PUBLIC WORKSHOP

How can sector coupling enable flexibility provision? - Technical and market integration challenges

10 October 2019

University Foundation - Rue d'Egmont 11, 1000 Bruxelles

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774309.

Agenda

<table>
<tr><td>10:00</td><td colspan="4">Welcome coffee</td></tr>
<tr><td>10:30</td><td colspan="3">Opening of the meeting
• Introduction of the topic
• Presentation of the MAGNITUDE project</td><td>Régine Belhomme, EDF</td></tr>
<tr><td rowspan="2">11:00</td><td colspan="3">Session 1:
New technical challenges for Multi-Energy Systems</td><td>Chair: Nicole Pini, EIFER</td></tr>
<tr><td colspan="3">• Shaping the future multi-energy systems: lessons learnt from the MAGNITUDE project case studies
• Heating and cooling perspective in energy integration
• Discussion</td><td>Nicole Pini, EIFER

Alessandro Provaggi, DHC+</td></tr>
<tr><td rowspan="3">12:00</td><td colspan="3">Poster session and demonstrations</td><td>Chair: Angelina Syrri, DTU</td></tr>
<tr><td>POSTERS</td><td>Flexibility provision by multi-energy systems for services to the electricity system</td><td>• Integrated pulp and paper mill in Austria
• Milan District heating plant
• Economic dispatch of heat pumps considering load shifting between electricity and heat</td><td>Cardiff University
RSE
MDH</td></tr>
<tr><td>LIVE DEMOS</td><td>Multi-energy market simulation and market price forecasting</td><td>• Demonstration of the market simulator for integrated multi-energy carrier systems
• A machine learning algorithm forecasting day-ahead electricity prices in Italy</td><td>VITO/N-SIDE

VITO/N-SIDE</td></tr>
<tr><td>13:00</td><td colspan="4">Lunch</td></tr>
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Agenda

14:00	**Session 2: Aggregation and market integration of multi-energy systems**	Chair: Kris Kessels, VITO
	• **Flexibility provision by multi-energy systems through aggregation in support of the power system** • Multi energy aggregation platform for the provision of flexibilities: the MAGNITUDE perspective • Energy Communities leveraging flexibility by Active Connected Buildings: experience from the FHP (Flexible Heat and Power) project	Christoph Gutschi, cyberGRID Chris Caerts, VITO
	• **Future market design for improved sector coupling** • Innovative market schemes for integrated multi-energy systems: the MAGNITUDE perspective • A local marketplace for electricity, district heating and cooling in Gothenburg: the experience of the FED project	Kris Kessels, VITO Magnus Brolin, RISE
	• **Discussion**	
15:15	**Coffee break**	
15:45	**Session 3: Modelling and Simulation of Multi-Energy Systems for flexibility quantification**	Chairs: Edoardo Corsetti, RSE Meysam Qadrdan, Cardiff University
	• Assessment of Multi-Energy Systems for flexibility maximization: the MAGNITUDE perspective • An orchestration tool for the optimal management of energy exchange over the networks: the PLANET proposal for a new approach to sector coupling • Discussion	E. Corsetti, RSE - M. Qadrdan, Cardiff University Gabriele Fambri, Politecnico di Torino
16:45	**Conclusion and next steps**	Régine Belhomme, EDF

Régine Belhomme, EDF

OPENING OF THE MEETING

Contents

- Flexibility provision to the electricity system
- Sector coupling and multi-energy systems
- The MAGNITUDE project
  - Objectives
  - Consortium
  - Concept and approach
  - Case studies
  - Work organisation
  - Main results

Flexibility provision to the electricity system

European targets in terms of reduction of greenhouse gas emissions and renewable energy integration will require **important changes in the electricity system**

… and **will lead to new risks and needs**

➔ **New or increased system risks:** for instance in terms of security of supply, network congestion, system stability, system adequacy (difficulty/impossibility (?) to cover the electricity demand at some periods of time), RES curtailments, etc.

➔ **Needs for more flexibility** to ensure efficient and reliable operation

- more active **involvement and collaboration of all the stakeholders** at all levels (from distribution to pan-European)
- need to harness the service provision capabilities of **both centralized** (e.g. central generation, large consumers) and **decentralized resources** or DER (consumers, producers, storage, etc.)
- in a **coordinated way**

Sector coupling appears now as one of the possible means to provide flexibility to the electricity system.

Flexibility provision to the electricity system

Needs	Services (MAGNITUDE Deliverable D3.1)
Balancing and frequency control	**Provision of reserves for TSOs** • Frequency Containment Reserve (FCR) • Automatic Frequency Restoration Reserve (aFRR) • Balancing, manual Frequency Restoration Reserve (mFRR) and Replacement Reserve (RR)
Congestion management	**Re-dispatching mechanisms or active power control** at both transmission and distribution levels
System adequacy	**Capacity requirement mechanisms** • Capacity markets • Strategic reserves
Reducing price risks & optimizing energy portfolios	**Energy trades** • Day-ahead energy market (spot market) • Intraday energy market

Other services have been or are being studied and defined, e.g. Fast/enhanced Frequency Response, Inertial response, etc.

Remark: voltage control

Sector coupling and multi-energy systems

Sector coupling: “coupling” or synergies between **different energy carriers:** electricity, gas, heat/cooling, H2, transportation, etc.

Cross-sector technologies: interfaces between sectors

Multi-energy systems (MES)

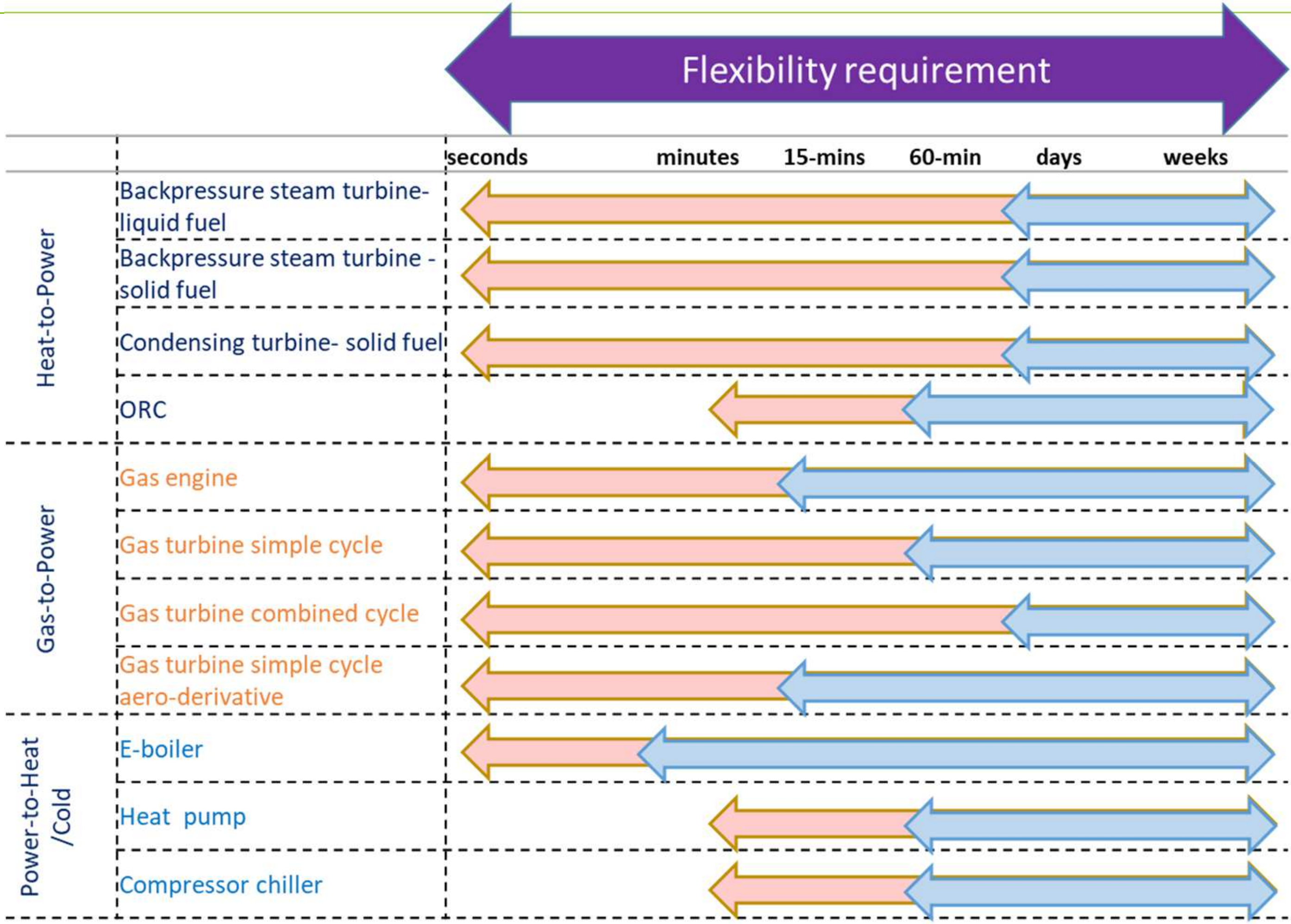
Different cross-sector technologies (from MAGNITUDE case studies)										**…and energy sectors**		
Biomass boiler	Gas boiler	Steam turbine	Gas turbine	Gas engine	Chiller	Thermal energy storage	Heat pump	Electric boiler	Anaerobic digestion	Electricity	Heating/ cooling	Gas

- Different **purposes**: industries, commercial and public sites, district heating/cooling, distributed units at consumers/prosumers
- Different **stakeholders and business models**: MES operators, consumers/prosumers, suppliers, network operators, etc.
- Different **regulations and market organizations**

Two main flexibility levers

- Fuel shift
- Storage capability

Sector coupling and multi-energy systems



Flexibility options provided by different technologies: orange arrows show capability for running technologies and blue arrows reflect capability including time needed for startup from hot state (**MAGNITUDE Deliverable D1.2**)

The MAGNITUDE project

MAGNITUDE is a Horizon 2020 European project

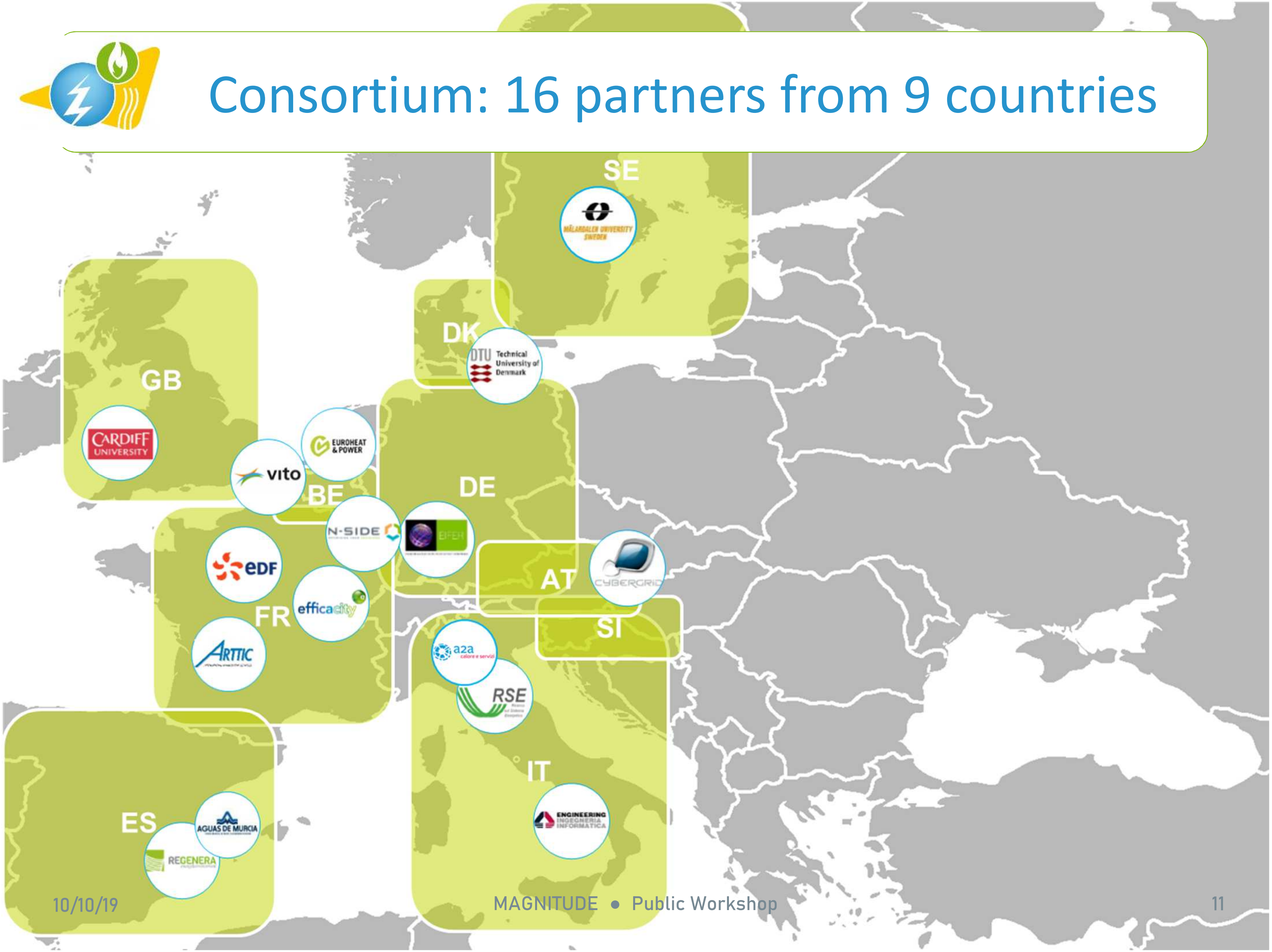
- Research and Innovation Action
- EC funding: 4 M€
- Duration: 3,5 years: 10/2017 → 03/2021
- Coordinator: EDF

MAGNITUDE aims to develop **business and market mechanisms,** and **coordination tools** to provide **flexibility to the European electricity system**, by enhancing **synergies between electricity, gas and heat/cooling systems**

MAGNITUDE will hence:

- Provide flexibility options to support variable **RES cost-effective integration** and **decarbonization** of energy system
- … and to enhance **security of supply**
- Bring under a **common framework** technical solutions, market design and business models
- Contribute to the **ongoing policy discussion** in the energy field

Consortium: 16 partners from 9 countries

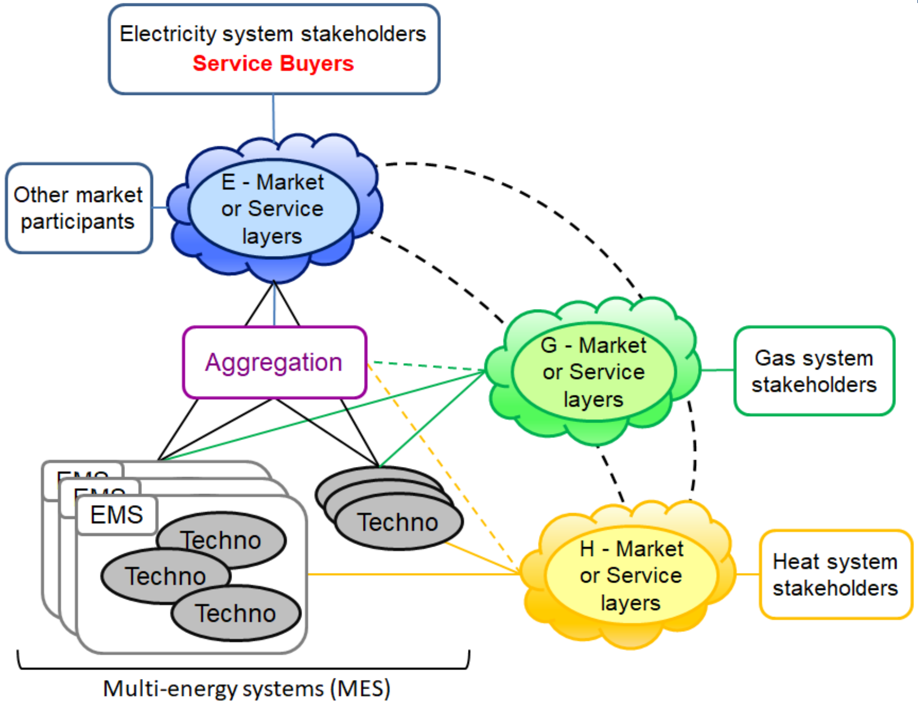


Consortium: a complementary and comprehensive expertise

	Country	Organisation profile	Energy sector			Orientation	
			Power	Heat	Gas	Technology	Market
EDF	France	International utility	■	■		■	■
REGENERA	Spain	Retailer	■				■
EUROHEAT & POWER	Belgium	Industrial association	■	■		■	■
a2a calore e servizi	Italy	Local multi utility	■	■	■	■	■
AGUAS DE MURCIA	Spain	Local utility				■	■
CYBERGRID	Austria	Aggregation solution provider	■			■	■
ENGINEERING INGEGNERIA INFORMATICA	Italy	Data solution provider	■	■	■	■	
N-SIDE	Belgium	Market solution provider	■				■
vito Energy Ville	Belgium	Consulting/research	■	■			■
RSE	Italy	Consulting/research	■	■	■	■	
efficacity	France	Consulting/research	■	■	■	■	■
EIFER	Germany	Consulting/research	■	■	■	■	■
CARDIFF UNIVERSITY	United Kingdom	University	■	■	■	■	
MÄLARDALEN UNIVERSITY SWEDEN	Sweden	University	■	■	■	■	
DTU Technical University of Denmark	Denmark	University	■	■		■	

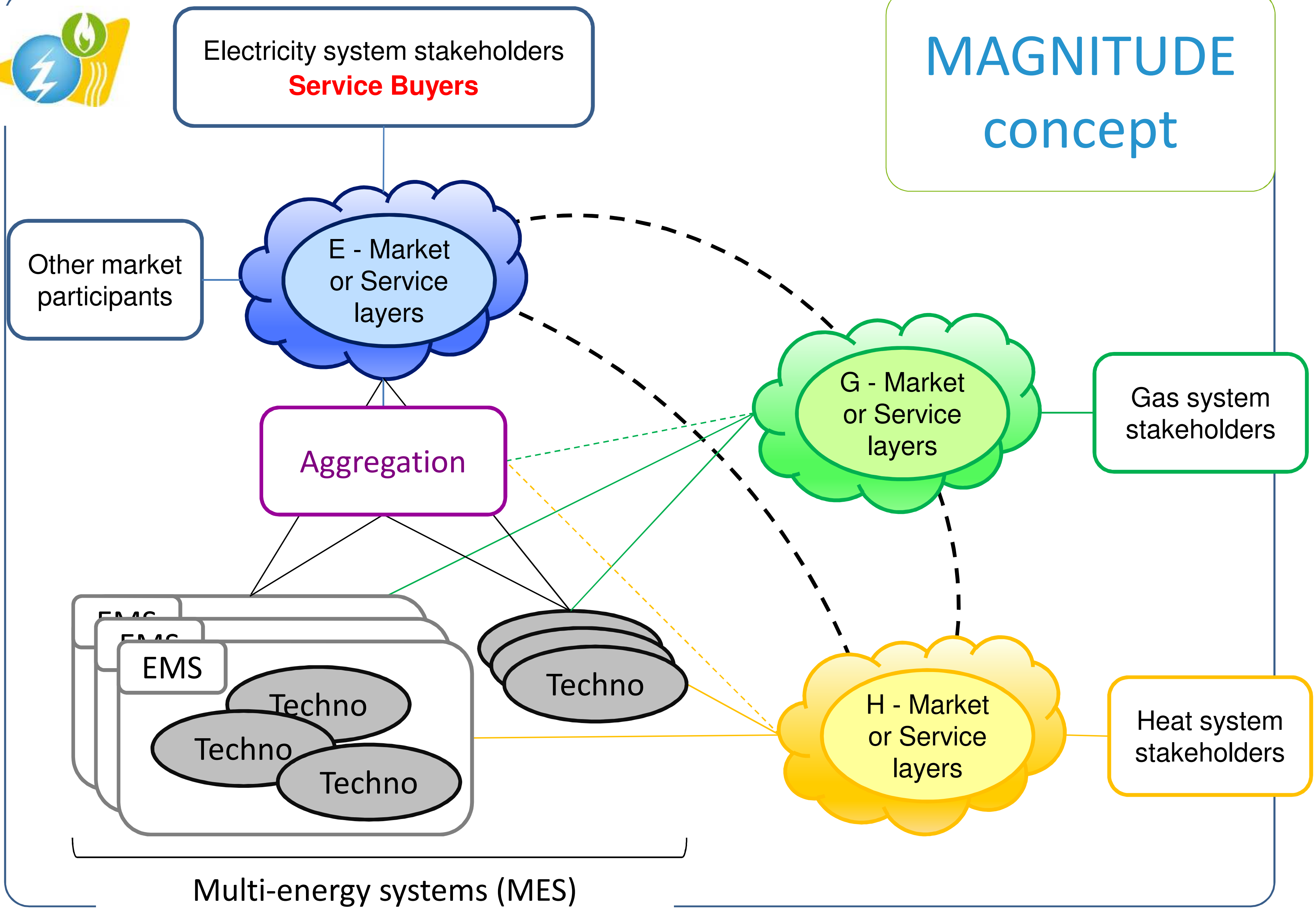
Concept and approach

- **Flexibility services** to be provided by **Multi-Energy Systems** (MES) to the electricity system
- **Flexibility provision capabilities** of identified **cross-sector technologies** and **MESs**
- **Simulated and optimized control strategies** of technologies and systems to maximize flexibility provision.

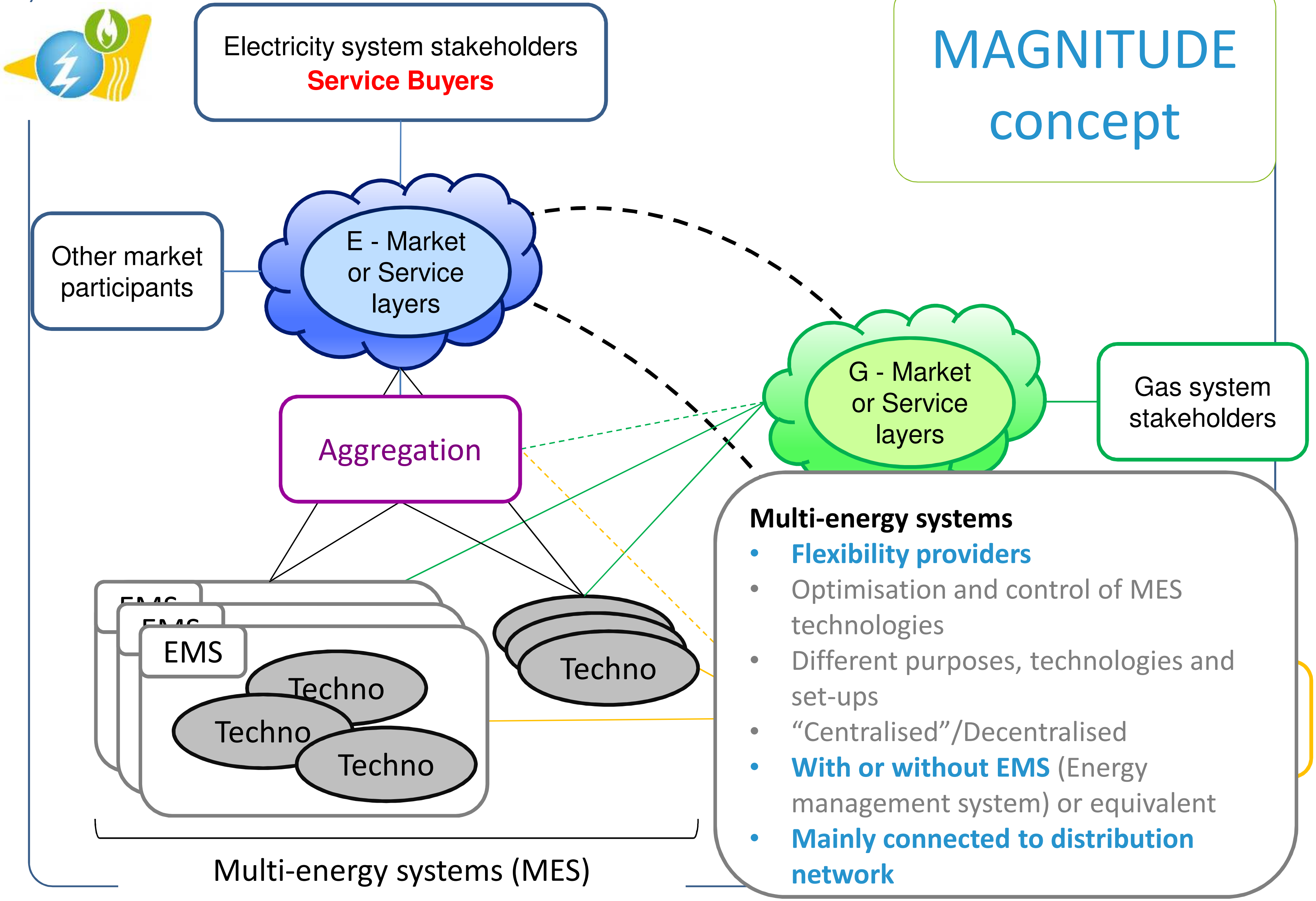


- **Innovative market designs** for synergies maximization, implemented and assessed on a **market simulation platform**
- **Benefits of pooling flexibilities** of portfolios of MESs through an **aggregation platform.**
- **Integrated system** (MES, aggregation, market) and associated **business models**
- **Policy strategy and recommendations** in a pan-European perspective

MAGNITUDE
concept



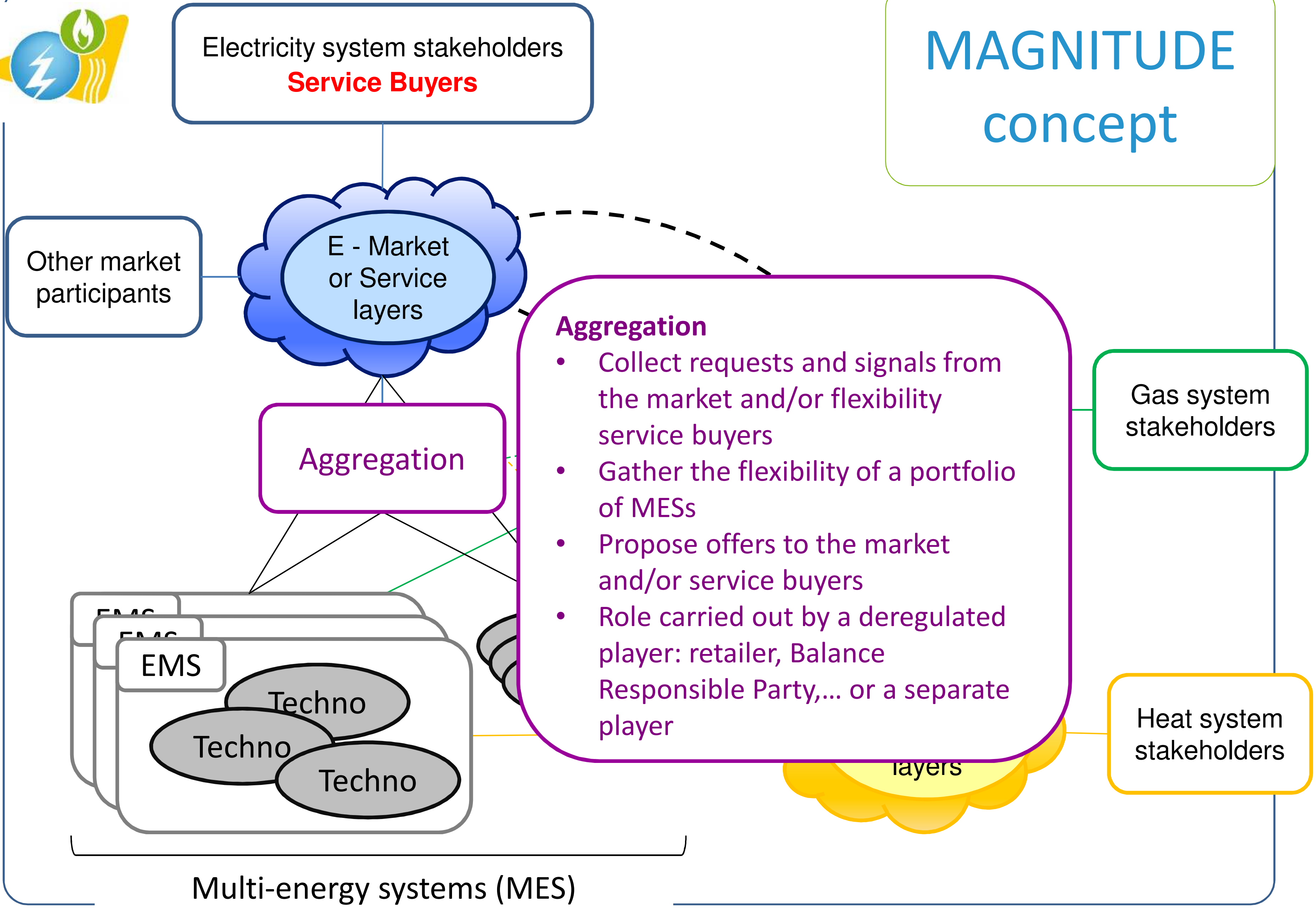
MAGNITUDE concept



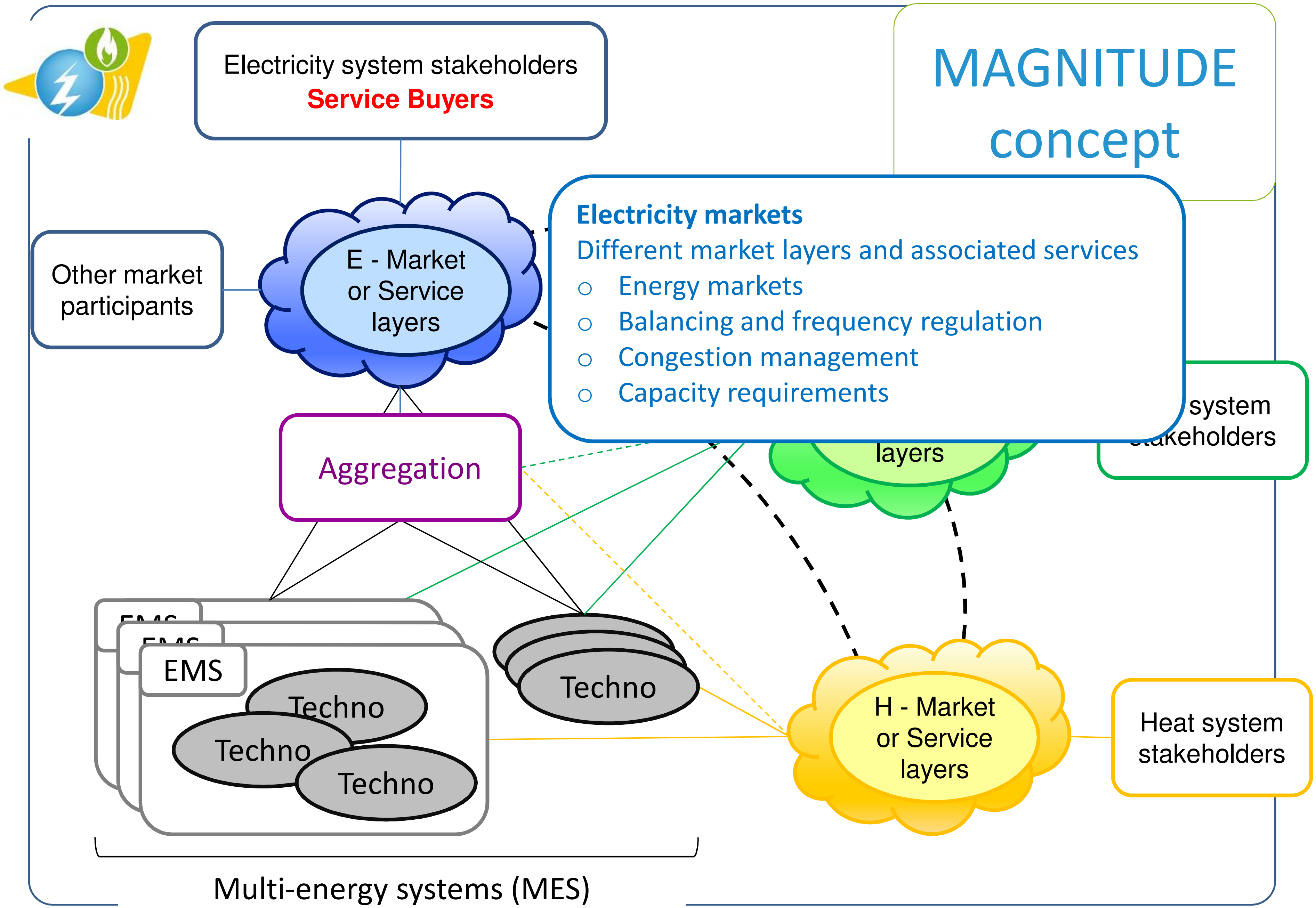
Multi-energy systems

- **Flexibility providers**
- Optimisation and control of MES technologies
- Different purposes, technologies and set-ups
- "Centralised"/Decentralised
- **With or without EMS** (Energy management system) or equivalent
- **Mainly connected to distribution network**

MAGNITUDE concept



MAGNITUDE concept

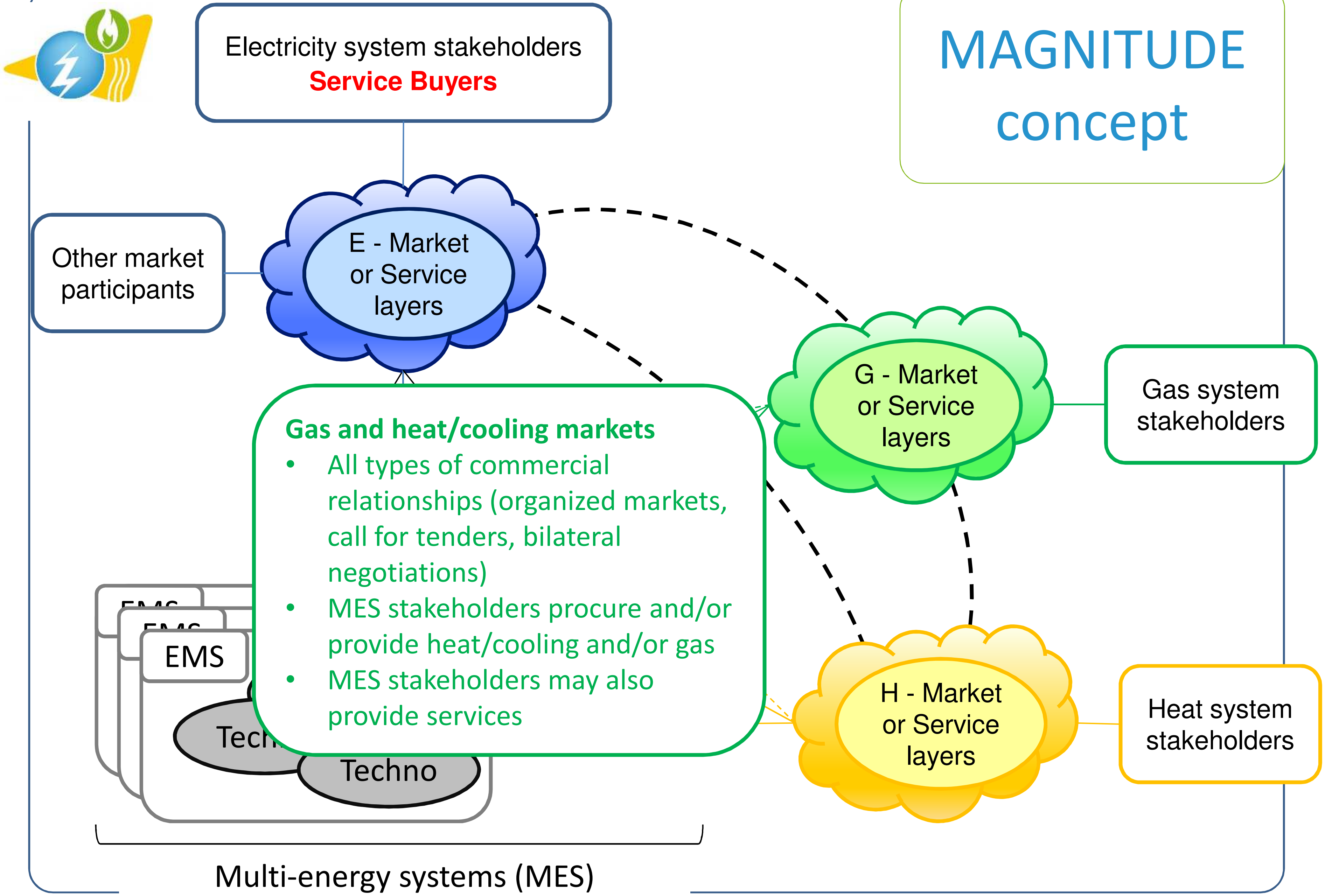


Electricity markets

Different market layers and associated services

- Energy markets
- Balancing and frequency regulation
- Congestion management
- Capacity requirements

