NORDIC CLEAN ENERGY WEEK
COPENHAGEN MALMÖ
21-25 MAY 2018

ISGAN
INTERNATIONAL SMART GRID ACTION NETWORK

Side Event: Perspective on Energy Storage Systems

Architecture center, Copenhagen 24 May 2018

21st Century POWER PARTNERSHIP
Accelerating the transformation of power systems

MISSION INNOVATION
Accelerating the Clean Energy Revolution

Agenda

09:30 – 09:35	**Welcome**. Dr Magnus Olofsson, ISGAN Annex 2.
09:35 – 09:45	**Keynote**. Dr Lawrence Jones, Vice President International Programs, Edison Electric Institute.
09:45 – 09:51	**Short-term chemical energy storage** – use of batteries for short-term power system balancing. Luciano Martini, RSE.
09:51 – 09:57	**Long-term chemical energy storage** – electrofuels for weekly/monthly storage. Richard Nayak-Luke, University of Oxford.
09:57 – 10:03	**Thermal energy storage** – use of thermal inertia in buildings to reduce electricity peak demand. Joachim Lindborg, CTO, Sustainable Innovation.
10:03 – 10:20	**Panel**. Bo Hesselbæk, Vestas. Dr Lawrence Jones, Edison Electric Institute. Bo Normark, EIT InnoEnergy/European Battery Alliance. Dr Jonas Persson, Vattenfall R&D.
10:20 – 10:25	**Summary and closing**.

EEI

Edison Electric
INSTITUTE

Energy Storage in a Modern Electric Grid

CEM9 Side Event – Perspectives on Energy Storage
Copenhagen, Denmark
May 24, 2018

Lawrence E. Jones, PhD
Vice President, International Programs
Edison Electric Institute

What If Energy Storage Today Existed 10, 20, . . . 50 Years Ago

> “To arrive at the truth, once in your life you have to commit yourself to undoing all the opinions that you have formerly taken for granted, and reconstruct anew all the systems of your knowledge”
>
> - Rene Descartes, *Remarques Sur Les Septiemes Objections*

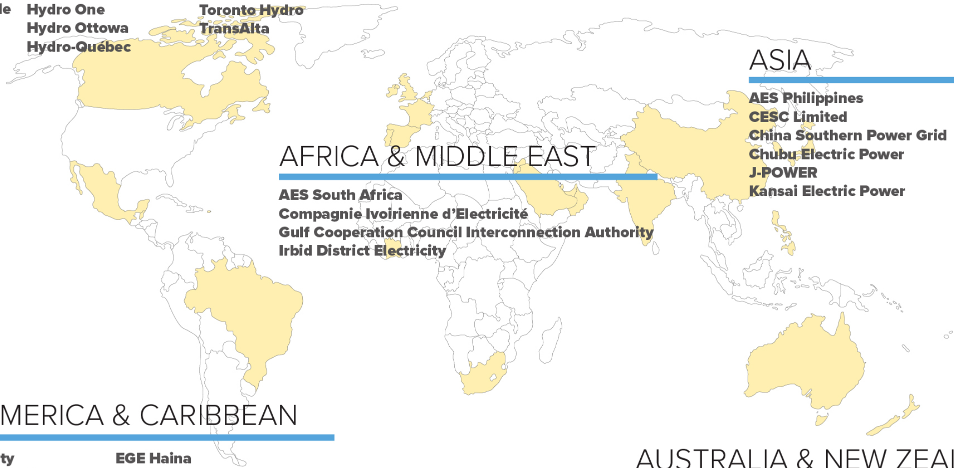
About EEI

The Edison Electric Institute (EEI) is the association that represents all U.S. investor-owned electric companies, and more than 60 international electric companies with operations in over 90 countries. Organized in 1933, EEI provides public policy leadership, strategic business intelligence, and essential conferences and forums.

Categories of Membership

- **U.S. Investor-Owned Electric Companies**
  All U.S. Investor-owned utilities and their subsidiaries (>200)
- **International Members**
  Non-U.S. based electric companies; can be share-holder owned, government-owned, or IPP (68 as of Sep 2017)
- **Associate Members**
  Providers of goods and services, but cannot be directly engaged in generation, transmission or distribution. (>280)

EEI Non-U.S. Members



NORTH AMERICA

Alectra
Altalink
APR Energy
ATCO Electric
Brookfield Power
Capital Power Corp.
Comisión Federal de Electricidad
Emera, Inc.
ENMAX
Entegrus Powerlines
Fortis, Inc.
FortisAlberta
FortisBC
FortisOntario
Hydro One
Hydro Ottowa
Hydro-Québec
Maritime Electric
Newfoundland Power
Nova Scotia Power Inc.
Ontario Power Generation
SaskPower
Toronto Hydro
TransAlta

EUROPE

AES Netherlands
Électricité de France
Energias de Portugal
Electricity Supply Board
Iberdrola
National Grid
Red Eléctrica de España
UK Power Networks

ASIA

AES Philippines
CESC Limited
China Southern Power Grid
Chubu Electric Power
J-POWER
Kansai Electric Power
Korea Electric Power
Power Assets Holdings
State Grid Corporation of China
Tohoku Electric Power
Tokyo Electric Power

AFRICA & MIDDLE EAST

AES South Africa
Compagnie Ivoirienne d'Electricité
Gulf Cooperation Council Interconnection Authority
Irbid District Electricity

LATIN AMERICA & CARIBBEAN

Belize Electricity
Bermuda Electric Light
Caribbean Utilities
CEMIG
Dominica Electricity Services
EGE Haina
FortisTCI
Jamaica Public Service
St. Lucia Electricity Services
St. Vincent Electricity Services

AUSTRALIA & NEW ZEALAND

Energy Queensland
Jemena
Orion New Zealand Ltd.
Powerco Ltd.
SA Power Networks
TasNetworks
Transpower New Zealand
Unison Networks Ltd.
United Energy & Multinet Gas
Vector Ltd.
Wellington Electricity

International Programs Overview

EEI International Programs provides members in the global electric power industry with a flexible platform for industry collaboration, dialogue, and thought leadership.

- **C-Suite Dialogue & CEO meetings**
- **Regional and Global Events**
- **Industry Working Groups**
- **Mutual Assistance Programs**

- **Thomas Edison International Fellowship Program**
- **Webinars**
- **Industry Surveys & Research**
- **On-Demand Resources**

Enhance Knowledge Exchange

Facilitate Energy Executive and Industry Expert Connections

Promote International Member Innovations

Monitor and Analyze Global Energy Developments

Unlock Access to EEI In-House Expertise

Energy Storage – Shifting Grid Paradigms

"The historian of science may be tempted to claim that when paradigms change, the world itself changes with them … It is rather as if the professional community had been suddenly transported to another planet where familiar objects are seen in a different light and joined by unfamiliar ones as well"

- – Thomas S. Kuhn, *The Structure of Scientific Revolutions*

Why Now?

Grid needs + **Market and policy drivers**

Deployment of distributed energy resources

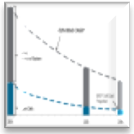
Integration of variable renewable resources

Grid operations and grid modernization

Resiliency improvements

Policy changes

Technology advances



Cost declines

Universal Access to Electricity
- Scaling-Up Grid-Scale Energy Storage -

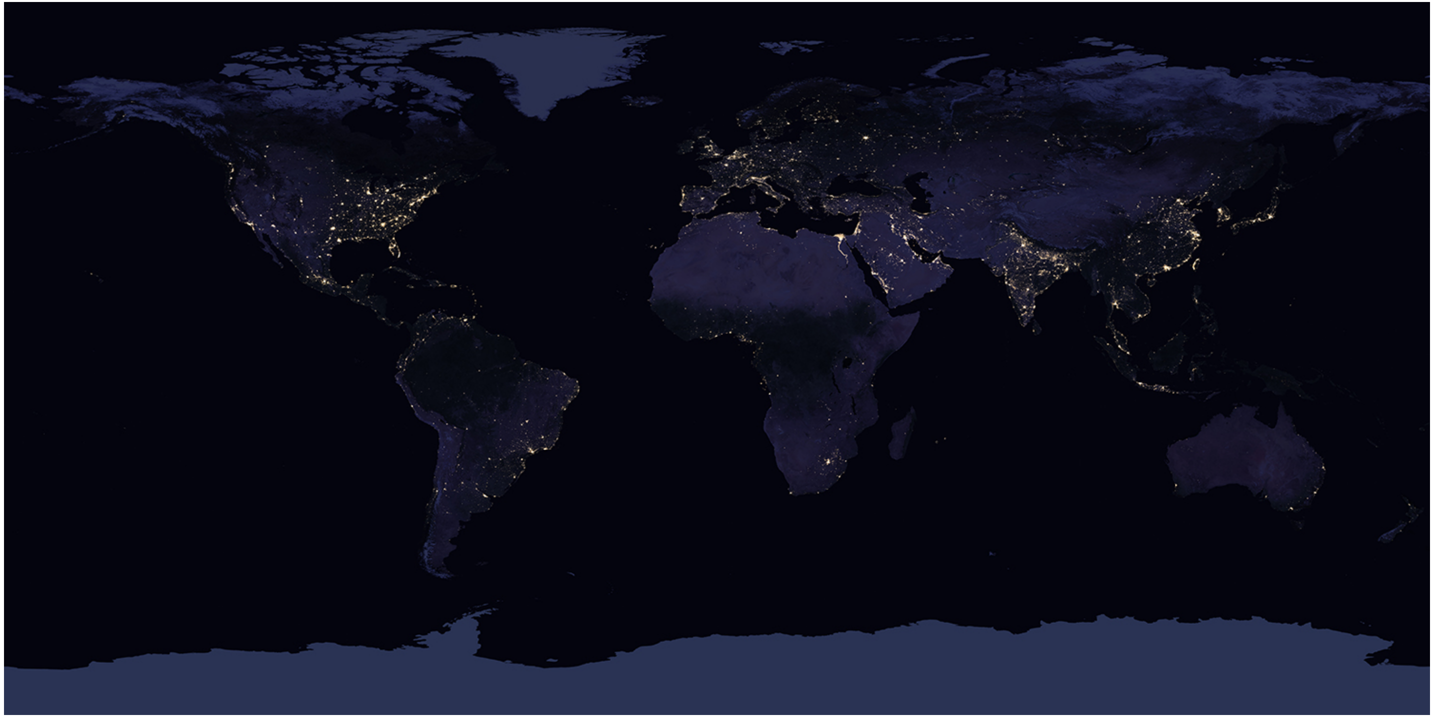


Image Credit: NASA/NOAA

Barriers to Greater Adoption

280 MW of advanced energy storage devices were installed in 2017, a 400-percent increase over 2014

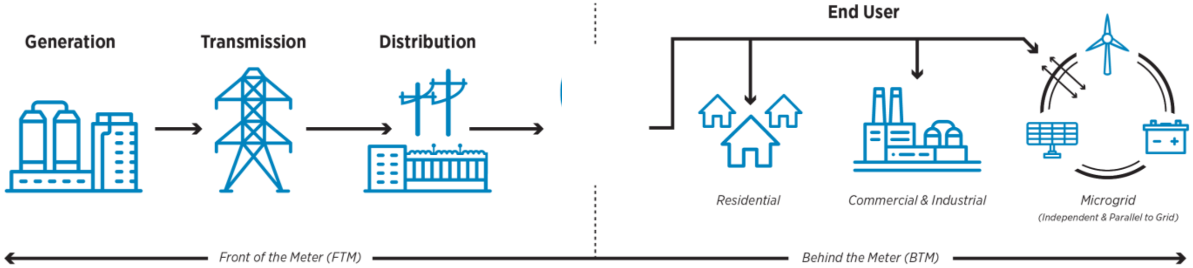
- Cost
- Technical Performance
- Regulatory Hurdles
  - Classification and flexibility
  - Ownership
  - Interconnection & Operation

Multiple Pathways to Scaling-Up Grid Scale Energy Storage

Building Win-Win Partnerships

Energy Storage Has Many Uses

Energy storage can be deployed in all parts of the energy grid, and has applications in all parts of the value chain.



