is 1.34 assuming 20 years of operation.

7.4. Barriers & obstacles

One of the major problems to setup the energy storage system is its price and the life expectancy. A cost of 1kWh lithium battery is ranging at 350 to 700 dollars in 2015. The price will continue to drop down, but still expensive. The life expectancy of ESS is last for 10 years.

On the other hand, electric power price for industry in South Korea is very economical; less than 0.2$/kWh in the peak time. It means that expected benefit of ESS is limited. Even after 10 years (the life expectancy of ESS) later, the initial setup cost and maintenance cost can be still greater than the financial benefit of ESS without any government support. In other words, the payback period exceeds 10 years.

7.5. Lessons learned & best practices

From 2016, Korea government has a strong promotion policy on the energy storage industry and renewable energy industry. According to regulation, a company can get incentive from the grid operator KEPCO by discharging ESSs on peak time or charging ESSs on off-peak time.

The three ESSs revenue of KERI increases 2-3 times more under the new regulation. From Nov 2016 to Oct 2017, the financial benefit analysis shows that almost 80% of the financial benefit of ESSs in KERI is from the incentive of the grid operator. The payback period of ESS under the new policy is now under 10 years, so ESS becomes an attractive option to industry in financial perspective.

The lesson learned from this case is that the powerful support of the government (or the grid operator) is the key to disseminate ESSs extensively.

7.6. Key regulations, legislations & guidelines

Korea government aims the percentage of renewable energy increases up to 20% by 2030. Thus, Korea government has reinforced their regulation on the energy storage industry and renewable energy industry to achieve this goal.

A company can get incentive from the grid operator KEPCO by discharging ESSs on peak time or charging ESSs on off-peak time. Those who install the both ESS and renewable energy generators can get additional incentives. This additional benefit will provoke many companies to engage in operating their own ESSs for demand management. Following is the brief summary of the incentive policy.

- You can get the 50% discount for battery charging cost if you charge on off-peak time.
- You can get the discount for basic charge by discharging battery on peak time. The discount rate is promotional to the discharge power and time.
- You can get a 20%-50% additional discount if you have both ESS and renewable energy source.

The current incentive policy is valid until the end of 2019 and there is great possibility to decrease dramatically after that period ends. In that regards, we hope extension of valid period of the current incentive policy.

8. Korea: Microgrid Smart Operation Platform and Business Model for Agricultural Industrial Complex

Project Information	
Project Title	Microgrid smart operation platform and BM for agricultural industrial complex
Location	Naju-si, Jeolla Province, South Korea
Time Period of Project	May 2016 – December 2018
Participating organizations	• Korea Institute of Industrial Technology • Chonnam National University • TOPINFRA • SG • SMSOFTWARE
Key Word (3-4)	Industrial Complex Microgrid, MG Operating Platform, e-prosumer, DC distribution network

Author Information	
Country	South Korea
Contributor	Jae Ha Ko
Organization	Green Energy Institute
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8.1. Project Summary

ESS, PCS, PV Converter, ESS Converter and AMI were installed in six factories in order to construct a microgrid of industrial complex in Dongshu industrial complex located in Naju City. Since the Peak power operation time differs from factory to factory, we have constructed an industrial complex microgrid that can freely trade surplus power through the ESS network (DC-grid) where surplus power is generated.

This type of industrial complex microgrid includes power trading for surplus power. It is important to decide how much power to send and receive at a certain point in time. Therefore, an energy management system capable of operating and processing these types is important, and various functions such as power generation prediction, load prediction, and DR response are required. This project is a project to study a smart operation platform that can handle them in an integrated way.

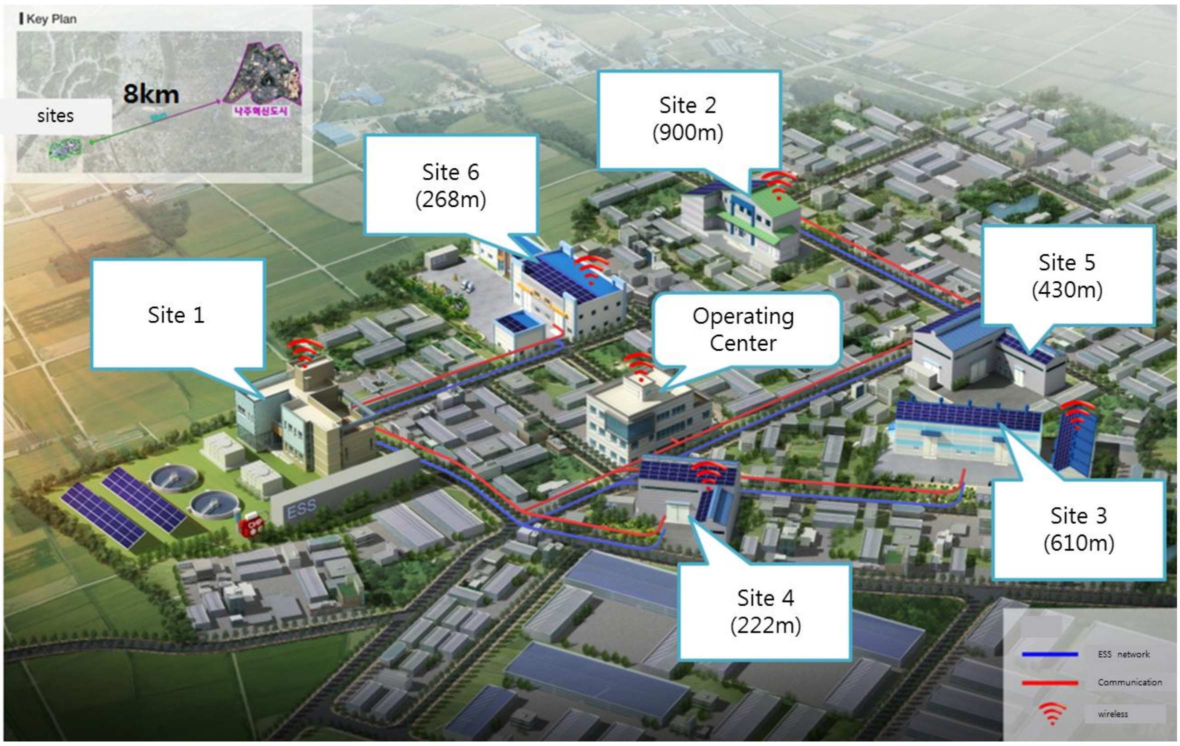

Figure 24: Target microgrid overview

8.2. Objectives of the project

- **Objective**: To create microgrid market for agricultural and industrial complexes, operating technology, and Deriving BM
  - Design and construct a microgrid smart operation platform based on DC grid suitable for agricultural industrial complex, and provide operating technology and business model through demonstration.
- **Infrastructure targets** : PV 600kW, CHP 100kW, ESS 1,500kWh, DC-grid 3.25c-km
- **Main goal of agricultural industrial complex MG smart operation platform**
  - Development of EMS algorithm for micro grid in industrial complex
  - Reduction of energy consumption and peak power for agricultural and industrial complex.
  - Construction of a stand-alone uninterruptible operation model for a specific customer.
  - Construction of Distributed Power (PV, CHP) Electric + Thermal Fusion Operation Model.
  - Construction of load management IoT terminal device and construction of industrial complex communication / sensor network
  - Established a solution for economic power trading and demand response

8.3. Current status & results (outcomes)

Current status: After the second year, the main infrastructure has been constructed. Currently, EMS algorithm optimization and MG operation of agricultural and industrial complex are being demonstrated. We will build additional distributed generation CHP 100kW class, and based on such site, we will find a microgrid business model for industrial complex.

Results & Outcomes:

- Completed construction of microgrid model for industrial complex for the first time in Korea.
- E-Prosumer Demonstration Site for Industrial Complexes
- Establishment of the first site capable of trading surplus power based on DC distribution by constructing 3.25km DC power distribution line.
- Completion of microgrid operating platform for industrial complexes capable of integrated management based on electricity trading and optical communication network.