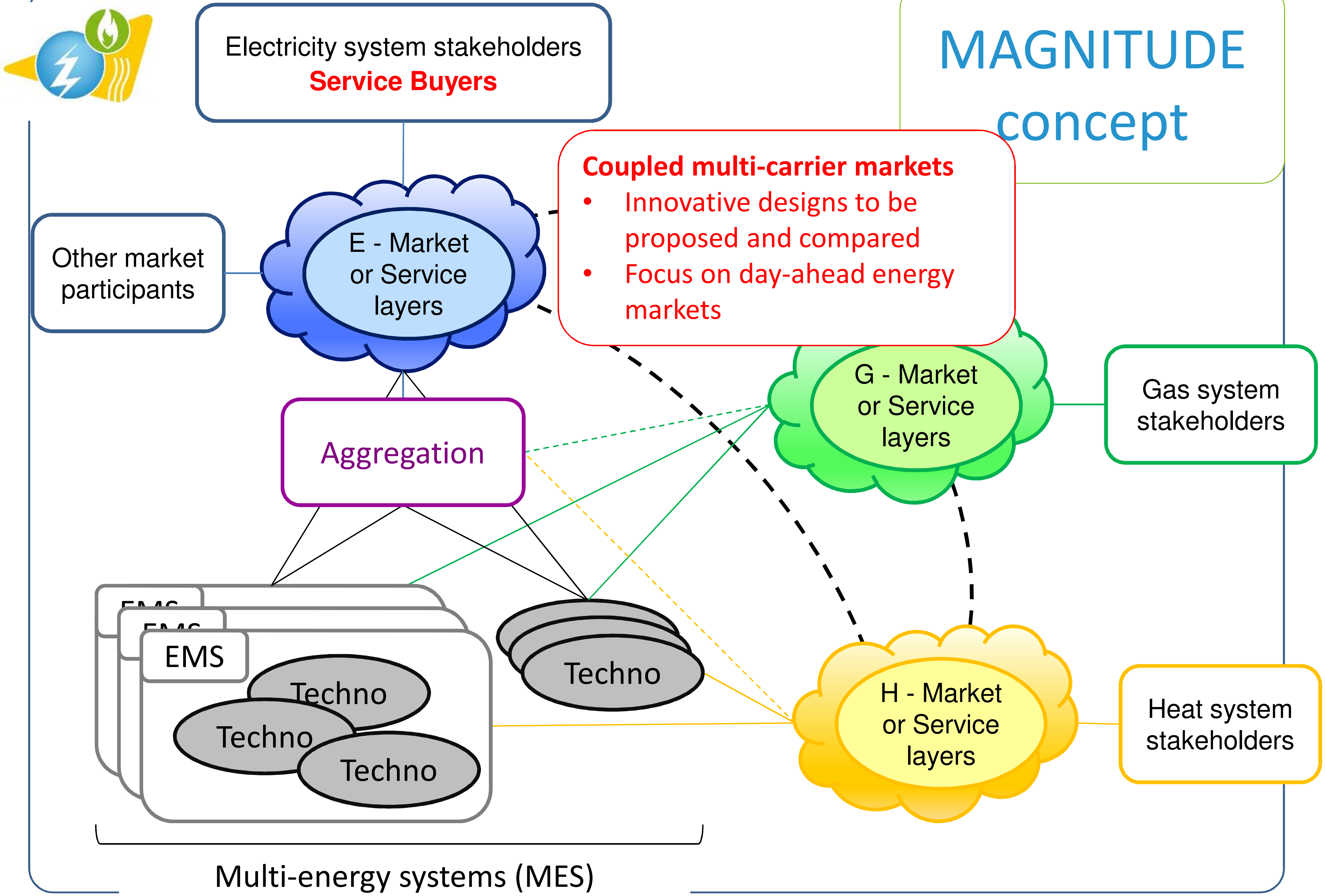
MAGNITUDE concept



Gas and heat/cooling markets

- All types of commercial relationships (organized markets, call for tenders, bilateral negotiations)
- MES stakeholders procure and/or provide heat/cooling and/or gas
- MES stakeholders may also provide services

MAGNITUDE concept

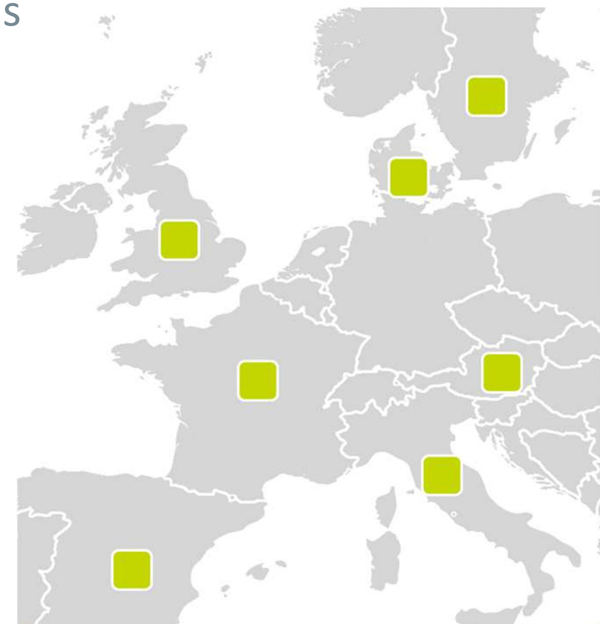


MAGNITUDE 7 real-life case studies

4 main MES categories

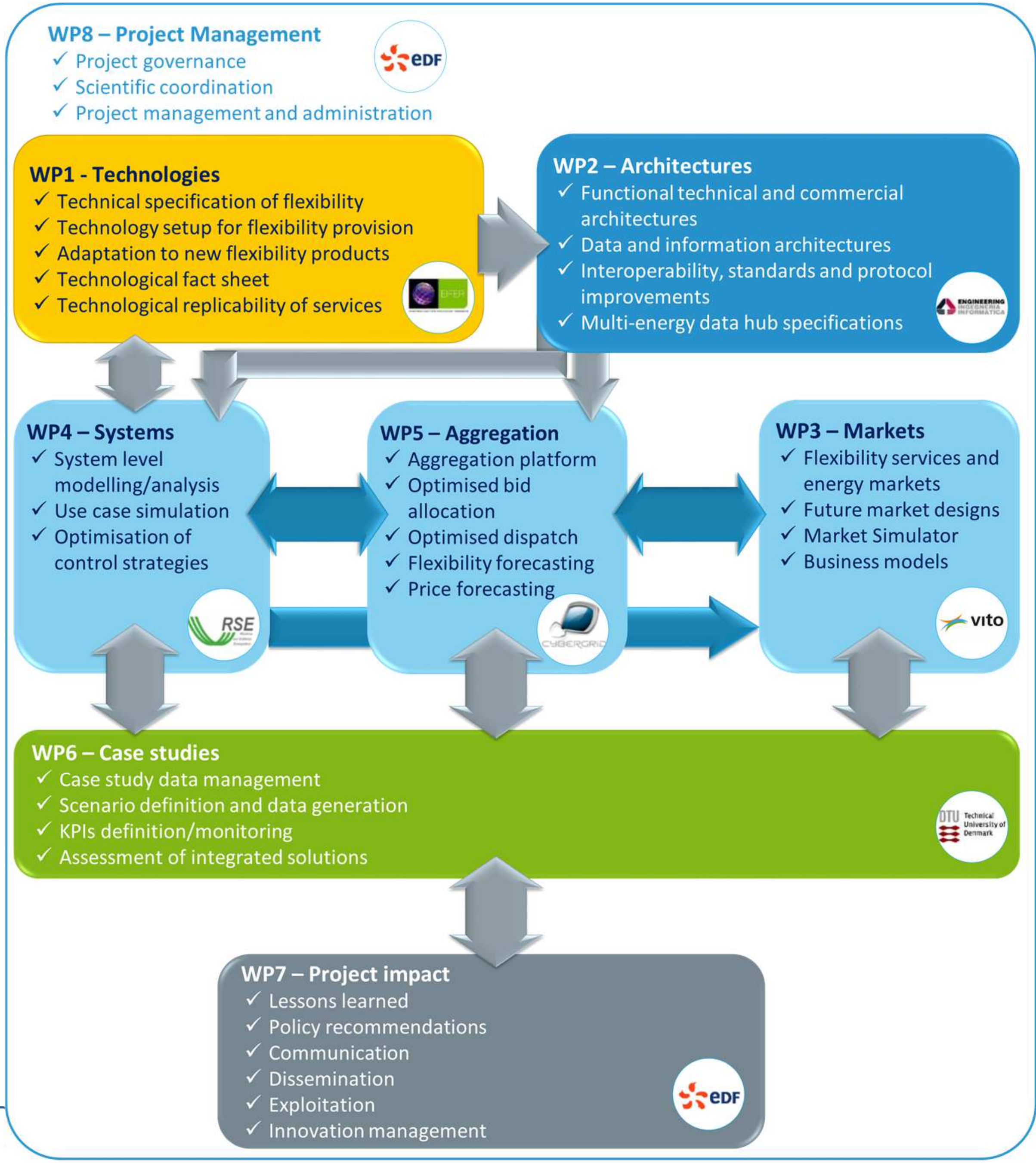
- Industries
- Large commercial and/or public sites
- District heating/cooling
- Distributed units at consumers'

7 countries: different regulatory frameworks, cross-sector technologies, stakeholders and business models



Mälarenergi Sweden	District heating and cooling
Paper mill Austria	Integrated pulp and paper mill
HOFOR Denmark	Distributed units + district heating
ACS, Italy	Milan district heating
Neath Port Talbot, UK	Industrial MES sites and large RES
EMUASA Spain	Waste water treatment plant
Paris Saclay France	District heating & cooling + distributed units

MAGNITUDE WP structure



Main results

- **Flexibility services** to the electricity system to be provided by MES – Deliverable D3.1
- **Innovative future market designs** for MES participation – Deliverable D3.2

- 7 real-life MES **case study technology setups** consolidated – Deliverable D1.1
- **Capabilities of MES technologies to provide flexibility services**, technical factsheets, technological adaptation, and associated technological and regulatory constraints and barriers – 2019 (Deliverable D1.2 available)

- **MAGNITUDE KPIs** and assessment procedure – Deliverable D6.1
- MAGNITUDE concepts, and **functional technical and commercial architectures** – 2019

- Specification of a **multi-energy data hub** and **adaptation layer for interoperability** between MES and the relevant stakeholders - 2020
- **Simulation and optimization tools** for maximization of flexibility provision by **MES** - 2020
- Multi energy **aggregation platform** and **market simulation platform** - 2020

- **Simulation of the real-life case studies** under baseline and future scenarios - 2020
- **Opportunities and barriers for replicating** studied flexibility products and market designs - 2020
- **Business model evaluation** of the different case studies for the simulated markets - 2020

- Final **evaluation of the integrated system**: MES, aggregation and market platforms - 2021
- **Project findings, lessons learnt and policy recommendations** addressing market mechanisms, regulation and standardization from a EU perspective - 2021

- Mid-term and final **public workshops** – October 2019 and March 2021

Chair: Nicole Pini, EIFER

SESSION 1: NEW TECHNICAL CHALLENGES FOR MULTI-ENERGY SYSTEMS

Session 1

New technical challenges for Multi-Energy Systems	Chair: Nicole Pini, EIFER
• Shaping the future multi-energy systems: lessons learnt from the MAGNITUDE project case studies • Heating and cooling perspective in energy integration	Nicole Pini, EIFER Alessandro Provaggi, DHC+
• **Discussion**	

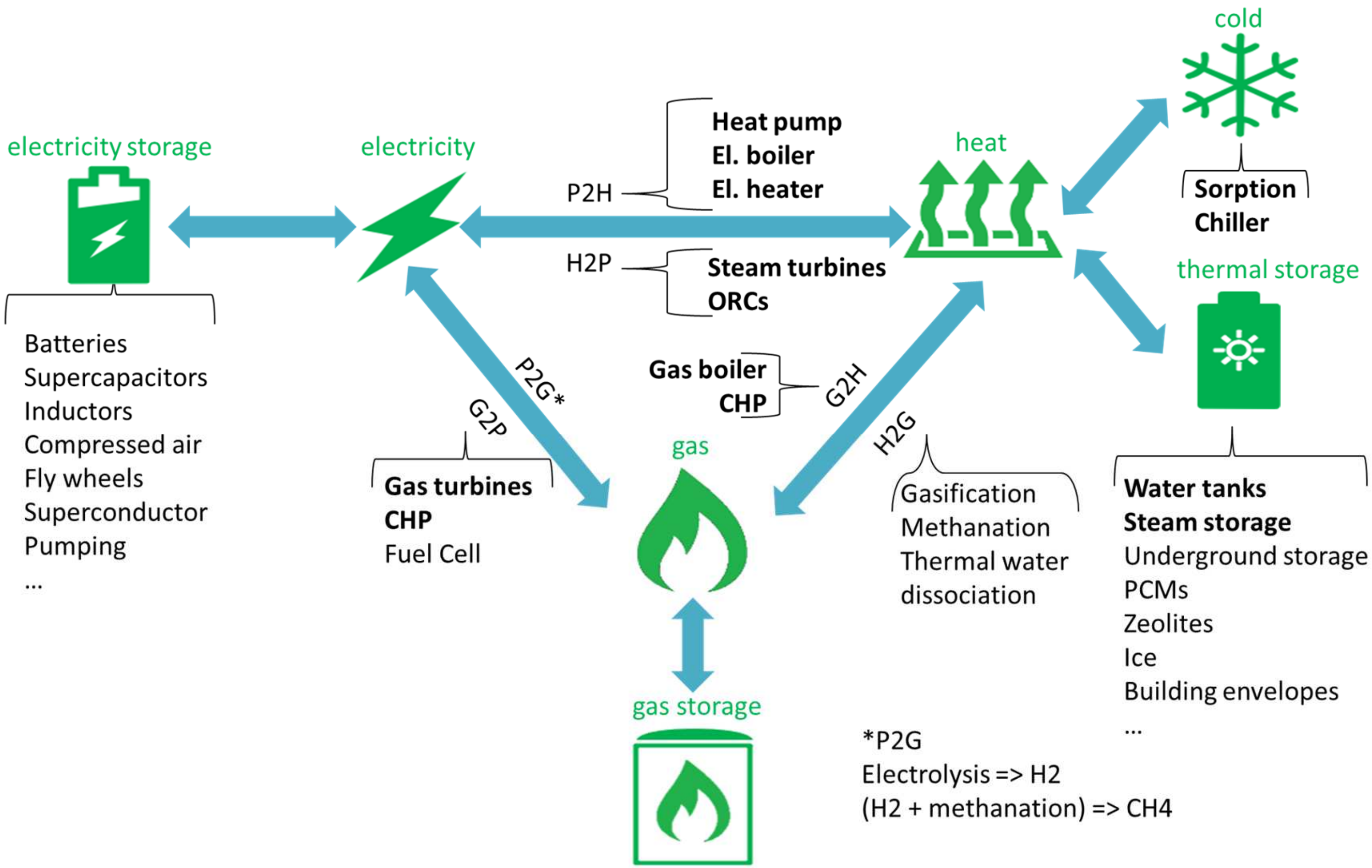
Nicole Pini, EIFER

SHAPING THE FUTURE MULTI-ENERGY SYSTEMS: LESSONS LEARNT FROM THE MAGNITUDE PROJECT CASE STUDIES

The question

How can Multi-Energy Systems provide flexibility to the power sector?

Sector coupling technologies



Our starting point: 7 case studies

Mälarenergi Sweden	District heating and cooling
Paper mill Austria	Integrated pulp and paper mill
HOFOR Denmark	Distributed units + district heating
ACS, Italy	Milan district heating
Neath Port Talbot, UK	Industrial MES sites and large RES
EMUASA Spain	Waste water treatment plant
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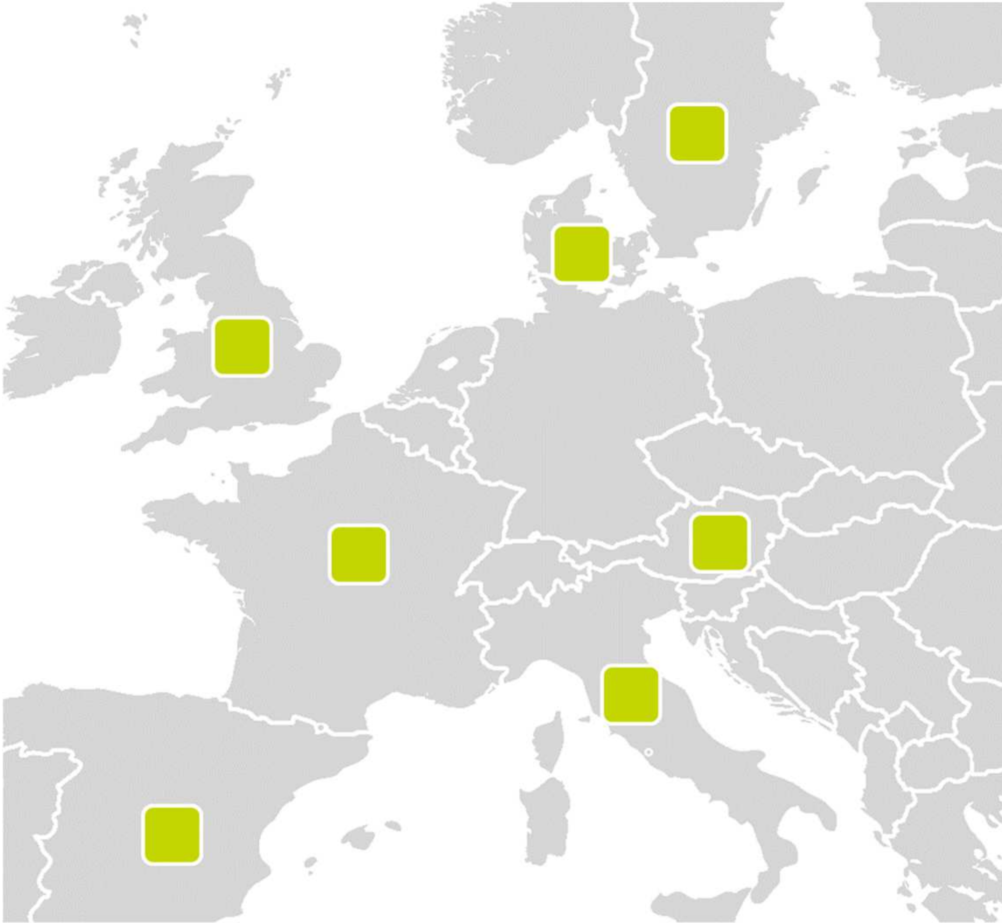


Our starting point: 7 case studies

	Mälarenergi Sweden	Paper mill Austria	Hofor Denmark	ACS Italy	Neath Port Talbot, UK	EMUASA Spain	Paris Saclay France
Industries							
Large commercial and/or public sites							
District heating/cooling	Heating and cooling		Heating	Heating			Heating and cooling
Individual units							

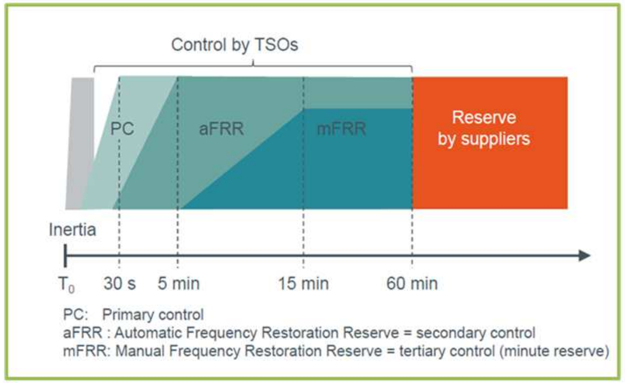
Case Study	Technologies										Networks			
	Bio-mass boiler	Gas boiler	Steam turbine	Gas turbine	Gas engine	Chiller	Heat pump	Electric boiler	(Bio)-Gas storage	Thermal Energy Storage	Heat	Cold	Gas	Power
Mälar-energi														
Mondi														
Hofor														
ACS														
Neath Port Talbot														
EMUASA		Biogas												
Paris Saclay														

Grid services (WP3)

Key needs	Services selected
System adequacy & incentive signals for investors	Guarantee to provide capacities to cover future demand • Capacity requirement mechanisms (FR, GB, IT possibly soon) • Strategic reserve (SE), capacity payment (ES)
Reducing price risks & Optimizing the energy portfolios	Energy trades • Day-ahead energy market = spot market • Intraday energy market
Balancing and frequency control	Provision of reserves for TSOs • Frequency Containment Reserve (FCR) • Automatic Frequency Restoration Reserve (aFRR) • Balancing, manual Frequency Restoration Reserve (mFRR) and Replacement Reserve (RR)
Congestion management	Re-dispatching mechanisms and active power control

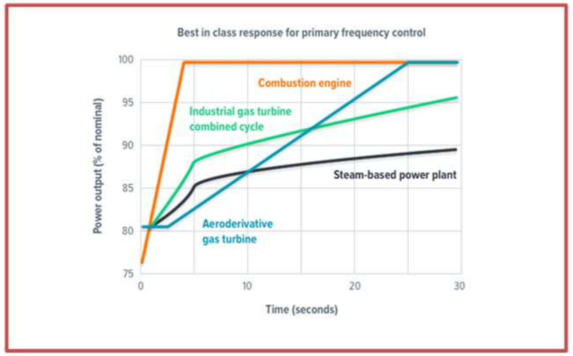
Improvement strategies

How can Multi-Energy Systems provide flexibility to the power sector?



Grid services

Technologies



From a technical perspective, 3 ways of action:

1. replacing a technology or adding a new one → (which often derives in an adaptation of the control strategy)
2. changing the control strategy of one or several energy assets
3. combining the two previous options

Improvement strategies

Case study	Improvement strategies
Mälarenergi	• Investigate the benefits of **thermal storage tanks** and of increase of the electricity generation from the CHP
Paper mill	• Installation of a new **steam accumulator** that would reduce steam blow-off and fuel consumed for steam generation and increase the flexibility of the steam turbines, thus allowing the provision of frequency control • Operation of the whole facility by minimizing gas and electricity peaks
Hofor	• Integration of a **control and communication** interface that allows aggregation and service provision through heat load shifting
ACS	• Improvement of **electrical network** which will allow to provide Frequency Containment Reserve • Investigate the benefits of increasing the **thermal storage capacity** • Investigate **new heat pricing models** for day/night tariffs to optimize heat demand response
Neath Port Talbot	• Investigation of how **gas-fired generators** using fuel from high-pressure gas distribution networks could provide flexibility
EMUASA	• Integration of a **chiller** for the production of cold and of a gas storage to exploit flexibility coming from the gas production line
Paris Saclay	• Integration of **heat pumps** and **thermal storage** in buildings and substations

→ 2 levers to increase the flexibility provision potential:

- Fuel shifting
- Storage

Technology and case studies factsheets

#	Technology
	Power consumption
	Power-to-Heat
1	Heat pumps
2	Electrical boilers
	Power-to-Cold
3	Compression chillers
	Power production
	Heat-to-Power
4	Organic Rankine Cycle
5	Steam turbines
	Gas-to-Power
6	Gas engines
7	Gas turbines
	Supporting technologies
	Storage
8	Thermal storage: Hot water & Steam
9	Gas storage / Gas upgrading
	Heat-to-Cold
10	Sorption chillers

Technologies (stand-alone)

- Short description
- Flexibility key characteristics
- Expected development

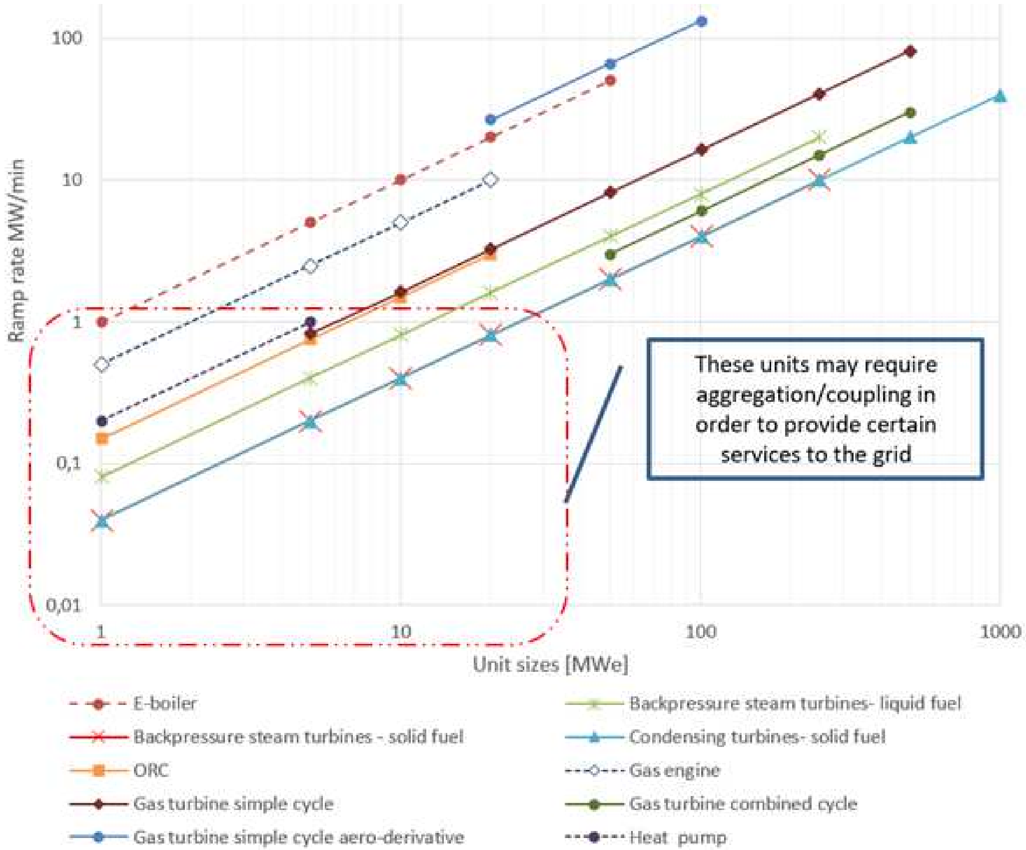
Integration in case studies

- Description of each technology within the CS system
- Additional key characteristics from integration
- Constraints (technical, economic, regulatory, contractual) for flexibility provision

Download the Deliverable 1.2 "Technology and case studies factsheets" here!

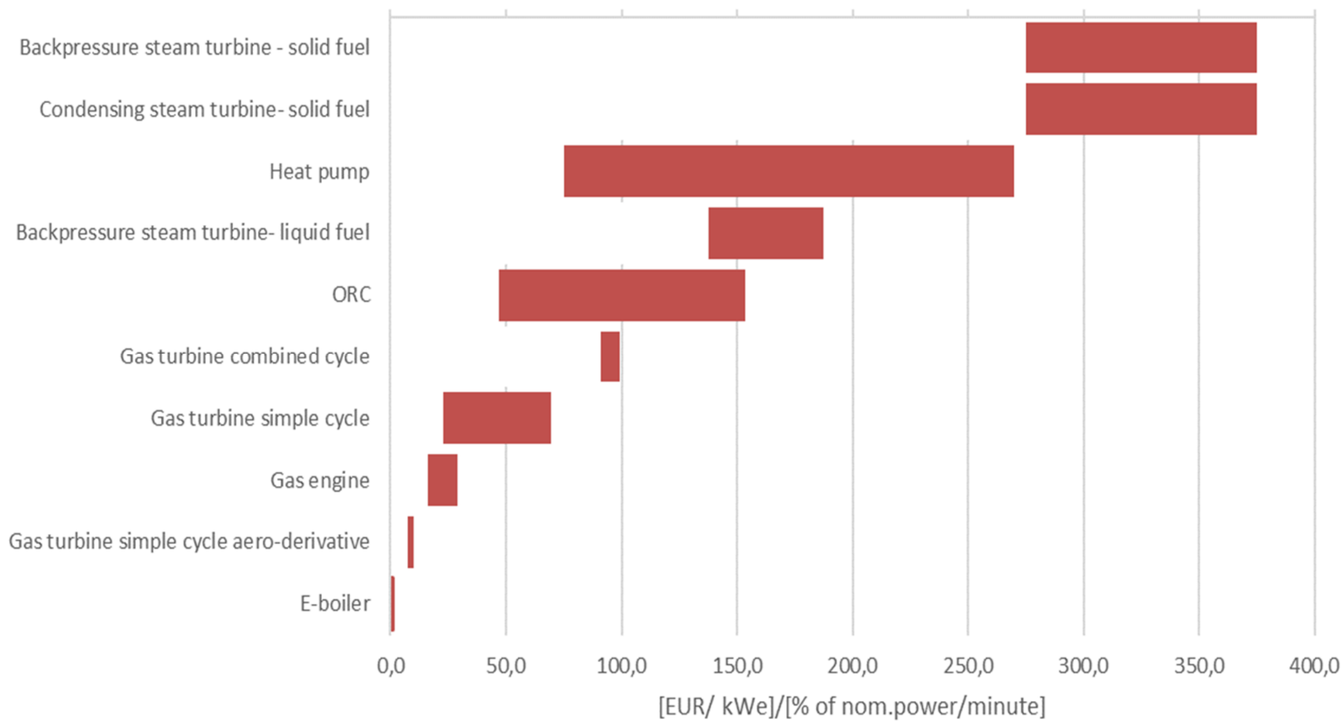
Technology and case studies factsheets

- Key parameters:
  - Power input and output
  - Operating temperature level input and output
  - Minimum load
  - Controllable range
  - Net efficiency or COP
  - Cold start-up time
  - Hot start-up time
  - Ramp-up/down rate
  - Specific investment cost



Power range of analyzed technologies and their ramp rates [MW/min]

Technology and case studies factsheets



Specific cost of investment divided by ramp rates for different technologies

Alessandro Provaggi, DHC+

HEATING AND COOLING PERSPECTIVE IN ENERGY INTEGRATION

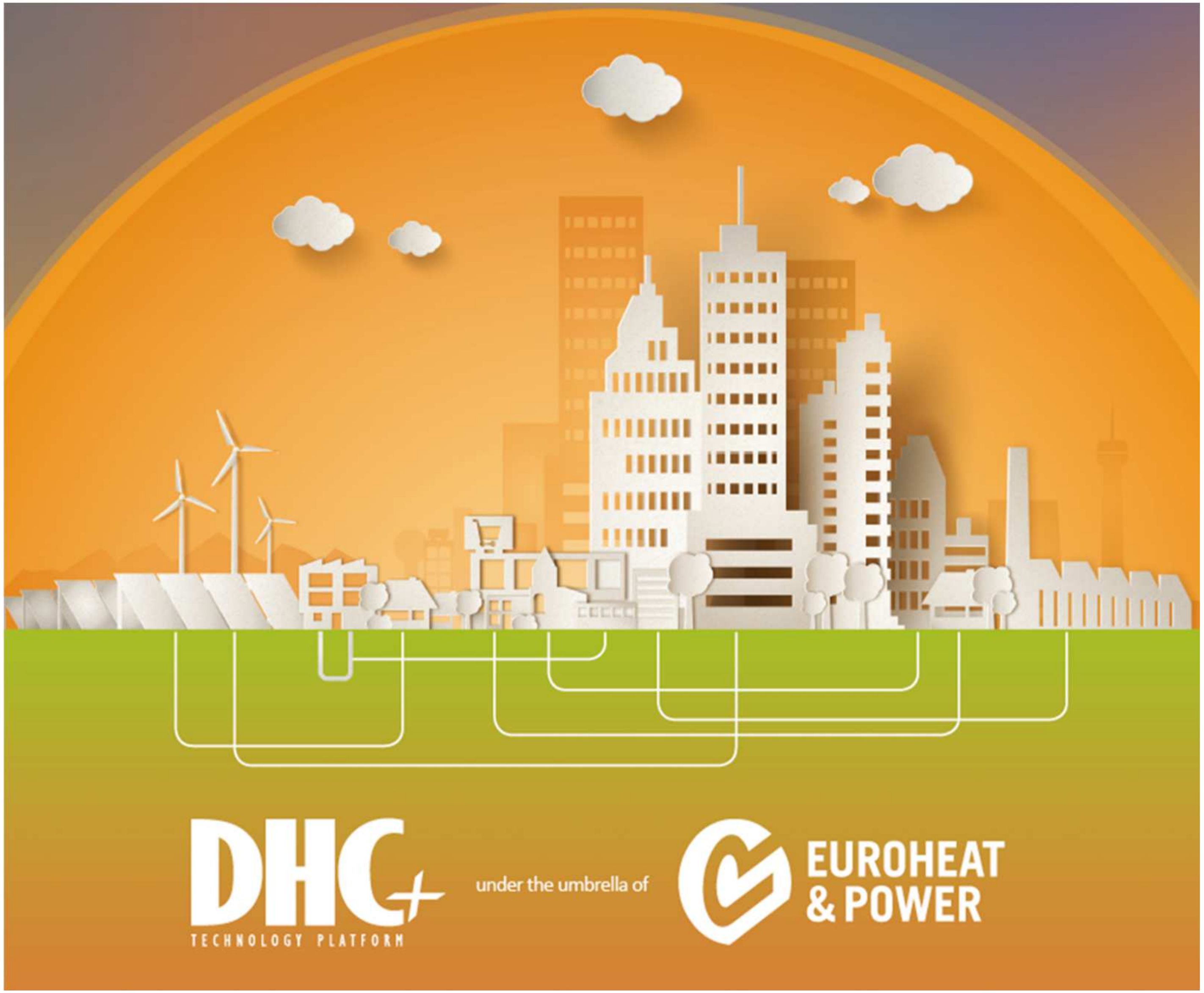
“Heating and cooling perspective in energy integration”