Enhance Electric Company Operations

- Alleviate high energy prices through time shifts
- Reduce the need for new generation

Provide Grid Support

- Regulate frequency
- Reduce spinning, non-spinning, and supplemental reserve requirements
- Voltage support
- Black start electricity restoration

Optimize Power System

- Defer transmission and distribution upgrades
- Relieve electricity congestion

Enhance Customer Experience

- Higher power quality and reliability
- Retail electric energy time shift

FERC REGULATED

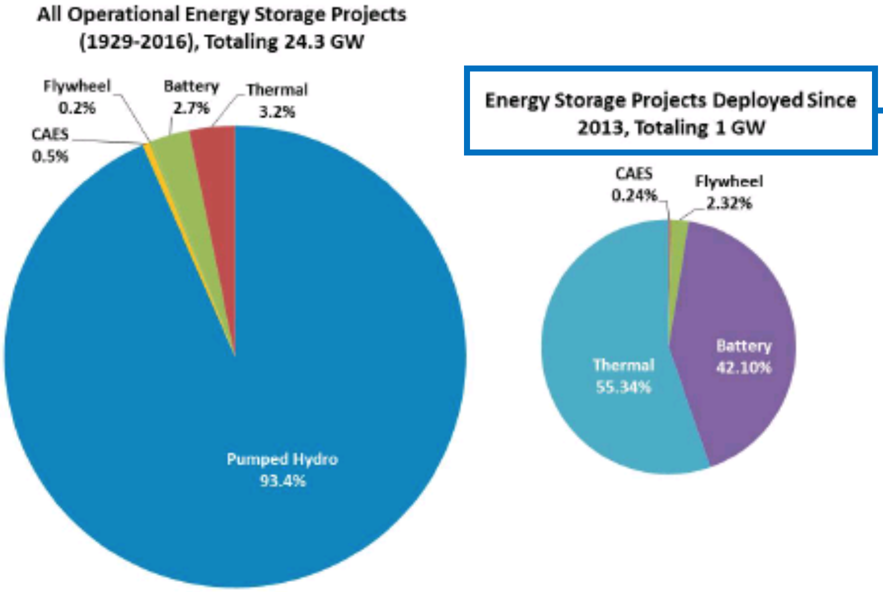
STATE REGULATED T&D

END USE

Source: Adapted from DOE/EPRI Handbook, EEI (graphic)

Electric Companies Driving the Storage Market

Comparison of Energy Storage Projects By Technology Type



All Operational Energy Storage Projects (1929-2016), Totaling 24.3 GW

Energy Storage Projects Deployed Since 2013, Totaling 1 GW

Energy Storage Deployed Since 2013
(Share of MW Installed)

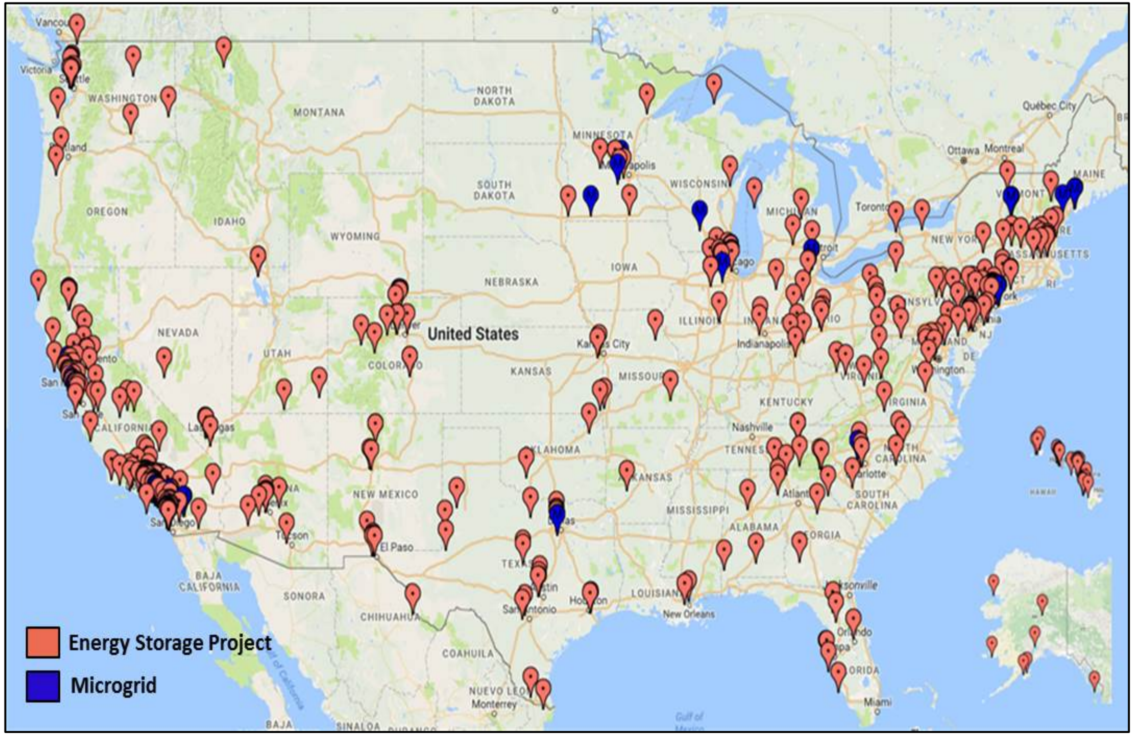
90%
Electric Companies

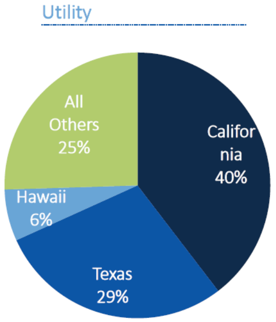
9%
Nonresidential

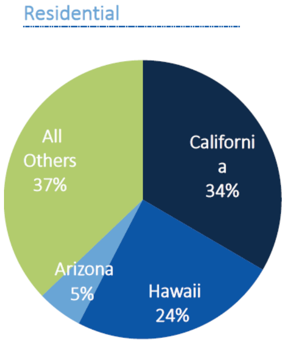
1%
Residential

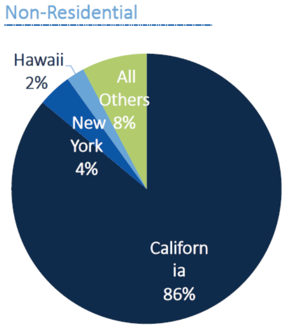
Source: Based on DOE’s Energy Storage Database

Energy Storage Projects in the U.S.



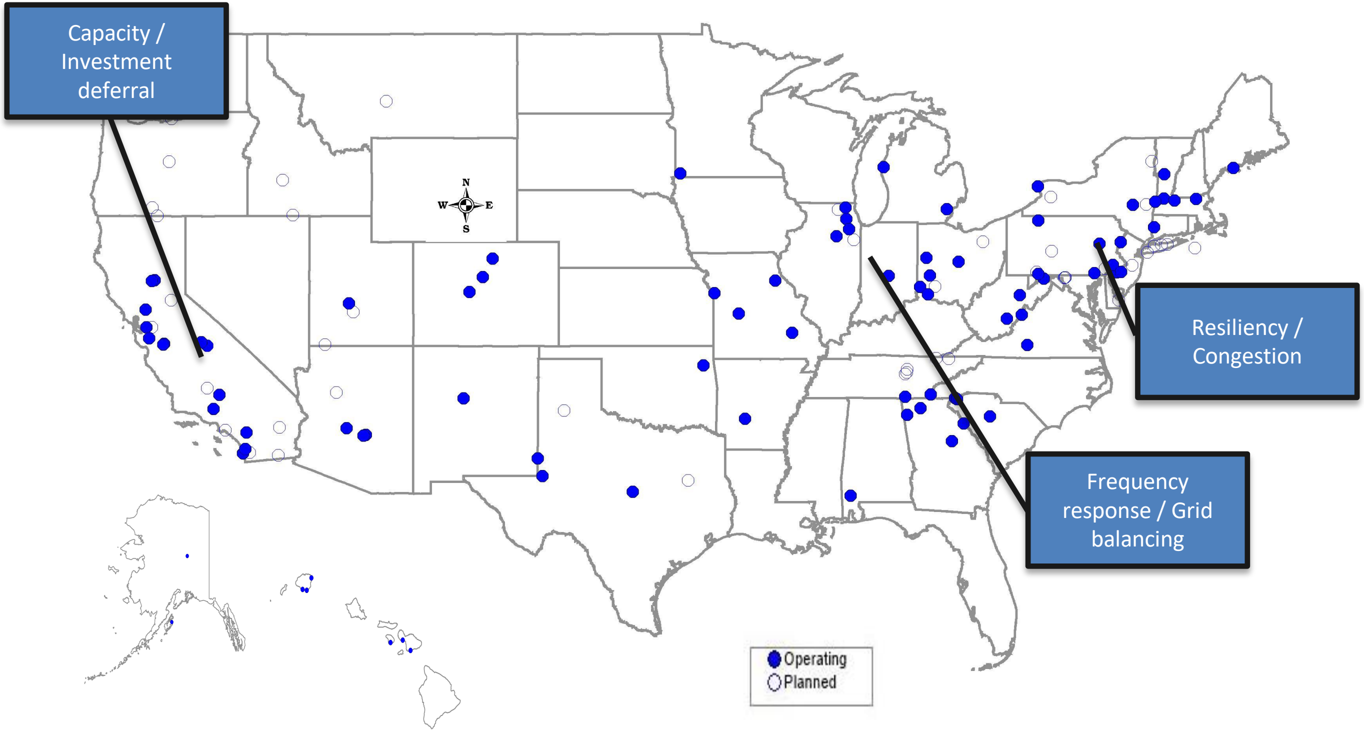






Source: *U.S. DOE Global Energy Storage Database (Accessed on April 27, 2017).*

Different Markets, Different Needs



Evolving Policies

Federal Government

FERC

ISO/RTO

States

Communities

Incentives

Interconnection

Business Models

RFPs

Rate Design

Targets/Mandate

Compensation and Valuation

IRPs and Dist. Planning

Market Access

Studies and Investigations

Pilots and Demonstrations

Smart Communities

And More…

Battery Storage in Australia

Growth and regulatory and market enhancements

There is a further 500MWs of announced and under construction BES systems in Australia. Moreover, the performance of Tesla's Hornsdale BESS has been exceptional particularly with regard providing various regulation frequency services.

With up-front and levelized costs of energy expected to decline further [as installed capacity doubles generally costs decline by c20%] BES systems become competitive. The full extent of what BES systems could contribute will become more transparent as further BES systems are deployed.

Key regulatory and market enhancements

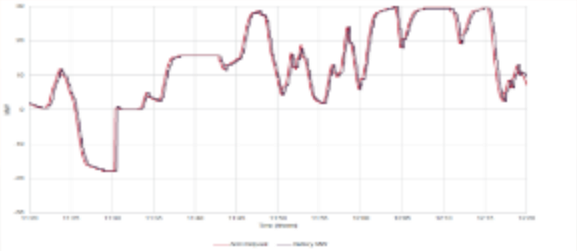
The view of the storage sector on the key regulatory and market enhancements to reduce barriers to entry and support competition include:

- **Level the playing field**– 5min price and settlement, defining frequency services to include fast acting devices, technology / asset neutral network investment rules, improved data and information revelation, lower RIT-D threshold
- **Remove regulatory barriers for beyond the meter –**make it easier to register storage beyond the meter
- **Recognise and reward the full value of storage behind the meter**- adopt national and state based rules to provide value for these services
- **Establish consumer protection standards –**need an Australian standard for product safety, state laws to change to require qualified safety regulators for installations, industry standards on recycling.