Table 9: Detailed System Specification

Site id	PV	ESS	Battery Type	PCS	PV DC/DC Converter	Battery DC/DC Converter
1	300kWp	1113.9kWh	Li-ion / 710V 69.6kWh * 16EA	100kW	300kW	100kW X 4EA
2	98.5kWp	208.8kWh	Li-ion / 710V 69.6kWh * 3EA	100kW	100kW	100kW
3	46.9kWp	149.1kWh	Li-ion / 710V 49.7kWh * 3EA	50kW	50kW	50kW
4	60.9kWp	49.7kWh	Li-ion / 710V 49.7kWh * 3EA	50kW	60kW	30kW
5	46.9kWp	49.7kWh	Li-ion / 710V 49.7kWh * 3EA	30kW	50kW	30kW
6	46.9kWp	110.5kWh	$LiFePo_4$ / 690V 55.3kWh * 2EA	30kW	50kW	50kW
Total	600.1kWp	1,682kWh		360kW	610kW	660kW

8.4. Barriers & obstacles

The construction of a microgrid model of industrial complex capable of electricity trading is a totally new model. There was no reference in licensing, so it took a lot of time for administrative processing.

The development of the electric power trading algorithm corresponding to the e-prosumer can be classified into the real-time electric power trading and the pre-planned electric power-based electric power trading. In addition, the power trading scheme due to the involvement of the prosumer and the consumer should be derived in consideration of the response speed of the micro grid facility and the facility operation plan in the event of a transaction failure.

In the case of the day before (planned operation) operation, the load and power generation forecast must be accurate and follow-up research and development of the consumer-based power trading market is required.

Operator-intervened power trading market is needed, and it is necessary to distribute profit to the participating consumers under appropriate policy.

8.5. Lessons learned & best practices

When the user uses the electric power network built by the utility company at the time of power trading, it requires the permission of the utility operator, which limits the electric power trading market among consumers.

Factory-to-factory electricity trading in a certain space such as an industrial complex can conduct electricity trading with a power grid (DC or AC) built by the operator, which can be fully promoted by opening the market for electricity trading.

If the plant is concentrated in a certain range, such as an industrial complex, the cost of constructing the grid is relatively low compared to a long distance, thereby improving the economic efficiency.

As a model for promoting commercialization based on the activation of consumers and e-prosumers, it can become an industrial complex micro grid, which can promote the energy efficiency of industrial complexes that consume a lot of electricity.

8.6. Key regulations, legislations & guidelines

The power conversion device is a device that converts to AC-DC or converts it to DC-DC. Since DC source such as solar is popularized, DC is used instead of DC-AC to connect to AC network of existing utility. Use of DC-DC converter is relatively gain in power conversion efficiency

In order to use such DC-DC power conversion devices and conduct electricity trading, the DC meter related laws must be specified in advance. There are no laws on DC power metering yet in Korea.

In order to activate the micro grid and e-prosumer of the industrial complex, it is necessary to open the electricity trading market, which is currently limited to utility companies.

9. Korea: POSTECH Microgrid System based on Energy Big Data

Project Information		
Project Title	POSTECH microgrid system based on energy big data	
Location	Nam-gu, Pohang-si, North Gyeongsang Province, South Korea	
Time Period of Project	January 2017 – December 2018	
Funding	(Government) N/A	(Private Sector) POSCO
Participating organizations	POSCO, POSCO ICT, RIST, POSTECH	
Link to Project Website	http://oibc.postech.ac.kr	
Key Word (3-4)	Big Data, demand load prediction, power generation prediction, economic dispatch	

Author Information	
Country	South Korea
Organization	POSTECH

9.1. Project Summary

- Need for smart energy system technology (micro grid), a key element of Smart City is increased
- A differentiated microgrid system technology utilizing Big Data / AI is required

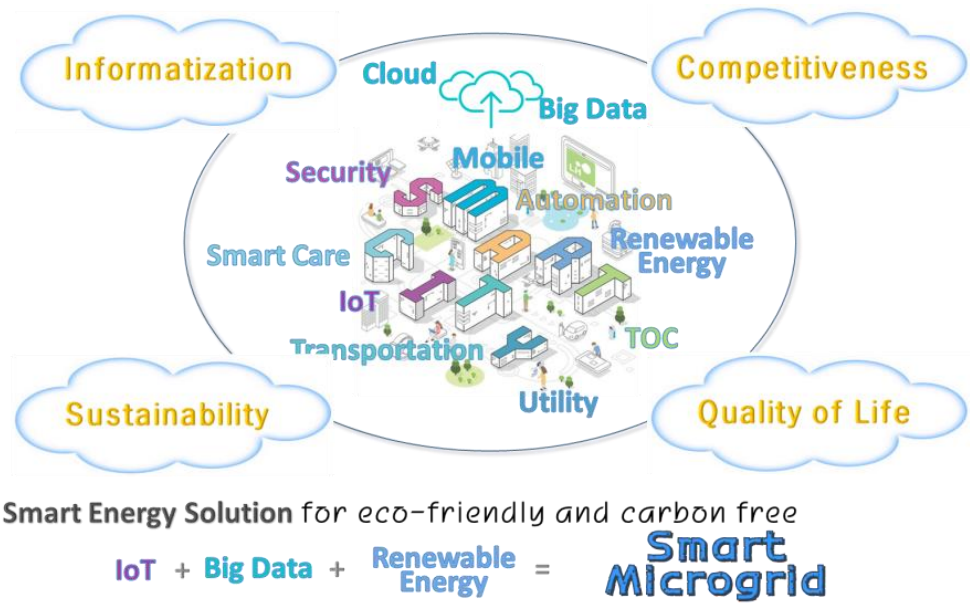

Figure 25: Overview of the POSTECH smart microgrid

9.2. Objectives of the project

- Develop prediction/ efficiency enhancement technologies using Big data and AI (POSTECH)
- Develop smart microgrid technologies by building low loss, uninterrupted micro grid system. (RIST)
- Develop and commercialize Smart microgrid solution by building a demonstration site. (POSCO, POSCO ICT)

9.3. Current status & results (outcomes)

- Building a Big Data-based Micro Grid System for Open Innovation on POSTECH Campus through close cooperation between Industry, University and POSCO Family, POSTECH and RIST.
- Collecting power data from a variety of spaces (laboratory, office space, living space, data center)
- Building Open Innovation Big Data Center to store and utilize power big data.
- Developing AI based demand forecasting and PV power generation forecasting algorithms based on power big data of the Open Innovation Big Data Center.
- Developing microgrid economy dispatch algorithm based on supply and demand forecast
- Building POSTECH microgrid System that achieved low loss and uninterruptability through optimal operation of PV and ESS using supply and demand forecasts and economic dispatch.