Magnitude Workshop

10 October 19

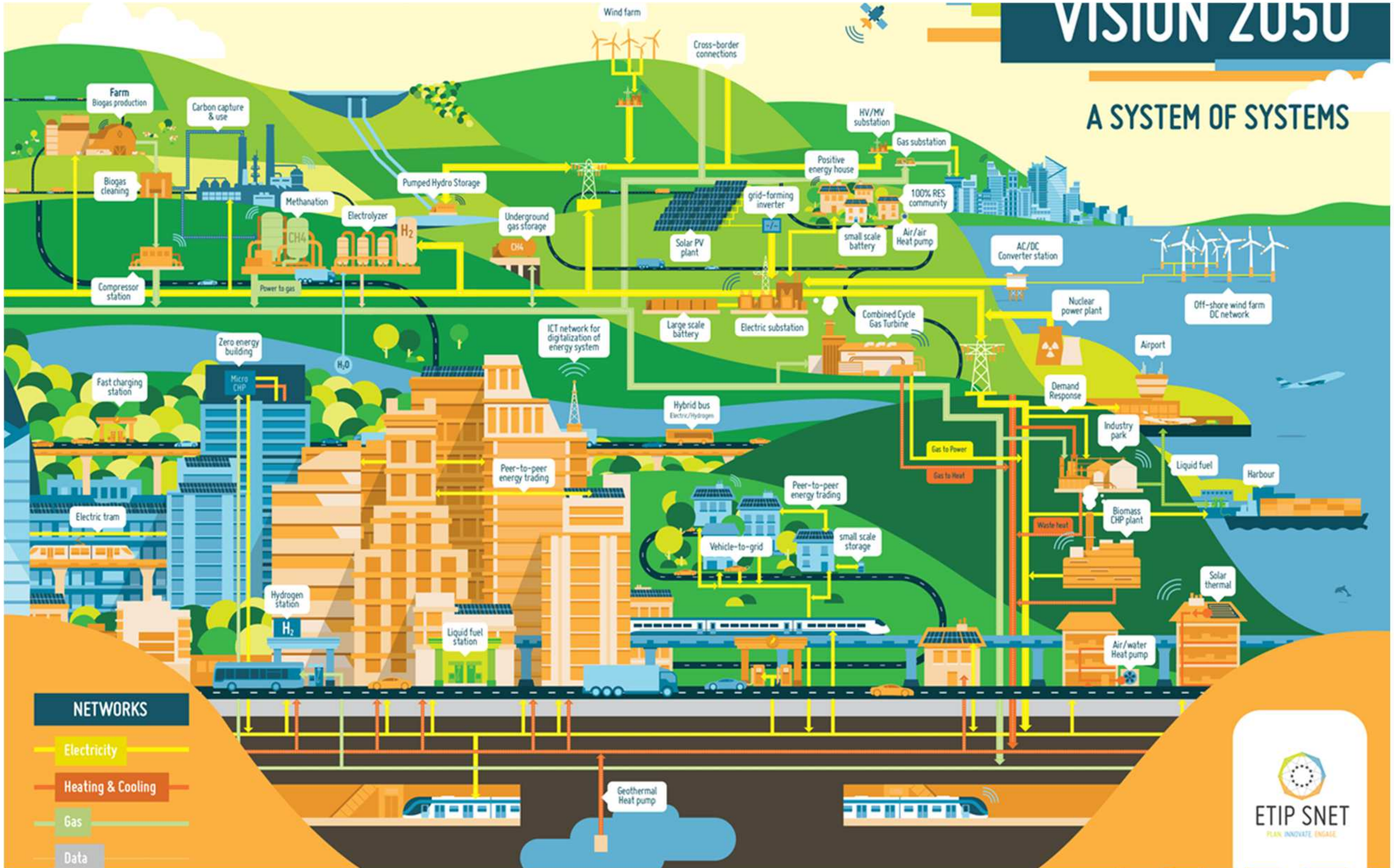
Alessandro Provaggi

Head DHC+ c/o Euroheat & Power



So much more than integrating gas and electricity

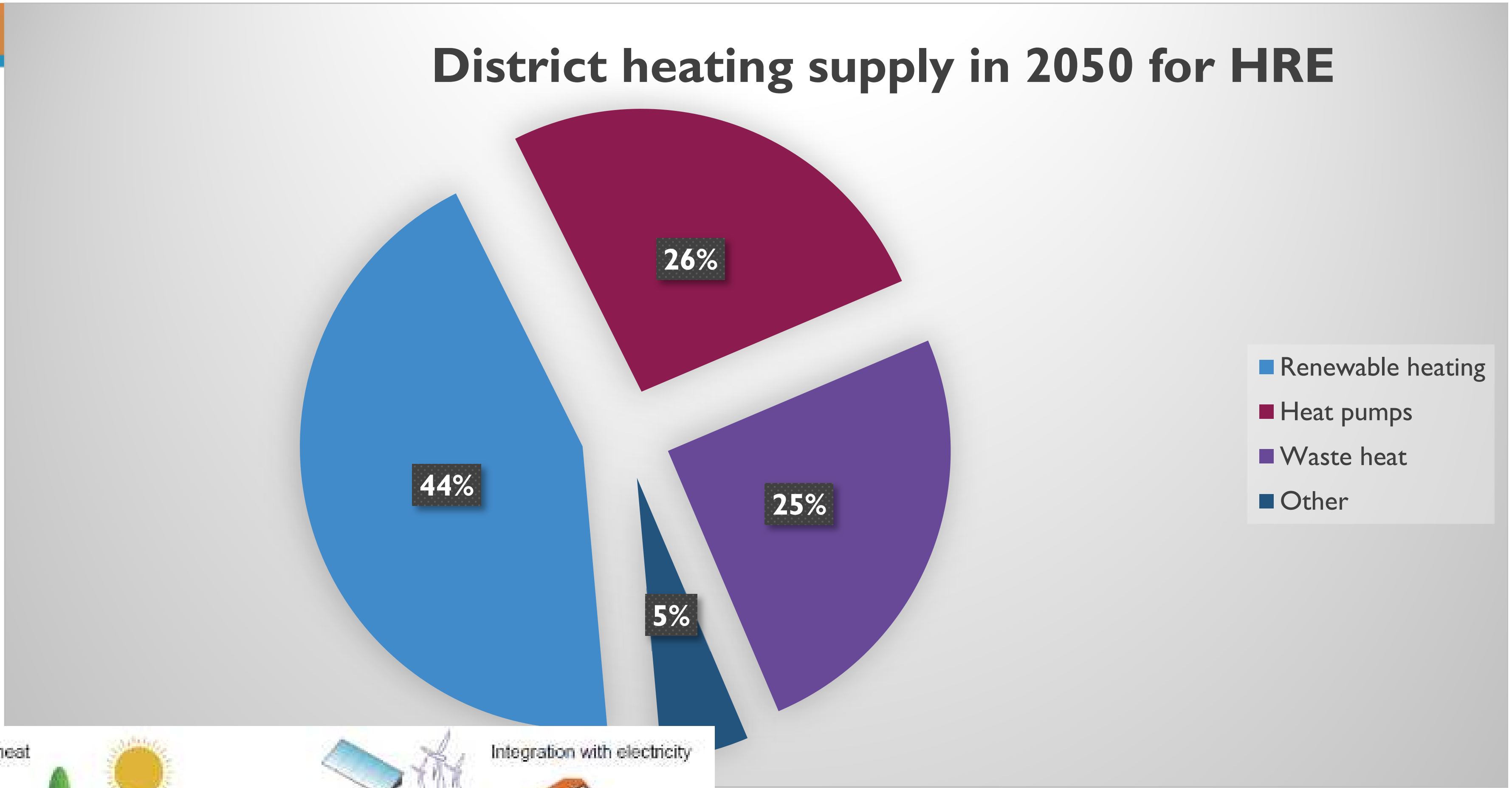
DHC+ TECHNOLOGY PLATFORM

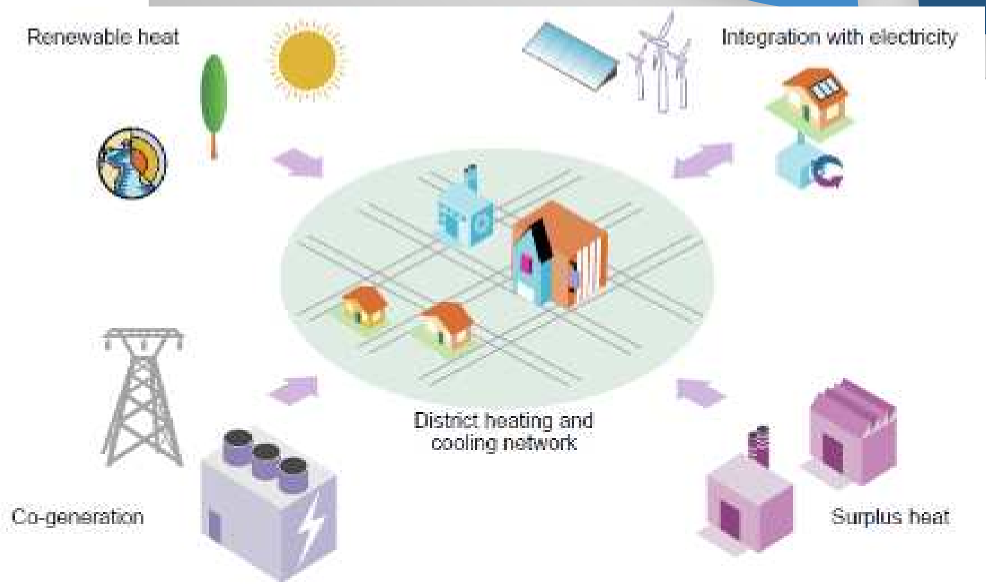


DHC+
TECHNOLOGY PLATFORM

Application of the subsidiarity principle

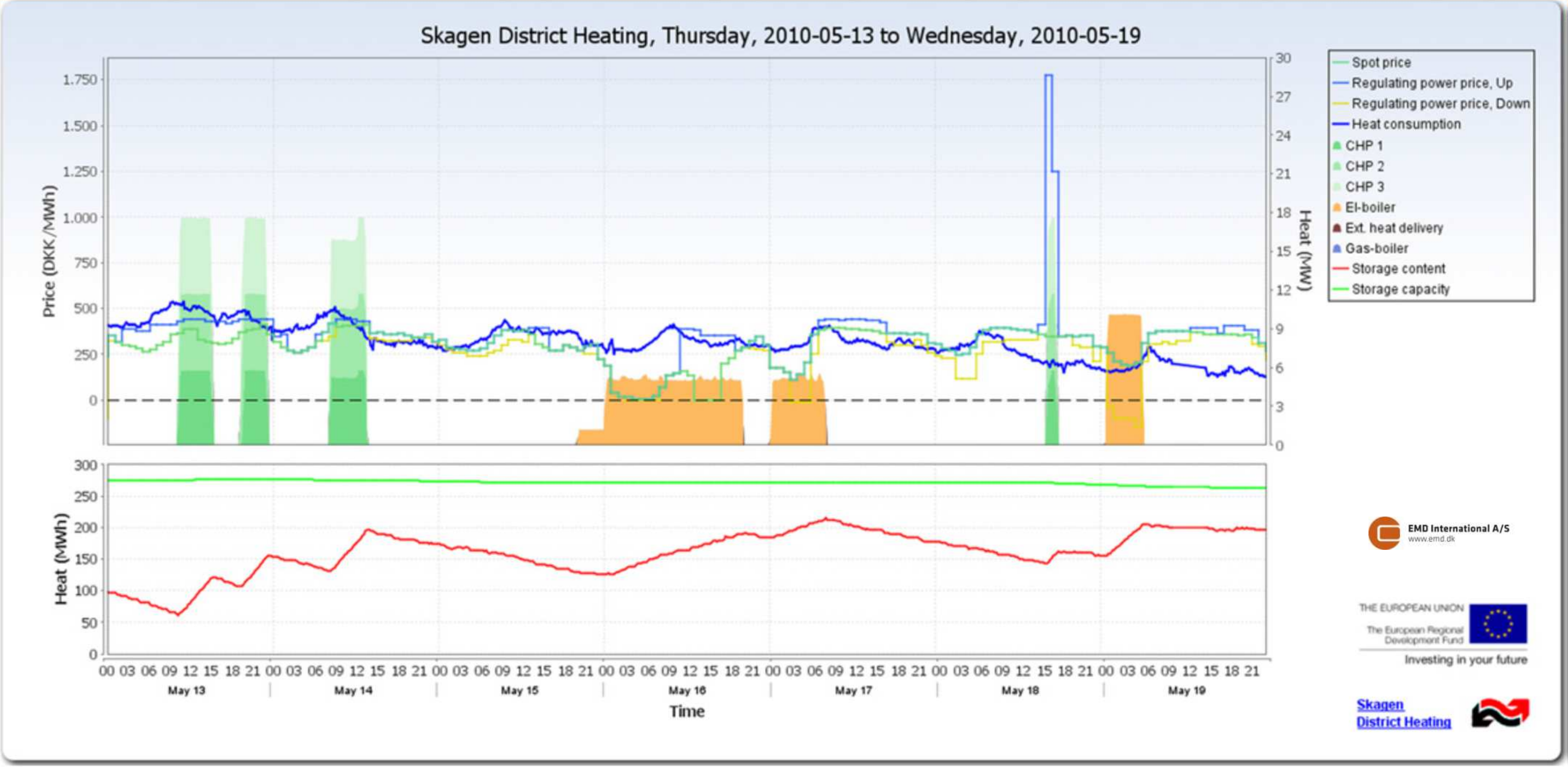
In 2050, the subsidiarity principle is applied to European energy systems. Monitoring and control of generation, conversion, storage and consumption in all energy sectors is done in an integrated, highly automated, fully-trusted way, within regions which are dynamically sized and cell-based. **The subsidiarity principle** means that energy systems are operated in such a way that actions are optimised locally (at the most immediate level). Actions that cannot be handled locally are handled at the next level.





Coupling points heat - electricity in each of the three main supply sectors

www.heatroadmap.eu
@HeatRoadmapEU



Conversion efficiency
Power-to-heat: 300 %
Power-to-gas: 50%

Thermal storage *many times cheaper than electrical ones – increase flexibility potential. From 2 hours to 2 days storage and seasonal storage as well.*

dalkia smart building

GROUPE EDF

SMARTGRID THERMIQUE

La production thermique se fait en toiture et en sous-sol des bâtiments. Elle est assurée par 60% d'énergies vertes et locales :

1 · la géothermie de surface

2 · l'aérothermie et la cogénération à l'huile de colza

3 · la récupération de chaleur sur eaux usées et l'échange de calories entre les bâtiments

4 2 ballons soit 90 m³ permettant de stocker l'eau chaude et l'eau glacée qui alimentent les bâtiments en chauffage, climatisation et eau chaude sanitaire.

2 Chaudières d'appoint au gaz permettant d'assurer la production de chauffage si les besoins sont trop importants en hiver.

SMARTGRID ELECTRIQUE

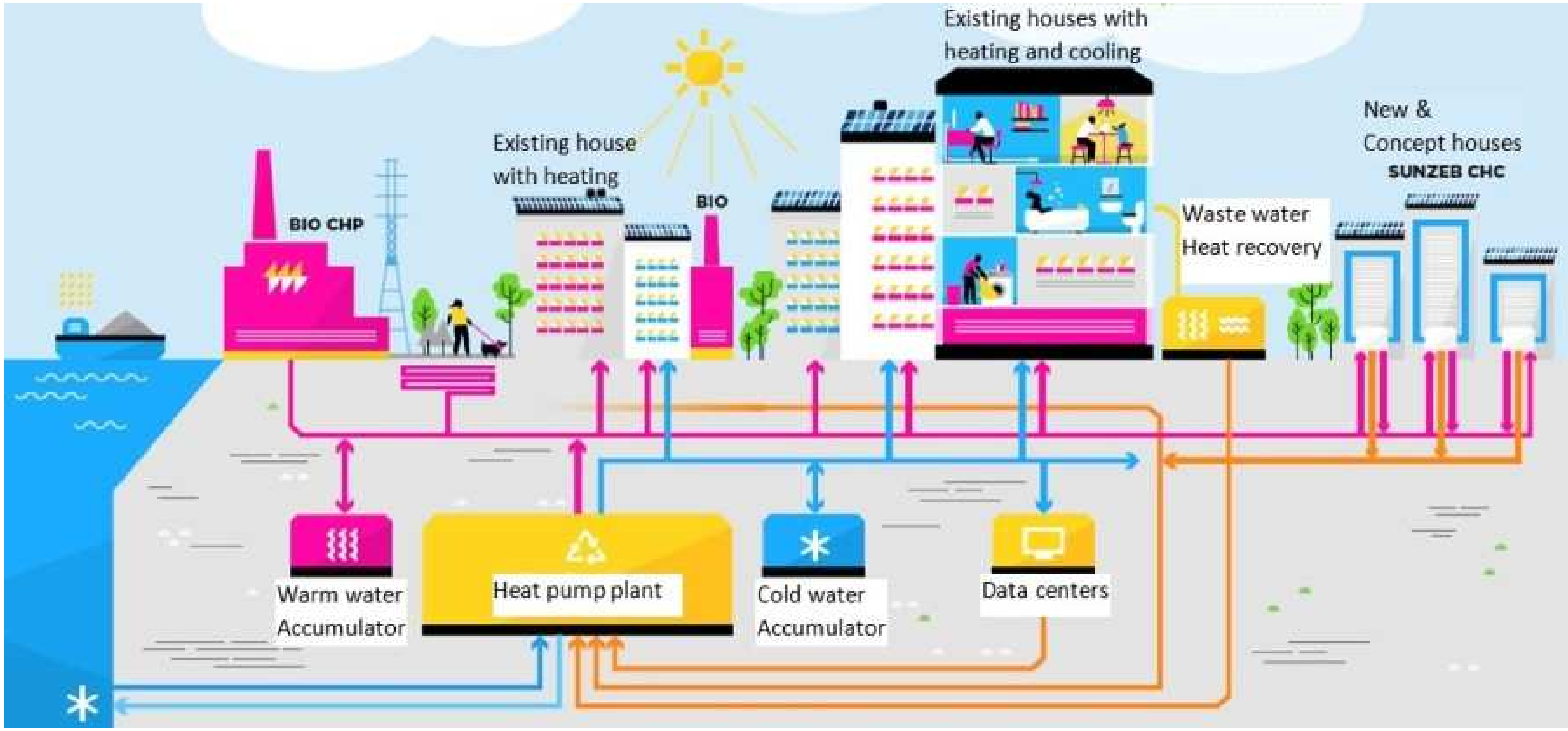
5 La production électrique est assurée par des panneaux photovoltaïques et la cogénération à l'huile de colza.

L'électricité produite est 100% auto consommée par les équipements électriques du réseau tels que les pompes à chaleur.

PILOTAGE NUMERIQUE

6 Le double smartgrid à la fois thermique et électrique est piloté en temps réel afin d'optimiser la performance énergétique et le niveau des charges pour les utilisateurs.

Helsinki - Helen example



Norwegian building stock heated with direct electric heating, while at the same time electrifying several sectors. Difficult to cope for grid investments.

The heating sector represent an opportunity to convert to hydronic systems and to district heating in the cities.

In multifamily buildings need of released electric capacity to enable onsite EV-charging.

Today buildings pay a considerable amount to the grid to upgrade the capacity to handle the EV-charging.

The conversion to district heating could free the capacity needed for these buildings to establish the charging.

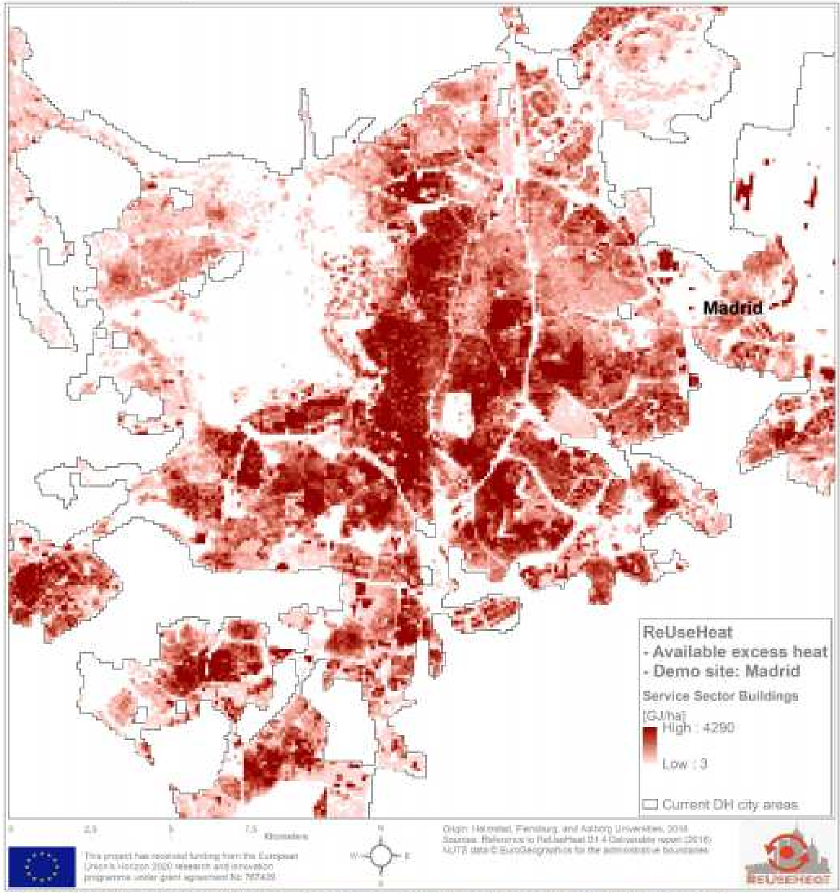


Figure 14. Available excess heat by hectare for service sector buildings. Close-up of the Madrid city area (ES).

www.reuseheat.eu
@ReUseHeat

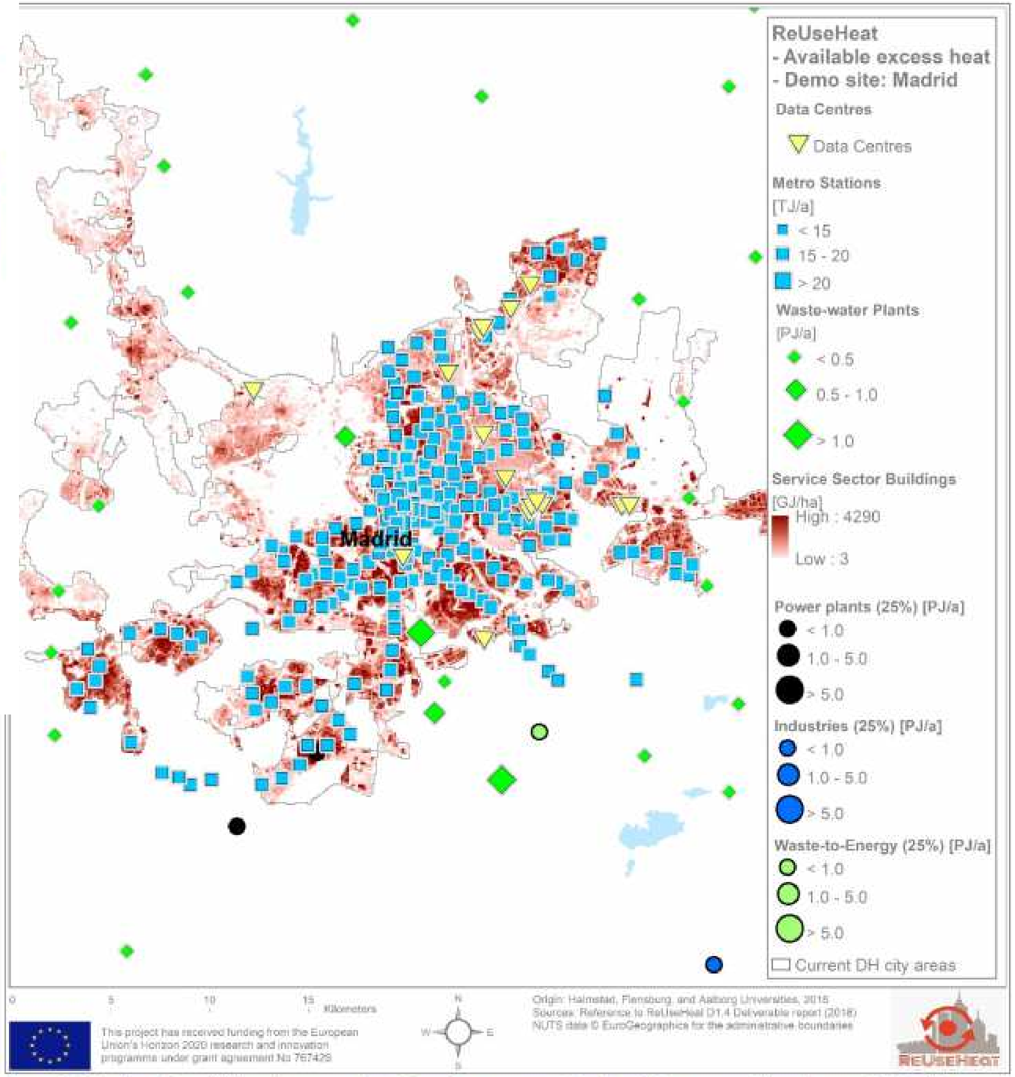


Figure 1. Mapping of available urban excess heat from four unconventional and three conventional sources in the city area of Madrid, one of four project demonstration sites.

We need digitalisation for sector coupling:

- Support operators in managing optimisation across heat, gas and electricity
- Production, distribution, storage and demand duly interconnected to exchange real-time data
- Technical interoperability between DHC and electricity to enable heat pumps and EV loading stations to be integrated
- Need for more pilots and R&D

how to design the market?

Magnitude

DHC+
TECHNOLOGY PLATFORM

Some barriers

Technical requirements for national balancing, wholesale and capacity market participation still prevent flexibility solutions from entering the market

Lower thresholds for entering member states' markets would be beneficial

need to add energy players with small individual capacity i.e; HP to the portfolio of an aggregator

TECHNOLOGY PLATFORM

ap@euroheat.org

Discussion

Poster session and demonstrations

Posters

Flexibility provision by multi-energy systems for services to the electricity system	• Integrated pulp and paper mill in Austria	Cardiff University
	• Milan District heating plant	RSE
	• Economic dispatch of heat pumps considering load shifting between electricity and heat	MDH

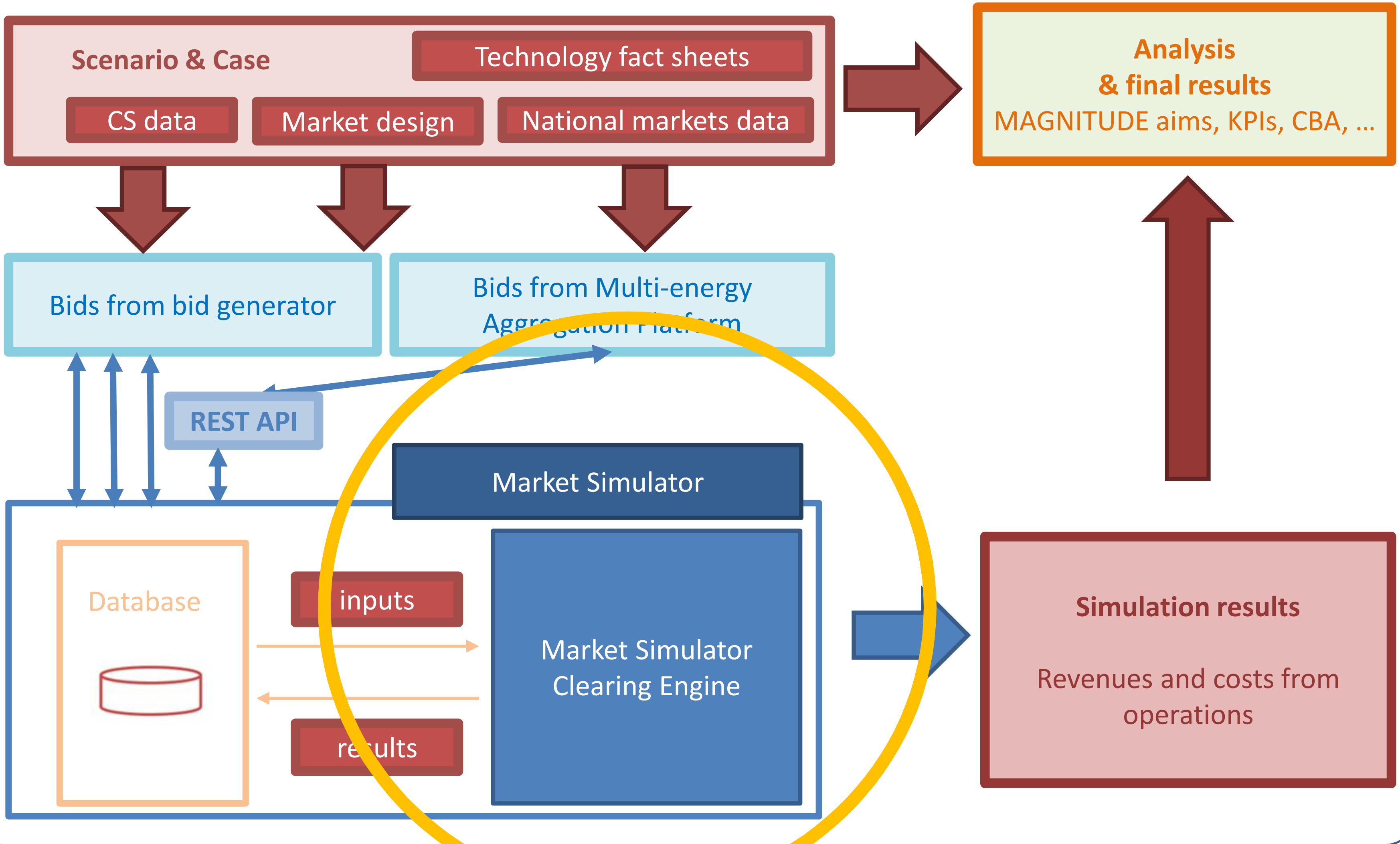
Live demos

Multi-energy market simulation and market price forecasting	• Demonstration of the market simulator for integrated multi-energy carrier systems	VITO/N-SIDE
	• A machine learning algorithm forecasting day-ahead electricity prices in Italy	VITO/N-SIDE

Live Demonstration

MULTI-ENERGY MARKET SIMULATION AND MARKET PRICE FORECASTING

High Level Overview



Market simulator components

- Market Scheme

Name	Value
MarketScheme	SimultaneousMarketScheme
Carriers	GAS, ELECTRICITY
Locations	BE
Timesteps	1

- Orders
  - Elementary orders

Id	Location	Carrier	Timestep	Sense	Price
1	BE	GAS	1	DEMAND	3000
2	BE	GAS	1	SUPPLY	10

  - Conversion Orders

Id	Location	Carrier_origin	Carrier_destination	Timestep	Price	Quantity	Efficiency
3001	BE	GAS	ELECTRICITY	1	0	15	0.71428571

  - Time-shifting orders
    - **For each time period: max energy that can be bought or sold**
    - **Efficiencies for “charging/discharging” (losses when buying / selling)**
    - **A markup for each MWh bought (and resold at some other period), on top of the market price**
    - **Buy and sell operations are profitable (optimal) over the day, given the computed market prices**
- Constraints
  - Pro-rata constraints
    - **constraint two orders to be accepted at same level**
  - Cumulative constraints
    - **limit on the (weighted) cumulated acceptance ratios of several orders**

Market simulator components

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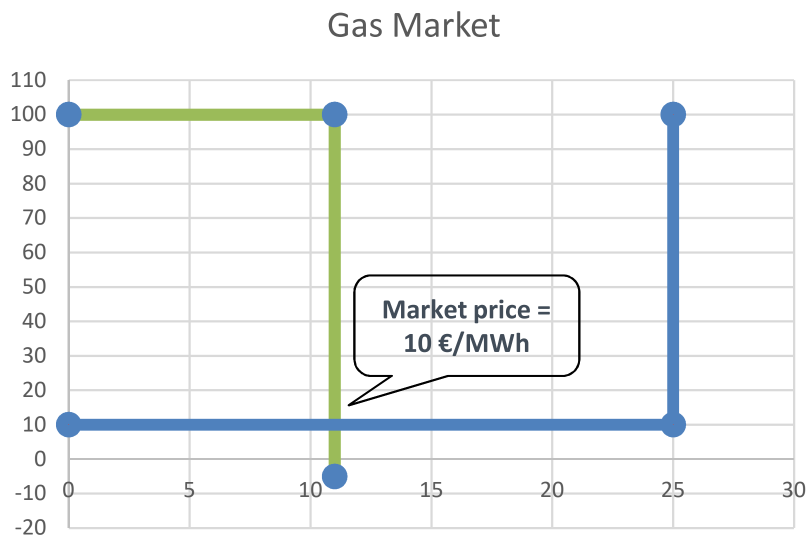
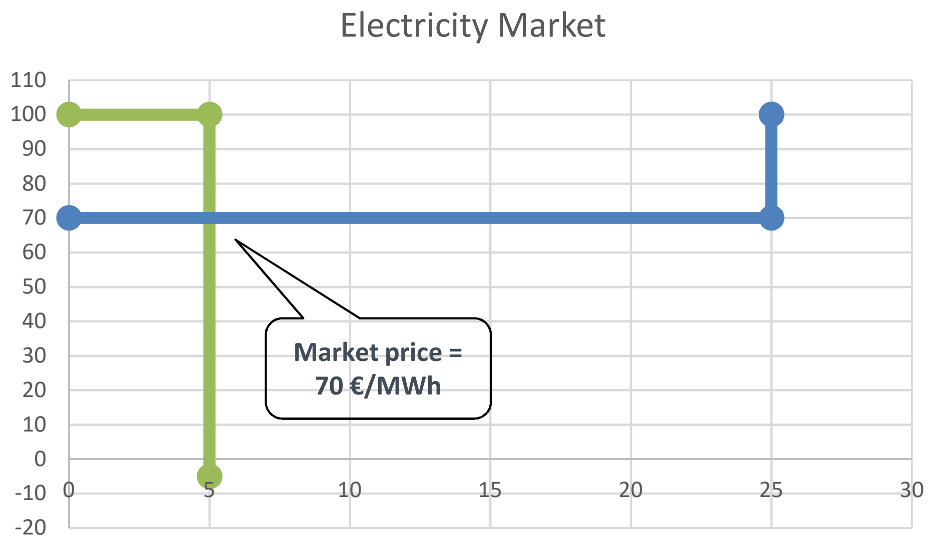
Elementary Orders

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	11	100
Gas Supplier 1	25	10

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	5	100
Elec. Supplier 1	25	70





- Bob buys 11 MWh-gas @ 10 €/MWh
- Bob buys 5 MWh-elec @ 70 €/MWh

In total, Bob pays 110€ + 350 € = 460 €

How to optimally operate a conversion technology without facing uncertainties ?

Alice has a conversion technology

- 7 MWh-gas are converted to 5 MWh-elec

  Efficiency = $\frac{5}{7}$

If the market price of gas = 10 €/MWh

Market price of electricity to break even ?

- Alice buys 7 MWh-gas @ 10 €/MWh
- She resells 5 MWh-elec @ P_e €/MWh
- → $P_e \geq \frac{7 \times 10}{5} = 14€/MWh$ for Alice to break even

If the market price of gas is P_g ?

- $P_e \geq \frac{7 \times P_g}{5}$ $\Leftrightarrow$ $\frac{5}{7} P_e \geq P_g$

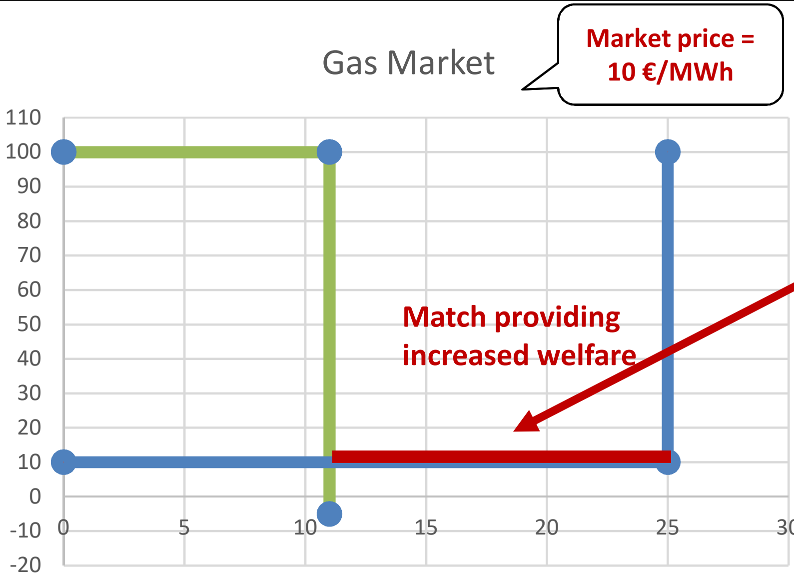
- How Alice can be sure of the price ratio before buying gas ?
- If price ratio turns out to be too bad, Alice will incur losses
- If she doesn't trade to full capacity but the price ratio is good enough, she will face opportunity costs

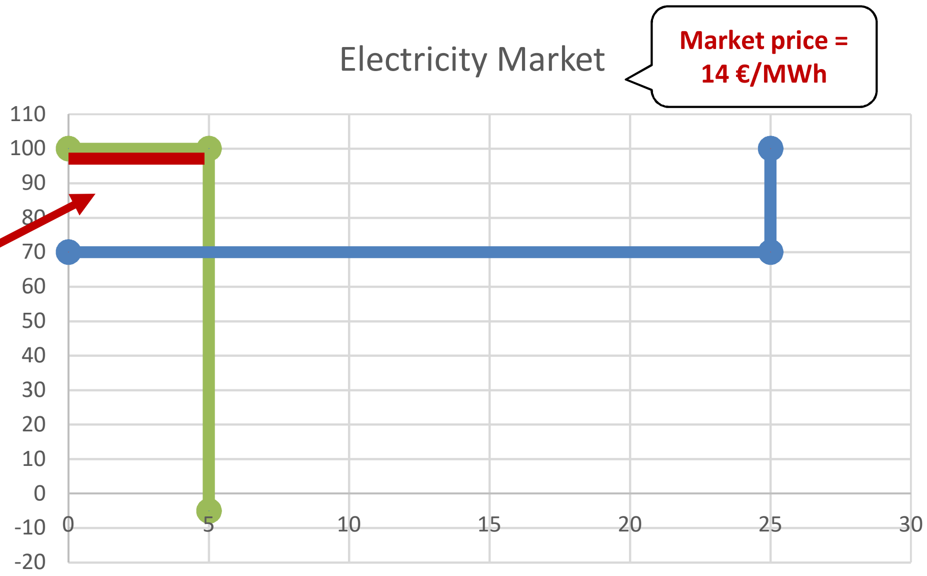
Conversion orders ensure an optimal outcome in all scenarios !