Tesla's Hornsdale Power Reserve – South Australia

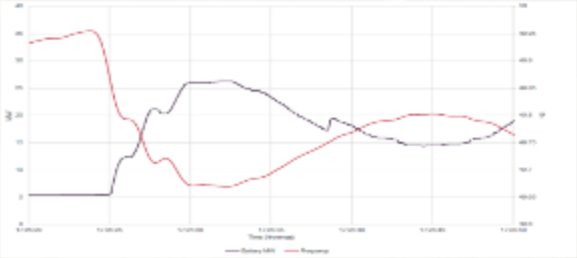
The HPR battery is rated at 100 megawatts (MW) discharge and 80 MW charge, and has a storage capacity of 129 megawatt hours (MWh). This capacity represents approximately 75 minutes at full discharge. The HPR shares the same 275 kilovolt (kV) network connection point as the 300 MW Hornsdale Wind Farm.

Dispatch – following instructions



AEMO report shows the HPR performing better than a traditional steam turbine.

Very Fast Response – trip of Power Station in NSW



AEMO report shows the HPR responding in milliseconds to the loss of supply from the unplanned outage.

NETWORK BATTERY IN AUCKLAND, NEW ZEALAND

Background

Auckland is one of the fastest growing cities in the world (>3% per year)

The Auckland distribution company, Vector, is 75% customer owned

Glenn Innes substation in 2015

- Existing substation established in 1959 in residential neighbourhood [2x 12MVA transformers (22/11kV)]
- Load expected to exceed capacity in the next few years due to new development, but uncertainty on timing and long-term demand

Options for Glen Innes considered

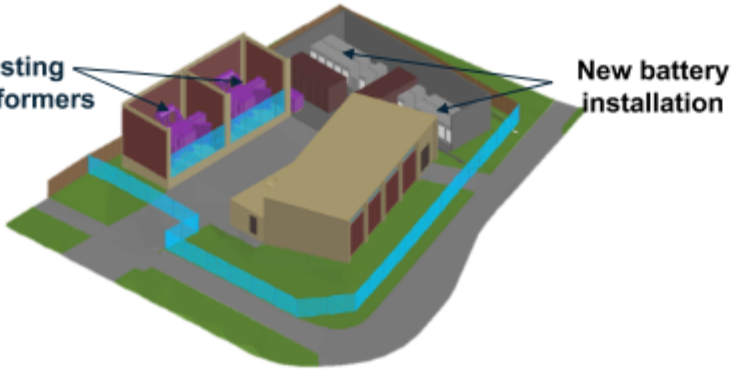
Traditional Solution

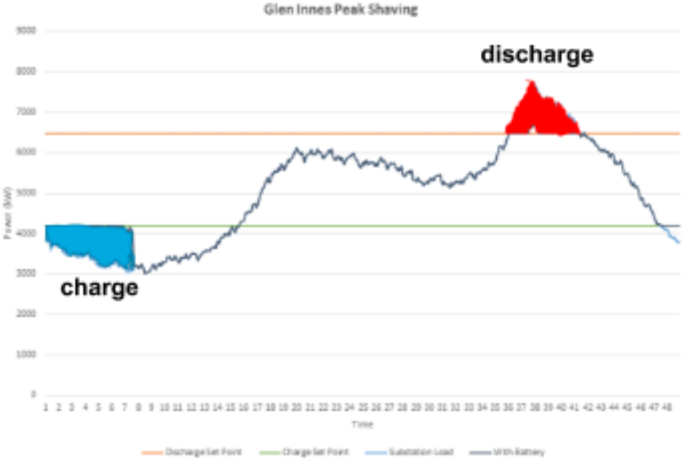
- Replacement of transformers and sub-transmission underground cables that feed substation

New energy Solution

- Install 1MW/2.3MWh LiIon battery investment at substation to defer traditional reinforcement investment with
- Advantages: Incremental investment (modular), Flexible investment (reduced stranded asset risk), minimizes public disruption during construction

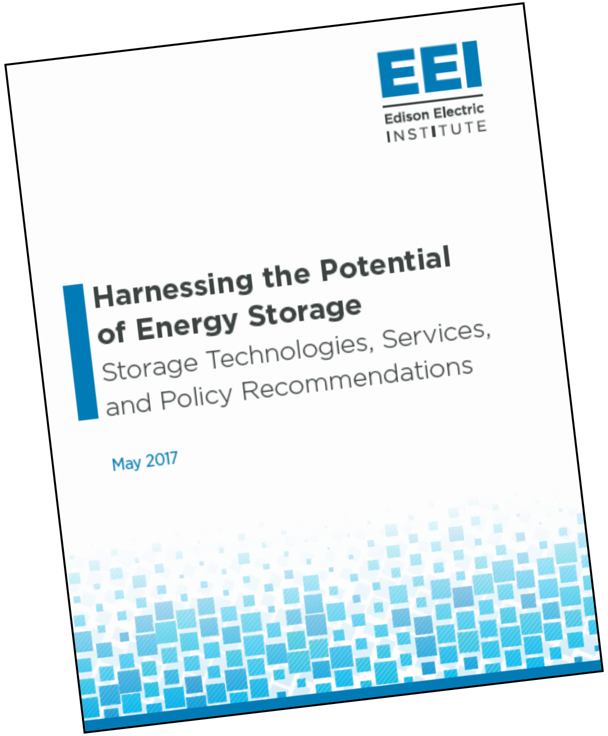
GLEN INNES SUBSTATION
SOUTHERN HEMISPHERE'S LARGEST GRID-TIED STORAGE SYSTEM
When opened in Oct 2016





Daily cycled – average of 13% peak reduction

Harnessing the Potential of Energy Storage



EEI
Edison Electric
INSTITUTE

Harnessing the Potential of Energy Storage
Storage Technologies, Services, and Policy Recommendations

May 2017

- Energy storage technologies
- Role of electric companies
- Storage benefits and services
- Costs and value
- Challenges to wider deployment
- Policy recommendations

The **Edison Electric Institute** (EEI) is the association that represents all U.S. investor-owned electric companies. Our members provide electricity for about 220 million Americans, and operate in all 50 states and the District of Columbia. As a whole, the electric power industry supports more than 7 million jobs in communities across the United States.

In addition to our U.S. members, EEI has more than 60 international electric companies, with operations in more than 90 countries, as International Members, and hundreds of industry suppliers and related organizations as Associate Members.

Organized in 1933, EEI provides public policy leadership, strategic business intelligence, and essential conferences and forums.

For more information, visit our Web site at www.eei.org.

Edison Electric Institute
701 Pennsylvania Avenue, NW
Washington, D.C. 20004-2696
202-508-5000 | www.eei.org

DSO storage projects

The GRID4EU project

CO - FUNDED BY
THE EUROPEAN UNION

ISGAN
Award of
Excellence
Winner | 2015

enel

- Project led by **6 Electricity Distribution System Operators** - covering altogether more than 50% of metered electricity customers in Europe
- Overall **27 partners** from various horizons
  (utilities, manufacturers, universities and research institutes)
- Duration: **51 months** from November 2011 to January 2016
- Total eligible costs: €54M - requested EC Grant €25.5M

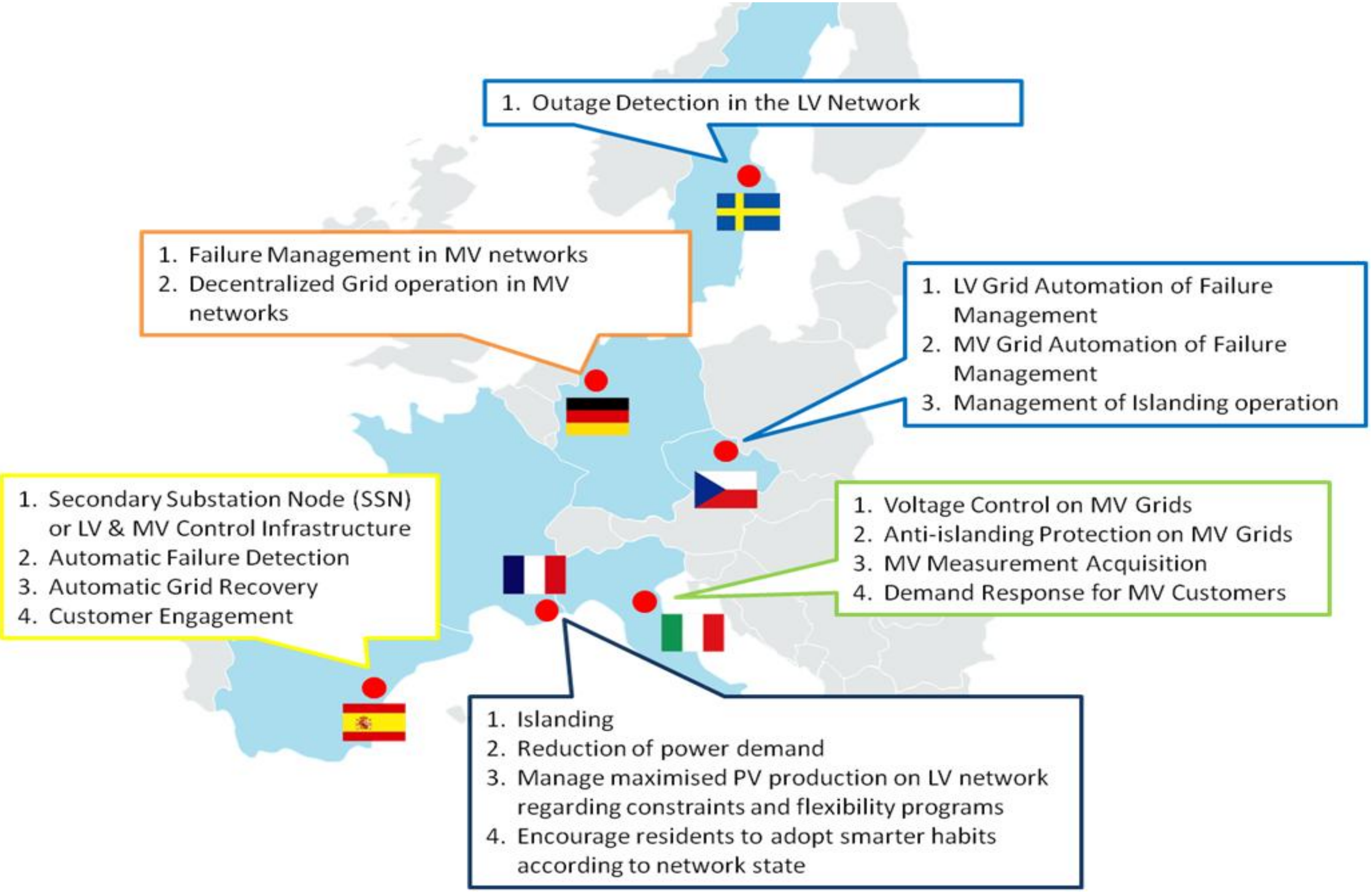
ENEDIS L'ELECTRICITE EN RESEAU	e-distribuzione	IBERDROLA
Project Coordinator	**Technical Director**	**Chairman of General Assembly**

ČEZ DISTRIBUCE

RWE
The energy to lead

VATTENFALL

Six demonstrators



1. Outage Detection in the LV Network

1. Failure Management in MV networks
2. Decentralized Grid operation in MV networks

1. LV Grid Automation of Failure Management
2. MV Grid Automation of Failure Management
3. Management of Islanding operation