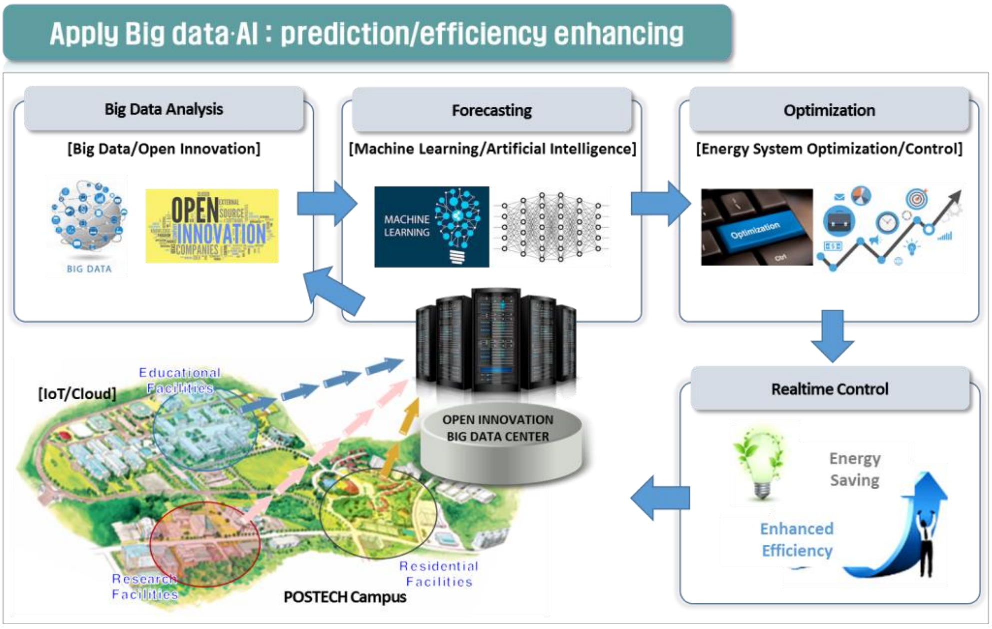

Figure 26: Apply big data and AI

9.4. Lessons learned & best practices

- Developing new concept smart grid system technology and configuring living lab.
- Available in key facilities such as schools / research facilities, high-tech industrial facilities, large buildings, military facilities, and energy independent islands
- Contribution to POSCO Family's Smart City business and national disaster response.

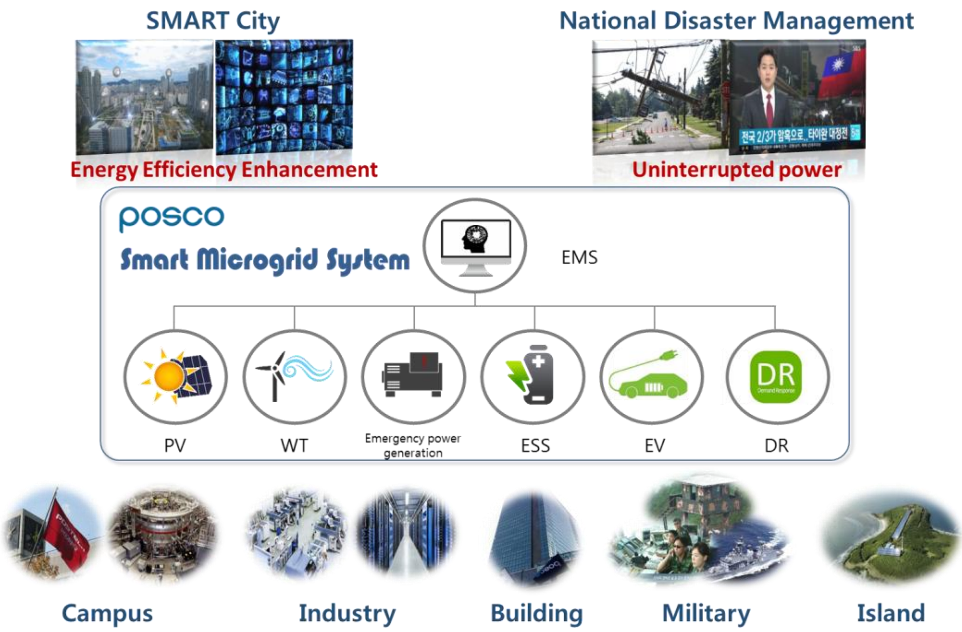

Figure 27: POSCO Smart microgrid system

10. Korea: Powell Energy Efficiency Enhancing System with ESS+DR+FEMS

Project Information	
Project Title	Powell energy efficiency enhancing system with ESS+DR+FEMS
Location	Nam-gu, Pohang-si, Gyeongbuk, South Korea
Time Period of Project	April 2017 – October 2017
Participating organizations	• Target : Powell • System construction : Gridwiz • Equipments : battery (LG), PCS (Plaspo)
Link to Project Website	
Key Word (3-4)	ESS, FEMS, Energy efficiency, Demand Response

Author Information	
Country	South Korea
Contributor	Gridwiz
Organization	Gridwiz
E-mail	www.gridwiz.com

10.1. Project Summary

Powell's sewage treatment and water reuse facility are always in operation, and they are using electrical energy. A sudden high peak load can be occurred when the utility rate has increased. However, since there was no integrated monitoring system for the power load situation, it was difficult to effectively control the peak load. For effective use and management of electric energy, Gridwiz has been building and operating an energy efficiency enhancing system, which combines FEMS and ESS, in Powell since October, 2017. The energy efficiency enhancing system consists of FEMS, which controls the energy management of factories, and ESS, which plays a main role of peak reduction and reduction of electric costs. Considering the power load pattern, efficiency and economic feasibility, the system was constructed with battery 1,644kWh and PCS 250kW. In addition, Powell is participating in the Demand Resources trading market with Demand Management (DR) resources.

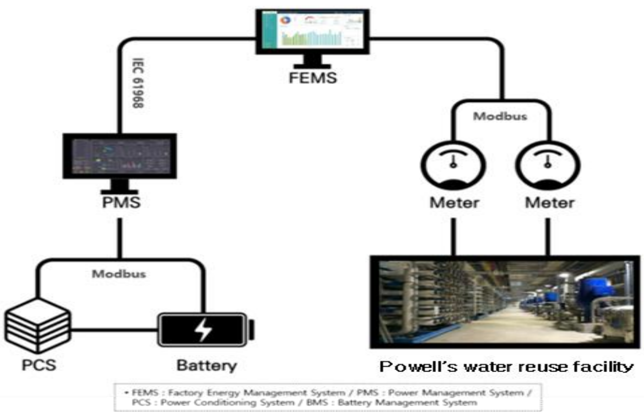

Figure 28: System Configuration

10.2. Objectives of the project

Powell aims to optimize facility operation by monitoring electricity usage in real-time through FEMS in operation of sewage treatment and recycling facilities, and to reduce energy costs by effective ESS operation (peak reduction / economical operation) by energy pattern analysis.

Powell's Energy efficiency enhancing system (ESS + FEMS) is expected to reduce peak demand by near 100kW annually, and electricity costs by about 160 million won over the next 15 years since October 2017.

- In consideration of energy usage pattern and optimal battery life, ESS performs charging / discharging once a day and performs ESS operation on average 23 days a month excluding Sundays and other public holidays
- ESS operation is operated in the form of economical operation or economical operation and peak reduction operation.
- The ESS is expected to be operated in the form of economical operation for the period from 2017 to 2020, which has the largest base rate and charge rate discount. In the period from 2027 to 2031, plan to reduce peak operation and economical operation

10.3. Current status & results (outcomes)

Gridwiz has been operating the system for 11 months since October 2017. Gridwiz has reduced peak load of 514kW (approximately 10%) from 5,380kW to 4,866kW through FEMS, and reduced electricity costs by about 200 million won within 10 months through ESS

ESS installed in Powell reports five events from August 2018. They are relatively simple faults such as momentary anomalies in the power system, natural disasters, and power outages.

- PCS AC Overvoltage Fault (effect: 3 minutes)
- Fault of PCS R phase overcurrent due to grid outage (effect: 42 minutes)
- System momentary power failure (no effect)
- PCS AC overvoltage (effect: 28 minutes)
- Earthquake (no effect)

Powell also has participated in the demand resource trading market, and we have been able to achieve a more stable demand reduction effect through the power of installed ESS.

Since July 2017, Gridwiz has installed and operated about 240 MWh ESS in 14 sites (34 PMS) and has been developing various technologies and softwares to provide excellent services from the beginning of the project.