Conversion Orders

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	11	100
Gas Supplier 1	25	10

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	5	100
Elec. Supplier 1	25	70





Bids	Capacity (MWh)	Efficiency	Cost of conversion
Conversion Order	15	5/7 (7MWh Gas = 5 MWh Elec.)	0 €/MWh

In total, Bob pays 110€ + 70 € = 180 €

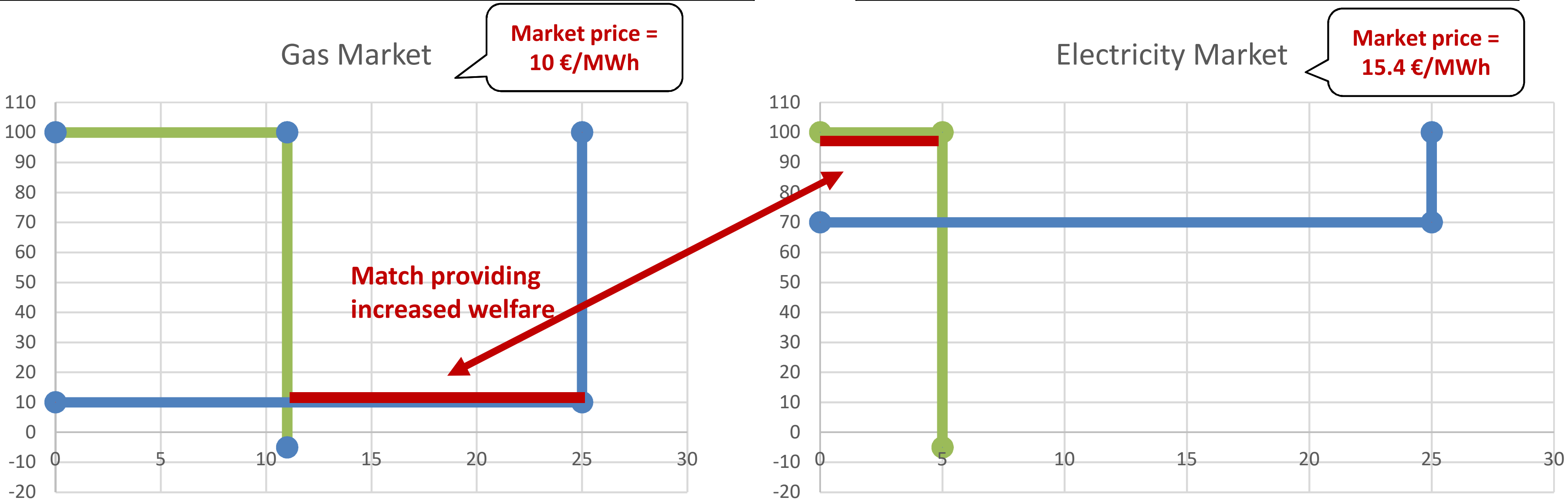
- Bob buys 11 MWh-gas @ 10 €/MWh
- Alice's conversion order
  - buy 7 MWh-gas @ 10 €/MWh
  - resell 5 MWh-elec @ 14 €/MWh
  - 7 * 10 €/MWh-gas = 5 * 14 €/MWh-elec
- Bob buys 5 MWh-elec @ 14 €/MWh

- Conversion order and gas supply fractionally accepted
- Should be "at-the-money" (market equilibrium / marginal pricing principle)

Conversion Orders

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	11	100
Gas Supplier 1	25	10

Bids	Quantity (MWh)	Limit Price (€/MWh)
Bob's demand	5	100
Elec. Supplier 1	25	70



Bids	Capacity (MWh)	Efficiency	Cost of conversion
Conversion Order	15	5/7 (7MWh Gas = 5 MWh Elec.)	1 €/MWh

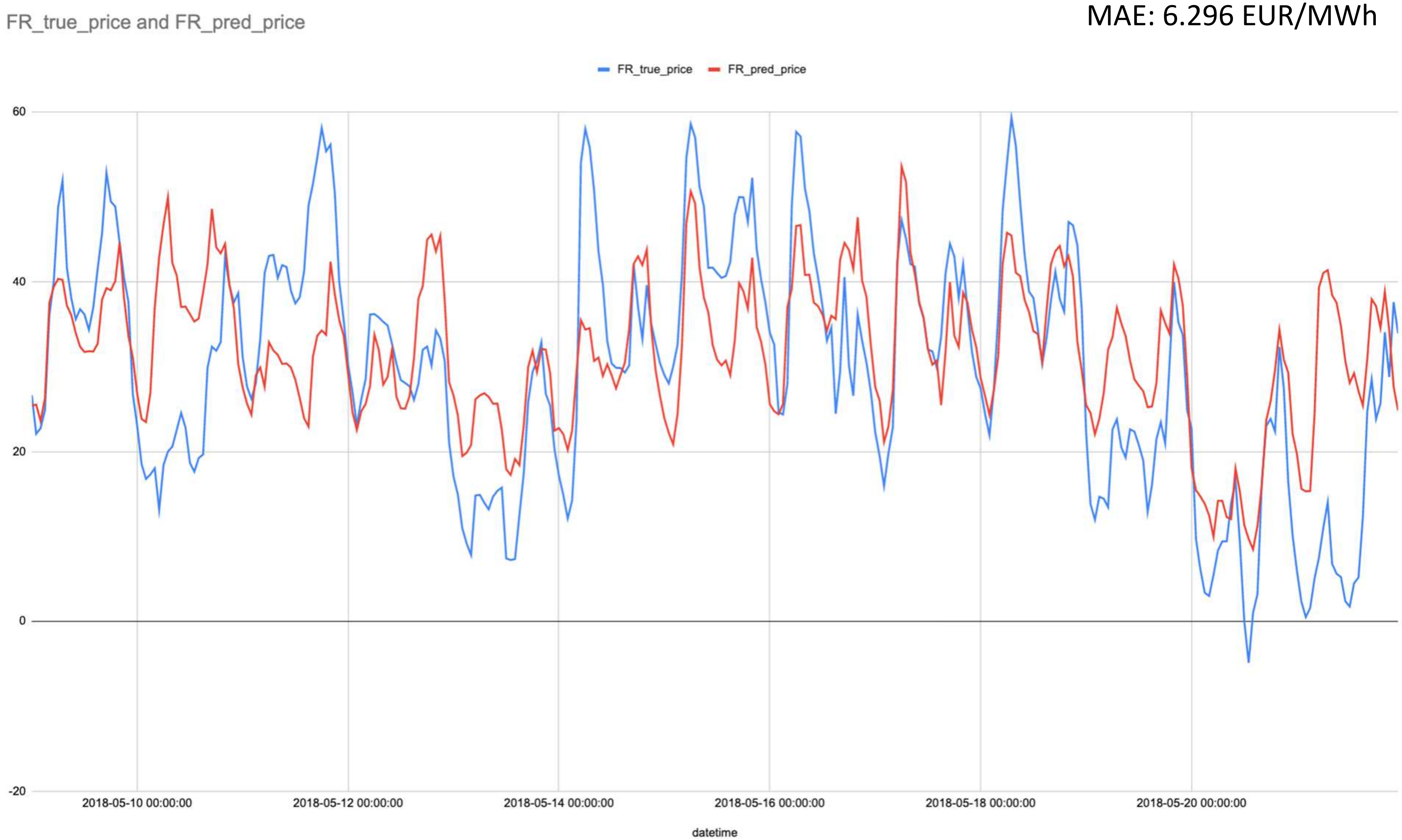
In total, Bob pays 110€ + 77 € = 187 €

- Bob buys 11 MWh-gas @ 10 €/MWh
- Alice's conversion order
  - buy 7 MWh-gas @ 10 €/MWh
  - resell 5 MWh-elec @ 14 €/MWh
  - 7 * [10 + 1] €/MWh-gas = 5 * 15.4 €/MWh-elec
- Bob buys 5 MWh-elec @ 15.4 €/MWh

- Conversion order and gas supply fractionally accepted
- Should be "at-the-money" (market equilibrium / marginal pricing principle)

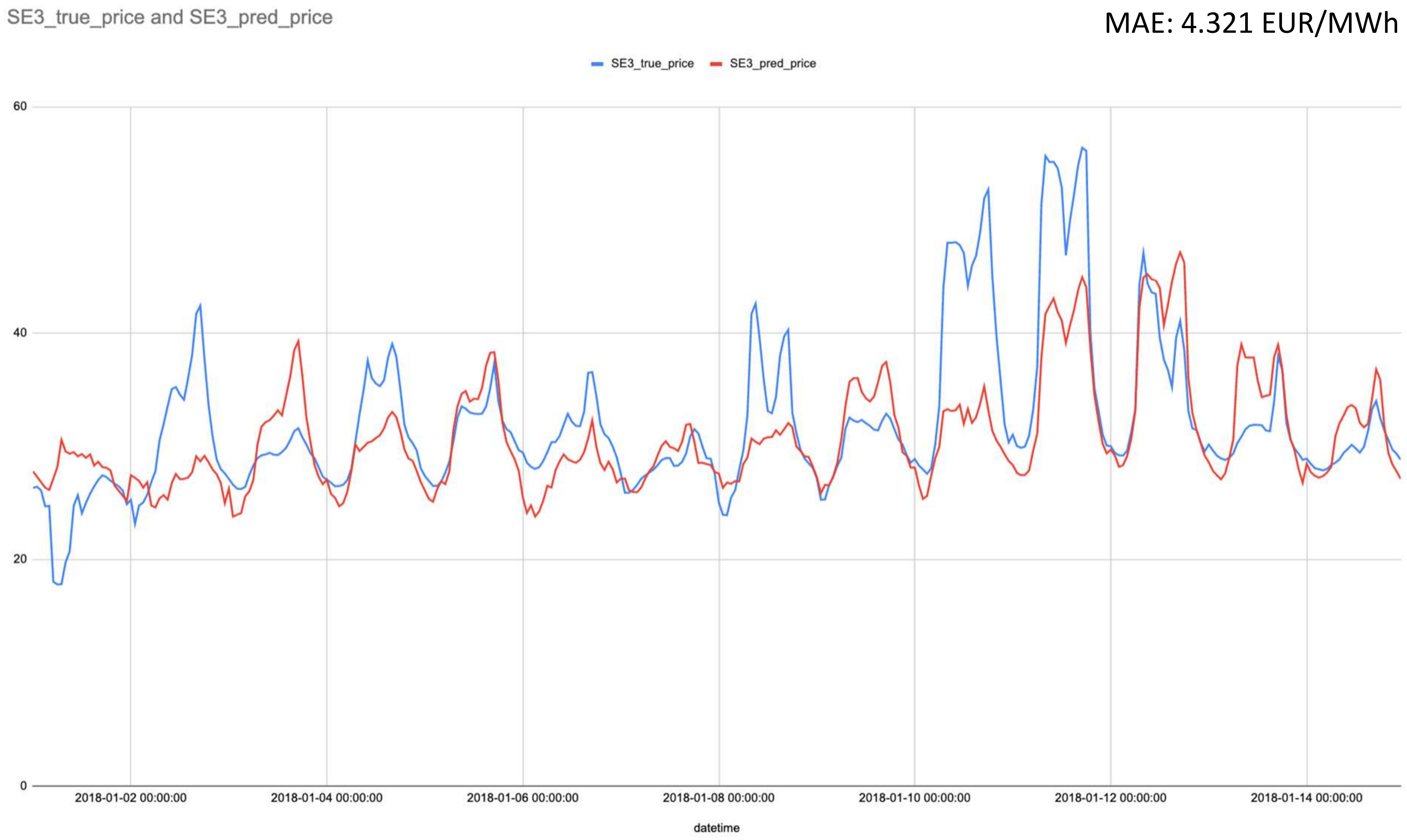
WP5: Forecast by VITO: France
Day Ahead Prices

MAE: 6.296 EUR/MWh



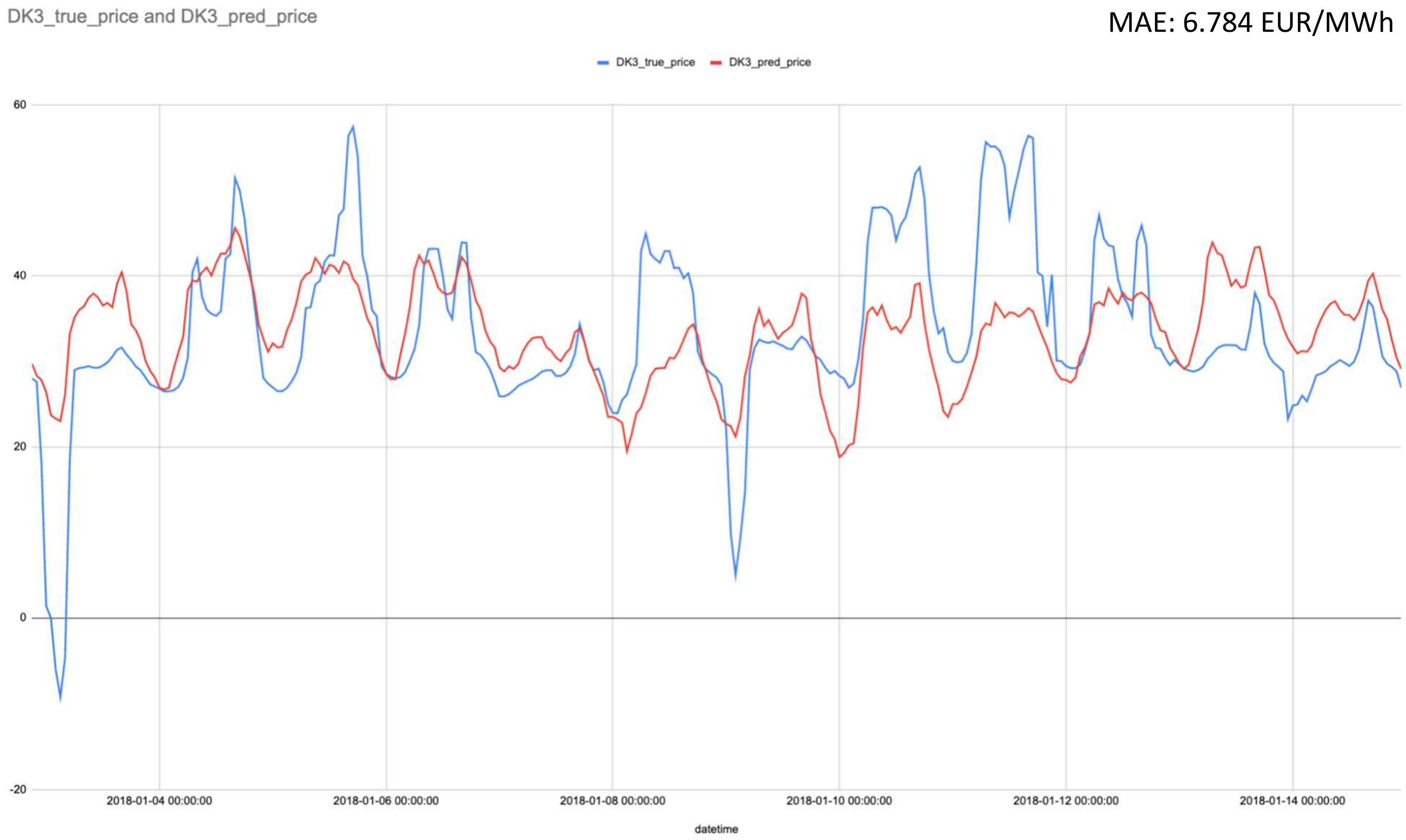
WP5: Forecast by VITO: Sweden Day Ahead Prices

MAE: 4.321 EUR/MWh

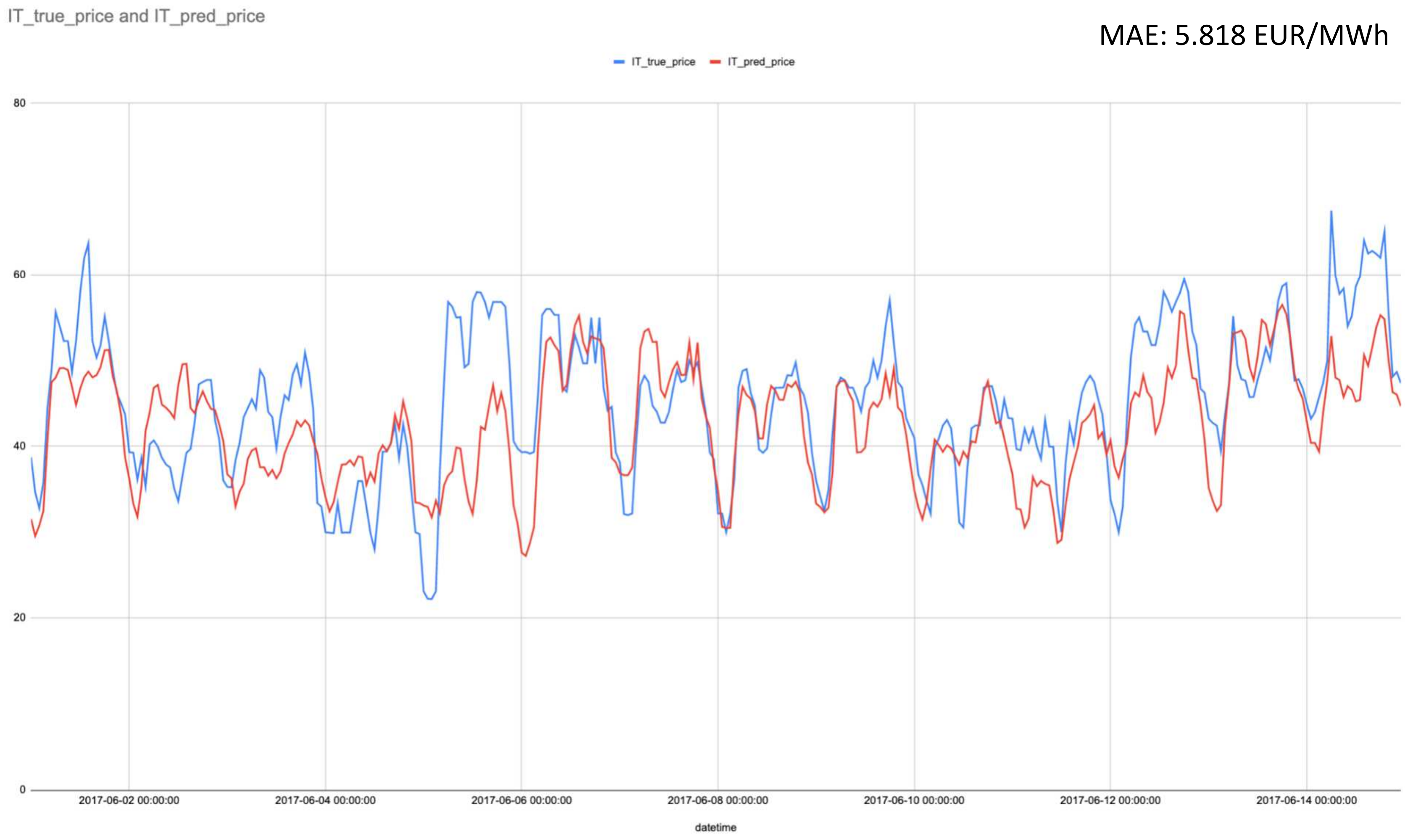


WP5: Forecast by VITO: Denmark Day Ahead Prices

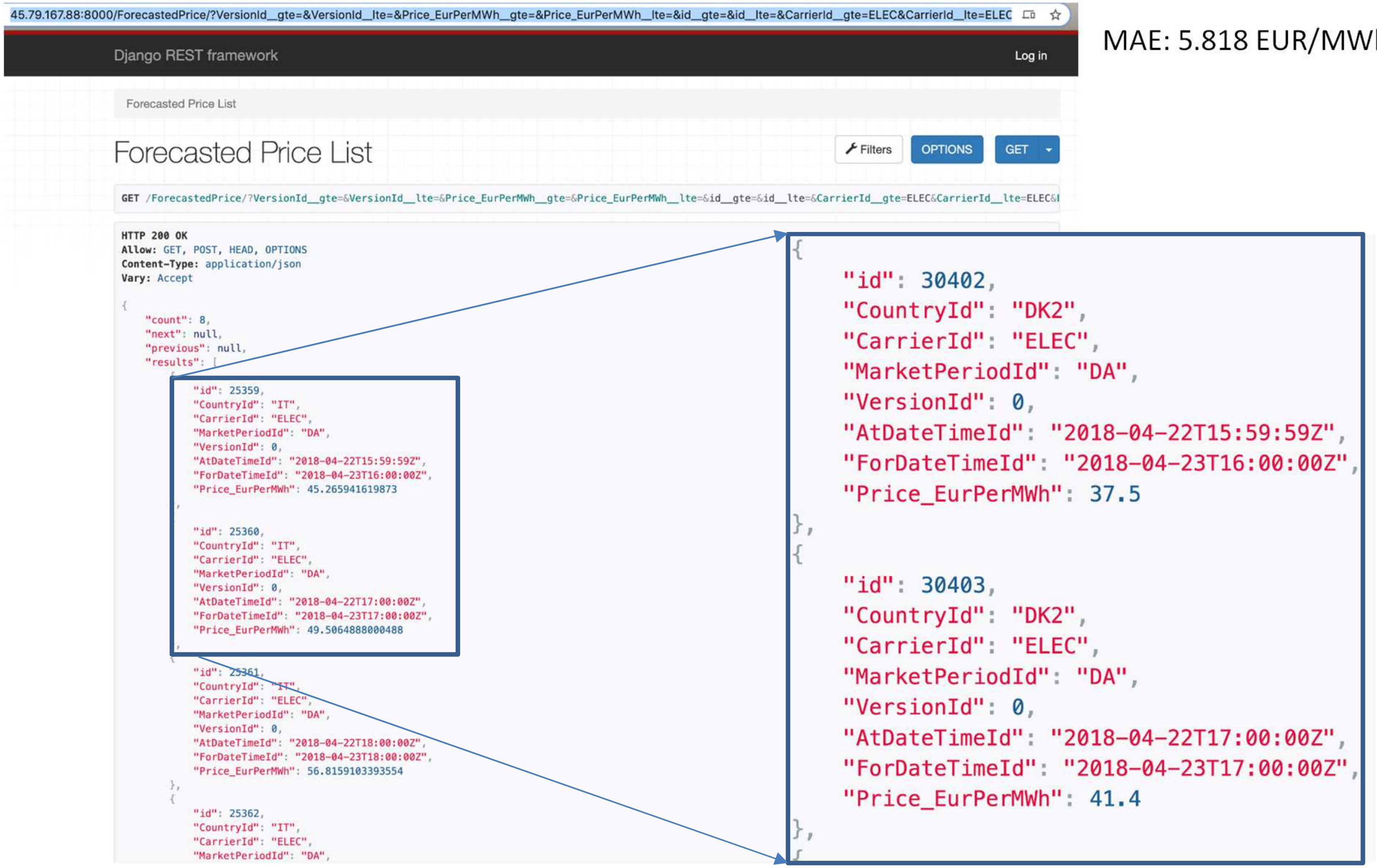
MAE: 6.784 EUR/MWh



WP5: Forecast by N-SIDE: Italy Day Ahead Prices

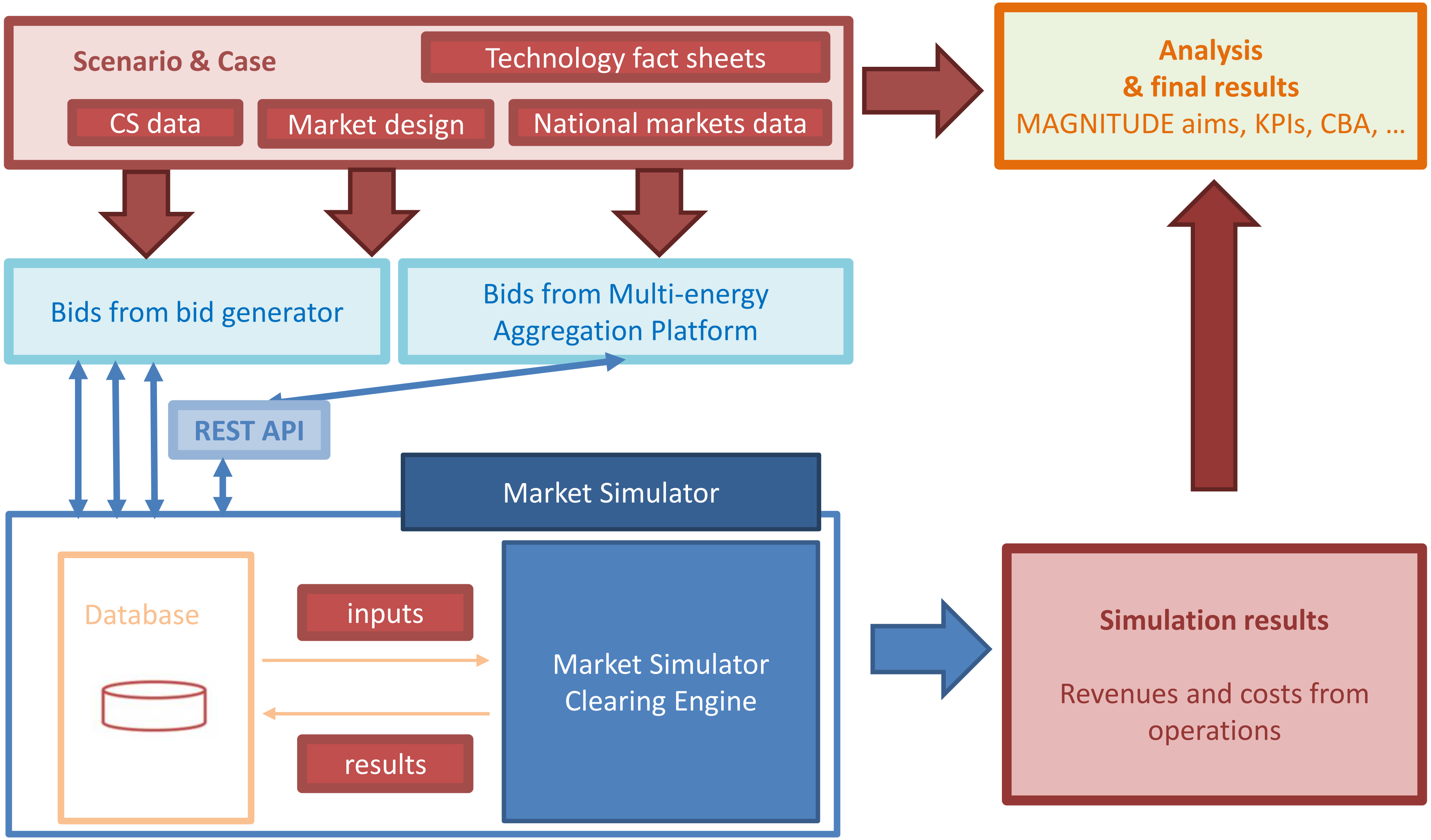


WP5: N-SIDE REST interface to read Forecasts



MAE: 5.818 EUR/MWh

Towards Implementation



Chair: Kris Kessels, VITO

SESSION 2: AGGREGATION AND MARKET INTEGRATION OF MULTI-ENERGY SYSTEMS

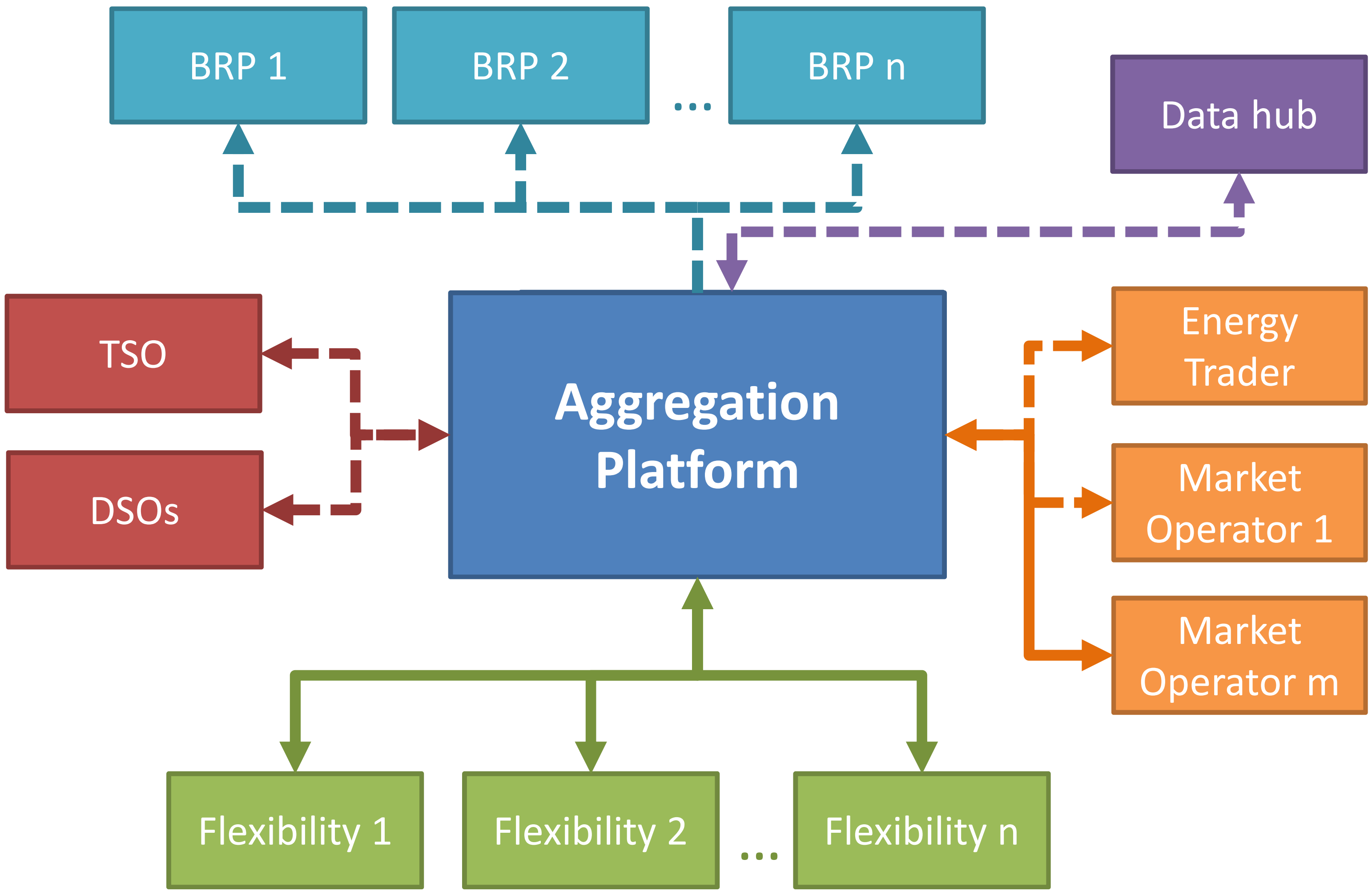
Session 2

Aggregation and market integration of multi-energy systems	Chair: Kris Kessels, VITO
• **Flexibility provision by MES through aggregation in support of the power system** • Multi energy aggregation platform for the provision of flexibilities: the MAGNITUDE perspective • Energy Communities leveraging flexibility by Active Connected Buildings: experience from the FHP (Flexible Heat and Power) project	 Christoph Gutschi, cyberGRID Chris Caerts, VITO
• **Future market design for improved sector coupling** • Innovative market schemes for integrated multi-energy systems: the MAGNITUDE perspective • A local marketplace for electricity, district heating and cooling in Gothenburg: the experience of the FED project	 Kris Kessels, VITO Magnus Brolin, RISE
• **Discussion**	

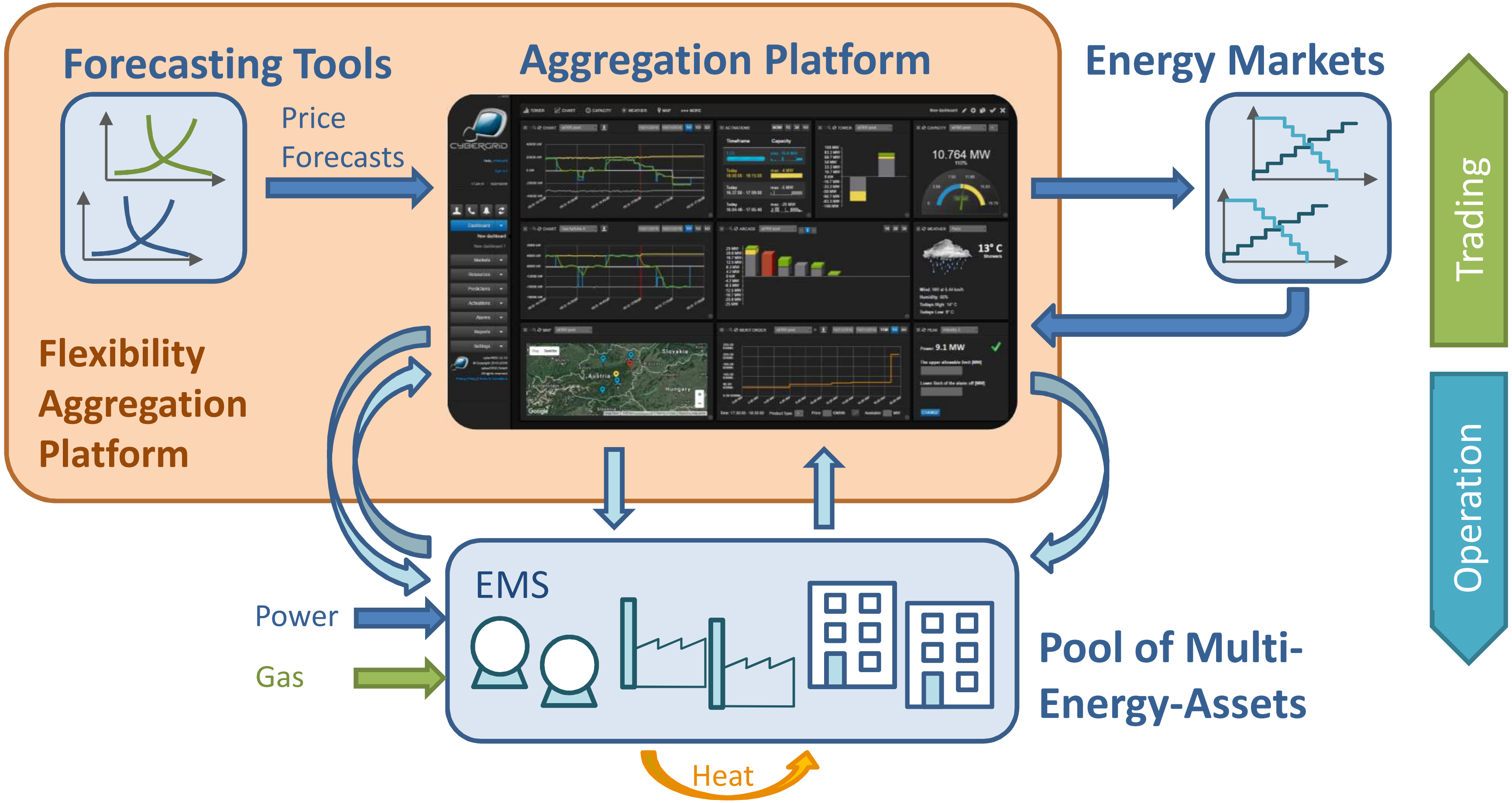
Christoph Gutschi, cyberGRID

MULTI ENERGY AGGREGATION PLATFORM FOR THE PROVISION OF FLEXIBILITIES: THE MAGNITUDE PERSPECTIVE

Overview of the aggregation processes



Scope of Flexibility Aggregation



“accelerated real-time”: timeframe and speed of simulation adapted to simulation targets

Flexibility Aggregation Platform

- The aggregation platform is considered as a technical service, not a business model
- Based on an existing VPP solution, which serves as “process controller” and database
- High scalability due to micro-service architecture
- Technology agnostic approach
- Flexibility Aggregation Platform can operate the 3 business phases in parallel:

- Additional modules to deal with challenges of multi energy system behavior
  - Price forecasts for all relevant markets
  - Management of uncertainties (assess required backup)
  - Assessment of behavior of large number or unmanaged units
  - Assessment of unmanaged units with storage behavior
  - Optimized market allocation of forecasted flexibility
- Integration with MES/EMS simulators and market simulators

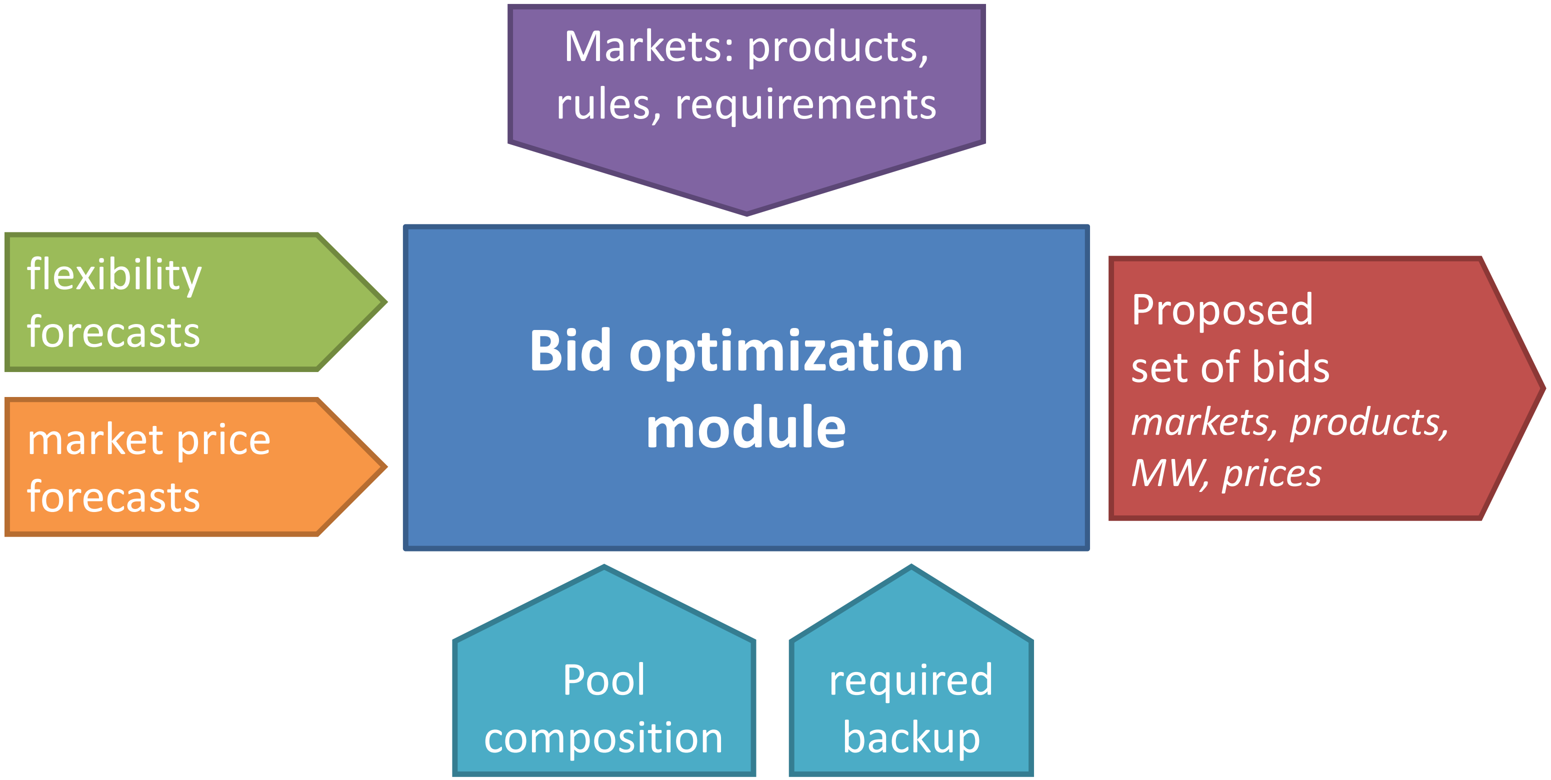
Relevant services and markets

Case study	Services identified in Deliverable D3.1						
	FCR	aFRR	mFRR	ID	DA	ReD	Cap
Mälarenergi AB	-	-	-	X	X	-	-
	-	-	X (HP)	X	X	-	X
Paper Mill	-	X[2]	X	-[1]	-[1]	-	-
	(X)	X	X	X	(X)	(X)	-
Hofor	-	-	-	-	-	-	-
	-	(X)	(X)	X	X	X	-
ACS	-	-	-	X	X	-	-
	X	X	X	X	X	X	(X)
Neath Port Talbot	X	-	X	X	X	-	-
	X	-	X	X	X	X	X
EMUASA	-	-	-	-	-	-	-
	-	X	X	X	X	-	-
Paris Saclay	-	-	-	-	-	-	-
	-	(X)	X	X	X	(X)	X