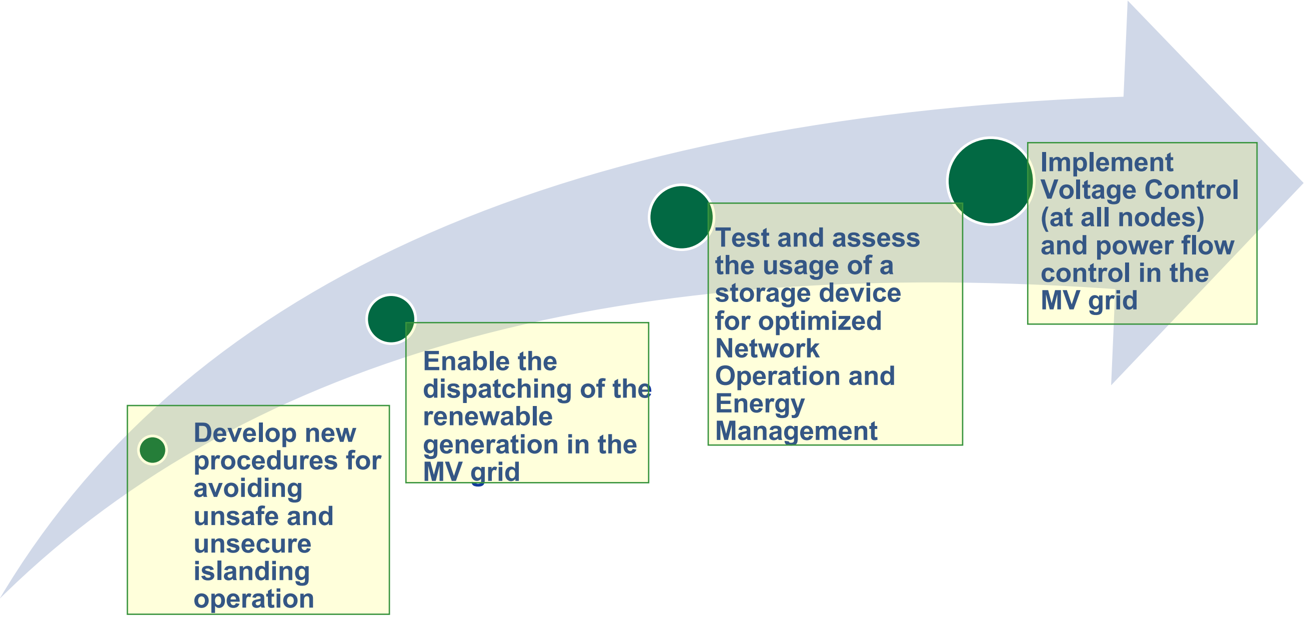
1. Secondary Substation Node (SSN) or LV & MV Control Infrastructure
2. Automatic Failure Detection
3. Automatic Grid Recovery
4. Customer Engagement

1. Voltage Control on MV Grids
2. Anti-islanding Protection on MV Grids
3. MV Measurement Acquisition
4. Demand Response for MV Customers

1. Islanding
2. Reduction of power demand
3. Manage maximised PV production on LV network regarding constraints and flexibility programs
4. Encourage residents to adopt smarter habits according to network state

The Italian demonstration project

Increase the Medium Voltage (MV) network's hosting capacity for Distributed Energy Resources (DER, in particular solar), introducing Active Control and Demand Response of MV generators, controllable loads and storage

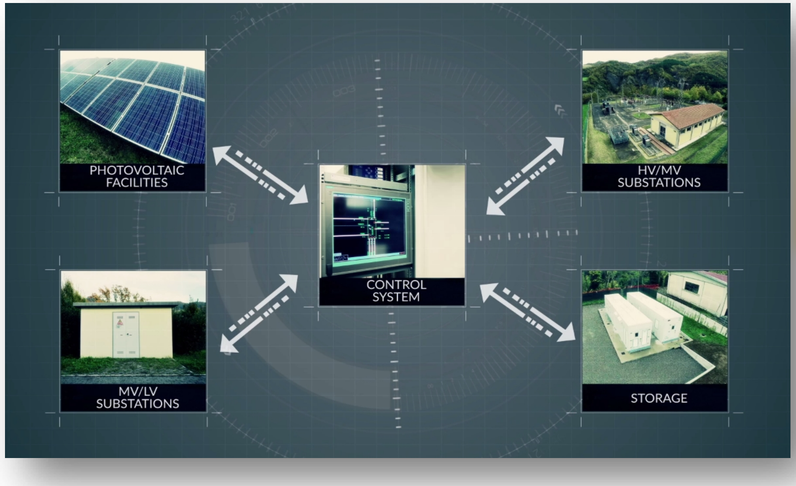


- Develop new procedures for avoiding unsafe and unsecure islanding operation
- Enable the dispatching of the renewable generation in the MV grid
- Test and assess the usage of a storage device for optimized Network Operation and Energy Management
- Implement Voltage Control (at all nodes) and power flow control in the MV grid

MV network Hosting Capacity

The overall system implemented

An **advanced control system** communicating with the renewable generators, HV/MV & MV/LV substations and storage facility.



An **“always on”, IP standard-based communication** solution connecting all the relevant nodes of the grid (LTE + PLC).

A **storage facility** (1 MVA / 1 MWh approx.) connected to the MV grid (with different connection options in terms of feeders).

EU SysFlex

Pan-European system with an efficient coordinated use of flexibilities for the integration of a large share of RES

Durata del progetto: 4 anni (2017-2021)

Enel Countries: Italia

Bando: Horizon 2020 - Energy – Call LCE-04-2017

Consorzio: 34 Partners (da 14 paesi EU):

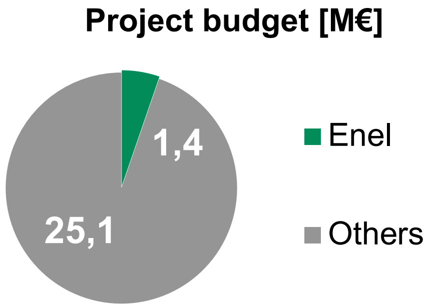
Coordinatore EirGrid (IRL)

Distributori nel Consorzio: e-distribuzione, Innogy (Germania), Helen Oy (Finlandia), EDP (Portogallo), Elektrilevi (Estonia)

Field tests: (Italia, Francia, Finlandia, Germania, Irlanda e Portogallo)

Budget totale: 26,49 M€

EU contribution (Enel + e-dis.): 0,96 M€ (70%)



Obiettivo:

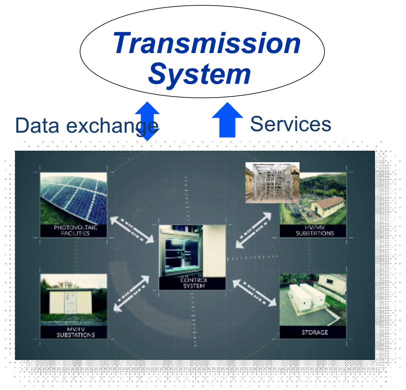
- Contributo al raggiungimento degli obiettivi di integrazione di fonti rinnovabili dell'Unione europea (UE), analizzando il quadro di mercato e regolatorio che favorisce lo sviluppo di un sistema elettrico flessibile per l'integrazione di elevati livelli di RES.

Metodologia - Tre fasi:

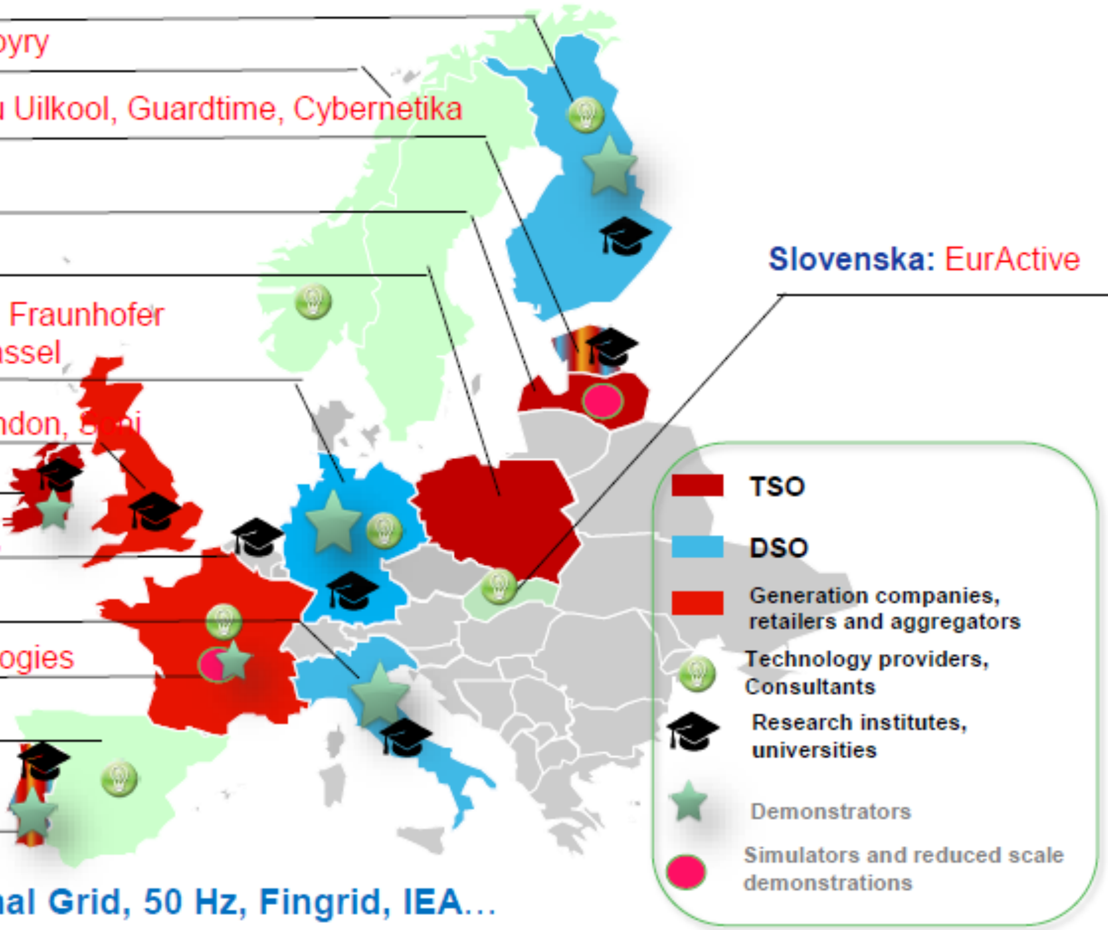
- Analisi dei requisiti tecnici per definizione di servizi di mercato necessari per supportare uno scenario con più del 50% di RES entro il 2030
- Analisi del contesto regolatorio e di mercato per abilitare i servizi
- Analisi dell'impatto sui ruoli degli attori coinvolti e rimozione di eventuali barriere

Dimostrativo Italiano:

- Scambio di dati TSO/DSO per incrementare osservabilità della rete
- Modulazione di Potenza attiva/reattiva a livello di cabina AT/MT utilizzando le seguenti leve:
  - 1MWA/ 1MWh Storage (EESS)
  - 1 On Load Tap Changer
  - 4 Generatori MT



EU – SYSFLEX - Overview of partners mix and demonstrations and its geographical distribution



Finland: VTT, Helen,

Norway and Sweden : Enoco, Poyry

Estonia: Elering, Elektrilevi, Tartu Uilkool, Guardtime, Cybernetika

Latvia: AST

Poland: PSE

Germany: Innogy-Mitnetz Strom, Fraunhofer IWES, Siemens, Enercon, Uni Kassel

UK: Upside, Imperial College London, Soni

Ireland: **Eirgrid** (Coord), UCD

Belgium: Energyville KU Leuven,

Italy: e-distribuzione, enel, RSE

France: EDF R&D, Akka Technologies

Spain: Zabala, Esade

Portugal: Inesc Tec, EDP Dis, EDP Cnet

Slovenska: EurActive

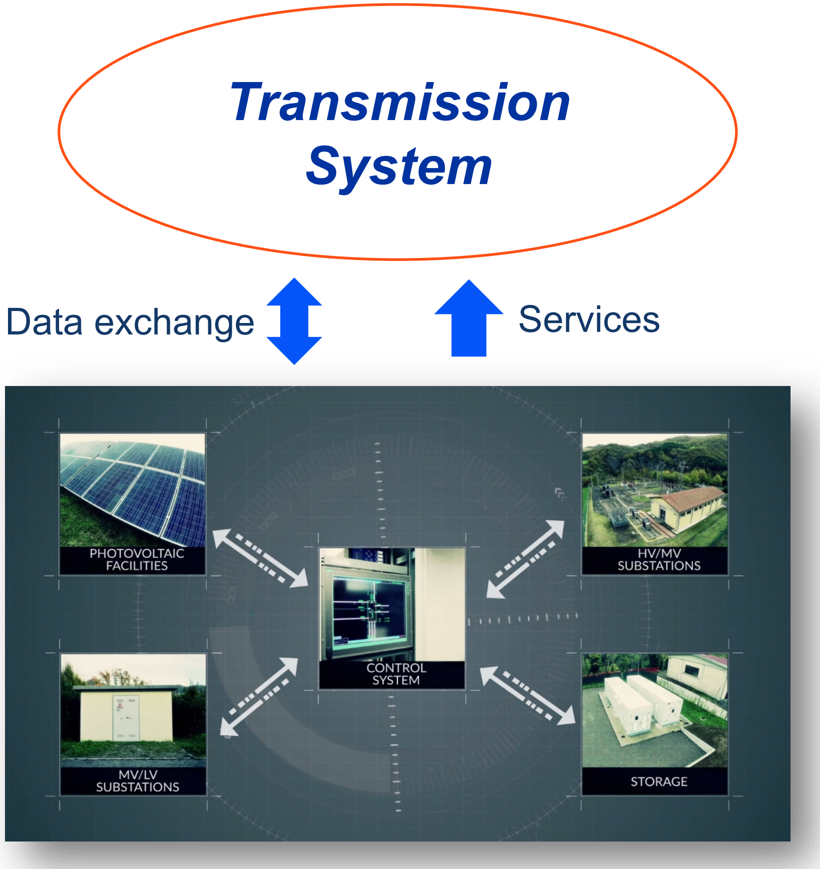
- 🟥 **TSO**
- 🟦 **DSO**
- 🟥 Generation companies, retailers and aggregators
- ● Technology providers, Consultants
- 🎓 Research institutes, universities
- ★ Demonstrators
- ● Simulators and reduced scale demonstrations