- optimum design S / W for stable ESS installation and operation
- optimum operating algorithm considering customer's power demand
- Multi-functional PMS for stable operation of ESS power equipment
- "ESS operation evaluation system" for 24-hour ESS monitoring and operation
- "EMS for TOC" for on-site facility monitoring of site with large capacity ESS
- ESS operation system for renewable energy (solar, wind, etc.)
- Simulation softwares for major equipments constituting ESS such as BMS, PCS, etc.

In addition, Gridwiz's ESS operation team operates 24/7 real-time monitoring and instant response to the event situation, and they are providing the best ESS operation service such as abnormal condition detection and efficiency improvement through data analysis.

10.4. Barriers & obstacles

Battery supply delay : The project was delayed because of battery supply delay (4 months) due to the lack of supply from the manufacturers, and business disruptions such as construction and operation. As a result, it was not possible to operate the energy efficiency enhancing system (FEMS + ESS) during the summer peak period and the peak could not be reduced.

Battery performance : It can be a serious problem if the battery performance is worse than the Battery manufacturer's guarantee during the 15-year operation period.

10.5. Lessons learned & best practices

For the stable execution of the project, accurate system analysis and calculation of the construction period are required. Establishment and realization of the supply strategy of the power facilities such as battery and PCS are key to the success of the project. In addition, it is important to establish a system of information sharing and decision-making consultation with customers so that they can deal with various problems that may arise during installation and operation.

Gridwiz's ESS solution on this project achieves the following results.

- Application of FEMS + ESS + DR Convergence Service
  - FEMS, ESS and DR services provided by Gridwiz increase energy efficiency and reduce costs.
- ESS consulting considering system specific characterization
  - Stable ESS operation due to low probability of PCS malfunction due to pump load due to sewage treatment facility
- Peak management optimization using FEMS
  - Peak management optimization through smart meter based real-time monitoring
  - Approximately 10% reduction in the applied power (5,380kW → 4,866kW)
- Operational optimization through real-time monitoring
  - Cumulative down time since November 2017 is only 73 minutes thanks to the fast remote action when power failure, AC overvoltage, earthquake, etc. occur
  - No shutdown due to Gridwiz PMS problem
- System stability
  - At the time of Ulsan earthquake (November 15, 2017), there was some communication disruption, but ESS and FEMS operation were not stopped

10.6. Key regulations, legislations & guidelines

Operation plan of ESS system

- Establish standard operating procedures
  - Providing business manuals and operator manuals for optimal operation of FEMS + ESS by season and load conditions
  - Periodic evaluation of the implementation of standard operating procedures
- Operate dedicated technical support organization
  - Early selection of operating staffs and request them supports of technology and information required for pricing policy and optimal operation
- Authority and Data Management
  - Keep security system at all times by setting permissions for ESS control and data management
  - Performs historical management and data backup on energy usage and status of major facilities
- Help Desk
  - Quick and systematic repair and maintenance system using professional company
  - Periodic simulation training to verify and maintain reliability of professional management program

11. The Netherlands: The Ice Buffer System

Project Information	
Project Title	The Ice Buffer System
Location	Municipality GOES, Netherlands
Time Period of Project	2012 – 2016 (4 years)
Participating organizations	Delta, Enduris, RWS Partners in Wonen, Marsaki.
Link to Project Website (In Dutch)	• https://www.marsaki.nl/het-ijs-van-columbus-ijsbuffersysteem/ • https://www.usef.energy/app/uploads/2016/12/End-report-prosecco.pdf
Key Word (3-4)	Standard grids, local seasonal storage, smart homes, social housing

Author Information	
Country	The Netherlands
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Organization	Netherlands Enterprise Agency (RVO)
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11.1. Project Summary

In the Smart Energy Collective & Co project (ProSECco), fourteen partners studied how energy grids, services and technologies can be adapted to the continually increasing demand for electricity. The project focusses on four user groups in order to test and develop a framework to deal with the increased need for flexibility. The overarching project ProSECco is testing and developing a single basic design for a new market model based on all four user groups called the Universal Smart Energy Framework (USEF). One of these projects combined cooling/heat generation and seasonal storage in the municipality of Goes, the Netherlands. The project at GOES renovated terraced houses and installed solar panels and 9m³ water tanks, among others, for cooling in the summer and heating in the winter months resulting in a more balanced energy profiles and lower energy costs in the long run.

Figure 29. Installation of ice/water storage tank Goes, Province Zeeland, courtesy Marsaki/RWS Partner in Wonen

11.2. Objectives of the project

The aim of the project was to offer the tenants the security of lower energy bills in the long run for their “all electric” houses. In the Netherlands in general energy consumers with installed PV panels buy additional energy during the winter to heat their houses and sell the surplus produced electricity during the summertime. The Ice Buffer Systems balances the energy profile considerably. Comparable ice buffering systems were up till recently only used for larger installations, like hospitals, and this project is one of the first to introduce it to residents. With an elaborate monitoring system, the awareness is raised of the energy usage in general.

11.3. Current status & results (outcomes)

The systems are installed and the monitoring has begun to evaluate the business model under the influence of two unpredictable factors, namely the weather and human behaviour. The monitoring system is being improved while more experience is obtained with the maintenance of the energy systems.

11.4. Barriers & obstacles

In the Netherlands new legislation is needed to improve the business model and especially a “one stop shop” is needed for obtaining the necessary permits from the local authorities and grid operators when introducing such systems.

11.5. Lessons learned & best practices

For installing new configurations of increasingly complex energy systems a steep learning curve awaits and some form of education and certification would be an option.

11.6. Key regulations, legislations & guidelines

The Ice Buffer System applied in social housing contributed to the development of a new “smart energy” framework. (https://www.usef.energy/)

12. The Netherlands: Standard Grids Smart Homes (SGSH)

Project Information	
Project Title	Standard Grids Smart Homes (SGSH)
Location	Netherlands
Time Period of Project	2015 - 2018 (3 years)
Participating organizations	• Alliander N.V. , • ENGIE Laborelec, • Technische Universiteit Eindhoven, • Technolution B.V. • Belgian network operators (EANDIS and ORES) also participated in the project, but without financial support from the Dutch government
Link to Project Website	https://projecten.topsectorenergie.nl/projecten/standard-grids-smart-homes-een-ideale-combinatie-00018993
Key Word (3-4)	Standard grids smart homes

Author Information	
Country	The Netherlands
Contributor	Project leaders: Standard grids Smart Homes (SGSH)
Organization	TUE.nl and Engie
E-mail	ralf.bosch@engie.com

12.1. Project Summary

The objective of the project has been to develop a Home Energy Management System (HEMS) for use in households. This HEMS enables the local system to remain within specific limits of injecting or demanding from the grid. The project has clearly demonstrated the feasibility of this objective. Large scale application can reduce grid investments substantially. For the implementation incentives for households need to be optimized and feedback simplified. The size of batteries need to be optimized for each household, in the pilot a 14 kWh battery would have been sufficient in al cases. Smart charging should always be implemented, regardless of the introduction of a HEMS.

Figure 30: Overview of SGSH

12.2. Objectives of the project

The objective of the project has been to develop a Home Energy Management System (HEMS) for use in households. This HEMS enables the local system to remain within specific limits of injecting or demanding from the grid. The SGSH HEMS measures the grid/ consumption/injection, automatically controls some devices, takes into account flexible user requests and reports to the user the information required. The algorithm that is used is self-learning and the PV-production was predicted by forecasting. The project aims to limit the exchange with the grid by using storage and flexibility of consumers. If successful, this potentially can lead to great savings in investments in distribution networks.