Services already provided by MES	X= yes, - = no
Services that could be provided through aggregation	X= yes, - = no, (X) = possibly
Services selected	X

[1] indirectly through the supplier
[2] starting in 2019

Creating the flexibility bids



Comparing markets: Different products and forecasting horizons

Example: Austria, 2018

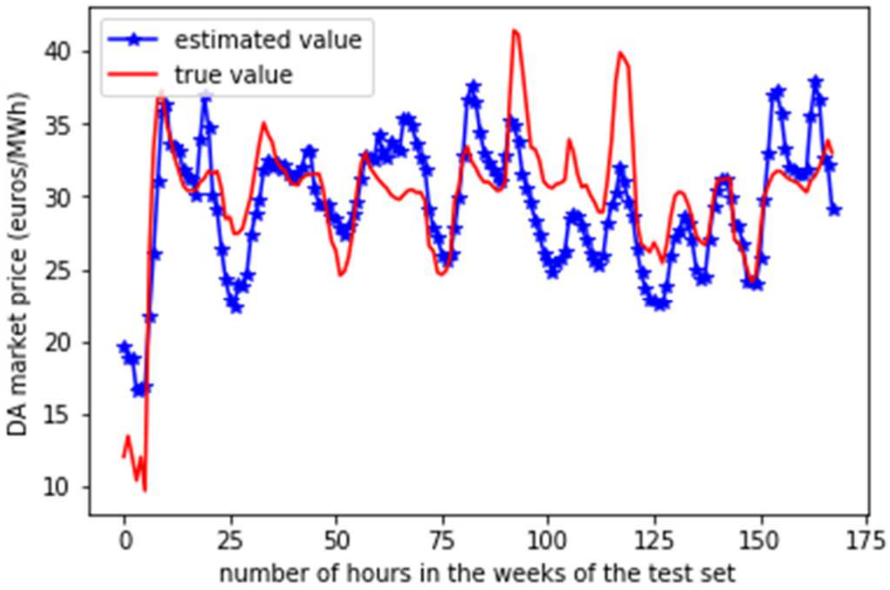
	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
	d	d+1	d+2	d+3	d+4	d+5	d+6	d+7	d+8	d+9	d+10	d+11	d+12
FCR weekly	GC						1 product						
aFRR daily		6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6
mFRR weekly			GC		6+6		6+6						
mFRR daily		6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6	6+6
DA		24	24	24	24	24	24	24	24	24	24	24	24
ID	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96	24/96
gas		1	1	1	1	1	1	1	1	1	1	1	1

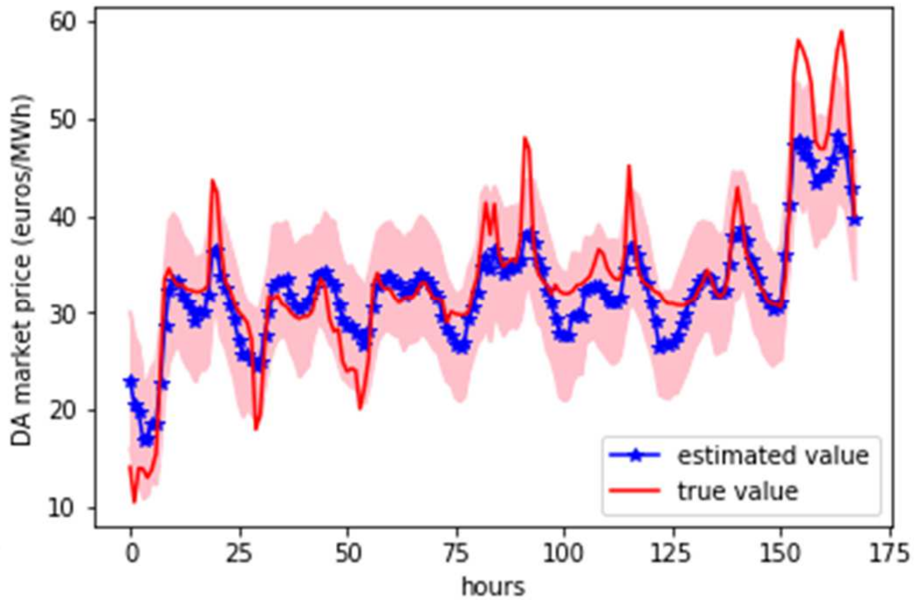
Price forecasting for d+1

Example: Denmark
Day ahead market
(source: VITO)

Time prediction window: 1-day (24h)

[€/MWh]	DK1	DK2
Average Error	**- 1.413**	**-0.576**
MAE	**2.745**	**2.865**
MSE	**0.260**	**0.273**
MAPE in [0,1]	**0.096**	**0.104**



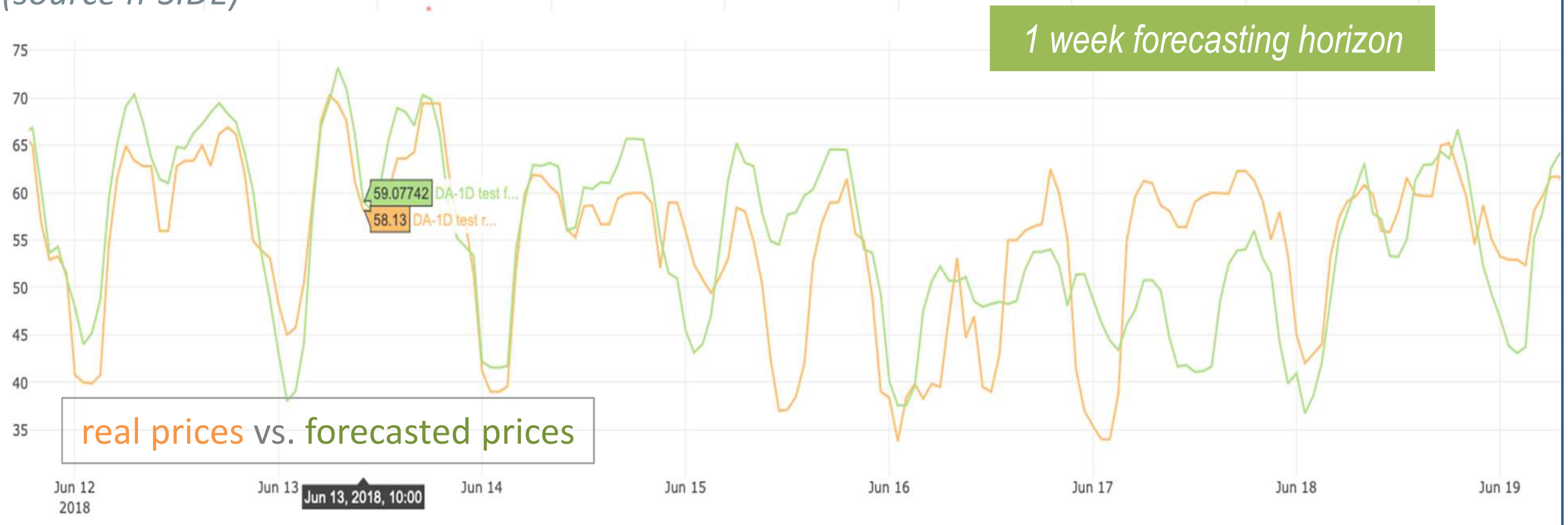


Price forecasting for w+1

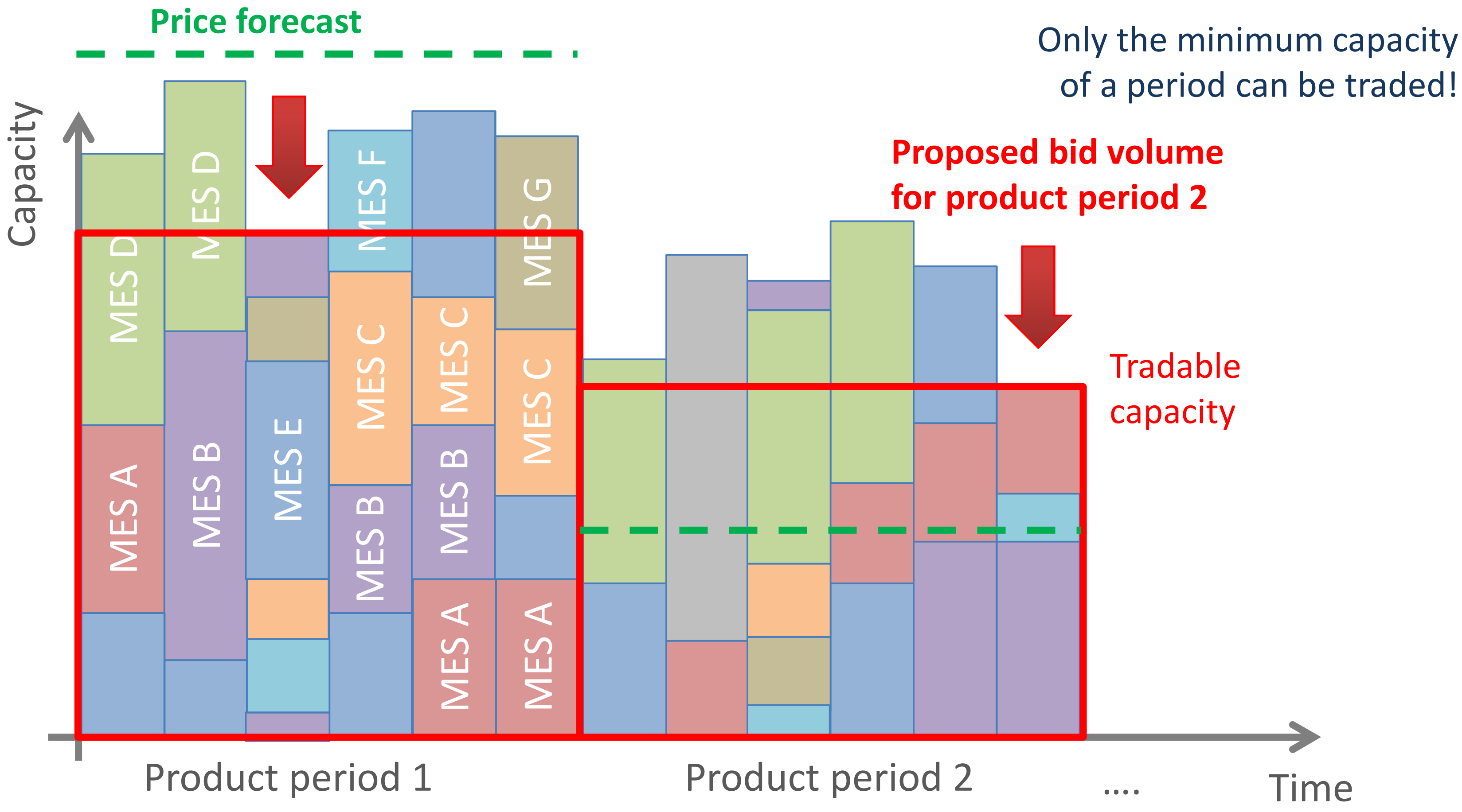
Example: Italy North - Day ahead market, 1-week forecast

- Training set (3y) & test set (1y)
- Input: history of several time series (prices and other)
- Output: prediction of future of that time series
- Technique: using gradient boost technique ('xgboost' library), open source
- Quality of result: MEA of 7 EUR/MWh (on training) & 7.5 EUR/MWh (on test)

(source n-SIDE)



Optimization: Capacity vs. Products

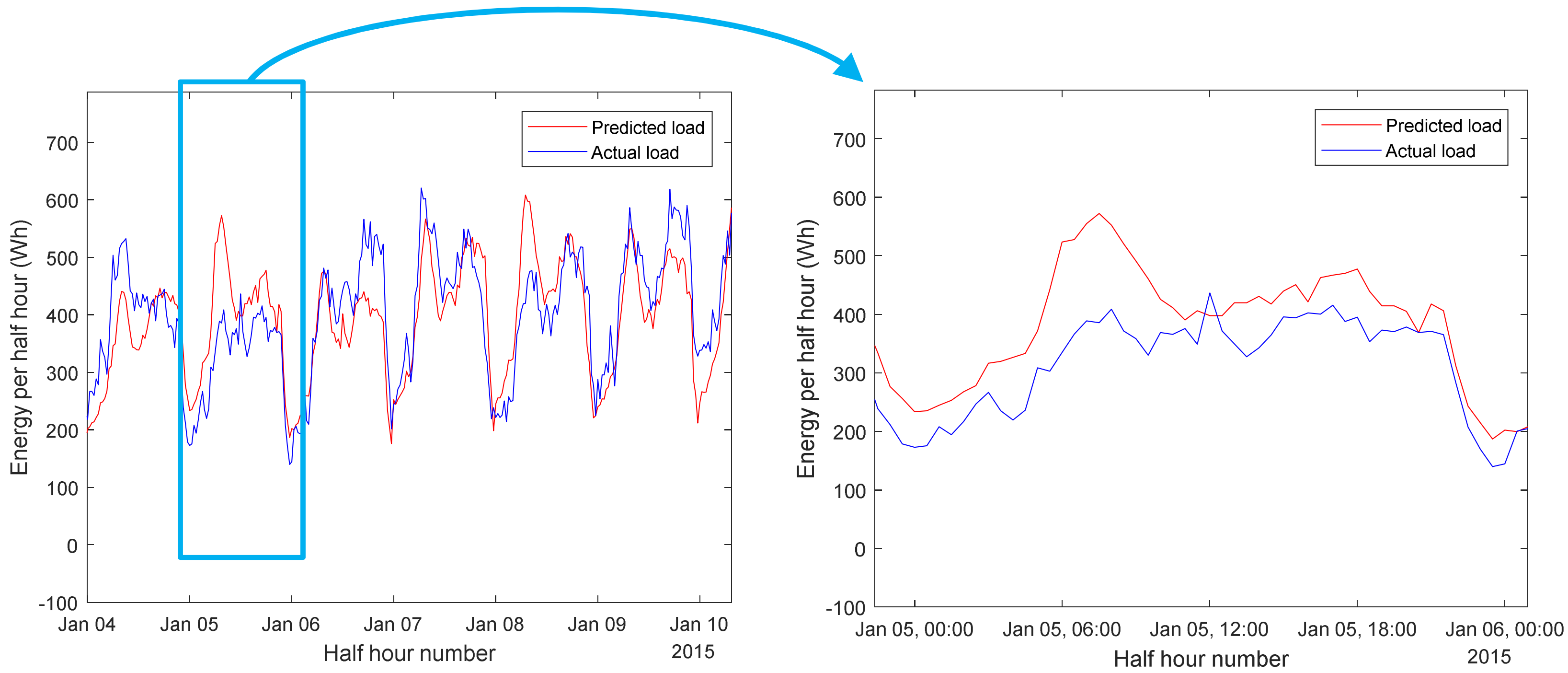


After this step the potential revenue on a certain market can be assessed.
The procedure is repeated for each relevant market.

Flexibility forecasting of “unmanaged units”

- Example: consumption forecasts of a pool of heat pumps in the UK
- *The flexibility parameters of the pool can be assessed from forecasted ambient temperature, forecasted consumption and type of heat pumps.*

(source: Cardiff University)



Bid optimization - Implementation

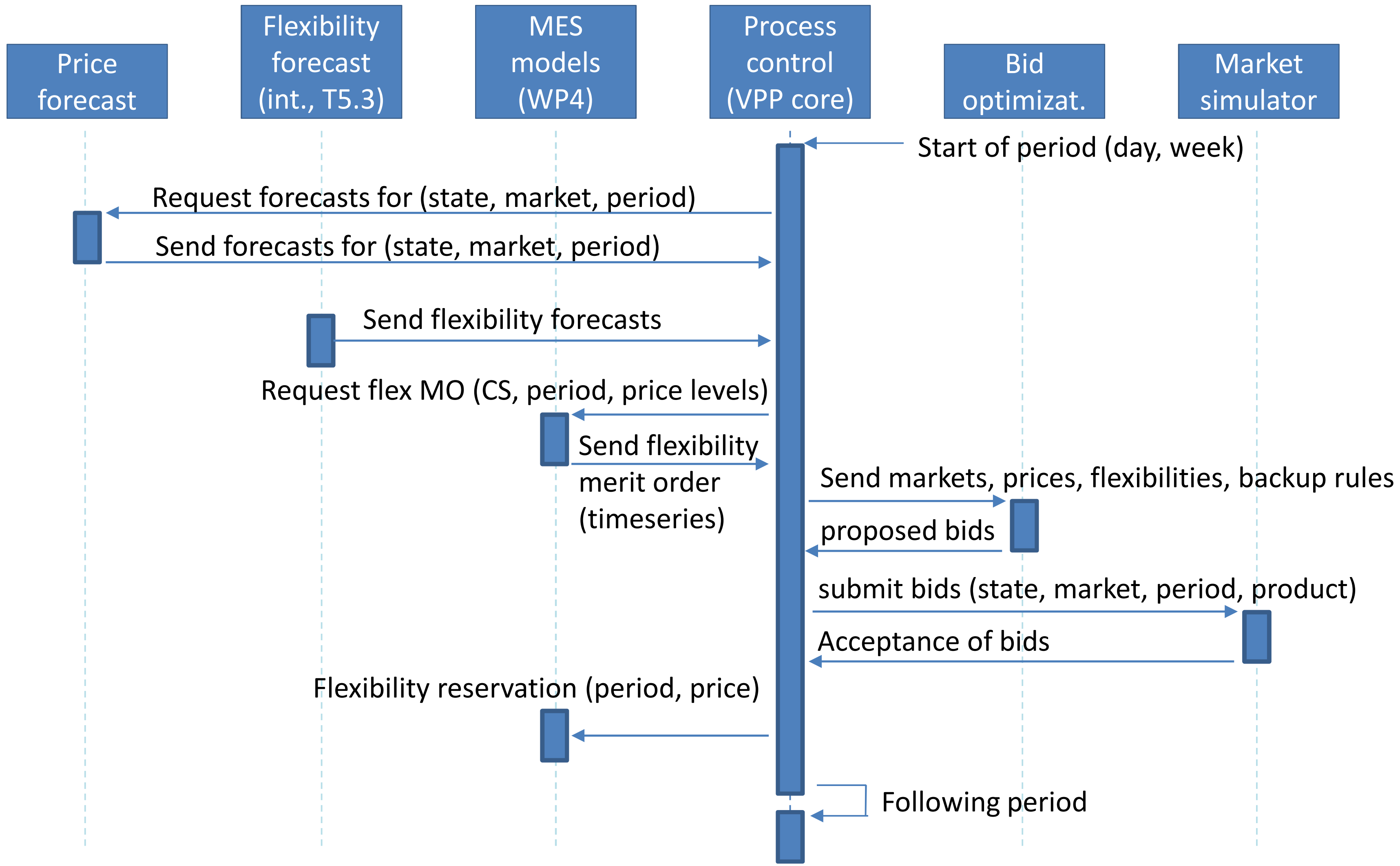
Assessment of optimized bidding strategy for defined markets, based on

- flexibility forecasts
- Price forecasts
- Backup rules

Comparison of results

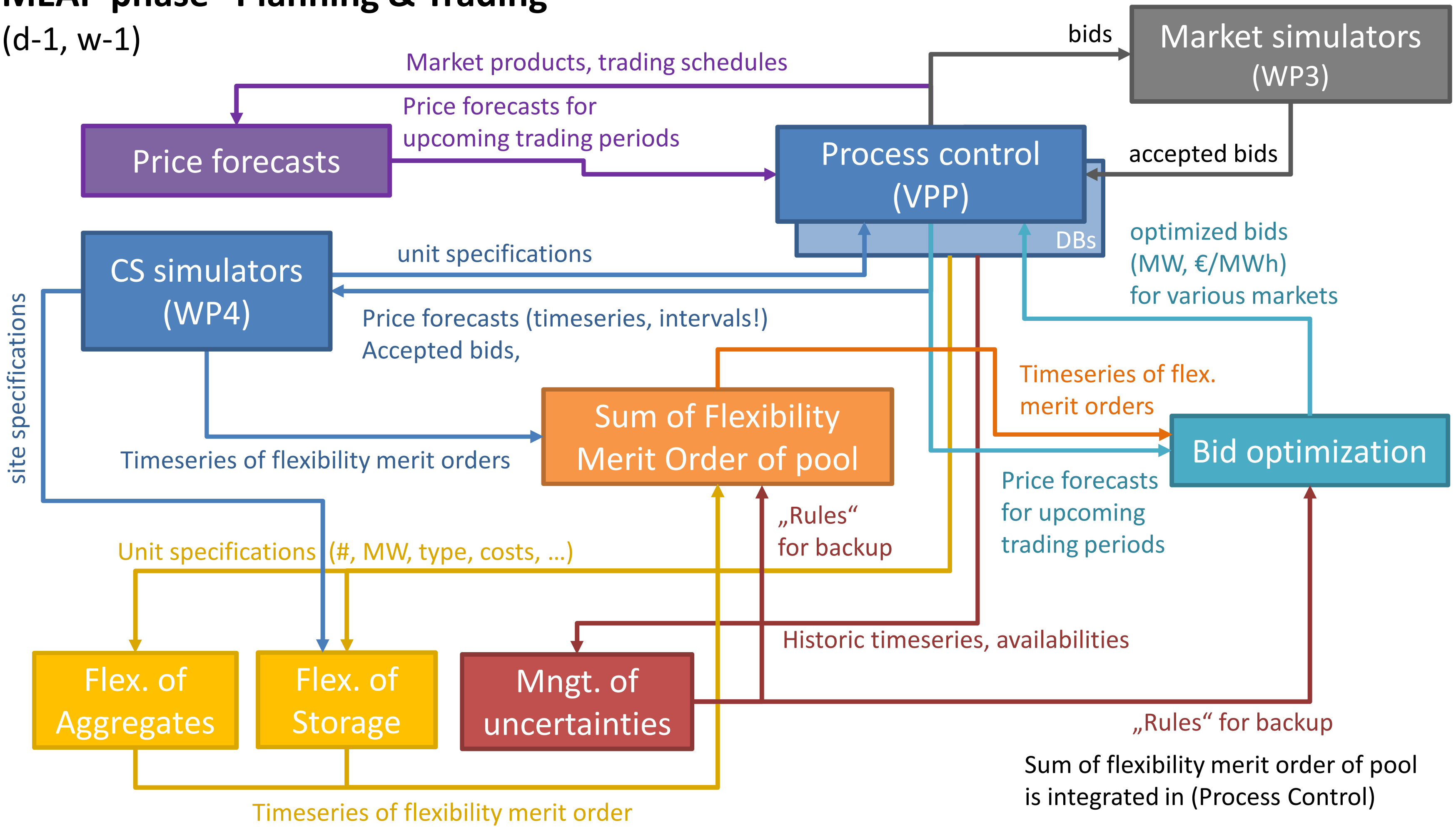
⇒ Proposal to aggregator/trader

The planning phase



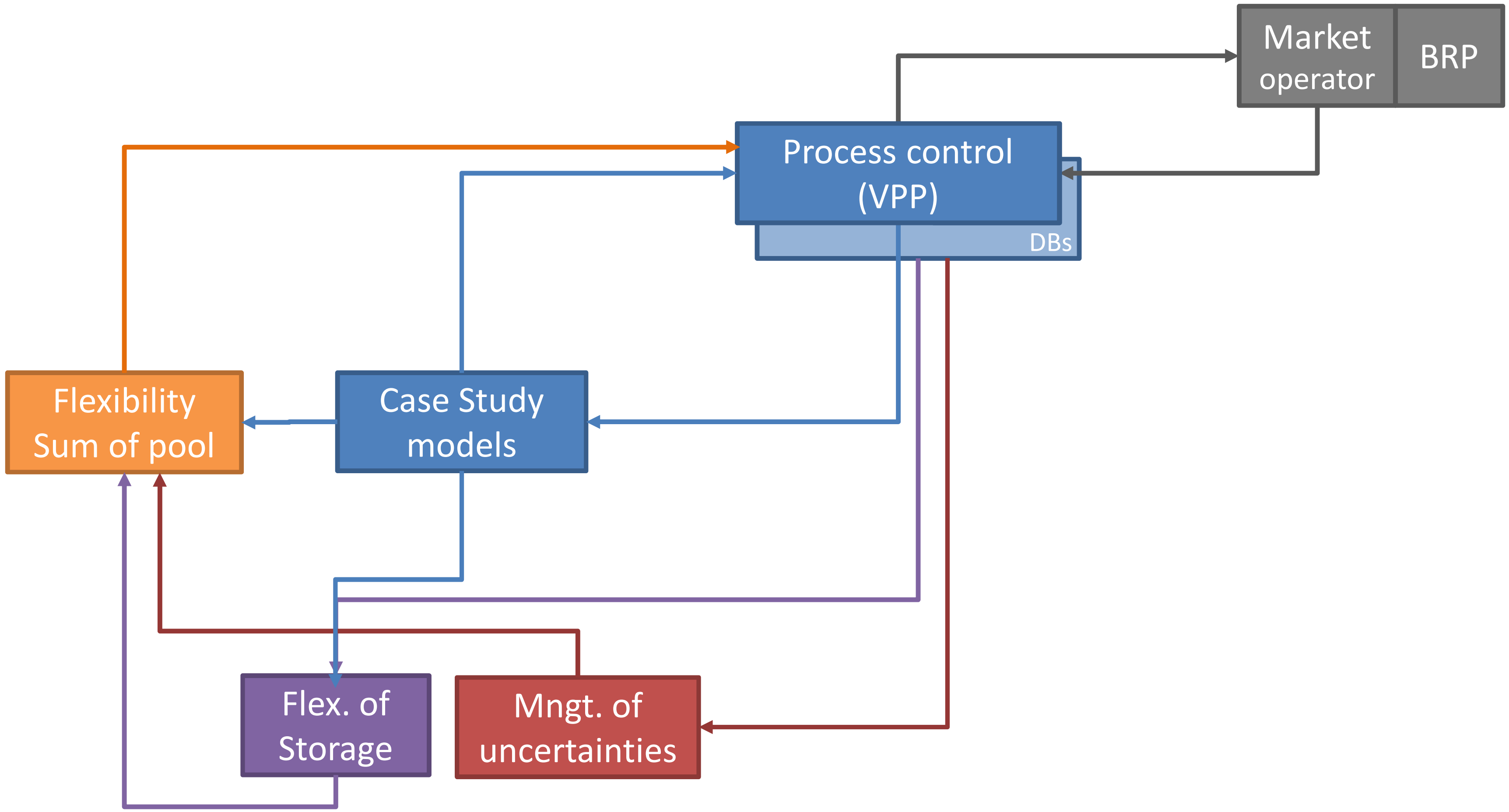
The planning and trading phase

MEAP phase "Planning & Trading"
(d-1, w-1)



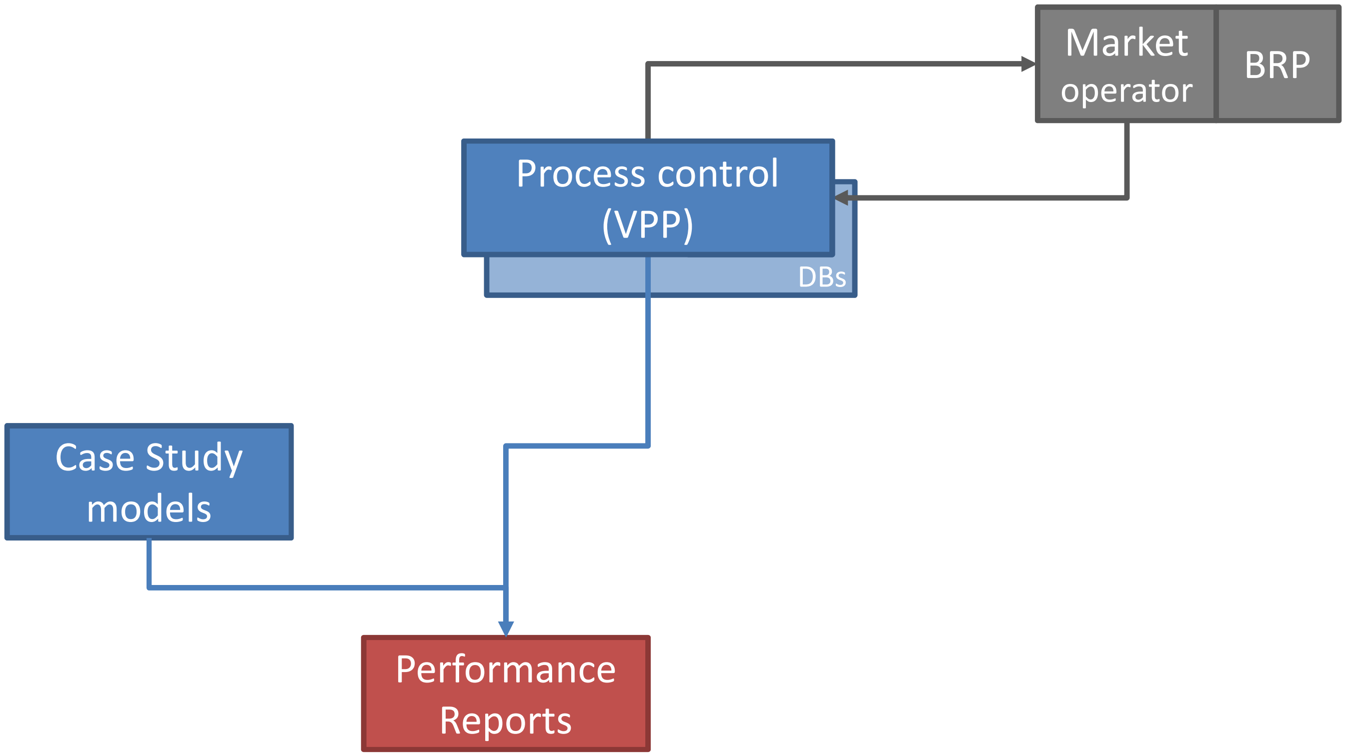
Sum of flexibility merit order of pool is integrated in (Process Control)

Real-time operation



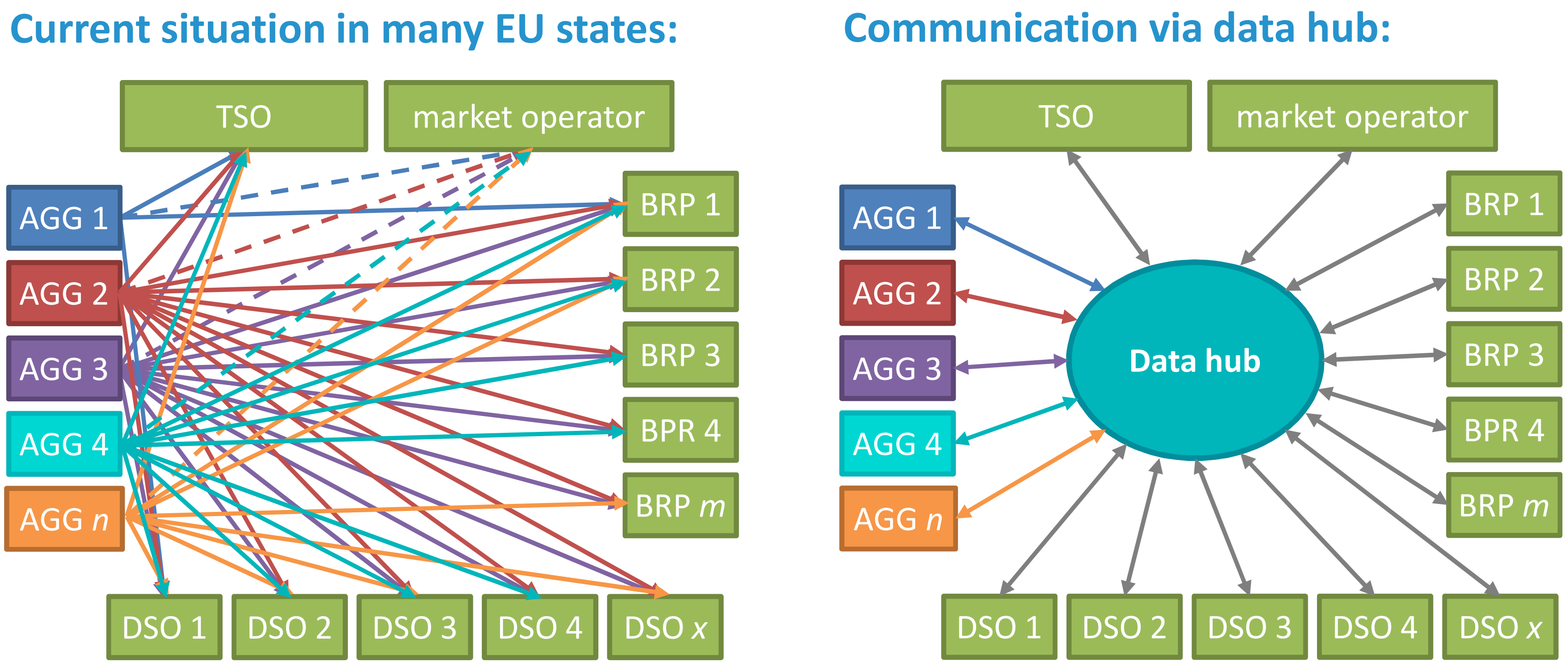
Reporting

Reporting
(d+1, w+1)



Performance reports are the basis for following calculations of KPIs, CBA, business model development etc.

Data hub from the aggregation perspective



Resume & Outlook

- In the MAGNITUDE project, we simulate the behavior of an Aggregation platform
  - considering incomplete information of the aggregator concerning flexibility and price at the time of delivery,
  - applying simple and robust algorithms, which can deal with the limited information given in the practical case
- Investigations focus on the trading of flexibility from MES.
- The Multi-Energy-Aggregation platform will be integrated in a simulation environment with MES simulators and market simulators.
- The developed algorithms and tools will be further developed to new software modules after the end of the project

Chris Caerts, VITO

ENERGY COMMUNITIES LEVERAGING FLEXIBILITY BY ACTIVE CONNECTED BUILDINGS: EXPERIENCE FROM THE FHP (FLEXIBLE HEAT AND POWER) PROJECT

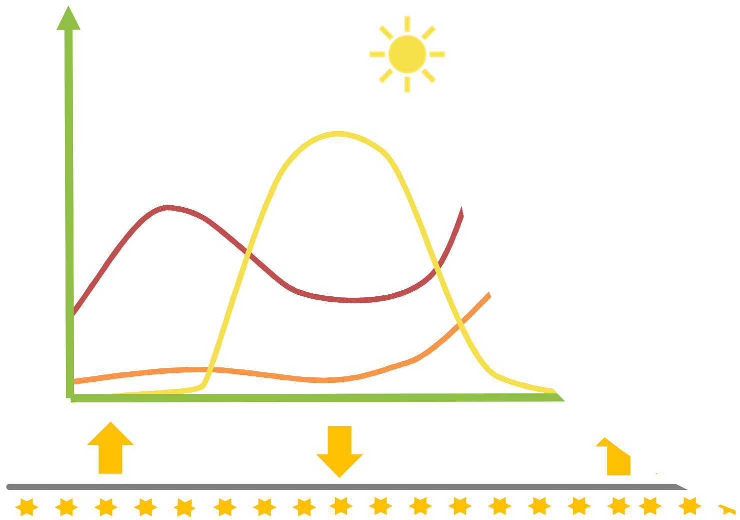
Energy Communities leveraging Flexibility from Active Connected Buildings

Chris Caerts (VITO)

FHP project is funded by European Union under the grant agreement no. 731231.