Advisory board: Terna, National Grid, 50 Hz, Fingrid, IEA…

Italian Demo - Functionalities

Main functionalities to be implemented and field-tested:

- TSO-DSO data exchange (measurements, generation/load forecast at the interconnection point i.e. HV/MV substation).
- Active and reactive power modulation at HV/MV substation level for TSO (132 kV) grid regulation
  - The **reactive power modulation** will be **provided by the DSO control system**, **coordinating in an optimal way** three main control leverages:
    - An **electric energy storage system** (EESS, 1 MVA, 1 MWh);
    - A **capacitor/inductor bank controllable in a continuous reactive power range** and installed at the MV side of the HV/MV transformer;
    - **PV generators,** the reactive power of which is controllable (participating on a voluntary basis).
  - The **active power modulation** will be **provided by the DSO control system using the storage unit** in coordination also with the measurements and forecast of the monitored MV generators.



Transmission System

Data exchange

Services

Long-term chemical energy storage: electrofuels for weekly/monthly storage

Ninth Clean Energy Ministerial (CEM9)

Richard Nayak-Luke, René Bañares-Alcántara

UNIVERSITY OF OXFORD

Copenhagen, Denmark
24th May 2018

Long-term chemical energy storage: electrofuels for weekly/monthly storage

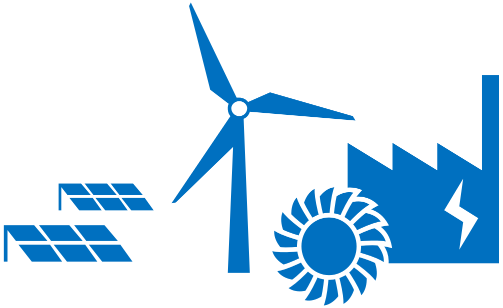
1 The importance of long-term storage

2 Why chemical energy storage?

3 Which chemicals?

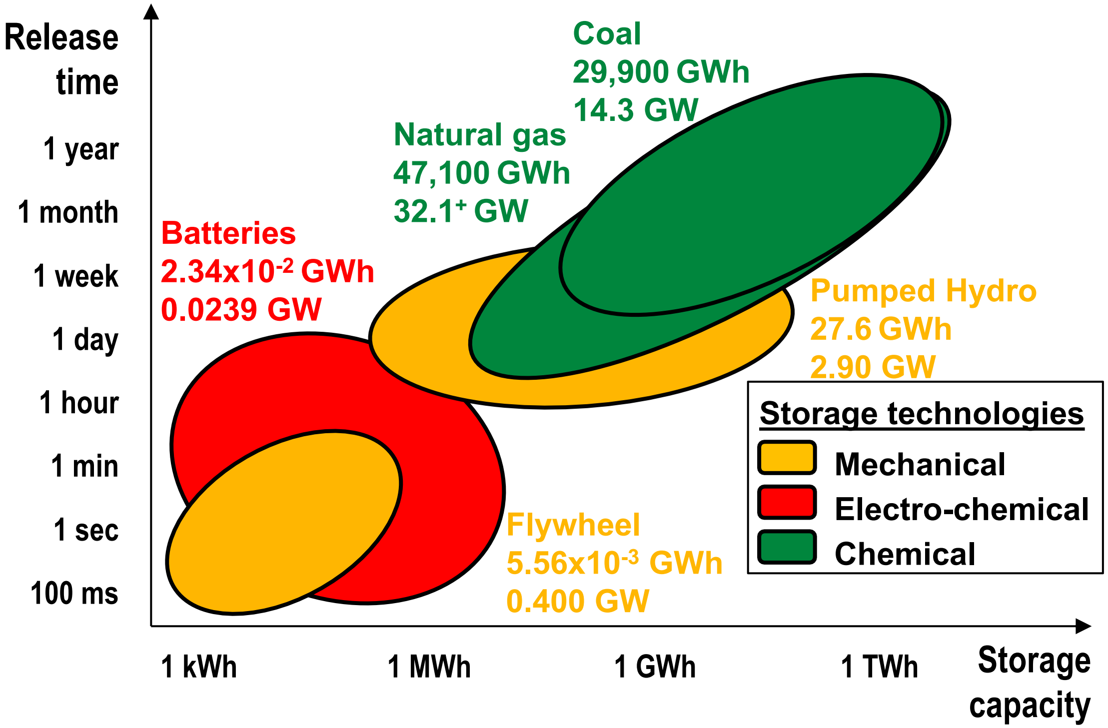
4 Required technical and regulatory developments

5 Conclusion



While we do have a mix of storage technologies the bulk of the UK's energy 'storage' is chemical as fossil fuels

Currently employed electrical energy storage technologies : The UK energy system

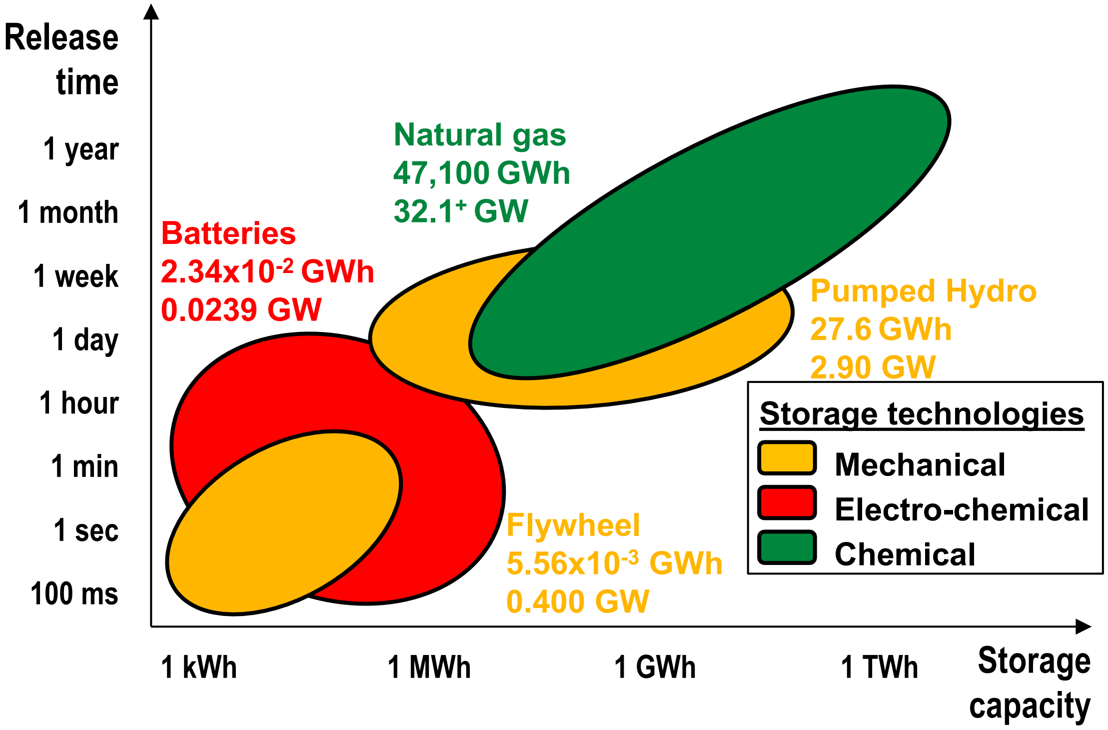


- > Currently fossil fuels are still the foundation of the energy network's flexibility
- > Batteries are playing a larger part in providing frequency response services
- > Pumped hydro despite being cited as the dominant energy storage method is in reality still only a small component
- > Pumped hydro is currently used mainly for diurnal variations and STOR services when required
- > Virtually all seasonal balancing of the network is met by fossil fuels

Source: Presentation by N Olson (NH3 Fuel Association), Rotterdam, May 2017. Adapted from Hydrogenius Technologies. Nuclear and Oil neglected due to data availability
Estimates from Wilson (2010), MacKay (2008), BEIS DUKES (2016), REA (2010)

While we do have a mix of storage technologies the bulk of the UK's energy 'storage' is chemical as fossil fuels

Currently employed electrical energy storage technologies : The UK energy system



> Currently fossil fuels are still the foundation of the energy network's flexibility

> Batteries are playing a larger part in providing frequency response services

> Pumped hydro despite being cited as the dominant energy storage method is in reality still only a small component

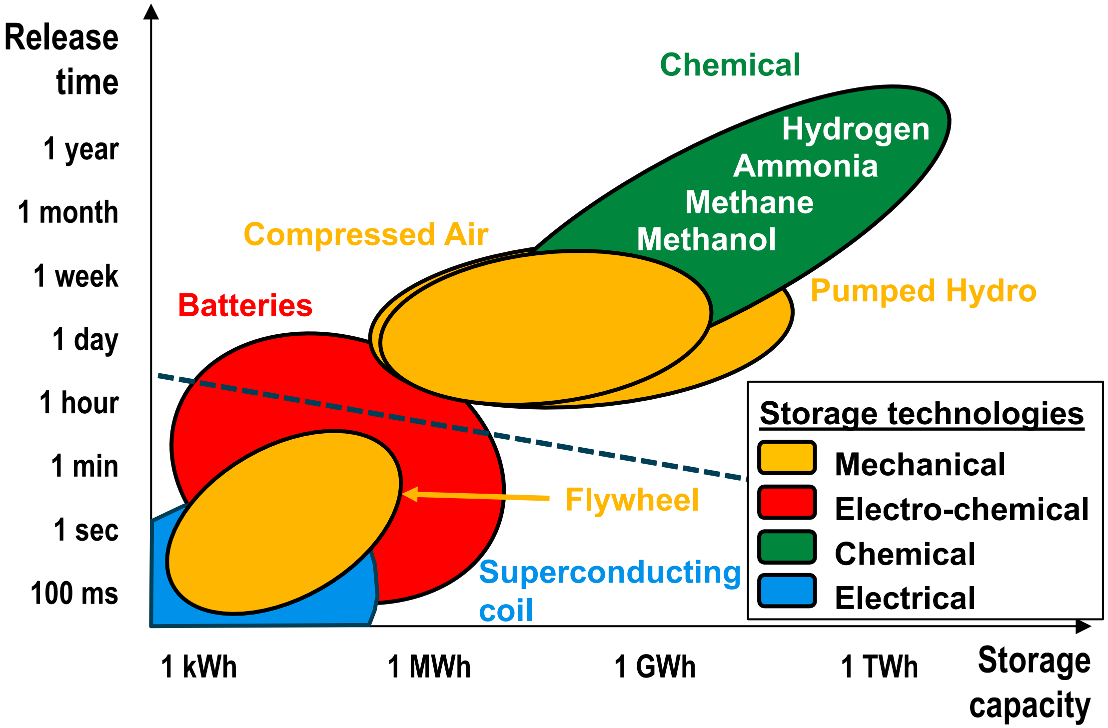
> Pumped hydro is currently used mainly for diurnal variations and STOR services when required