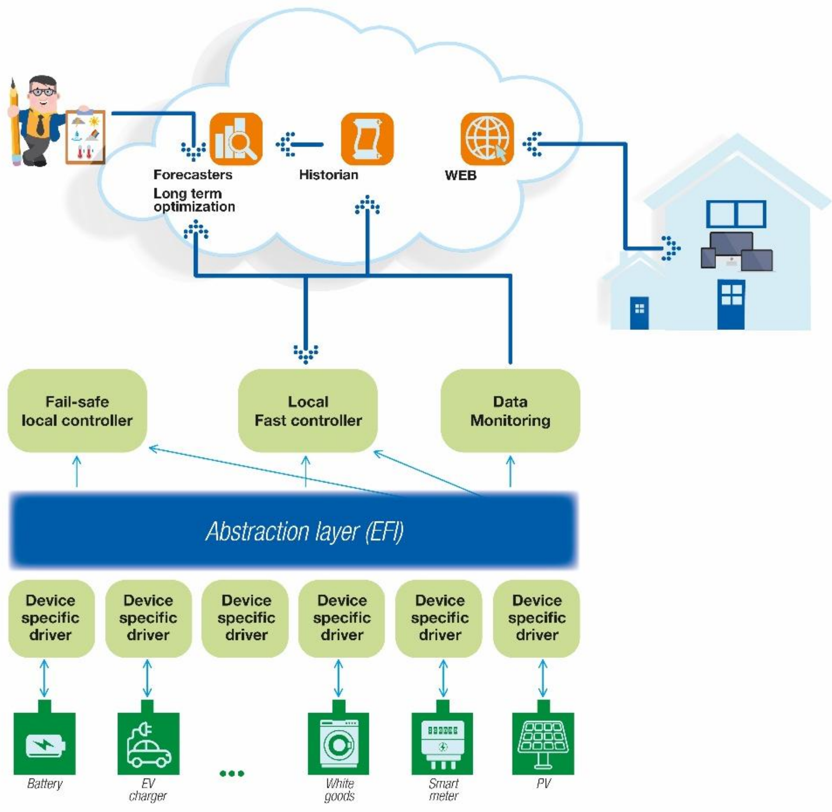

Figure 31: SGSH-architecture

12.3. Current status & results (outcomes)

The SGSH HEMS measures the grid/consumption/injection, automatically controls some devices, takes into account flexible user requests and reports to the user the information required. The HEMS consists of a local part and a back-office. The HEMS first has been tested in the ENGIE Laborelec laboratories. Next, a one year field study has been executed at the homes of 16 ‘friendly users’ in Belgium (11) and the Netherlands (5). All households had PV panels installed, 10 received a battery system, 5 used hybrid and full EVs and one household owned a heat pump. Feedback to the users has been provided by a HUE lamp and a Graphical User Interface. The functioning of the HEMS system has been analysed from a social, technological and economic perspective.

The overall conclusion of the project is that the technical objectives of a HEMS as developed in this project have been met: installing the SGSH HEMS with a battery greatly reduces the impact of distributed generation and new large loads on the current distribution networks. It can be considered a feasible option to deal with the great challenges the energy system is facing now and in the future. However, there is not yet a business case for suppliers, distribution network operators or communities to implement a HEMS as has been investigated in this project. Final report will be available at the end of 2018.

Figure 32: Example user set-up

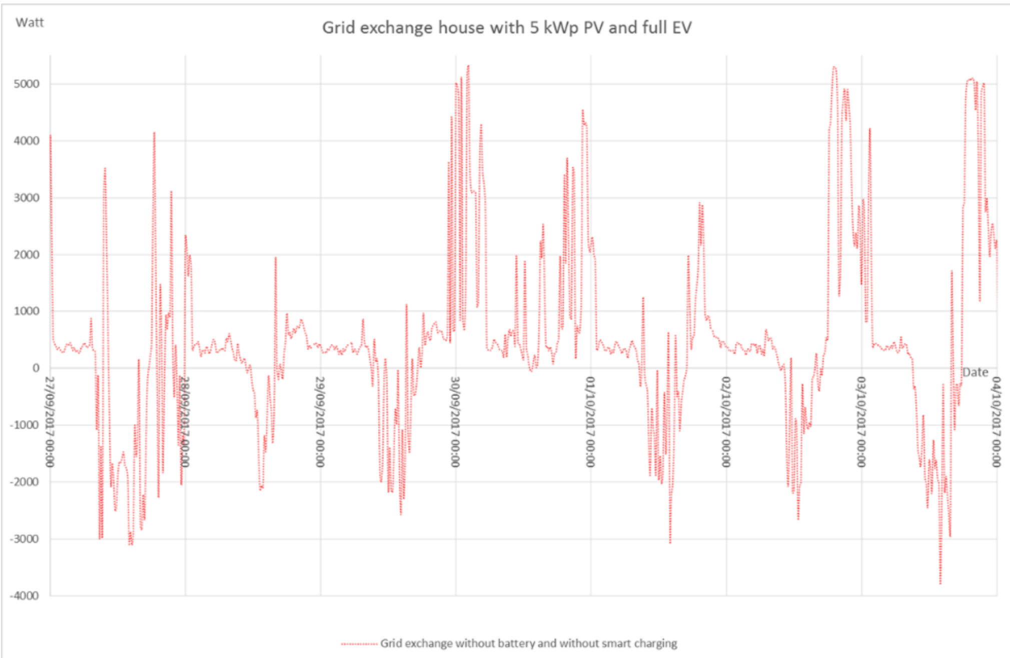

Figure 33: Original profile of the user

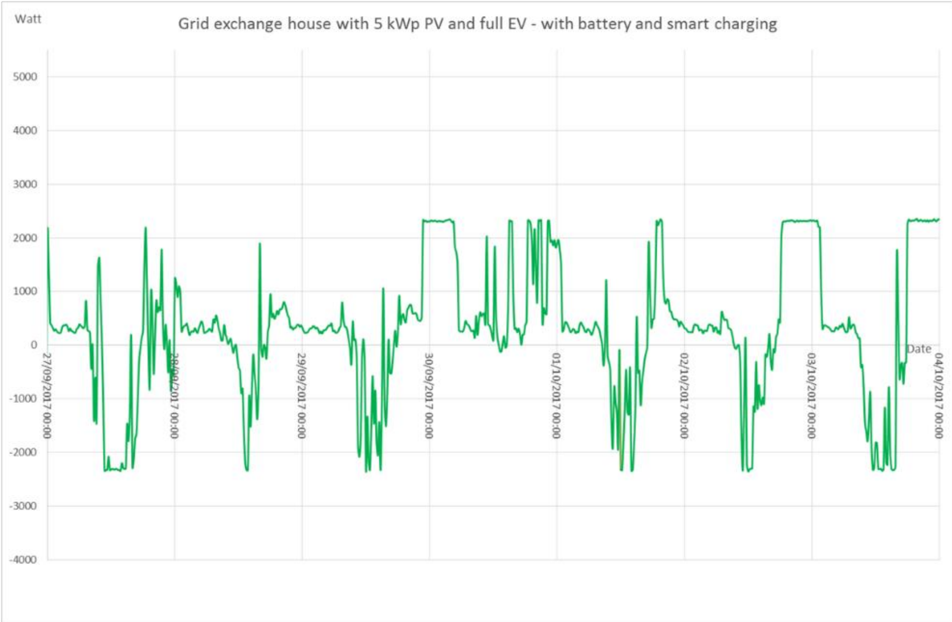

Figure 34: Profile left to the grid with the SGSH-system and limits on 10A

12.4. Barriers & obstacles

The feasibility of a HEMS as has been developed in this project depends on changes in the regulatory framework. At the moment, there is no viable business model available. Depending on political decisions, it will become clear which business model will have the best chance to succeed. The main barriers are the current tariff system for use of the grid and the net metering policy, making investments in storage not attractive as the grid can be regarded as a limitless storage system (“copper plate”).