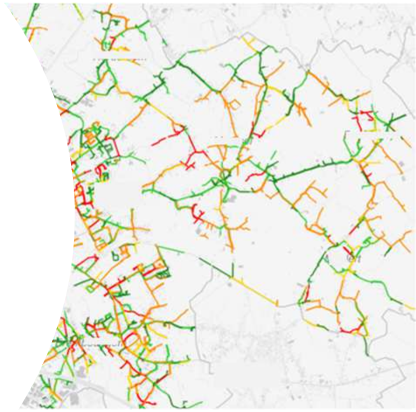
The challenge

Building: consumption and gener



Medium-sized city

penetration rate of HP & EV



ion	Colour	Probability of Failure
ible	Dark green	0 %
y Unlikely	Green	< 20%
Unlikely	Light Green	< 40%
Possibly	Yellow	< 60%
Likely	Orange	< 80%
Very Likely	Red	≤ 100%

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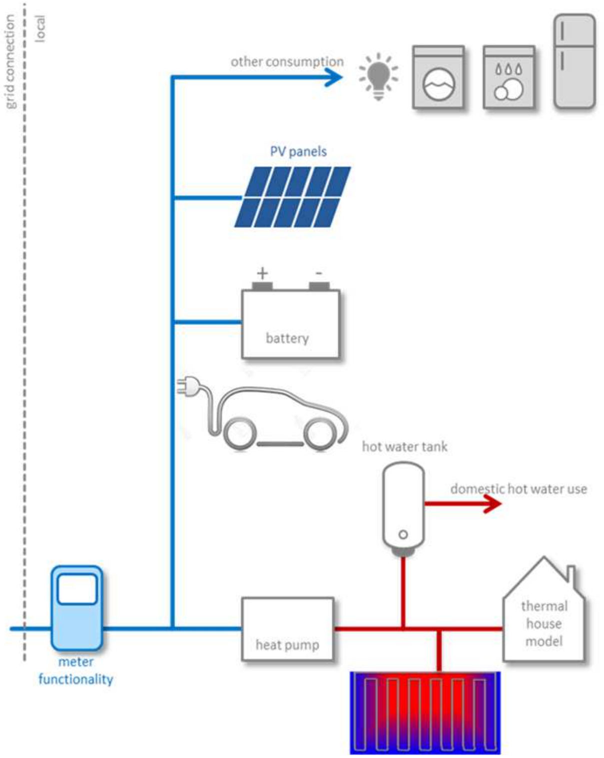
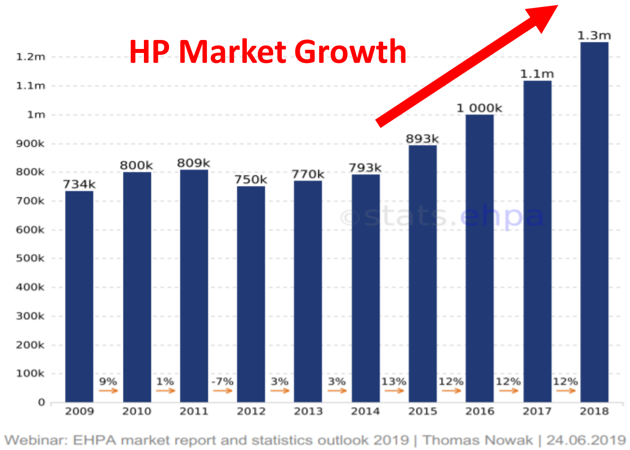
Buildings as clusters of Flexibility



Flexibility: shifting, modulating, buffering energy

Power-to-Heat: building thermal mass, DHW vessel, long-term (seasonal) storage

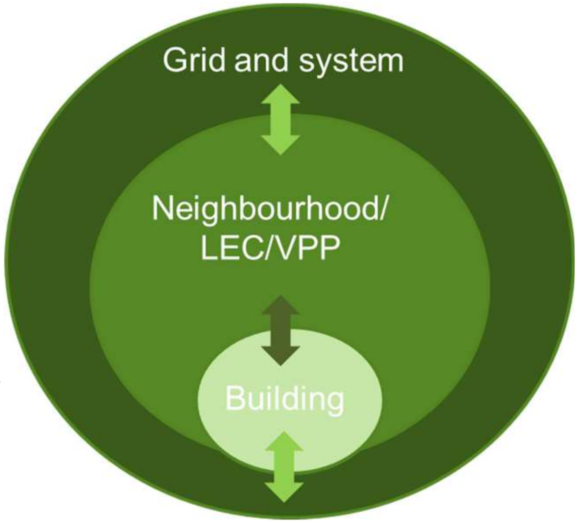
- Energetically large(st) source of flex, and supports decarbonization
- Flexibility provision = 2nd business case (next to heat)
- Challenge: On/Off ➔ finer granularity and more deterministic



Energy Communities leveraging Flexibility from Active Connected Buildings
Magnitude Workshop – October 10th 2019

Need for local coordination: Energy Communities

- Mitigate local grid problems
  - ‘non-frequency ancillary services’
- Energy Community Optimization
  - Energy Exchanges/Trading
  - Aggregated service offering
  - ‘balancing responsibility’ of Energy Communities
- Ensure frequency/balance ancillary services do not cause local grid problems
  - TSO/DSO/**Prosumer** coordination



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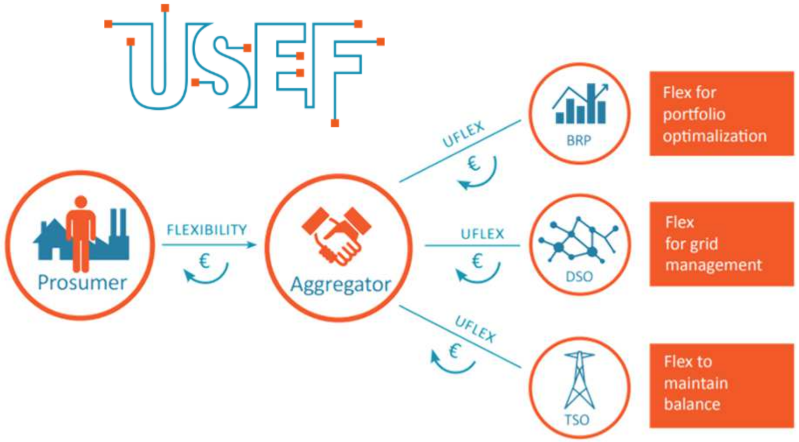
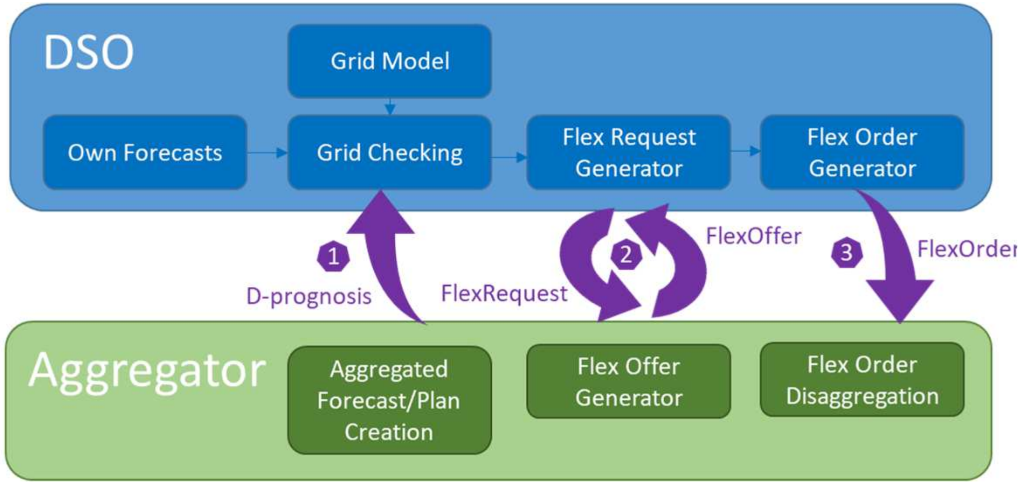
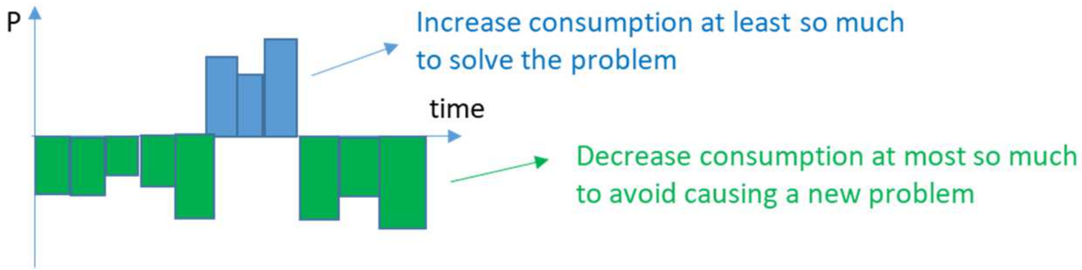
USEF: Universal Smart Energy Framework







1. Forecast (Plan) Prosumption
2. Request/Offer Flex
3. Order Flex

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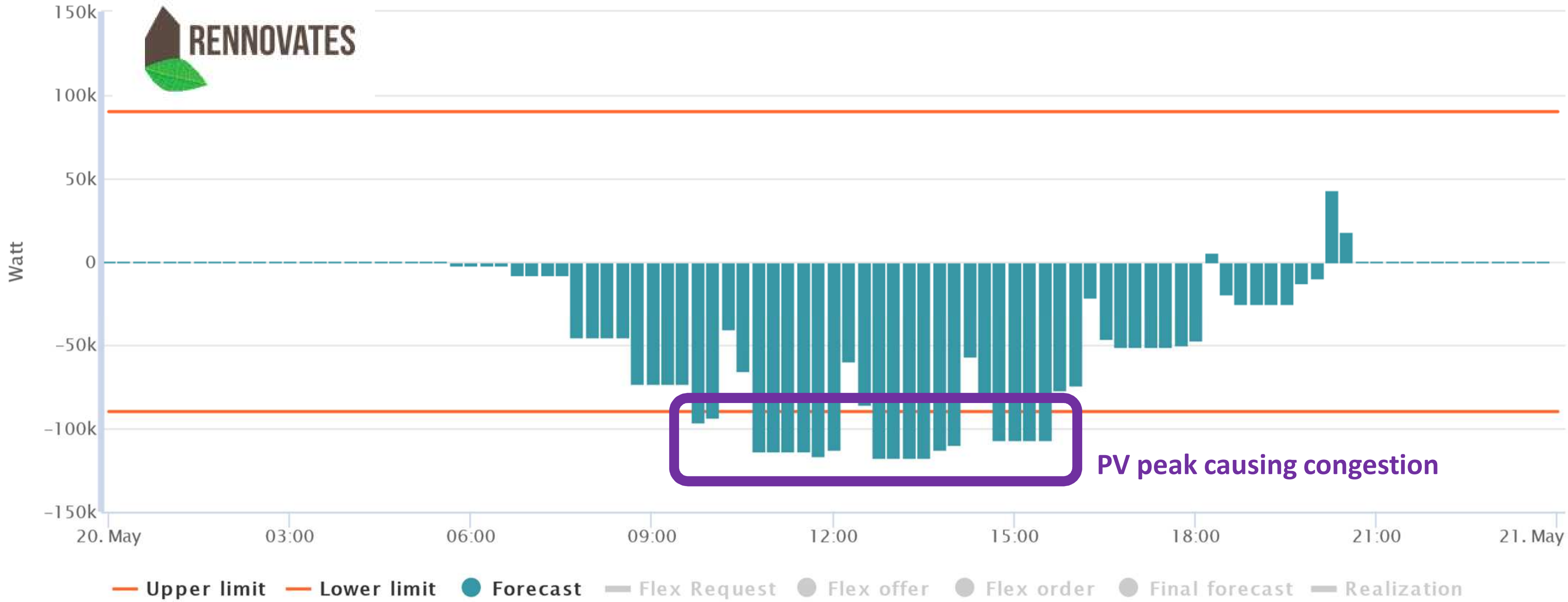
under the grant agreement no. 731231.

USEF Example: Forecast



Source: EnergyNxt platform (ICT group)

Energy Communities leveraging Flexibility from Active Connected Buildings
Magnitude Workshop – October 10th 2019

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under the grant agreement no. 731231.

USEF Example: FlexRequest

Source: EnergyNxt platform (ICT group)

USEF Example: Matching Flex Offer

Source: EnergyNxt platform (ICT group)

Energy Communities leveraging Flexibility from Active Connected Buildings
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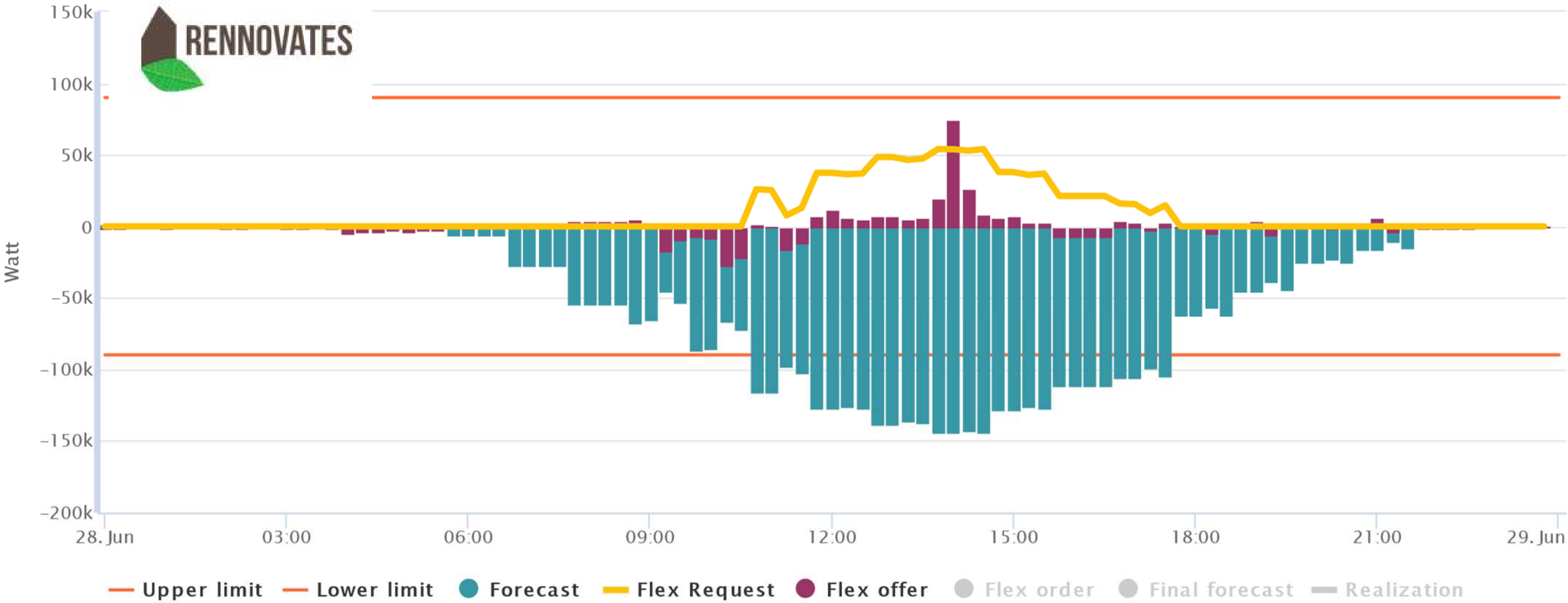
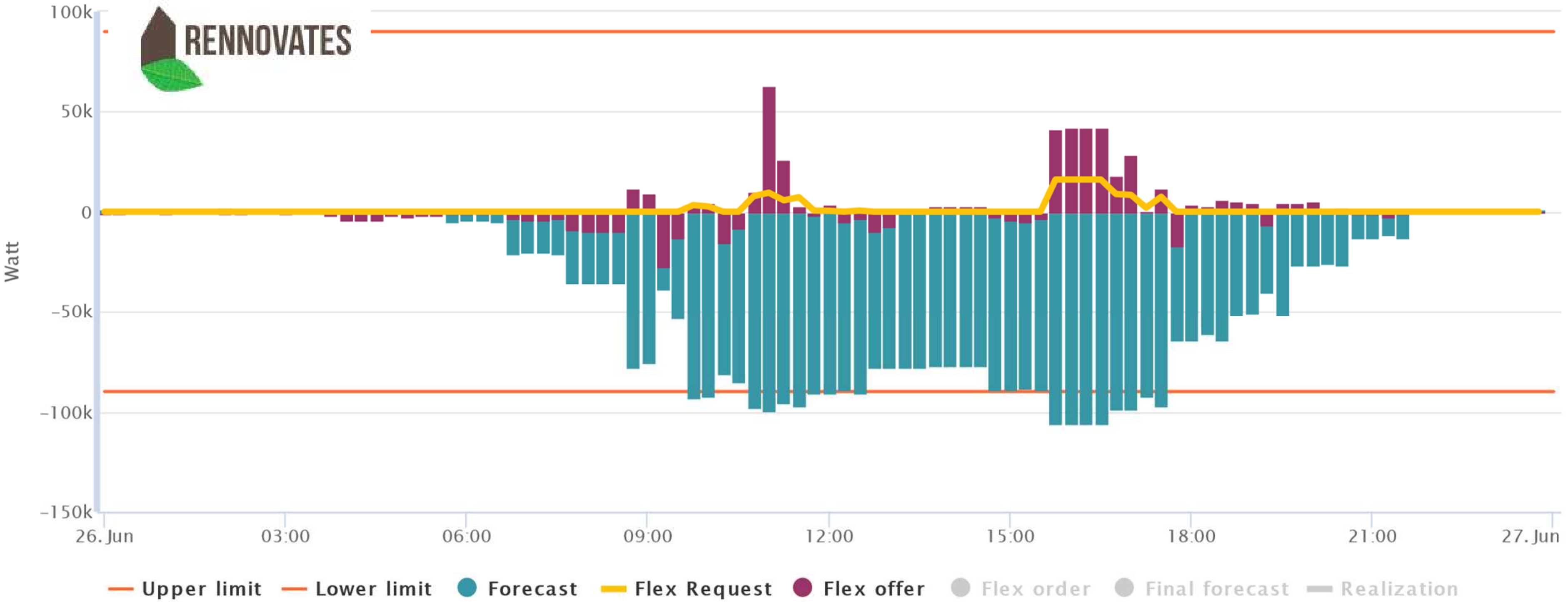
USEF Example: Insufficient Flex



Source: EnergyNxt platform (ICT group)

FHP project is funded by European Union
under the grant agreement no. 731231.

USEF Example: More than needed Flex



Source: EnergyNxt platform (ICT group)

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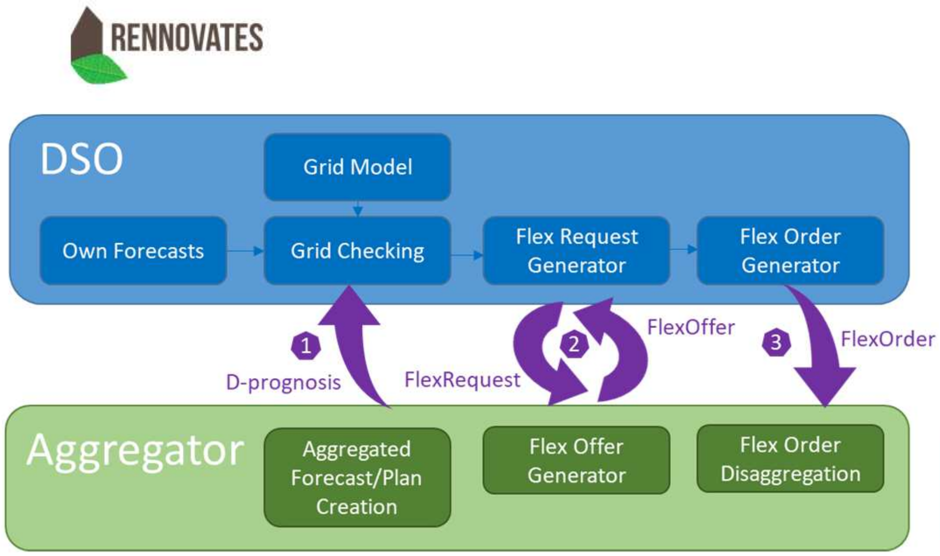
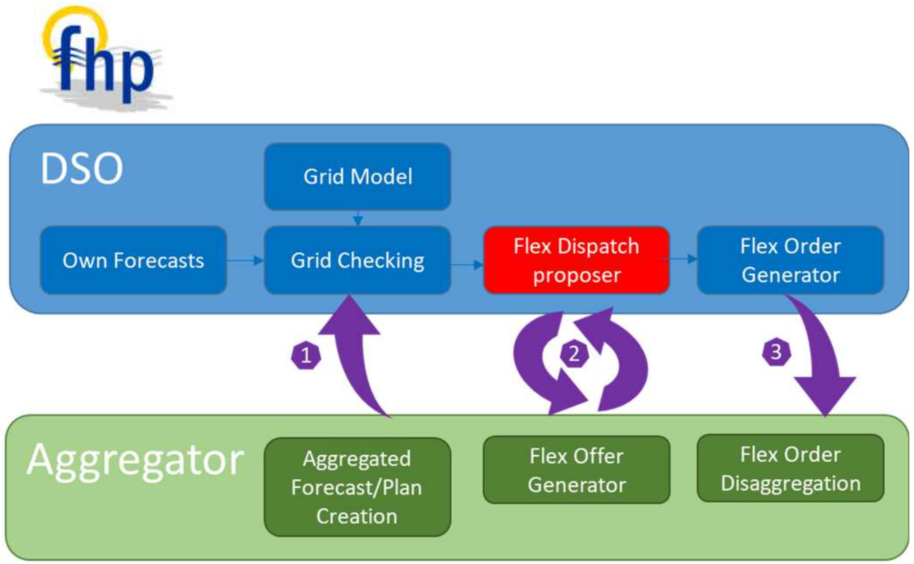
FHP addition to USEF enabling Optimal Flex Dispatch



1. Forecast (Plan) Prosumption
2. Request/Offer Flex (iterate)
3. Order Flex



1. Forecast (Plan) Prosumption & Flex
2. Propose/Confirm Optimal Flex Dispatch
3. Order Flex Dispatch

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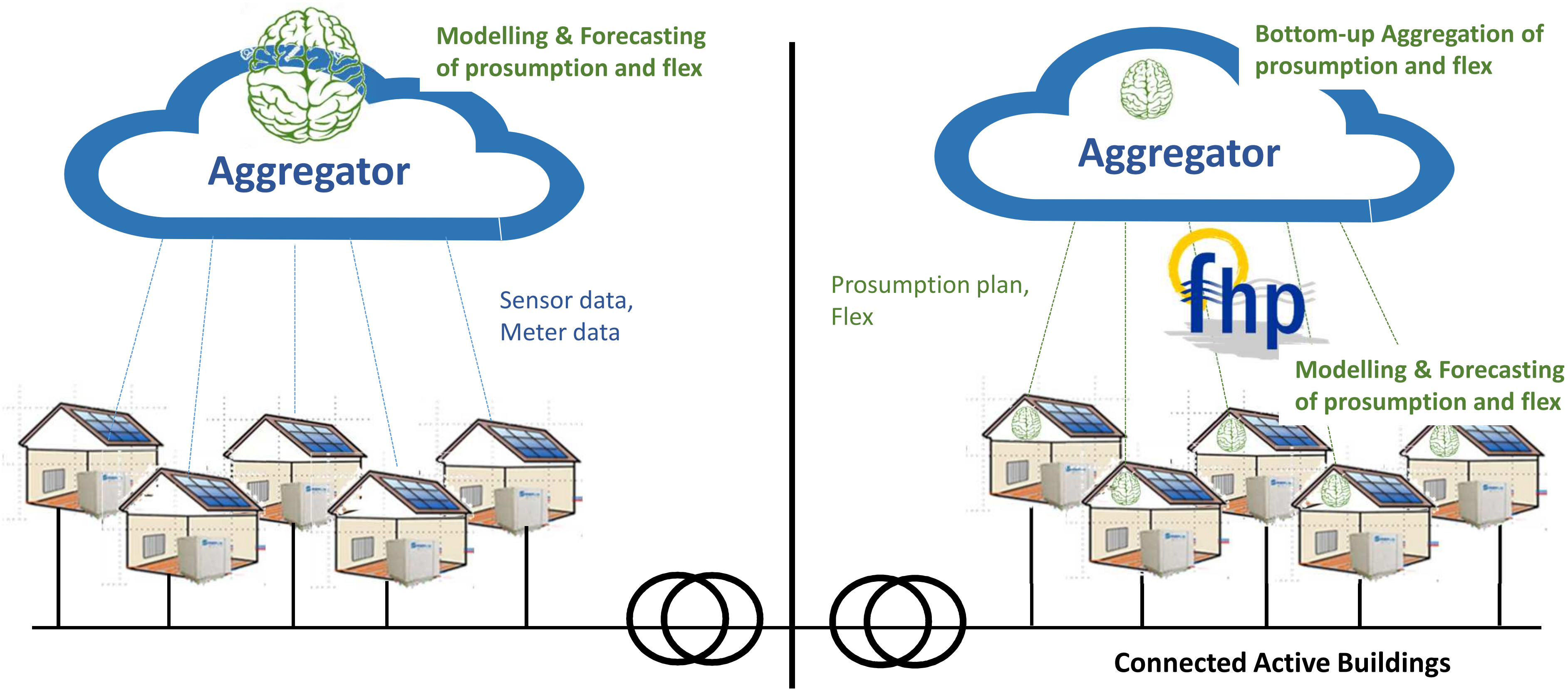
Flex Trading by Active Connected Buildings



FHP project is funded by European Union
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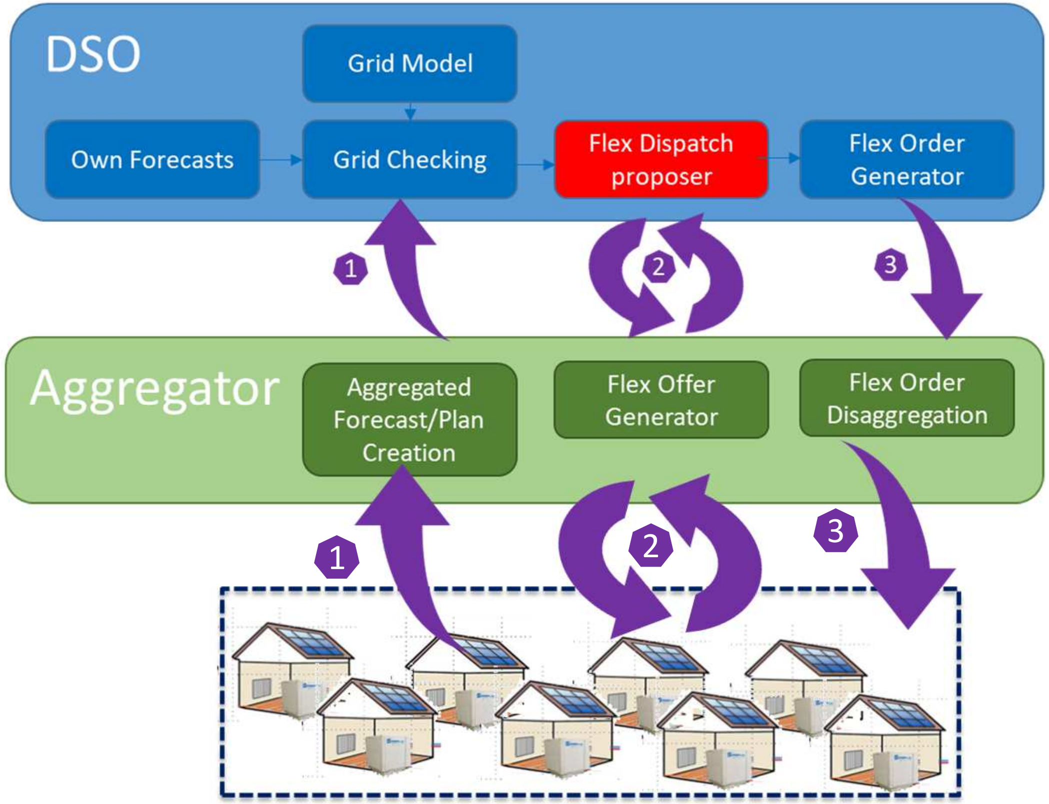
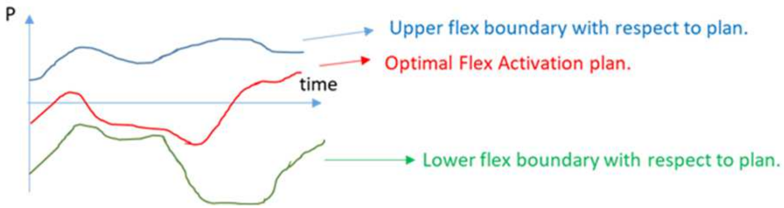
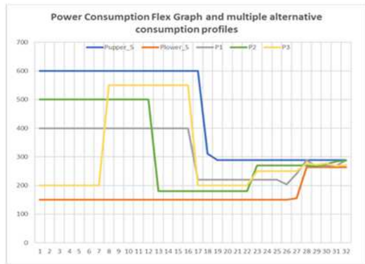
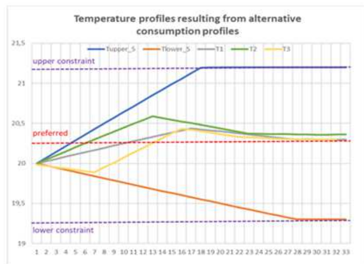
FHP Aggregation and Flex Trading process flow









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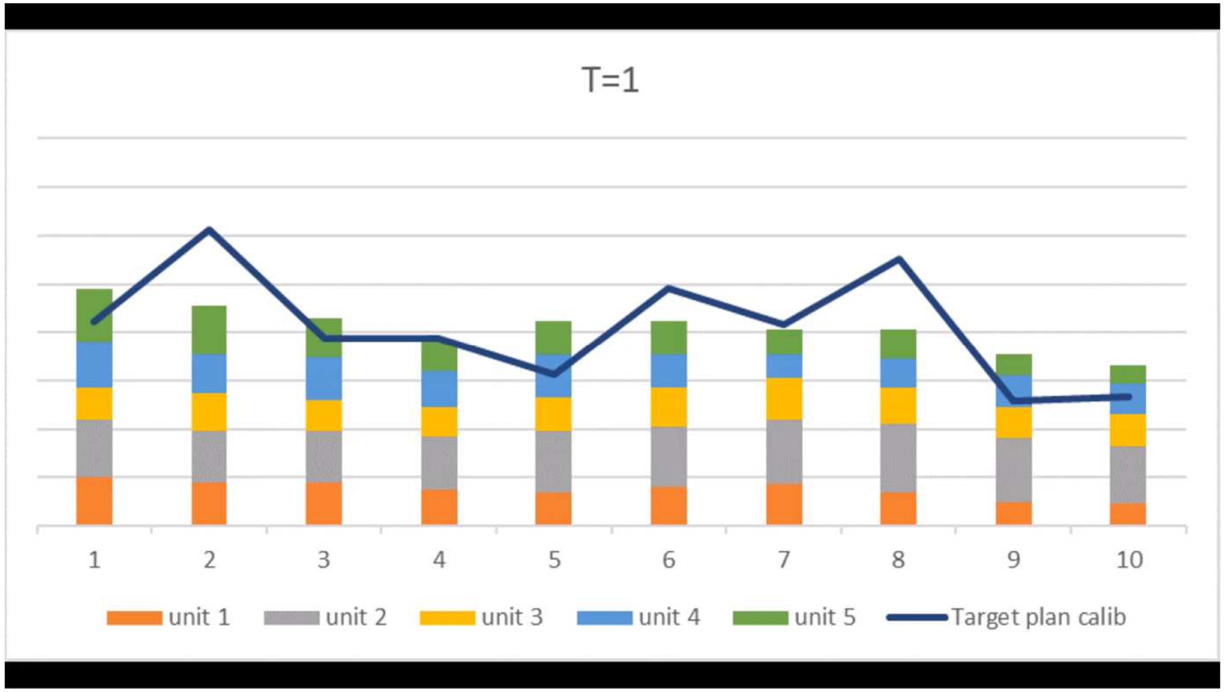
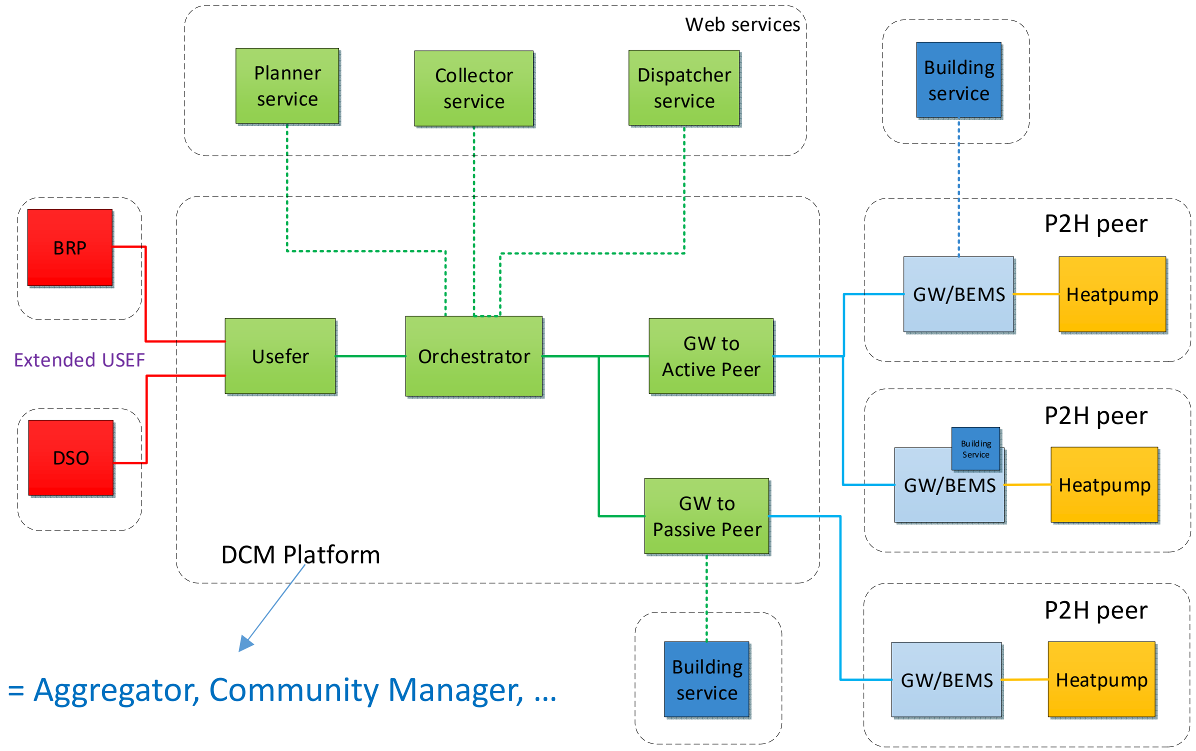
Disaggregation by decentralized optimization



Note: simplified animation created for concept visualization.

DCM*-centric Multi-Agent System

**DCM = Dynamic Coalition Manager*



Building Service:

- Create Optimal Plan and Flex Graph

DCM-Collector:

- Aggregates info from Building Service + optional additional processing

DCM-Planner:

- Cluster level optimisation
- Superimpose service e.g. for BRP

DSO:

- Optimal Flex Dispatch (versus USEF Flex Request)

DCM-Dispatcher

- Disaggregate Optimal Flex Dispatch request using distributed optimization (ADMM)

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Simple text partners bar

Thank you!

Questions?