> Virtually all seasonal balancing of the network is met by fossil fuels

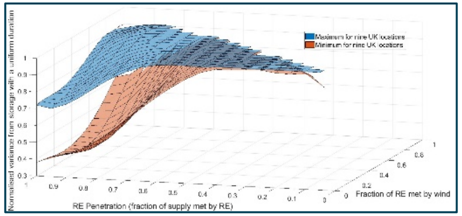
Source: Presentation by N Olson (NH3 Fuel Association), Rotterdam, May 2017. Adapted from Hydrogenius Technologies. Nuclear and Oil neglected due to data availability
Estimates from Wilson (2010), MacKay (2008), BEIS DUKES (2016), REA (2010)

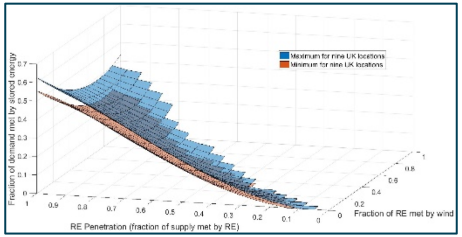
To balance a system with higher dependence on renewable power sources we need all storage technologies, including long-duration GWh capacity

Current energy storage technologies



- > Every network has different storage requirements dependent on multiple variables (e.g. renewable resource, dispatchable supply and demand profile)
- > To identify these requirements and how the storage requirement changes we developed the storage duration index (SDI)

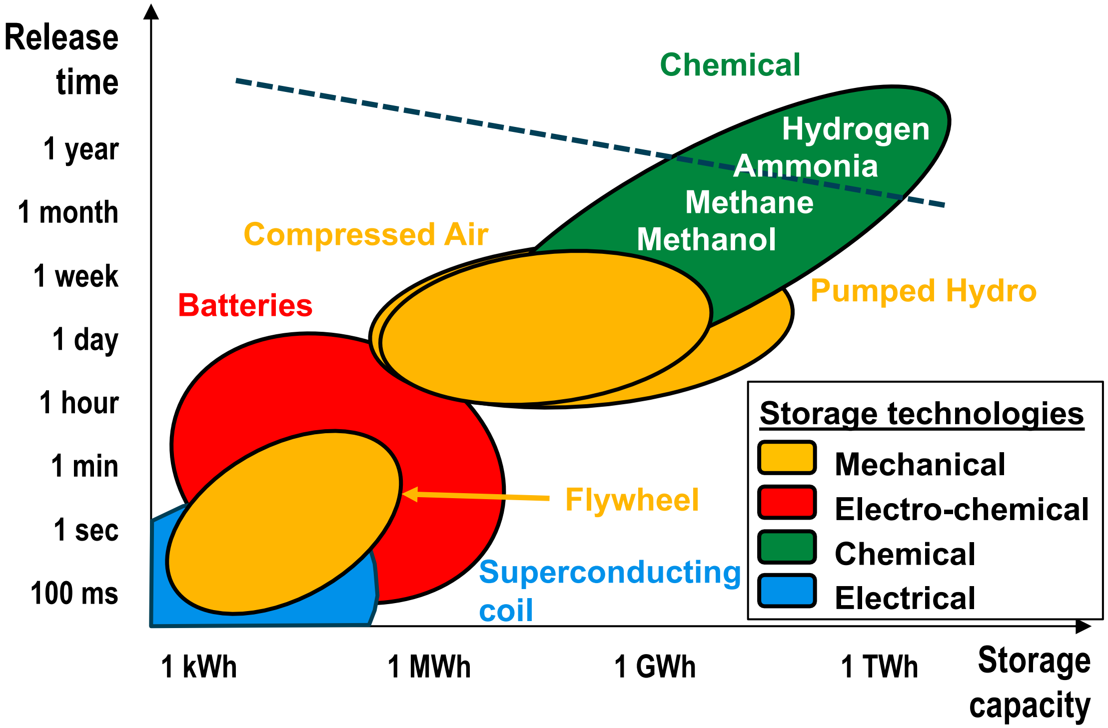




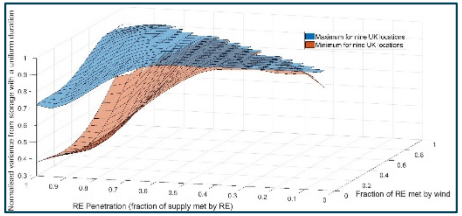
Source: Presentation by N Olson (NH3 Fuel Association), Rotterdam, May 2017. Adapted from Hydrogenius Technologies
Nayak-Luke, R.M., R. Bañares-Alcántara, S. Collier, Islanded power-to-ammonia production process (2018) NH3 Event, Rotterdam

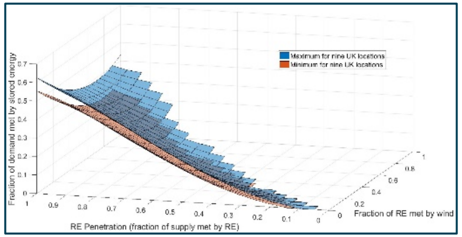
To balance a system with higher dependence on renewable power sources we need all storage technologies, including long-duration GWh capacity

Current energy storage technologies



- > Every network has different storage requirements dependent on multiple variables (e.g. renewable resource, dispatchable supply and demand profile)
- > To identify these requirements and how the storage requirement changes we developed the storage duration index (SDI)

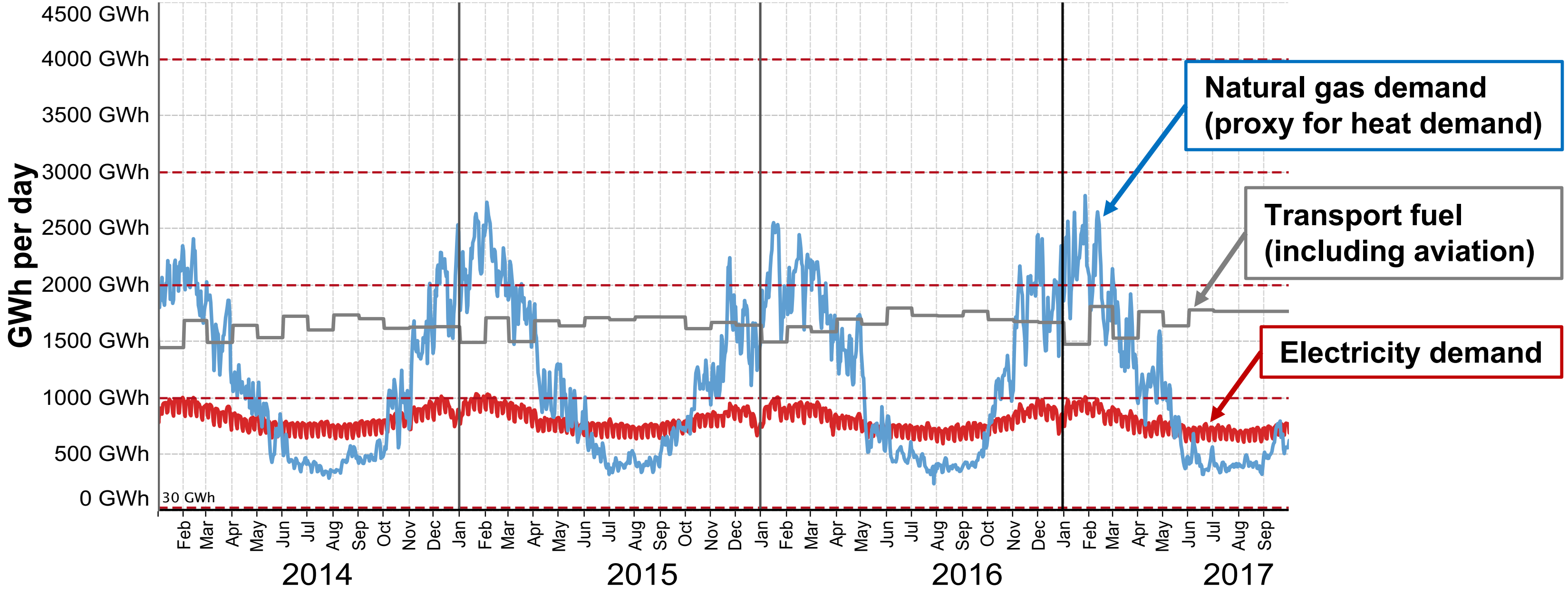




Source: Presentation by N Olson (NH3 Fuel Association), Rotterdam, May 2017. Adapted from Hydrogenius Technologies
Nayak-Luke, R.M., R. Bañares-Alcántara, S. Collier, Islanded power-to-ammonia production process (2018) NH3 Event, Rotterdam

Electrification of transport and in particular heating will greatly exacerbate the average electrical demand and network flexibility required

A whole energy system perspective: The UK energy system



Natural gas demand (proxy for heat demand)

Transport fuel (including aviation)

Electricity demand

Data are from National Grid, Elexon and BEIS. Charts are licensed under an Attribution-NoDerivatives 4.0 International license
Charts can be downloaded from http://bit.ly/energycharts

by Dr Grant Wilson grant.wilson@sheffield.ac.uk

Source: I.A. Grant Wilson et al. / Energy Procedia 62 (2014) 619 – 628

Electrification of chemical production to facilitate chemical energy storage also has multiple other considerable benefits

The value to electrifying chemical production

1) Energy storage

> Power to a chemical (P2X) is an excellent long-term storage method due to low energy losses and OPEX

> Unlike most energy storage methods power and energy is decoupled

2) Sector coupling / smart grid

> As an industrial energy demand it is able to ramp power demand to provide flexibility to the grid (DSM)

> The chemical product can be used in multiple sectors: feedstock to other industry, electrical energy storage, transport fuel, heating (low and high grade)

Electrifying chemical production

> Chemical production processes currently account for a substantial fraction of global fossil fuel consumption and consequently a notable amount of CO_2 emissions

> They are particularly dependent on fossil fuels given their dependence on them for both energy and feedstock

3) Decarbonising the production process

> Multiple revenue streams can be realised given the multiple uses of the chemical product