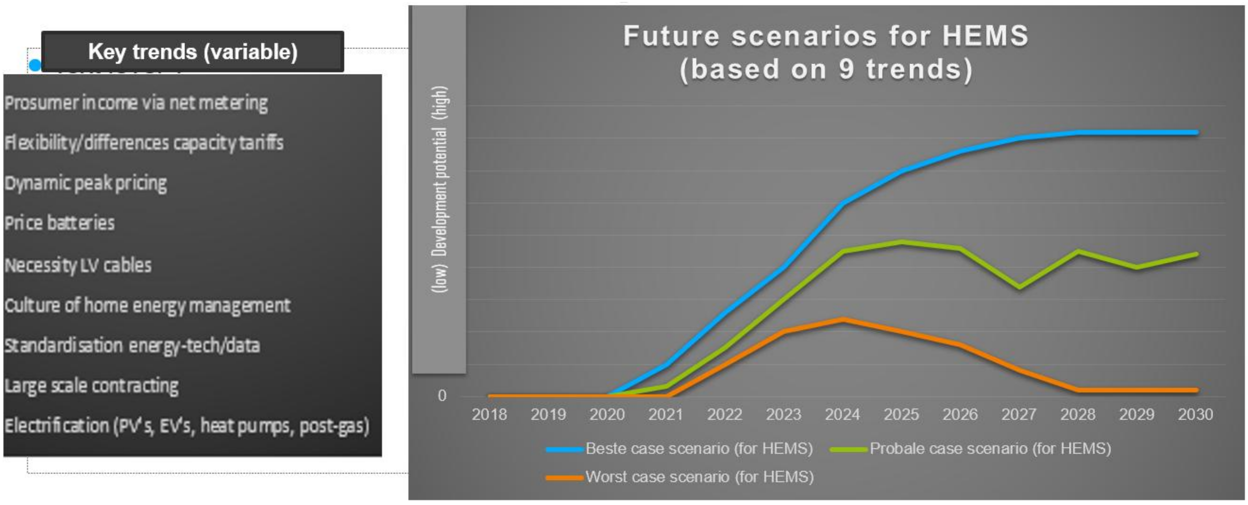

Figure 35: Key trends and future scenarios for HEMS

12.5. Lessons learned & best practices

HEMS need to be adapted to the local circumstances and demand profile, but also to the preferences and wishes of the households in order to be acceptable and attractive. The field research shows that there is some flexibility in energy consuming routines, but other routines are not open for negotiation. Flexibility in combination with HEMS and storage has a lot of new benefits for the future.

More specifically from the social study (field study & business models):

- Direct feedback (by a lamp) has been more meaningful for households than a GUI. Both forms of energy feedback provided almost all households with more insights into their energy consumption.
- The social response of households to HEMS and its integration into energy-related routines seems to depend on the type of energy consuming routines: some routines are flexible (mainly related to washing and EV charging) while others are not.
- Shifting routines depends both on negotiations among household members and the physical presence in the home; Tariffs and incentives, like future capacity tariffs and dynamic prices, and the price of the HEMS (including battery) shape the willingness of households to become more flexible;
- Depending on the development of the future energy system, different business models for a HEMS can be deigned: a commercial model with a focus on the commercial products and service delivered by companies, a public model with a major role for grid operators and the government guaranteeing public values and a community model where local prosumers and organizations focus on autonomy and self-sufficiency.

From the technical study

- The HEMS succeeds in decreasing substantially the number of injections (69%) or demanding (76%) exceeded the Ampere limit set; the maximum demand and injection peaks have been reduced substantially (38, resp. 26%);
- The introduction of a battery has an effect on both the size and timing of the peak of injection and demand. If implemented on a large scale this has an important positive impact on the power profile. If simultaneousness decreases, peaks reduce and grid investments can be postponed or even prevented;
- Not all users need to have a 6 kW battery to prevent the evening peak; the users with EV and heat pump require a (larger) battery;
- The maximum load by EVs can be reduced substantially (50%); even without HEMS, smart charging reduces the impact on the grid by 30- 40%;
- The control algorithm of the SGSH HEMS increases the auto consumption of the electricity generated by the PV system, slightly, but the user profile, the size and the orientation of the PV system have a larger impact

12.6. Key regulations, legislations & guidelines

At the moment (anno 2018) there is no business case, the main reason being the current net metering regulation. There are several societal trends (economic, regulatory, cultural, etc.) that will determine the potential of a HEMS. Assessing the impact of those trends, it seems that a business case becomes interesting per 2021-2022 for all models.

13. Sweden: Energy Storage with Nano Coated Salt

Project Information		
Project Title	SaltX-Vattenfall EnerStore Pilot	
Location	Berlin, Germany	
Time Period of Project	2017 – 2018 (2 years)	
Funding	(Government) Swedish Energy Agency	(Private Sector) Vattenfall Germany, SaltX Technology AB
Participating organizations	• SaltX • Vattenfall	
Link to Project Website	www.saltxtechnology.com	
Key Word (3-4)	Energy Storage, Balancing Power, Grid Storage, New Technology	

Author Information	
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Organization	SaltX
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13.1. Project Summary

SaltX Technology is a Swedish innovation company that has developed and patented a ground-breaking technology that makes salt usable to store energy.

SaltX together with Vattenfall in Berlin and with the support of Swedish Energy Agency is now setting up the first ever large-scale energy storage installation based on the thermochemical storage principle. The installation will have 1MW power output/input and a thermal storage capacity of 10MWh.

The pilot plant will be placed in the combined heat and power plant, CHP plant Reuter, in the north western parts of Berlin and will be adding energy to the district heating network.

When storing energy in Nano-coated salt you can release high temperatures (up to 500 degrees Celsius) into any demanding energy processes for industry but also electricity production. The pilot project described in this document will use valley price electricity from the grid for charging the salt and discharge heat into the district heating network.

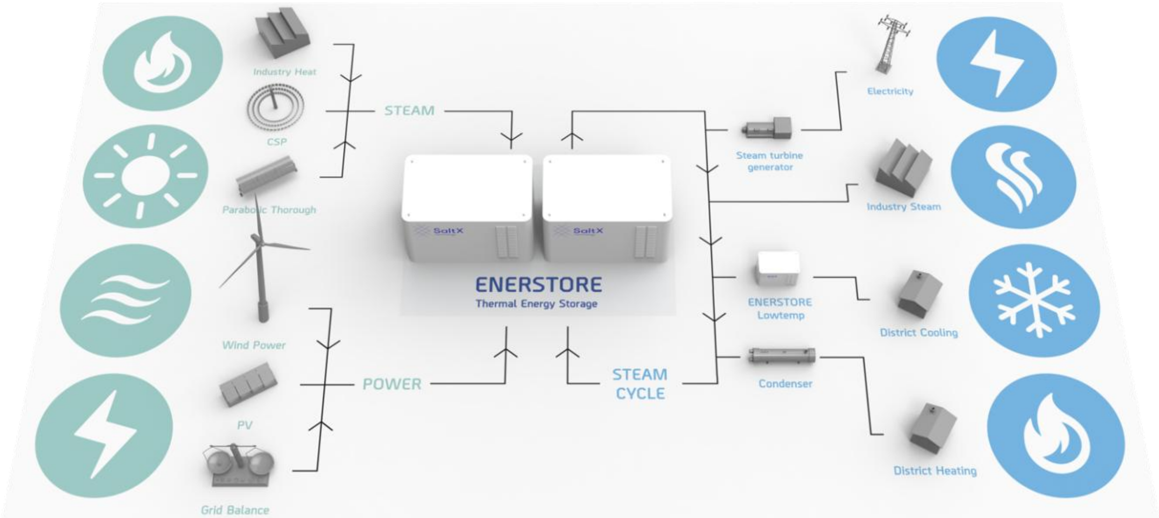

Figure 36: Chart describing the different sources for charging & discharging of EnerStore

13.2. Objectives of the project

Main objective is to prove and demonstrate the large-scale feasibility of Energy Storage using a thermochemically charged salt. Vattenfall will operate and evaluate the project during 2018-2019.

13.3. Current status & results (outcomes)

The SaltX EnerStore is being produced by SaltX partner ETIA and erected in Berlin.