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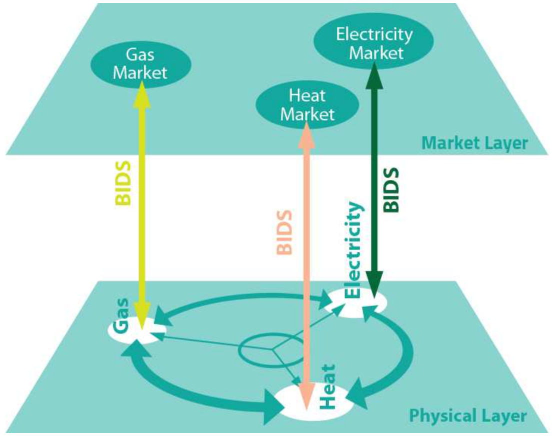
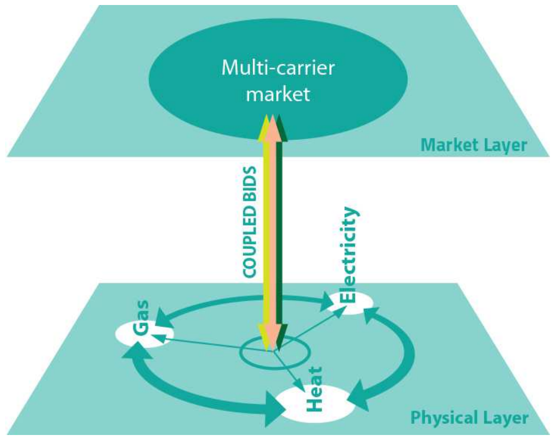
Kris Kessels, Shahab Shariat Torbaghan, Ana Virag, Hélène Le Cadre (VITO, EnergyVille)
Guillaume Leclercq, Peter Sels, Mehdi Madani (N-SIDE)

INNOVATIVE MARKET SCHEMES FOR INTEGRATED MULTI-ENERGY SYSTEMS: THE MAGNITUDE PERSPECTIVE

Motivation and background

- Several drivers point towards a need for more energy system integration, also at the market level.
  - Increasing penetration of multi-carrier conversion technologies and storage technologies
  - Increased ambition for local energy sufficiency and independency
  - Recent changes specifically in gas markets and emerging trends to move towards more ST trading in all energy markets
  - Increased integration of VRES and the subsequent need for extra flexibility

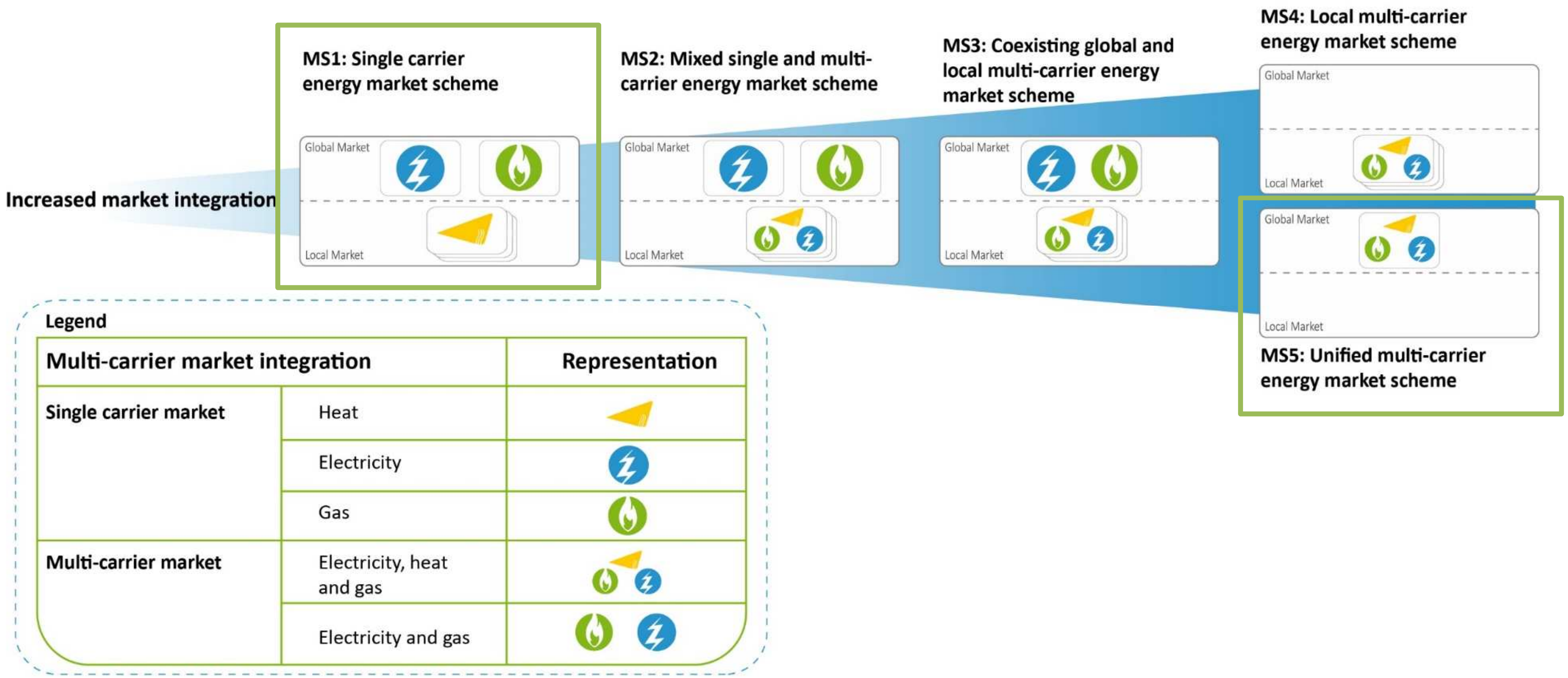




Assumptions

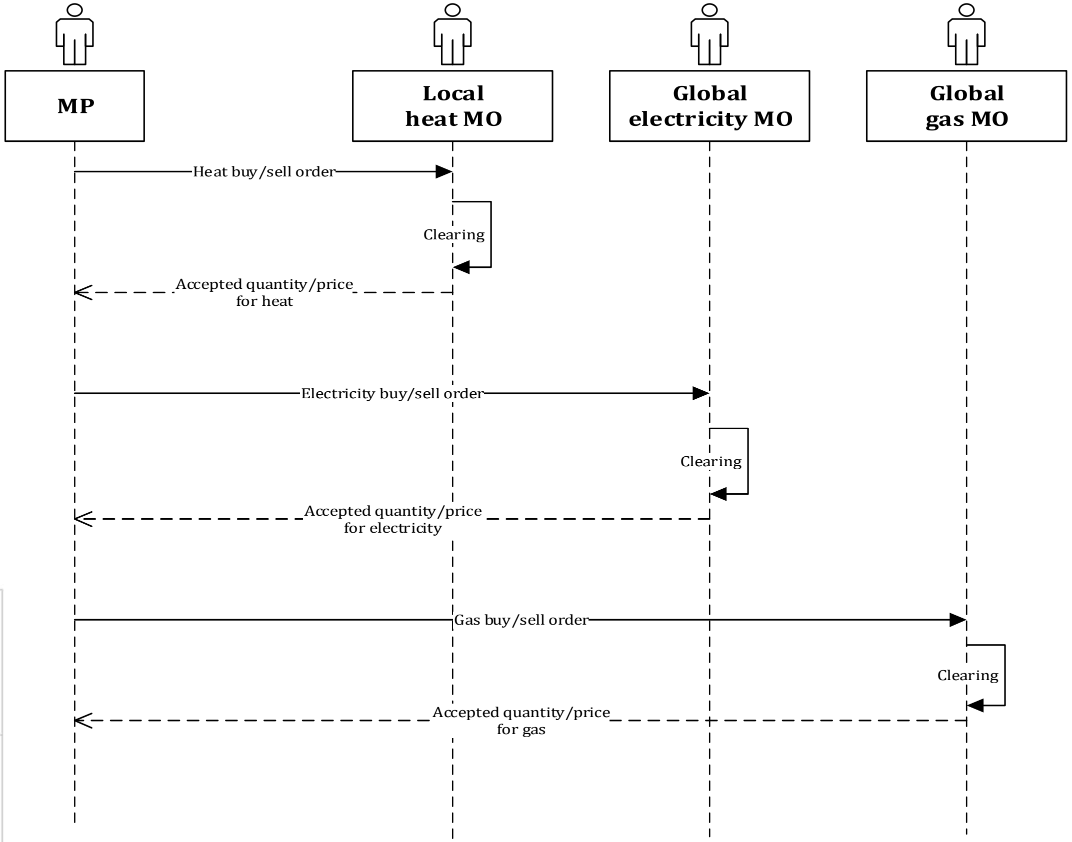
- **Multi-carrier market scheme**
  - comprises a set of sub-markets to trade different energy carriers
  - can be described by two market dimensions :
    - multi-carrier market integration (the combination of single and/or multi-carrier markets chosen)
    - locality of these markets (the consideration of local and/or global markets)
- **Focus**
  - day-ahead energy markets
  - 3 carriers: i.e. heat, electricity and gas

Multi-carrier market schemes



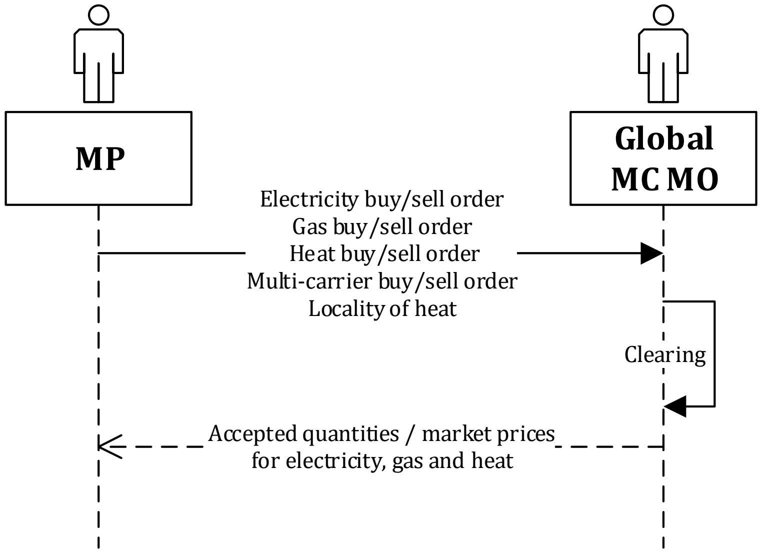
Multi-carrier market schemes

MS1: Single carrier energy MS



Multi-carrier market schemes

MS5: Unified multi-carrier energy MS



Qualitative evaluation

Indicators	Market Scheme				
	MS1	MS2	MS3	MS4	MS5
Social welfare [1]	● Lower	● Moderate	● Moderate	● Moderate	● Highest
Confidentiality level [2]	● Higher	● Moderate	● Moderate	● Moderate	● Moderate
Resemblance to current market designs [3]	● Highest	● Higher	● Moderate	● Lowest	● Lower
● Highest ● Higher ● Moderate ● Lower ● Lowest					

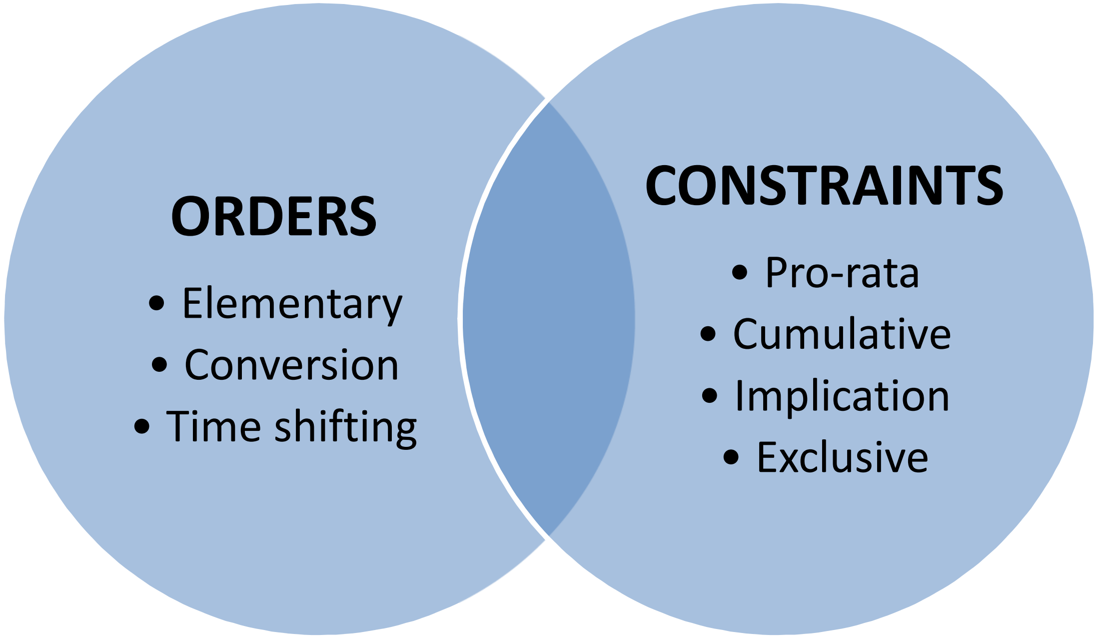
[1] Sum of economic surpluses across all market parties

[2] Level of detail of information about technical and economic constraints of the underlying portfolio of the market participant shared with the market operator

[3] Extent to which the proposed multi-carrier market resembles the current market design across the EU regarding legal, economic, and administrative aspects

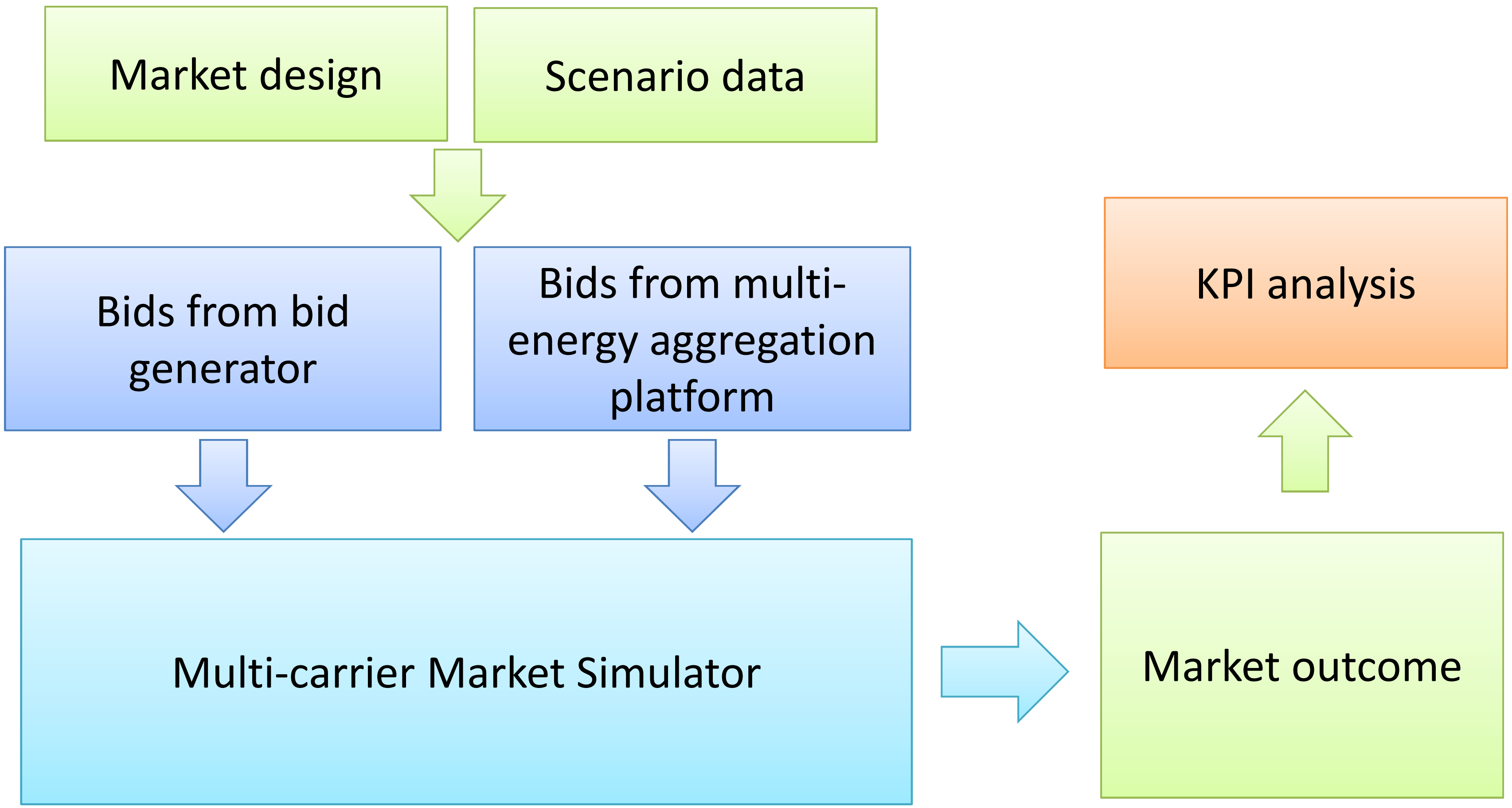
MS 1: Single carrier energy MS
MS2: Mixed single and multi-carrier energy MS
MS3: Coexisting global and local multi-carrier energy MS
MS4: Local multi-carrier energy MS
MS5: Unified multi-carrier energy MS

Product definition for multi-carrier markets



"Products are predefined combinations of order types and constraint types"

Multi-carrier market simulation framework



Next steps

Finalizing deliverable on MC market designs

↓

Finalizing MC market simulator

↓

Performing market simulations

↓

Quantitative evaluation of MC market designs

Market simulations Milan CS

- Min 3 multi-carrier (MC) market designs
- Comparison of designs based on KPIs
- Scenario
  - Geographical area = one bidding zone (Italy Nord)
  - Three carriers (gas, electricity, heat)
  - “Representative” (portfolios) of market participants (>100)
  - Predefined period = 1 week
    - 6 weeks per market design
      - 4 weeks for each season
      - 2 extreme weeks
  - Time resolution = 1 hour

Magnus Brolin, RISE

A LOCAL MARKETPLACE FOR ELECTRICITY, DISTRICT HEATING AND COOLING IN GOTHENBURG: THE EXPERIENCE OF THE FED PROJECT

Fossil Free Energy District – A local marketplace for electricity, district heating and cooling

Magnitude Workshop
How can sector coupling enable flexibility provision?

October 10, 2019

Magnus Brolin
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EUROPEAN UNION
European Regional Development Fund

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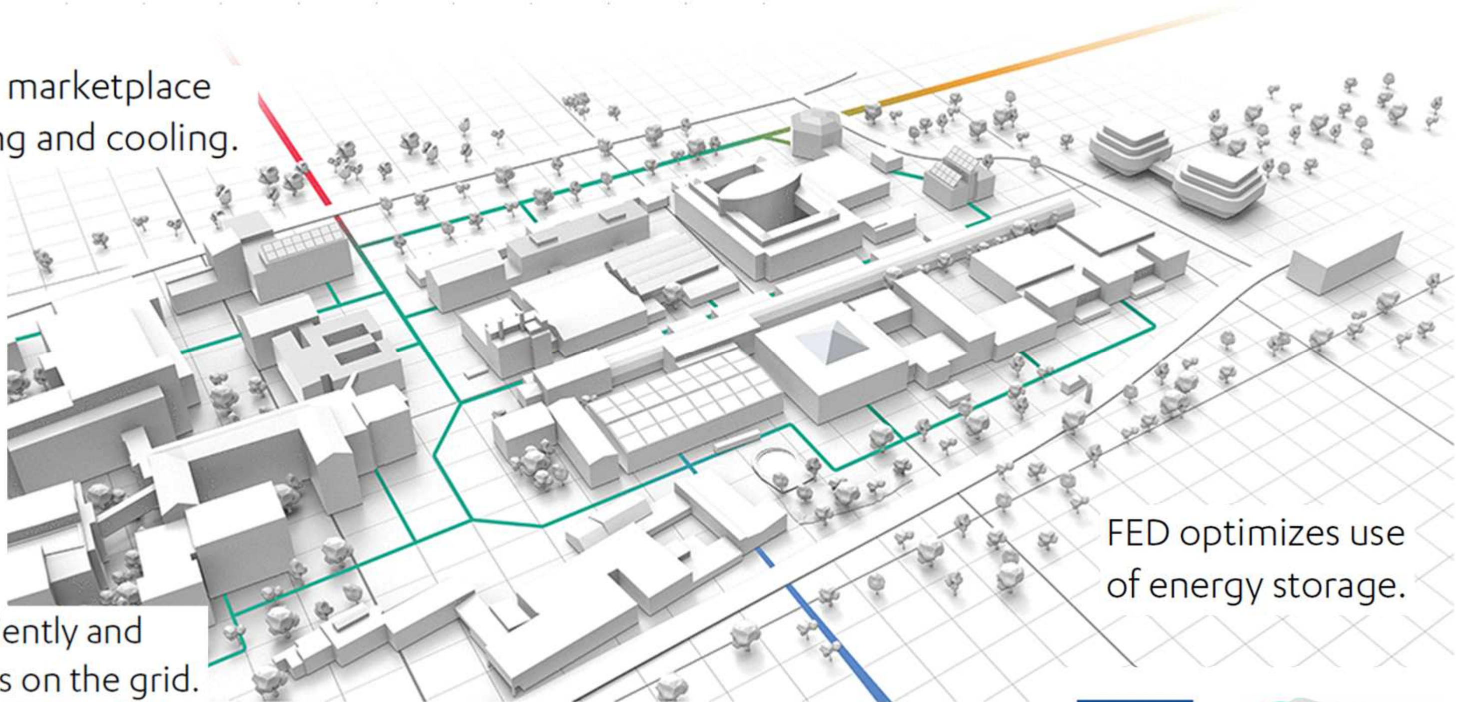
FED ON CAMPUS JOHANNEBERG

FED develops a local marketplace for electricity, heating and cooling.



FED optimizes use of energy storage.

FED uses energy efficiently and avoids fossil fuel peaks on the grid.

EUROPEAN UNION

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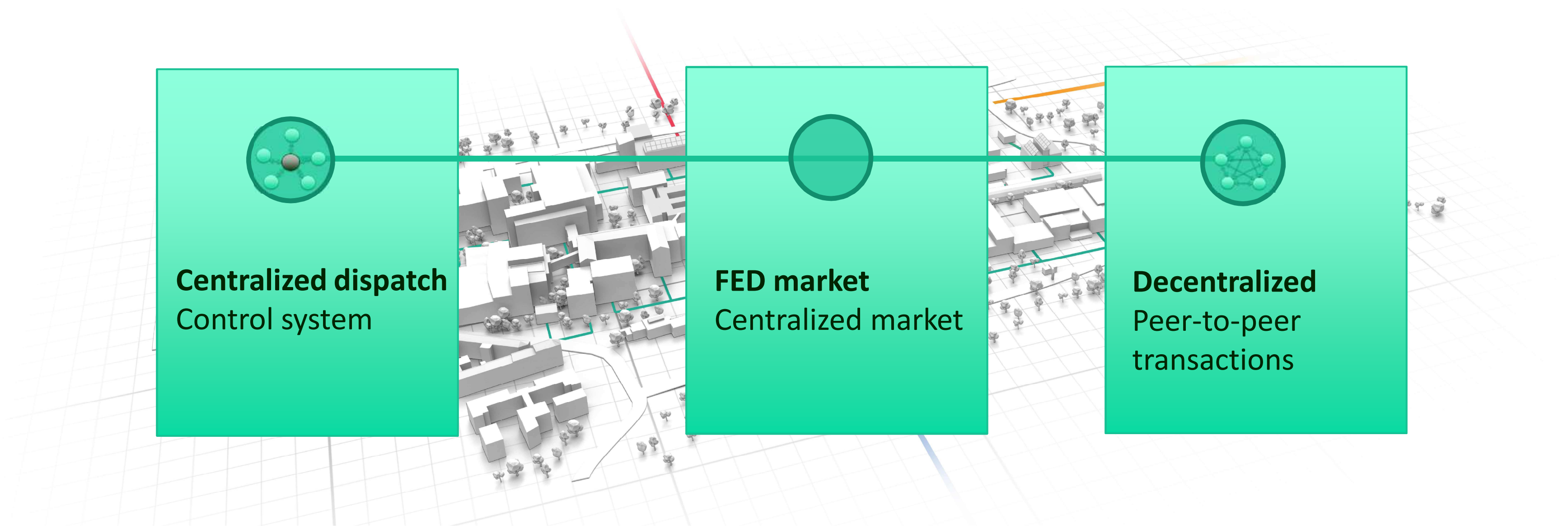
Local market actors

External production and distribution

Aims of the market place

- Facilitate coordination of local resources and external system/market through exchange of energy.
- Lower thresholds for local actors to take an active market position by offering functionality for flexibility.
- Enhance the integration of different energy carrier systems such as heating, cooling and electricity.

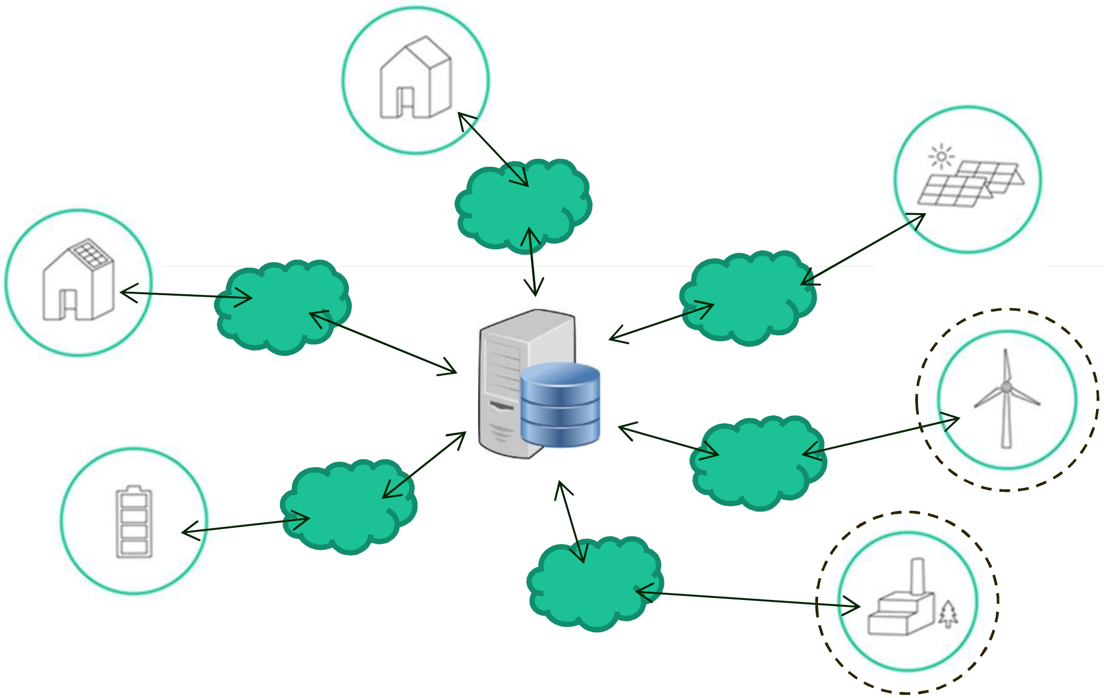
FED market place



What is the FED market place?

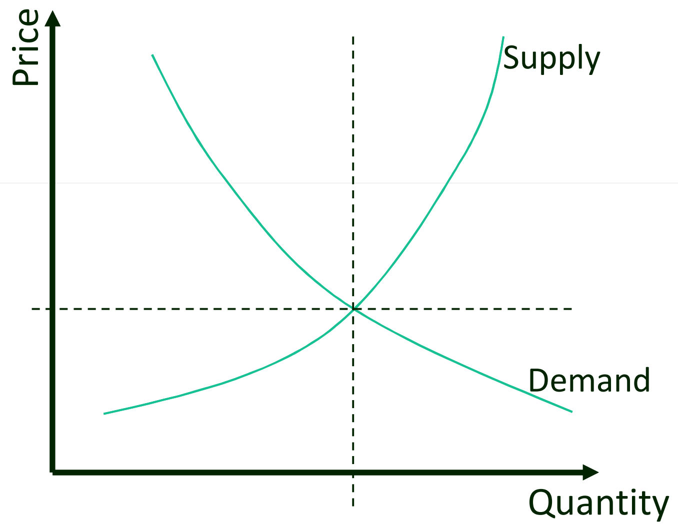
- Hub for exchange and trading.
- Energy demand and supply matching function.
- Integrating different energy carriers (heating, cooling, electricity).
- Defines prices and transactions.
- Energy market and system service market.

FED market

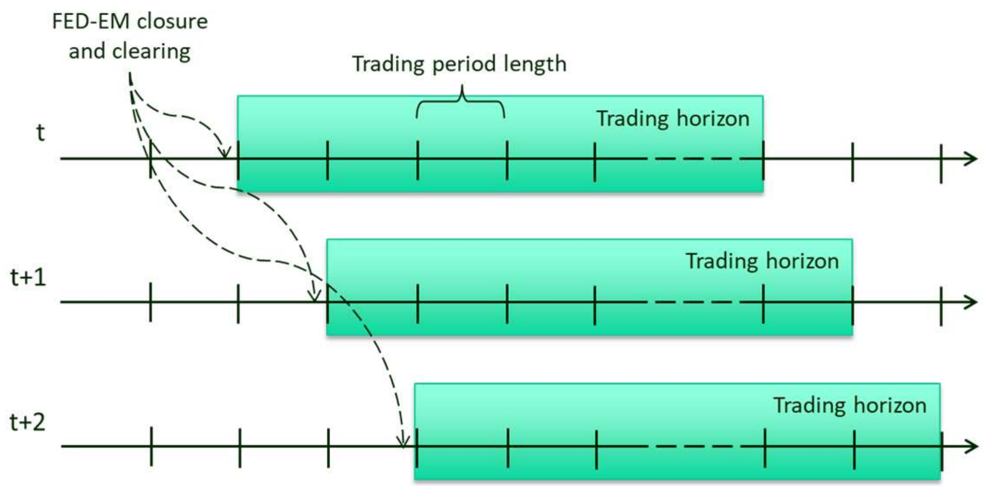


FED Energy Market – Main characteristics

- Two-sided auction.
- Integrated market for electricity, heating and cooling.
- Local infrastructure (grids) explicitly included.
- Locational Marginal Pricing – prices dependent on time, location and energy carrier.

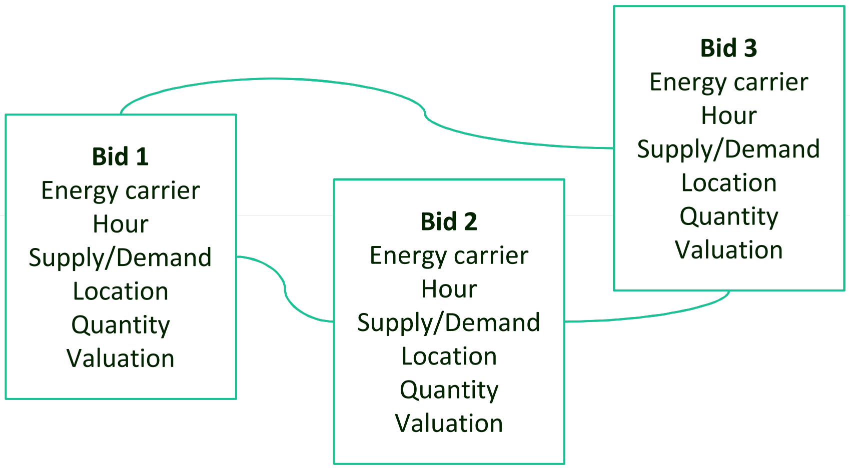


FED Energy Market – Bid submission & gate closure



- Agents decide on bids and submit them to the FED market place.
- Allowing the market to plan for flexible resources requires multiple trading periods to be included in the clearing.
- A rolling time window (including a number of trading periods) is applied, where the cleared trading positions for the first period are *binding* while the remaining are *advisory*.

FED Energy Market – Bids and dependencies



Simple bid structure:

- Quantity (in kWh) and valuation (in currency/kWh).
- Energy carrier, node and hour.

Bid dependency:

- A relation between individual bids ("creating complex molecules from simple atoms")
- Facilitating e.g. switching options and demand flexibility.

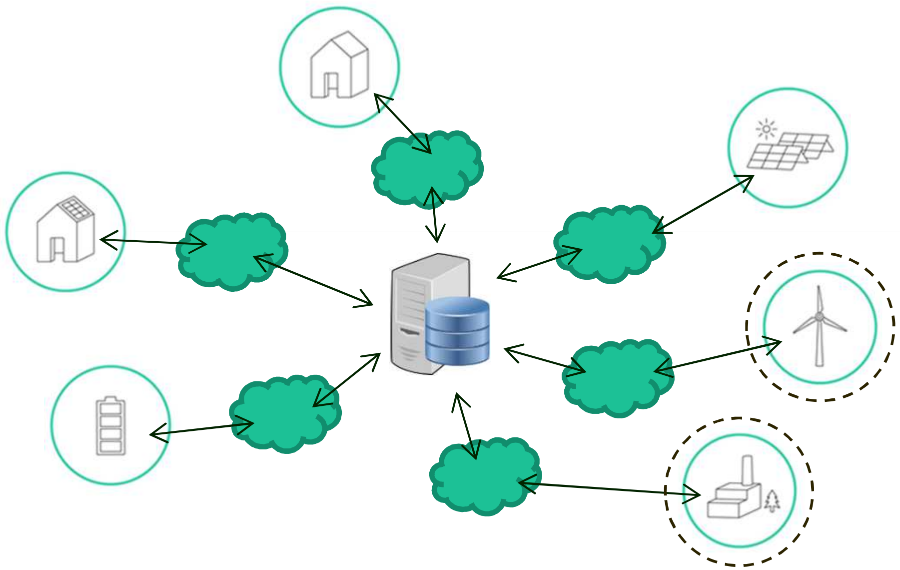
FED Energy Market – Bids and dependencies

Dependency	Description
AND	The bids should be treated by the market as complements that need to be accepted or rejected in tandem.
OR	The bids should be treated by the market as substitutes, such that at most one of the bids can be fully accepted.
LE	The sum of the accepted quantity from the bids should be less than or equal to a certain amount.
GE	The sum of the accepted quantity from the bids should be greater than or equal to a certain amount.
EQ	The sum of the accepted quantity from the bids should be exactly equal to a certain amount.

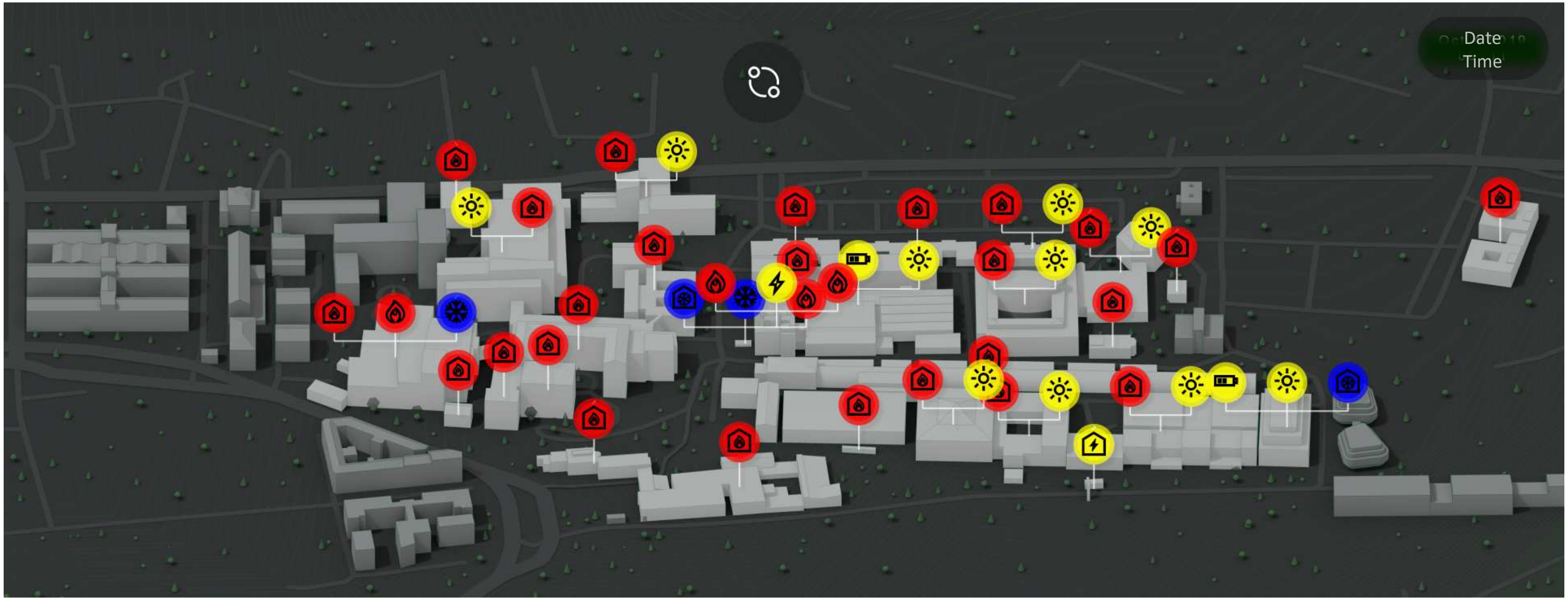
Examples

- Building with a heat pump and district heating
  - Two bids: one for the heat pump, one for the district heating
  - Dependency: The bids should be treated by the market as substitutes (OR).
- Building with demand flexibility
  - A number of time sequential bids
  - Dependency: The sum of the accepted bids should equal a certain amount (EQ).

FED Energy Market Clearing



- Formulated as a linear optimization problem
- Objective to maximize consumer and producer surplus
- Constraints includes bid dependencies, grid constraints (electricity and district heating) and power balance for each node.
- Market clearing prices obtained as the values of the dual variables for power balance constraints.