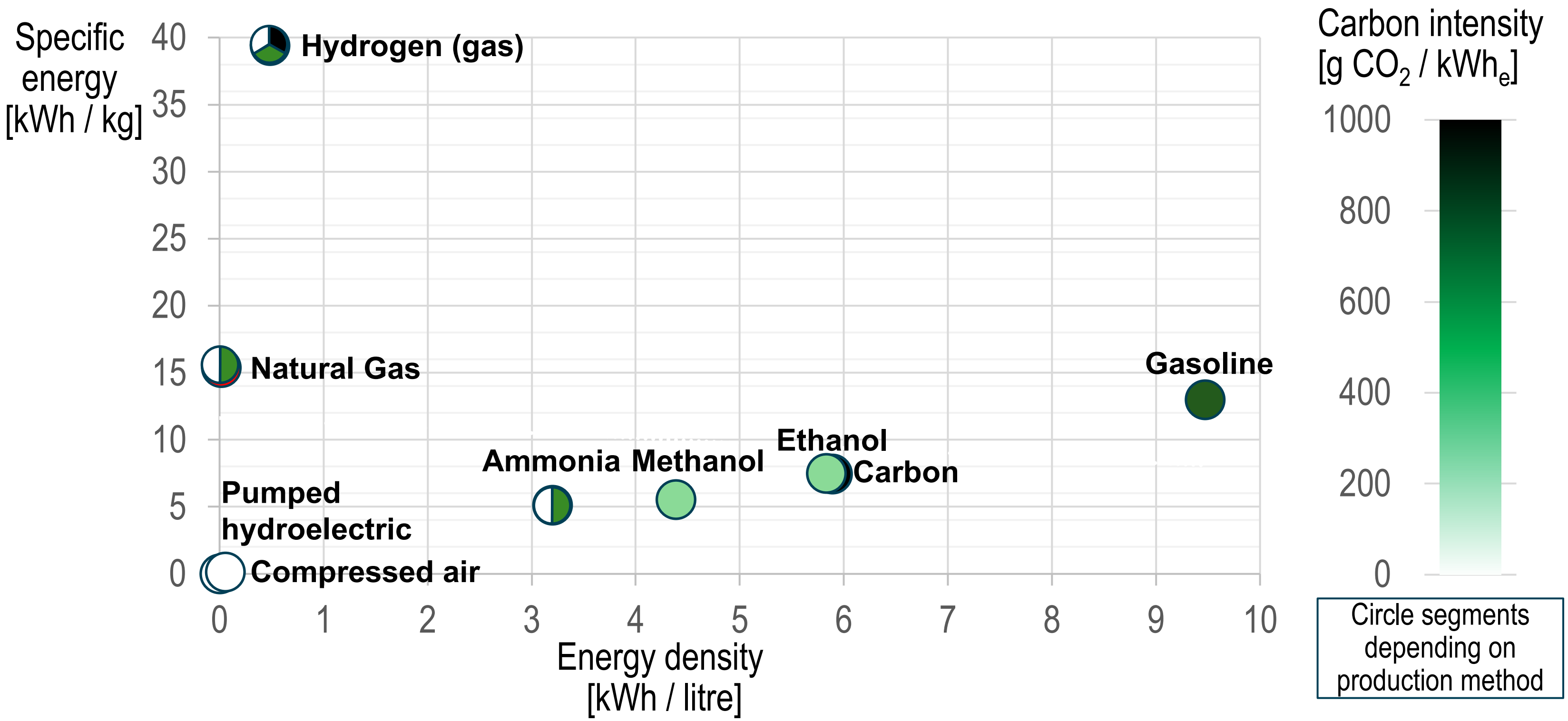
> This reduces the probability of low initial demand and cyclic demand, while reducing dependence on one market

4) Risk mitigation

Source: Philibert, C., Renewable energy for industry: From green energy to green materials and fuels (2017) International Energy Agency (IEA). Adapted from Roland Berger GmbH, Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities (2017)

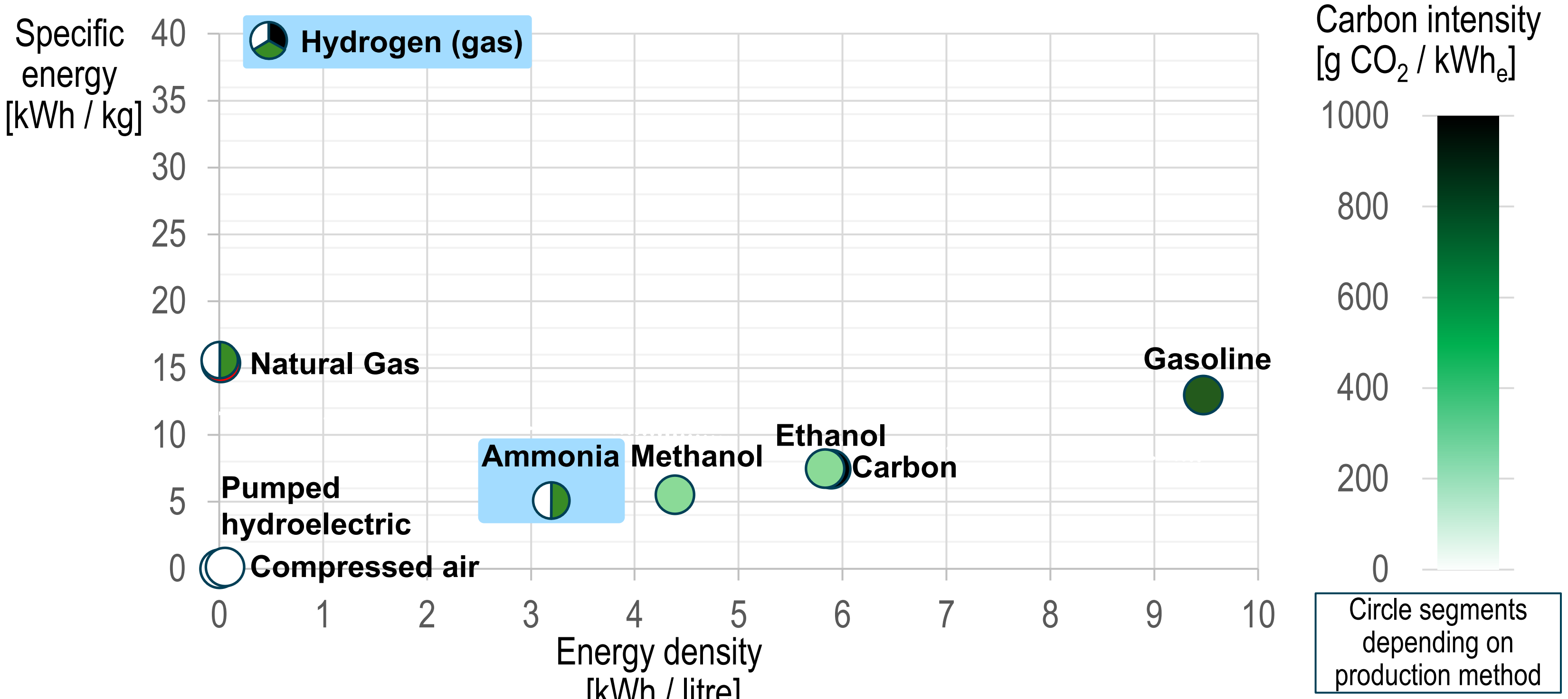
Many chemicals have potential for use as an energy storage vector, they can be differentiated by carbon intensity and chemical characteristics

Comparison of energy storage characteristics and carbon intensity



Many chemicals have potential for use as an energy storage vector, they can be differentiated by carbon intensity and chemical characteristics

Comparison of energy storage characteristics and carbon intensity



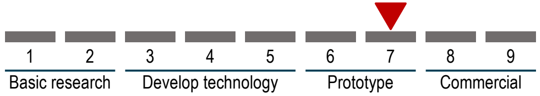
Power-to-gas see: Bailera, M. et al., Power to Gas projects review: Lab, pilot and demo plants for storing renewable energy and CO2. Renewable and Sustainable Energy Reviews, 2017. 69: p. 292-312.

Competitive 'green' hydrogen production is the key to the commercial viability of P2X, but has substantial importance in its own right

Case study: Hydrogen (H_2)

Overall technology readiness: Competing technologies continue to reduce cost of mature electrolyser technology thereby enabling demonstrating projects of considerable size

Technology readiness level:



Overview

- > Estimated market of \$115.25bn in 2017, predicted to grow to \$154.74bn by 2022
- > Well understood conversion from (electrolysers) and to (fuel cell) power
- > Expensive to store for long periods of time relative to other chemicals due to its chemical characteristics (boiling point of -253°C at 1atm)
- > Majority of hydrogen still produced from fossil fuels (gas and coal) at present
- > Has potential to be a vector in both the transport and heating sectors

Demonstration projects / deployment examples (selection)

Project	Country	Start	Description
Network management by injecting hydrogen (GRHYD)	🇫🇷	2013	Two year preliminary study and five-year demonstration phase of hydrogen injection into natural gas distribution network with blend level of up to 20%
WindGasFalkenhagen (E.ON)	🇩🇪	2014	Green hydrogen production from 2 MW wind power to be fed into gas distribution network, grid operation by OntrasGastransportGmbH
H21 Leeds City Gate Project	🇬🇧	2017	Determining the feasibility, from both a technical and economic viewpoint, of converting the existing natural gas network in Leeds to 100% hydrogen

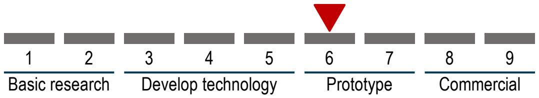
Source: IEA, Global Trends And Outlook For Hydrogen (Dec 2017) http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_Dec2017_WEB.aspx (Accessed 22nd May 2018)
Roland Berger GmbH, Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities (2017)

There is an environmental imperative to decarbonise ammonia production given the global dependence on it for fertiliser production

Case study: Ammonia (NH_3)

Overall technology readiness: Proven at lab scale and with small demonstrator plants. Small pilot plants are planned for launch in 2020

Technology readiness level:



Overview

- Accounts for ~1.3% of CO_2 emissions
- Over 80% is used for fertilisers
- Current production levels of over 190m t/year
- The commodity value of €300-€400/t, leading to a commodity market value of over €55bn
- Production today uses the Haber-Bosch process and relies on natural gas (or is a few cases coal) as the hydrogen feedstock
- Conventional production combined with increasing demand is at odds with the national & international emission targets

Demonstration projects / deployment examples (selection)

Project	Country	Start	Description
University of Minnesota	🇺🇸	2013	Electrolytic Haber-Bosch 25t/year demonstration plant supplied by x2 1.65MW wind turbines
Siemens, University of Oxford and Cardiff University	🇬🇧	2018	Electrolytic Haber-Bosch supplied by 0.03 MW wind with integrated ammonia combustion for conversion back to power
Hydrogen Utility (H2U) & ThyssenKrupp	🇦🇺	2020	Electrolytic Haber-Bosch 40t/day demonstration plant, 15MW electrolyser with solar power
Proton Ventures, Yara & Siemens	🇳🇱	2020	Electrolytic Haber-Bosch 40-50t/day demonstration plant, 20MW electrolyser with tidal and wind power

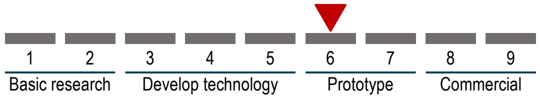
Source: Bañares-Alcántara, R., et al., Analysis of islanded ammonia-based energy storage systems. 2015, University of Oxford: Oxford, UK.
T. Brown, The Sustainable Ammonia Synthesis Investment Universe process (2018) NH3 Event, Rotterdam

There is an environmental imperative to decarbonise ammonia production given the global dependence on it for fertiliser production

Case study: Ammonia (NH_3)

Overall technology readiness: Proven at lab scale and with small demonstrator plants. Small pilot plants are planned for launch in 2020

Technology readiness level:



Overview

- > Accounts for ~1.3% of CO_2 emissions
- > Over 80% is used for fertilisers
- > Current production levels of over 190m t/year
- > The commodity value of €300-€400/t, leading to a commodity market value of over €55bn
- > Production today uses the Haber-Bosch process and relies on natural gas (or is a few cases coal) as the hydrogen feedstock
- > Conventional production combined with increasing demand is at odds with the national & international emission targets

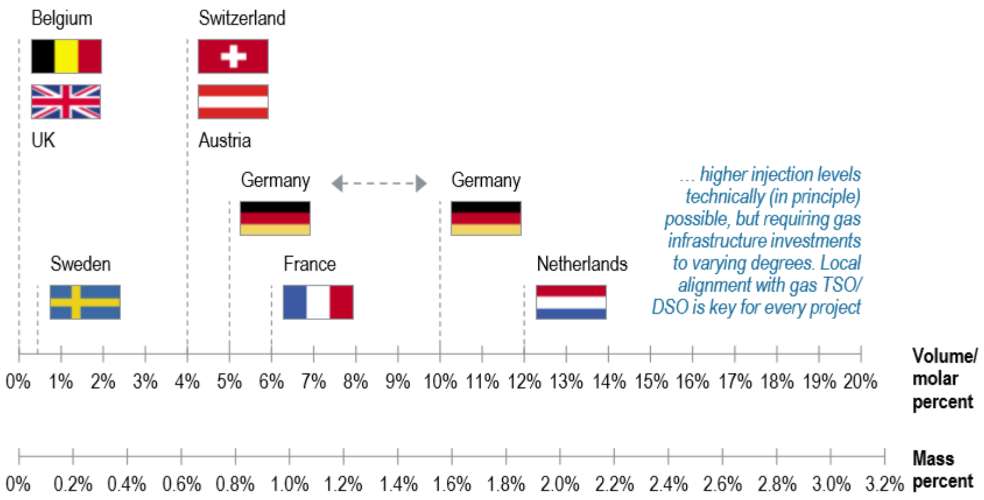
Demonstration projects / deployment examples (selection)