The systems main parts will be:

- SaltX material - Nano-coated salt (CaO^{NCS})
- Transporting & heating device for Nano-coated salt – Spirajoule by ETIA. The Spirajoule technology is an exclusive and patented process for thermal treatment
- CaO silo – Carbon steel silo. Insulated with glass wool and external aluminum casing
- $Ca(OH)_2$ silo - Carbon steel silo. Insulated with glass wool and external aluminum casing

The Nano-coated salt will be prepared by SaltX licensed supplier, protected by SaltX worldwide patents.

The process is straight-forward and requires little adjustments in the supplier's production line. The salt and nanoparticles are procured and sourced by a bulk- and commodity suppliers. The SaltX EnerStore component and salt will all be shipped to site and assembled by ETIA.

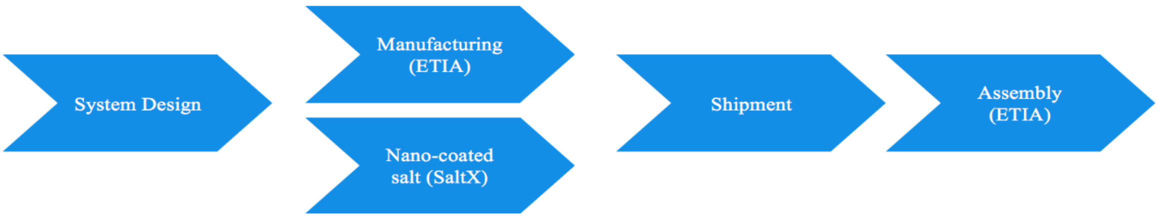

Figure 37: Implementation process SaltX EnerStore

Berlin 1MW Pilot Plant Setup

- Silo for storing discharged salt $Ca(OH)_2$
- Dehydration screw that separates $Ca(OH)_2$ into steam (H_2O) and CaO
- Silo for storing CaO
- Hydrating screw that combines steam and CaO, resulting in $Ca(OH)_2$ and heat

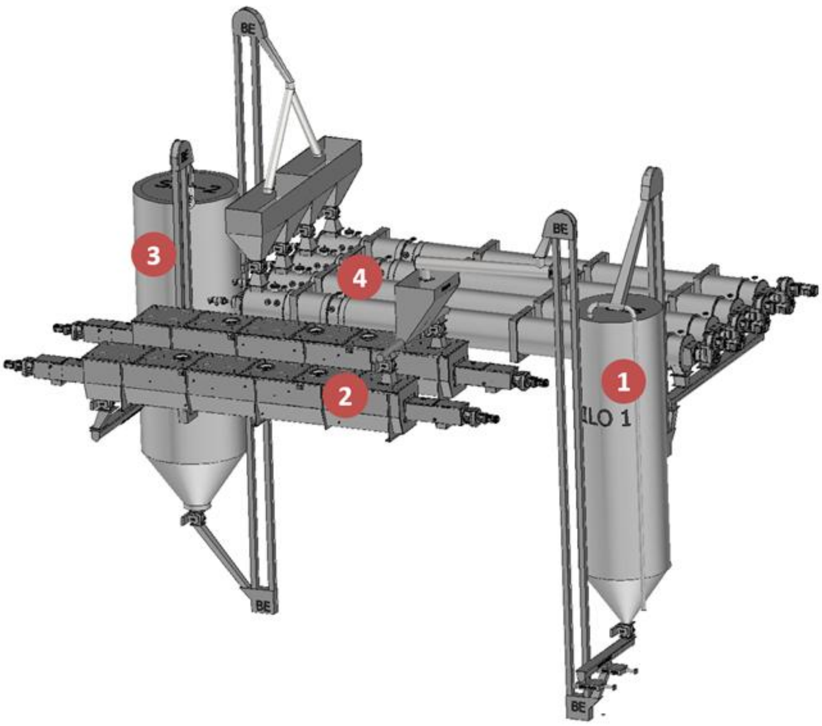

Figure 38: Equipment setup & description

13.4. Barriers & obstacles

One main issue was how to make it possible to dry a big amount of salt in such a large amount and do it in an efficient way. Other questions where related to the speed of the reaction as well as to the control over the process.

With an innovative approach we have with the help of our partners overcome the main technical hurdles.

The pilot project will be conducted with Vattenfall and research and knowledge company Energiforsk, technical consultant Sweco and Stockholm University.

As a next step SaltX together with our partners will work on modularization of the power unit for simplification of scale and market adaptation.

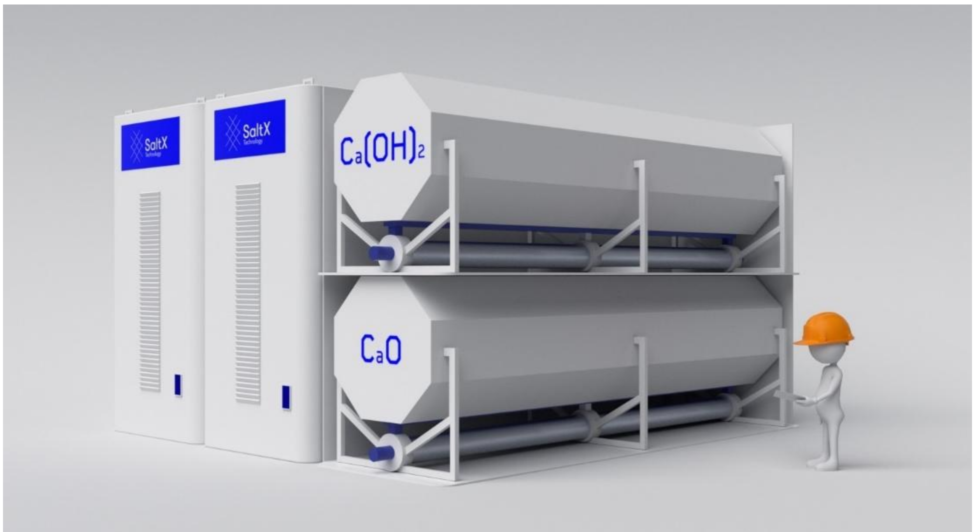

Figure 39: Modularization concept of 500kW EnerStore power units

13.5. Lessons learned & best practices

Final report will be available at the end of 2018.

14. Sweden: Coordinating Power Control

Project Information		
Project Title	Coordinating Power Control	
Location	Uppsala, Stockholm	
Time Period of Project	2017 - Present	
Funding	(Public) Swedish Energy agency	(Private Sector) 50%
Participating organizations	• Sustainable innovation (http://sust.se) • Ngenic (http://ngenic.com) • Ferroamp (http://ferroamp.com) • Chargestorm (http://chargestorm.com) • Upplands energi (http://upplandsenergi.se/) • STUNS (https://stunsenergi.se)	
Link to Project Website	http://www.sust.se/en/projekt/coordinating-power-control/	
Key Word (3-4)	Flexibility; Power; Peak Demand Respons; EndUser participation; local energy communities	

Author Information	
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14.1. Project Summary

The project began as an insight that the DSO (local grid owners) will never be able to know what smart devices customers are bringing into their homes. Charging of home and car batteries, heating, hot water, flexible lighting, and so on. There will be a myriad of different technologies installed, provided by many different companies.

In the deregulated energy market in Sweden, these smart autonomous systems would in a few years time collapse the entire bidding process on the deregulated energy market. Simultaneously, they will induce severe power peaks in the local distribution grid if their use is based only on cheap hourly energy prices.

The way we have approached the problem is via bottom-up thinking and the fact that consumers are already now investing in smart connected equipment. We must bring the companies providing thes devices onboard and integrate the systems to unlock the flexibility needed for the transformation into renewables.