Project	Country	Start	Description
University of Minnesota	🇺🇸	2013	Electrolytic Haber-Bosch 25t/year demonstration plant supplied by x2 1.65MW wind turbines
Simens, University of Oxford and Cardiff University	🇬🇧	2018	Electrolytic Haber-Bosch supplied by 0.03 MW wind with integrated ammonia combustion for conversion back to power
Hydrogen Utility (H2U) & ThyssenKrupp	🇦🇺	2020	Electrolytic Haber-Bosch 40t/day demonstration plant, 15MW electrolyser with solar power
Proton Ventures, Yara & Siemens	🇳🇱	2020	Electrolytic Haber-Bosch 40-50t/day demonstration plant, 20MW electrolyser with tidal and wind power

Source: Bañares-Alcántara, R., et al., Analysis of islanded ammonia-based energy storage systems. 2015, University of Oxford: Oxford, UK.
T. Brown, The Sustainable Ammonia Synthesis Investment Universe process (2018) NH3 Event, Rotterdam

Regulation is currently a barrier to commercial deployment in many countries, it must be changed to incentivise these beneficial technologies

Required technical and regulatory developments



… higher injection levels technically (in principle) possible, but requiring gas infrastructure investments to varying degrees. Local alignment with gas TSO/ DSO is key for every project

- >Regulation to incentivise 'green' chemical production: directly intervening through either low carbon targets (similar to biofuel i.e. target of 10% 'green' component by 202X) or subsidies
- >Permissible hydrogen content in gas networks: considerably different legislation by country. KPMG analysis has suggested that 'green' hydrogen is not only more sustainable but also more economical than reinforcing electrical networks and electrifying heating demand
- >Clarification and adaptation of regulation with regards to electrical storage: Despite the benefit that storage provides to the stability to networks, storage operators are commonly punished for being both a demand and then subsequent supply to the grid.

Source: KPMG, 2050 Energy Scenarios: The UK Gas Networks role in a 2050 whole energy system. 2016.
Roland Berger GmbH, Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities (2017)

Chemical energy storage has significant potential to meet long-term requirements, but its importance and additional benefits must be recognised

Key messages

1. Long-term balancing of electricity networks will become increasingly important as renewable penetration increases
2. Chemical storage is the standout solution to meet this long-term requirement
3. There are multiple chemicals that could act as energy vectors
4. Electrification of this chemical production would have multiple additional benefits
5. Regulation is currently a major barrier in many countries and should be changed to recognise the multiple benefits of these technologies

Acknowledgements

Our deepest thanks go to EPSRC and Siemens for financially supporting this work under the iCASE Award

For their continued assistance on the project we would like to specifically thank Mr Sam Collier (University of Oxford, Engineering Science), Dr Ian Wilkinson (Siemens CT) and Prof. Edman Tsang (University of Oxford, Chemistry)

Sustainable Innovation

ISGAN
Award of Excellence
Winner | 2018

Sustainable innovation

2018-05-24 Heat based energy storage in grid

@Sustify @joachimlindborg

Smart home is happening quickly

Ny kundregistrering | Mitt konto | Kundservic

CONRAD Europas största webbutik för teknik och elektronik

200 000 produkter ✓ Över 90 års erfarenhet ✓ Två års garanti ✓ Fri frakt över 999 kr

Alla kategorier

Energiförsörjning

eMobility

eMobility @ Home (1335)

AUTOMATISERING FÖR HEMMET

Kjell & Compan

Sortiment | Tillbehör till | Kunska

Du är här: Hem > Sortiment > El > El-produkter > Starkström

Välj underkategori

Fjärrkontrollssystem - Free Control

Fjärrkontrollssystem - HOMEeasy

Fjärrkontrollssystem - HomeMatic®

Fjärrkontrollssystem - RSL

Infälld mottagare på/av

Automationssystem - KNX

Termometer / hygrometer

VÅRKAMPANJ

SMARTA HEM-VECKA

20/3 - 26/3

NYA PRODUKTER VARJE VECKA

GÖR DITT HEM LITE SMARTARE

Vårkampanj på Inet

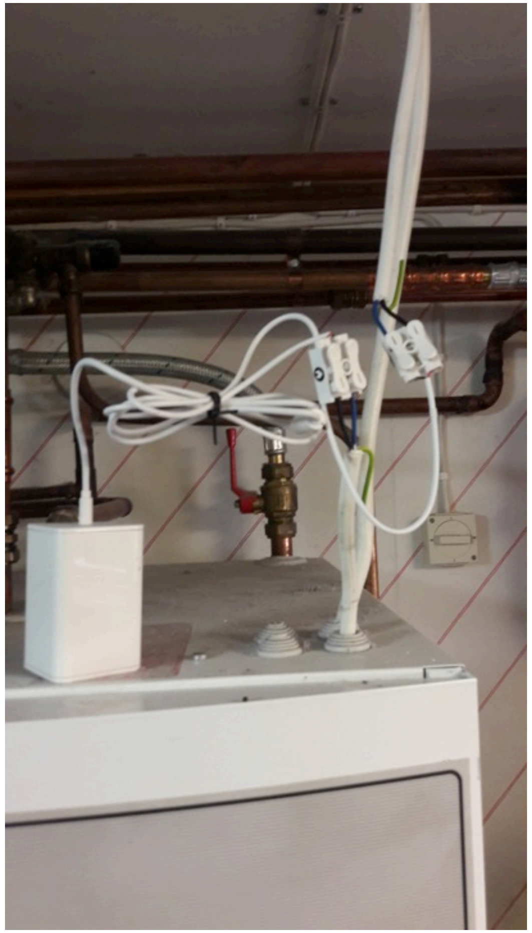
Under vår smarta hem-vecka hittar du bl.a. lampor, röstassistenter, sensorer, styrenheter, routrar och övervakningskameror till nedsatta priser. Vårkampanjen sträcker sig till och med 2/4 där vi uppdaterar med nya produkter varje vecka!

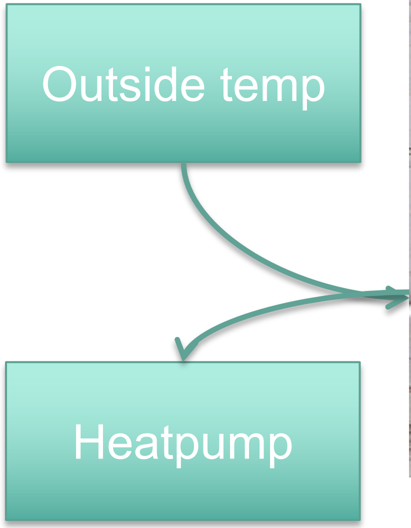
Project goals

- 500 empowered villas in the grid
- 1MW manageable power
- Energyefficiency +10%
- Bussiness models, share the profit
- New types of dynamic grid tariffs
- Customer feedback

NGENIC

How do we tap in





Outside temp

Heatpump

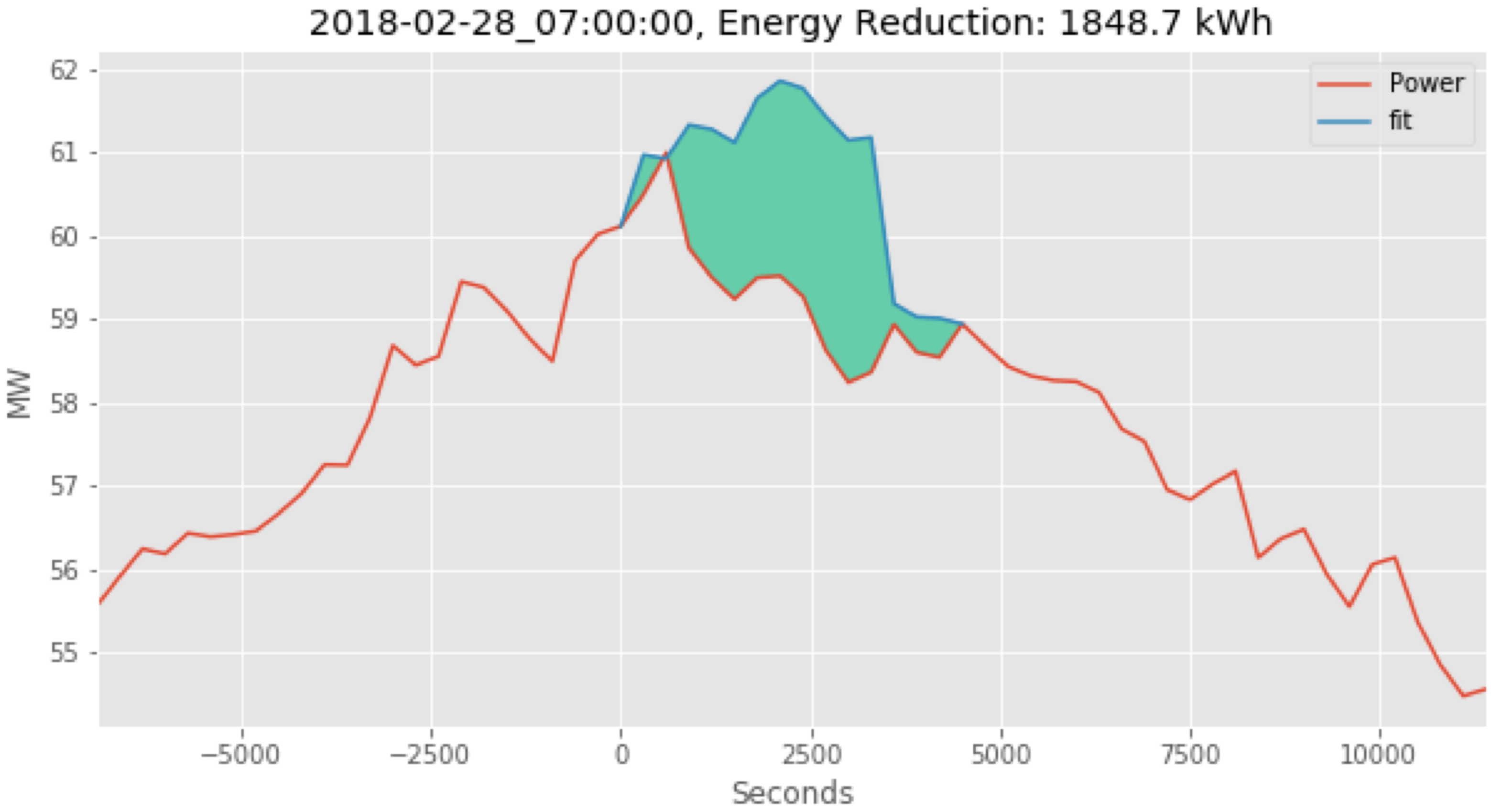
Potential:
250 villa systems unleash > 1MW

60,503 MW -> 13 279€ sek

48 500€ saved

1 500 000 waterbased heating villas in sweden

6GW



About Joachim Lindborg

- Currently CTO of sust.se, I'm a technology enthusiast that believe that IoT is really about human interaction with systems adding value to life and that closed systems will die in favor for open one.

- For the past 15 years I have been working with system integration, especially at the intersection of energy and IT. I was one of the founders of homesolutions.se a start-up company integrating systems for supervision and maintenance of buildings.

- In the IT boom during the late 1990s I was employed by the swedish Utility Vattenfall to develop solutions for the smart home. It was an exciting time but it ended in disappointment. Now we are back again and with Internet of Things and a more stable technology I do believe that this time we will succeed. Right now I am working with companies in home security, heating and air conditioning, with energy companies and service developers in a project integrating all these technologies with sound business models for smart home services for energy control and efficiency.

Email: joachim.lindborg@sust.se
Linkedin: se.linkedin.com/in/joachimlindborg/