14.2. Objectives of the project

The scope of our project is to create a cost-effective optimization of a distribution grid in the county of Uppland in Sweden. We are addressing the technical, regulatory, and psychological challenges associated with this. Our project brings together a community of market actors, including several IOT smart-grid service providers, the regulatory bodies, and a local DSO (grid owner).

Our objective is three-fold. Firstly, we need the relevant technologies installed in the grid. This includes:

- 500 connected water-based heating systems, providing more than 1 MW of flexible electricity power.
- 60 sites with rooftop PV, connected and measured, providing 200kW of production.
- 36 kW Electric vehicle charging
- 80 kWh of batteries with 60 kW instant power flexibility

This hardware, connected via different companies, communicates with our platform, providing a time-forward optimization of power usage based on forecasts and local congestions.

Secondly, we need a win-win for the customers and the involved companies and DSO. This means:

- Offering all resources the opportunity to participate or opt out in the optimization of the distribution grid.
- Letting all participants share the gained value of the efficiency increase at every instance.
- Testing a blockchain-based sharing system for peer-to-peer transactions.

Thirdly, we need a balance between incentives and regulations, by cooperating closely with tech providers, regulatory bodies and the DSO. The DSO is customer owned which gives us a possibility to test regulatory changes and incentives but will always be a win win for the customers since they in fact own the grid.

14.3. Current status & results (outcomes)

Current status is that we have been able to show substantial results and in fact that the stored energy in the water based heating in the villas can count for as much as 6 GW of flexible power. Which can be used continually as a base control to lower strains in the grid from the TSO or peak load management from the DSO in the local grid.

When we now combine this with energy hubs, batteries solar cells and smart car chargers we could easily and with lower investment than ordinary grid investments even out peaks both from car charging and domestic usage in Sweden.

Figure 40: Heatpump control system

Source: http://ngenic.com

Figure 41: Smart car charging

Source: http://www.chargestorm.com

Figure 42: Energy hub

Source: http://ferroamp.com

On the 28th of February the Swedish energy system was at strain with as much as 26700 GW peak load at 8-9 AM overlapping that period starting at 07:00 the Väx_El project was active in the local DSO grid of Upplands energy where we were able to remove 1,8MWh and more than 1MW peak power.

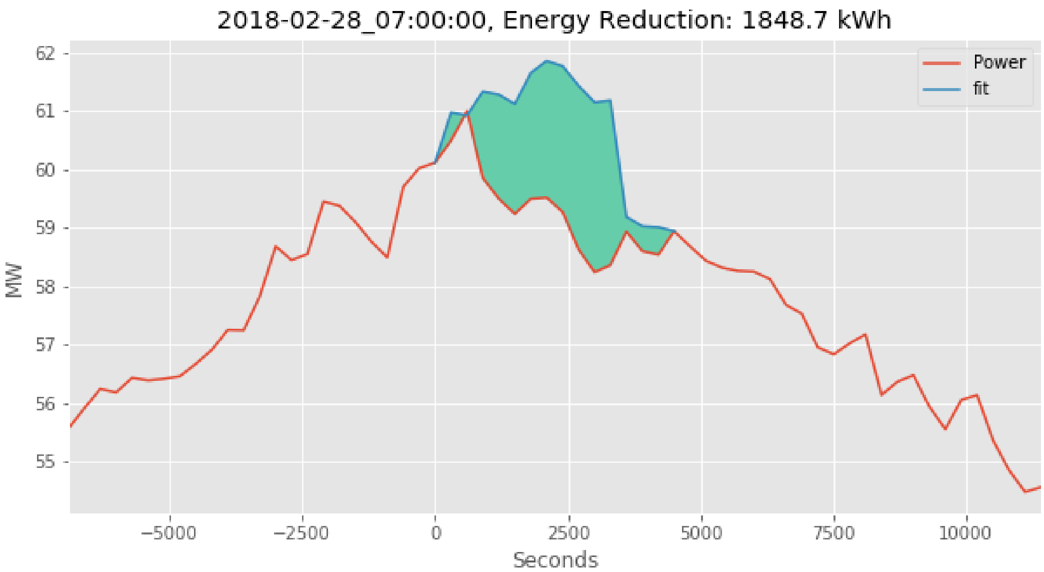

Figure 43: Red actual load curve with active control. 0 at 07:00, blue, the power curve if we hadn't controlled based on a system model that matches the time before and after the control

This means that we helped the Swedish TSO with the overall system level but since the project had a local grid focus and the local grid peak was earlier we made the major contribution on the local level.

The monetary gain for the DSO on this hour was 48 500 €. They still received a penalty of 13 000 € on the remaining power peak at 60,5 MW, notable is that the energy value is just 220€.

Notable result is that the energy removed from the houses 1,8 MWh “green area in the graph” of was restored in the houses after the control period but because of the morning sun and smart control we didn’t have any returning load peak. Since the peak in the local grid is 1 h before the whole system it’s important for largescale deployment that these systems look at optimizing not only the local but also the overall peak.

When scaling up this technology we can gain 3-6 GW of flexible power in the grid, which in the Swedish grid combined with hydro make a large difference to the amount of renewables that can be utilized In the grid.

14.4. Barriers & obstacles

Customer barrier

Being controlled and to sacrifice comfort is one of the larges barriers getting smart devices into the customer premices. We have shown that we instead give a better comfort and smart usage and energy efficiency. So the customers are really very pleased of being part in a program that helps Sweden to have an energy transition towards more renewables.

Battery regulations in homes

The mounting rules for batteries in domestic housing are not clear and leads to barriers in the rollout of new distributed battery systems. Especially firesafety needs to be thought through.

Online island mode

Going Off grid or staying on grid is becoming an interesting question when batteries get cheaper. In Sweden today all solar installations and battery installations are not prepared for being in island mode nor prepared for being online and help the grid. We see that there is no governmental demand on creating systems that can cooperate with the grid and in case of emergency go off line and be a resilient part of the network. And In other cases help the grid with system services rather than just being a tool for not buying electricity.

Restrictions on R&D at grid companies

In the current regulatory model we have a restriction because grid companies are not allowed to count R&D as a cost that they can move over to the customers. This is of course good so grid companies cannot engage in large research projects that don’t lead to any efficiency gains. But it also leads to the fact that grid companies don’t have the knowledge nor economy to do small pilots with innovative solutions.

Uncertainty of what is allowed in the current regulatory framework

New innovative tariff models and pilots are in Sweden not happening mostly due to uncertainty of what is actually allowed. Already today there is a lot you can do in the regulatory model currently in place in Sweden but with the combination of not being able to do R&D most grid companies doesn't start any pilots or test new business cases.

14.5. Lessons learned & best practices

Utilizing the assets above we have been able to show that smart grid technology within customer premises, behind the meter can work as a major part of the whole system solution and this cost far less than investing in big grid size solutions.

We can also increase resilience with autonomous houses that can sustain during grid failures.

Cooperation between stakeholders and a common understanding of the overall system goal of increasing the amount of renewables is important.

The evolvement of "local energy communities" will be a vital regulatory change. The fact that our tests have been conducted in a grid that has been customer owned for 100years shows that local solutions can bring end user engagement much further and also drive down costs before profit.

14.6. Key regulations, legislations & guidelines

One of the most important barriers that the VäxEl project highlights is the regulatory issues between a wholesale market moving energy at hourly peaks to real time power where the local grid or constraints in the distribution grids are at stake.

To combine the power of a resilient grid with local solar/batteries hubs that can survive a major breakdown in the grids. The installation rules of solar cells and batteries need to be combined and combined and clarified that solutions with possibility to help the grid with power and going offline in island mode when crisis occurs.

Sweden has several subsidiaries:

- Car charger 25% up to 1000€
- Batteries 60% up to 5000€
- Electric light vehicles 25% up to 1000€
- EV up to 6000€ tax bonus

The only follow up on these is that you need to report energy production for 3 years for the solar panels. There are no demands for smartgrids.