FED BENEFITS

1. Renewable Energy Systems
2. Fossil peak reduction
3. Power shortage
4. Grid stability
5. Multiple energy carriers
6. Local waste heat recovery

FED AGENTS AND TRANSACTIONS

- 16 kinds of participants
- 165 digital twins
- 51 agents
- 1,968,852 submitted bids
- 573,323 cleared bids

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www.johannebergsciencepark.com/fed

www.uia-initiative.eu

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Discussion

Coffee break

Chairs:

- Edoardo Corsetti, RSE
- Meysam Qadrdan, Cardiff University

SESSION 3: MODELLING AND SIMULATION OF MULTI-ENERGY SYSTEM FOR FLEXIBILITY QUANTIFICATION

Session 3

Modelling and Simulation of Multi-Energy System for flexibility quantification	Chairs: Edoardo Corsetti, RSE Meysam Qadrdan, Cardiff University
• Assessment of Multi-Energy System for flexibility maximization: the MAGNITUDE perspective • An orchestration tool for the optimal management of energy exchange over the networks: the PLANET proposal for a new approach to sector coupling	Edoardo Corsetti, RSE Meysam Qadrdan, Cardiff University Gabriele Fambri, Politecnico di Torino
• **Discussion**	

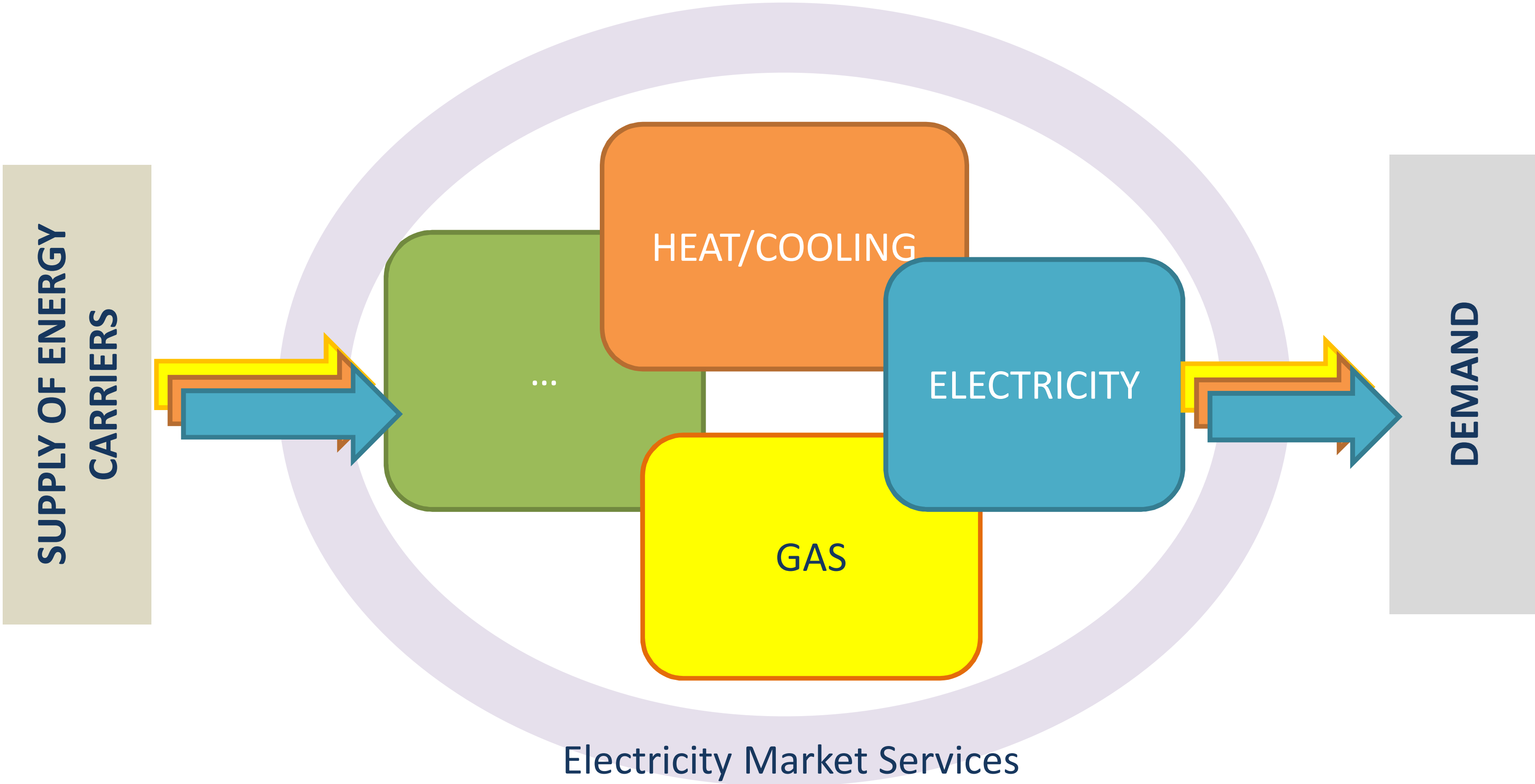
Edoardo Corsetti - RSE
Meysam Qadrdan - Cardiff University

ASSESSMENT OF MULTI-ENERGY SYSTEM FOR FLEXIBILITY MAXIMIZATION: THE MAGNITUDE PERSPECTIVE

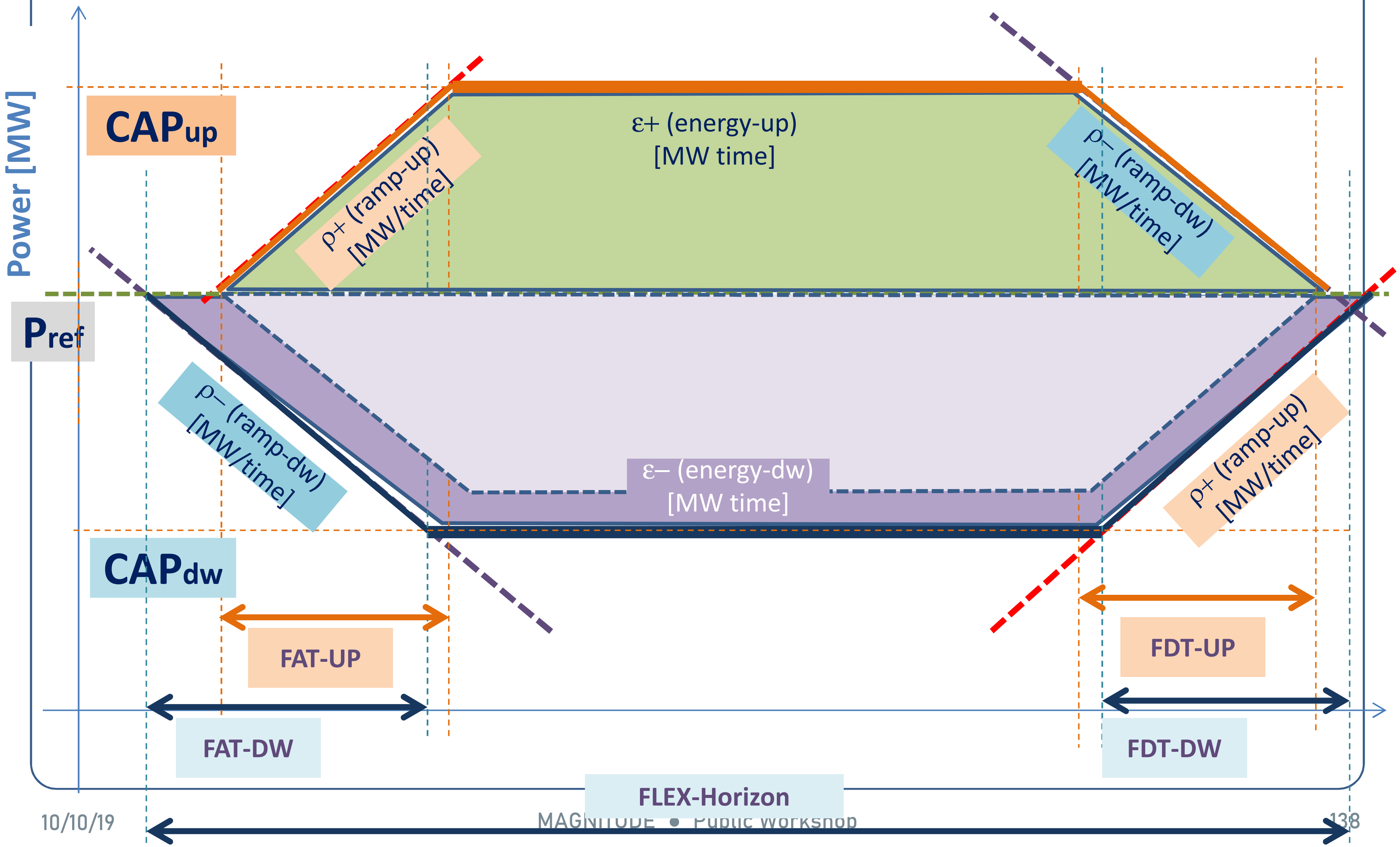
Outline

- The Multi-Energy Systems
- (Operational) Flexibility from MES
- Methodologies adopted to model and analyse MES
- A few examples from case studies: ACS, Mondi …
- Conclusions

The MES concept



Representation of flexibility
(non-symmetrical)



Representation of flexibility
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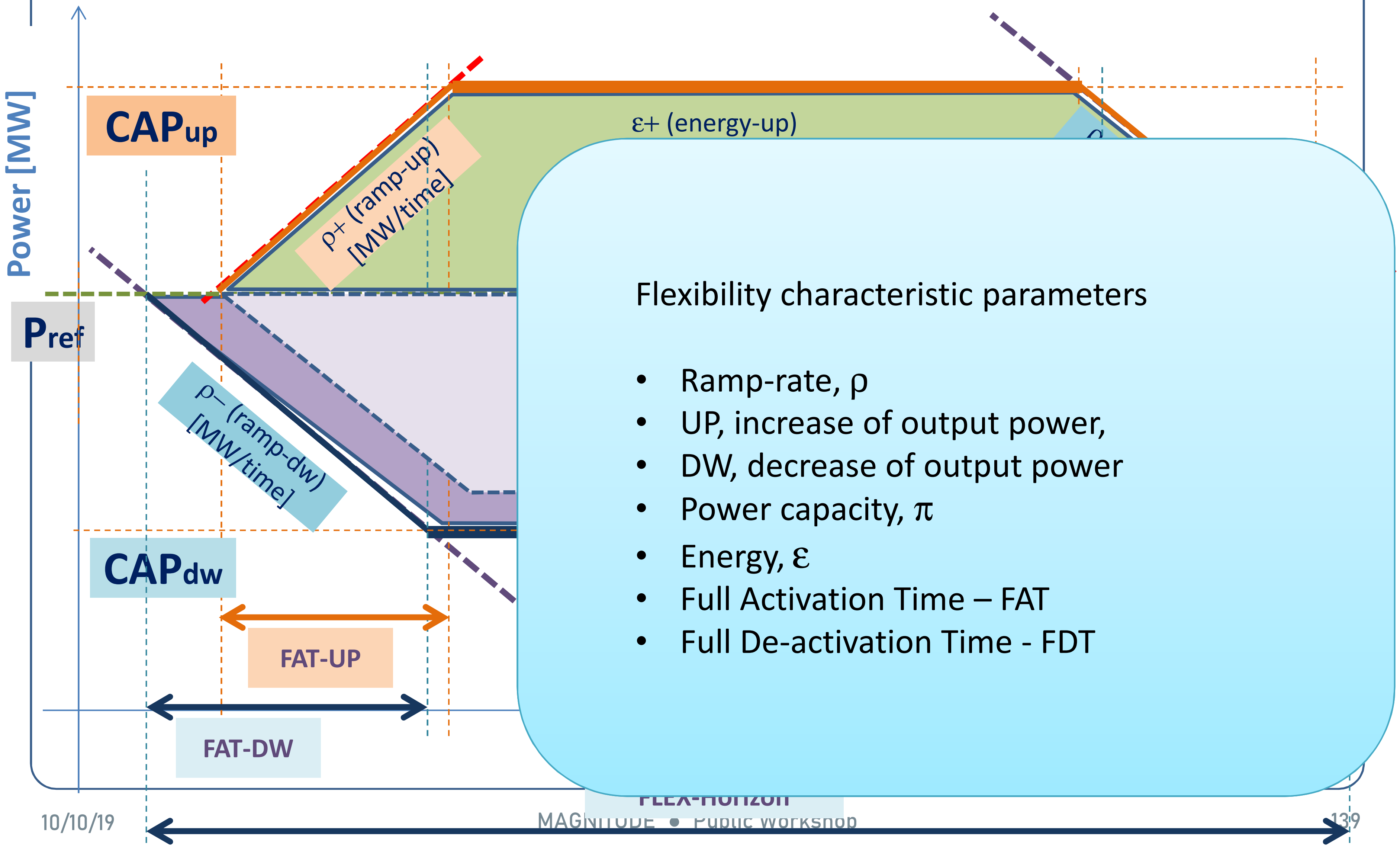


Flexibility characteristic parameters

- Ramp-rate, ρ
- UP, increase of output power,
- DW, decrease of output power
- Power capacity, π
- Energy, ε
- Full Activation Time – FAT
- Full De-activation Time - FDT

Methodologies: scope of the work

Long term planning (decades)
Medium term planning (years)
short term planning (h/days)
Very short term planning (min)
Operation (real-time program implementation) (sec)
Low level control (sec)
Power quality (msec)

Methodologies: the modelling stage

In
(physical and control)
variables

Differential equations

Finite difference equations

…

Black/grey box
system functionality behaviour

Out
(physical)
variables

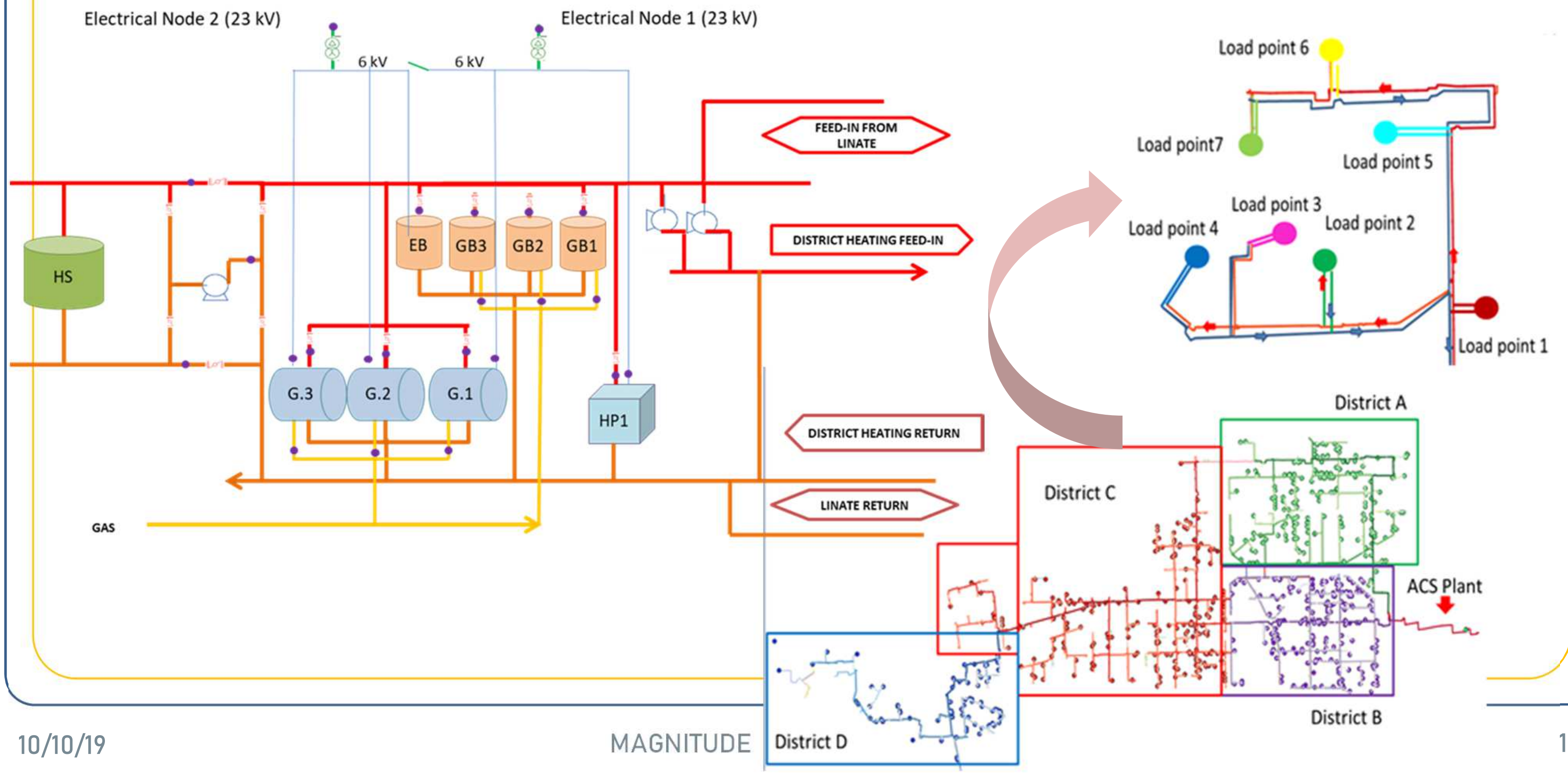
Quality of the system real data (complete representation of the system dynamics)

Validation of the model: output variables compared against the system real data

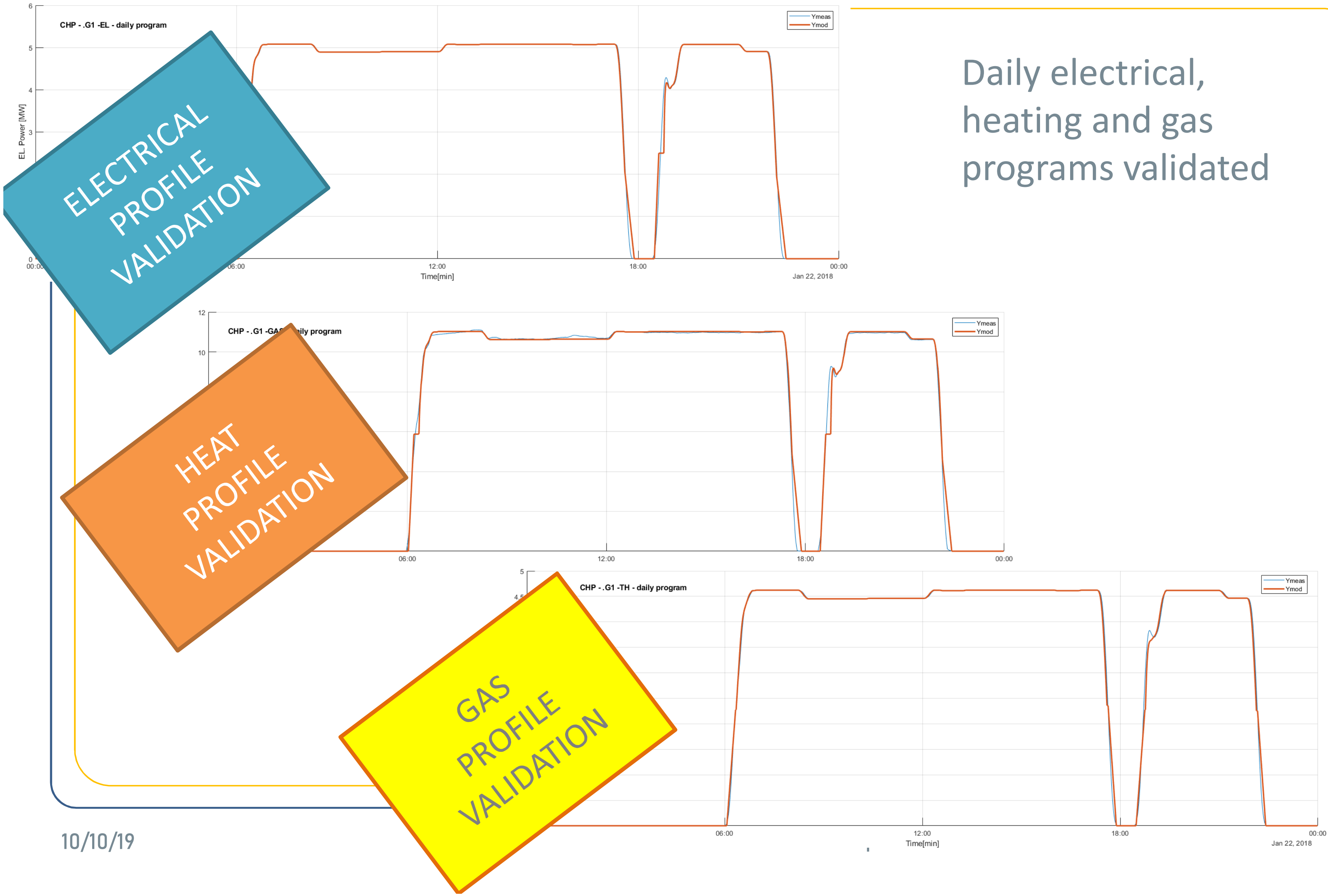
Assessment

The ACS Case Study

- ACS case study is a “3rd generation” district heating network system located in the east side of Milan (called “Milano-Est”). It includes:
  - 3 CHPs gas-engine (5 MWel, 4.8 MWth), 3 Gas-Boilers (15 MWth), 1 HP (12.5 MWth), Heat Storage (22 MWth ch/dch, 70 MWh), Electric Boiler (5 MWth);

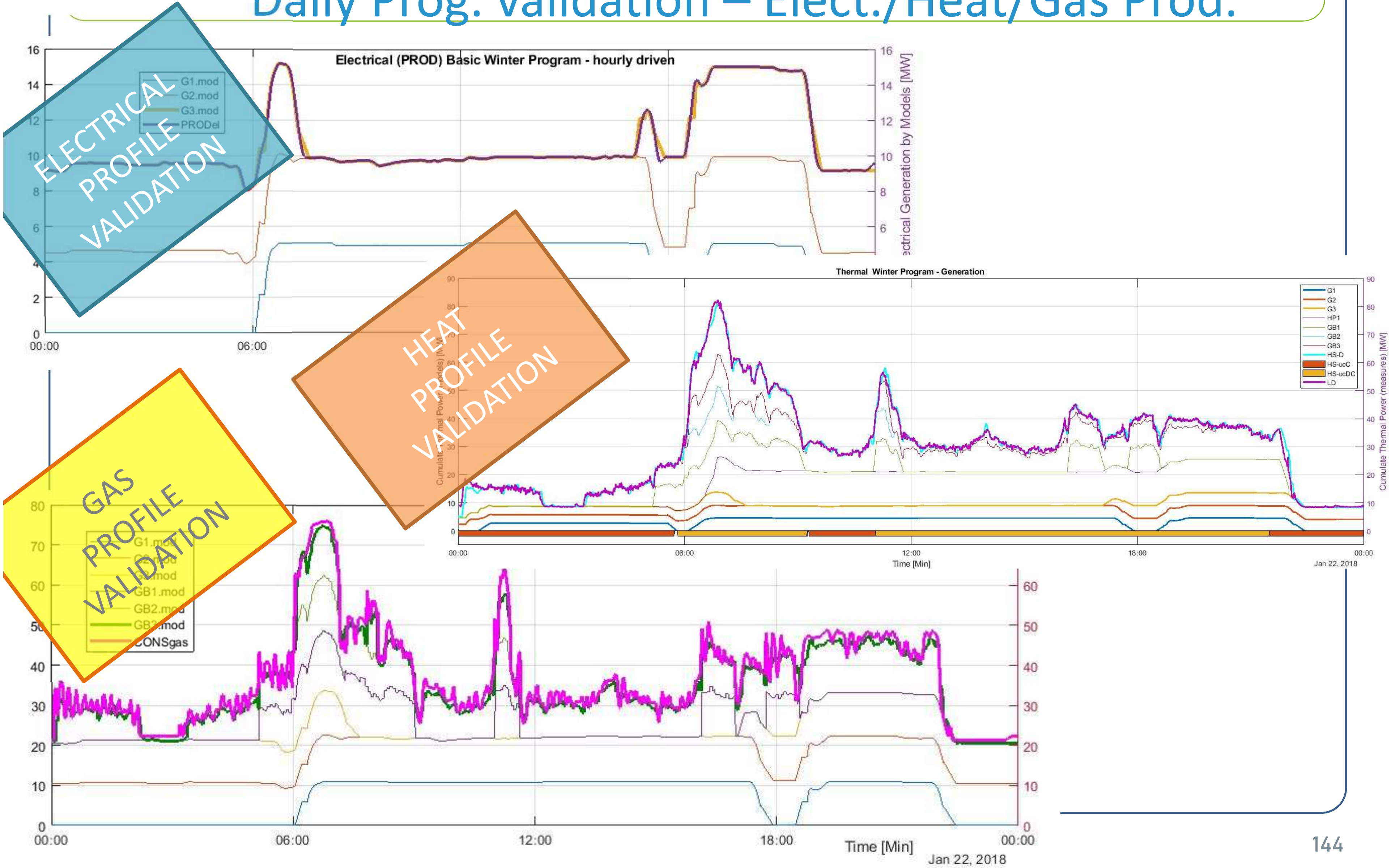


The device/plant modelling step:
CHP model validation

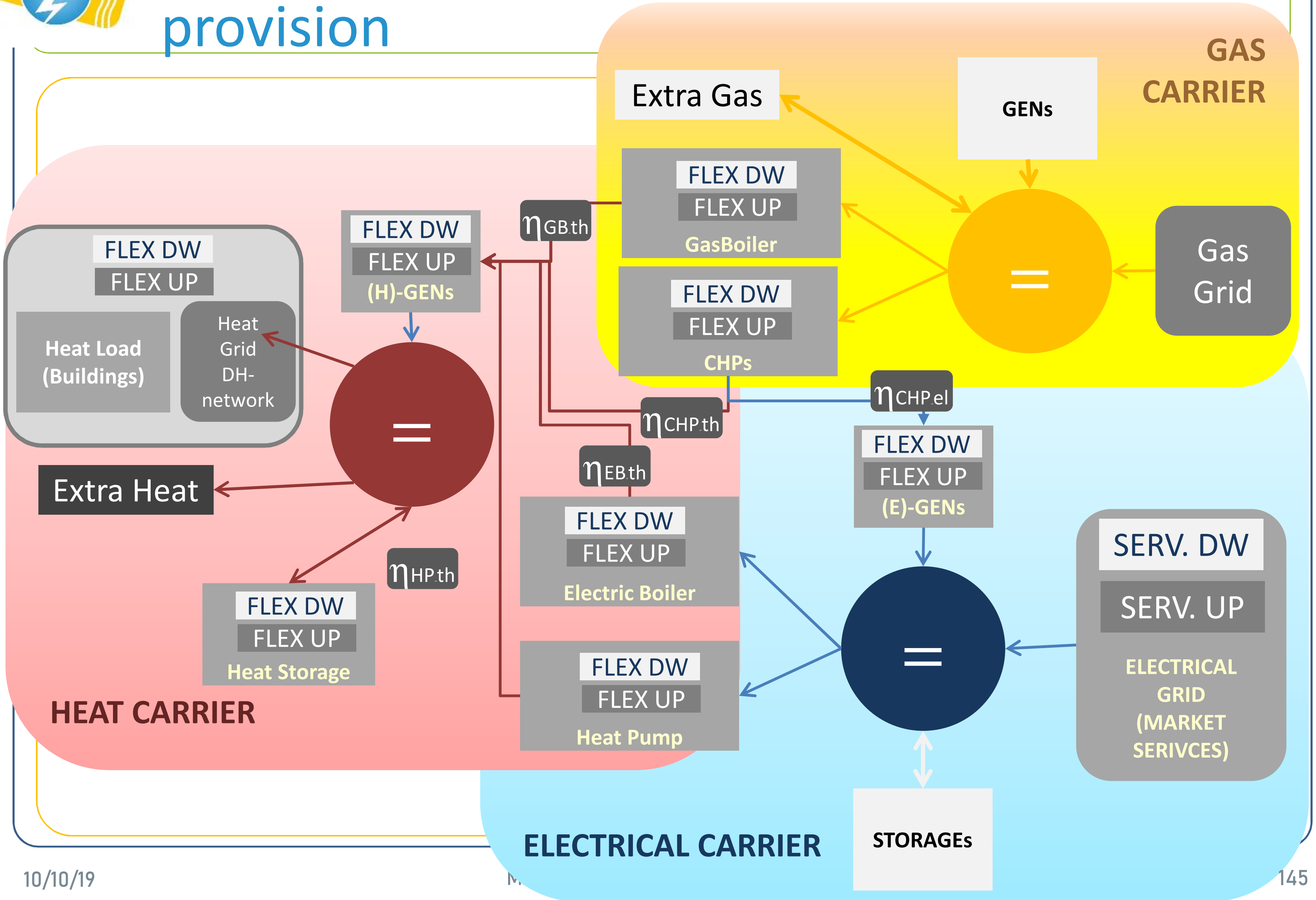


Daily electrical, heating and gas programs validated

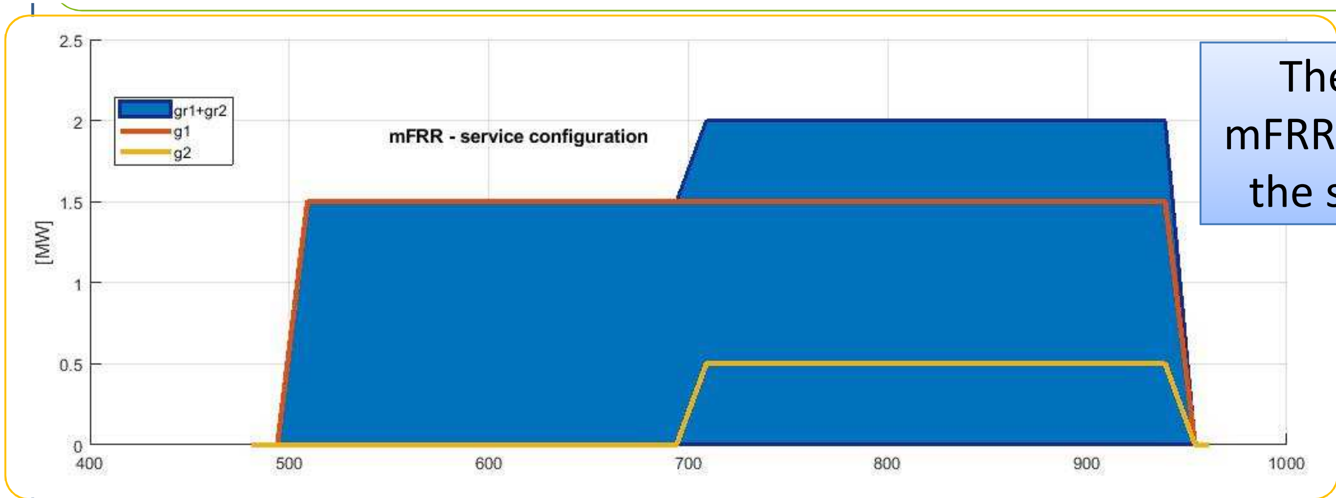
BASE CASE:
Daily Prog. validation – Elect./Heat/Gas Prod.



The EMS to regulate and plan the service provision

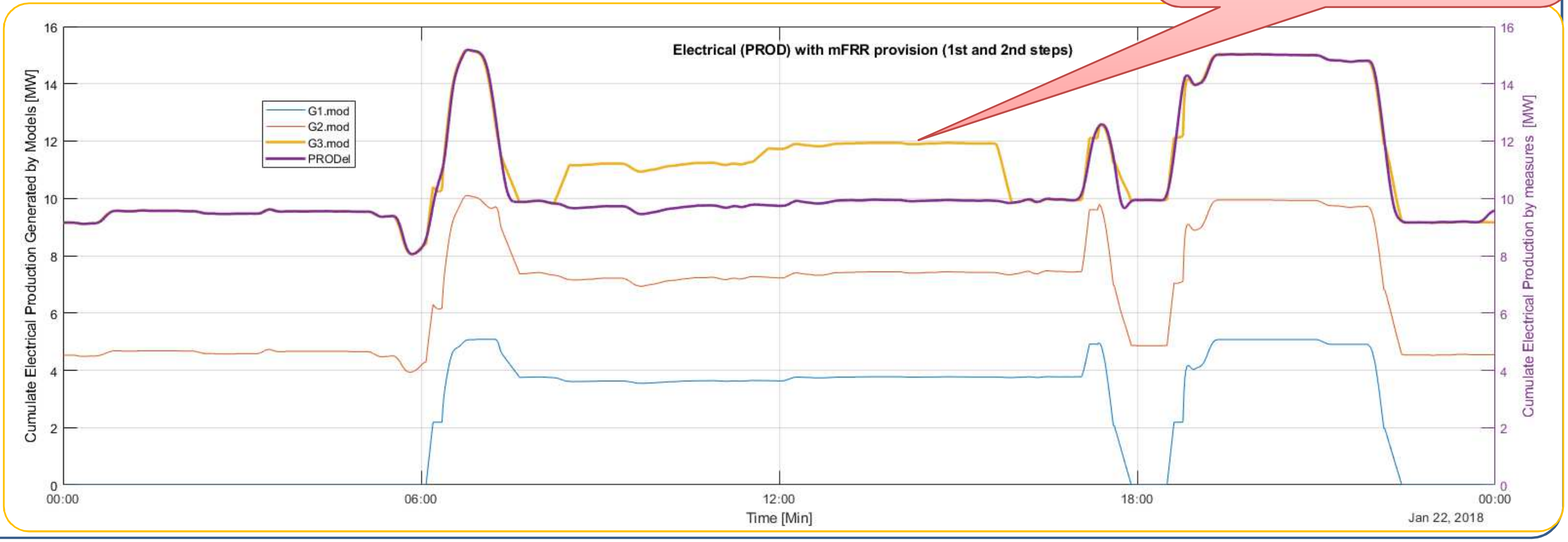


The modelling step: service provision - mFRR



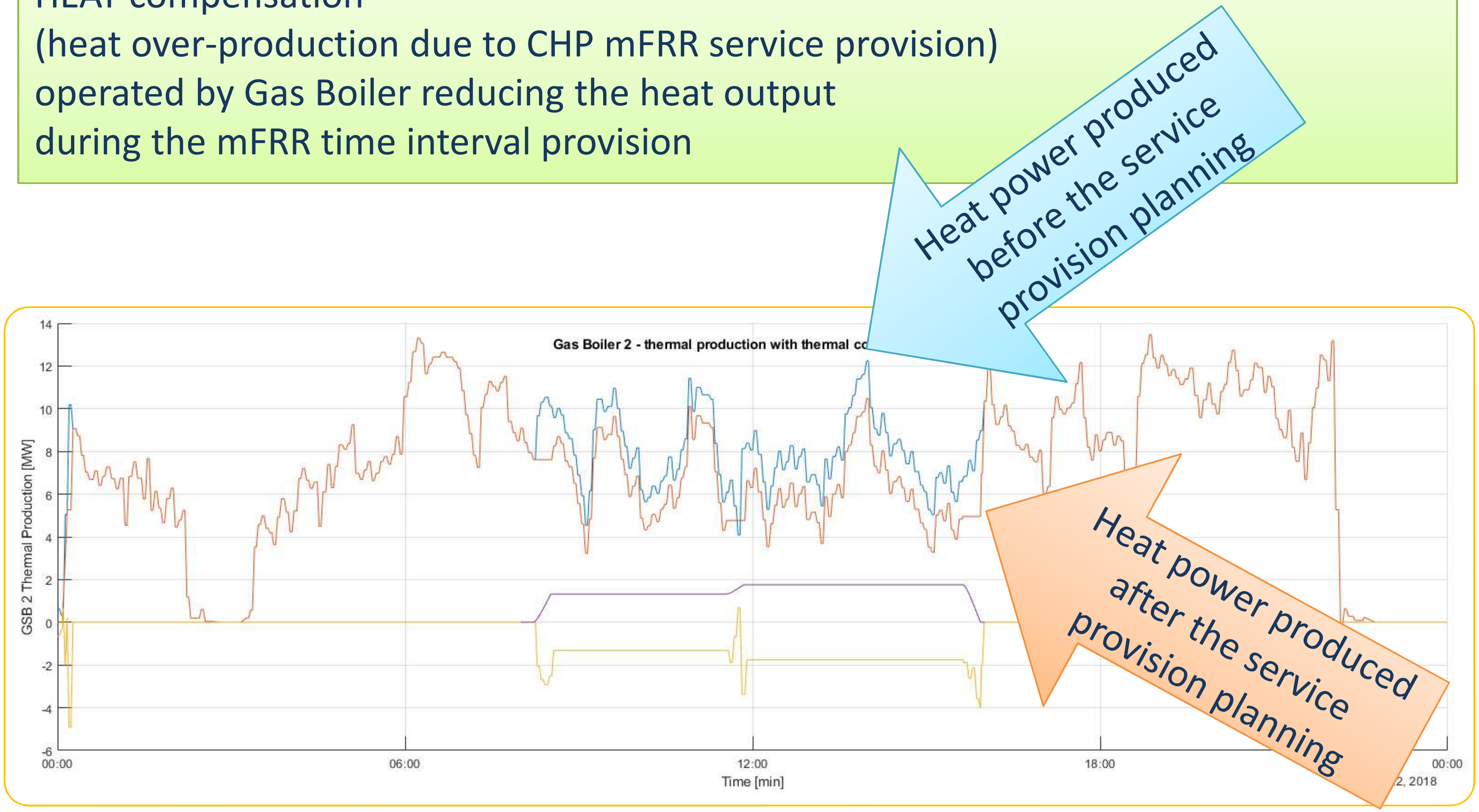
The service mFRR shaped for the simulation

The service mFRR as appears on the plant electrical network

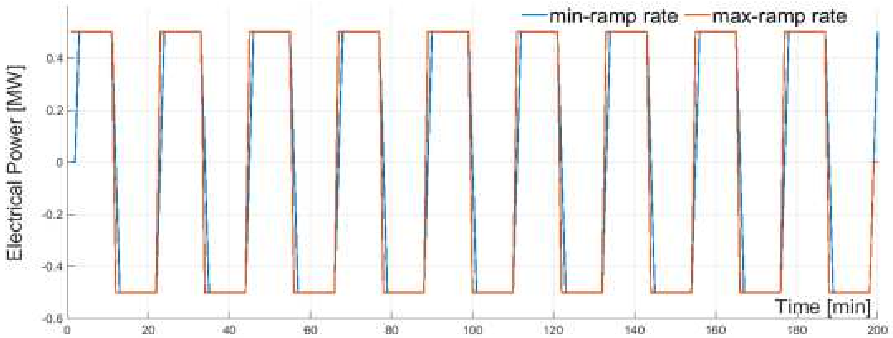


Carriers balancing maintains the base-case equilibrium

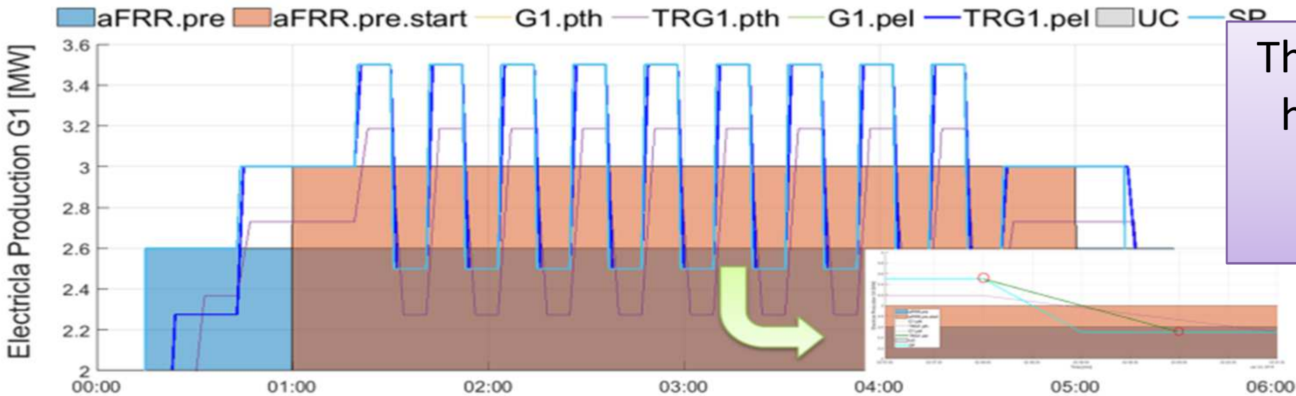
HEAT compensation
(heat over-production due to CHP mFRR service provision)
operated by Gas Boiler reducing the heat output
during the mFRR time interval provision



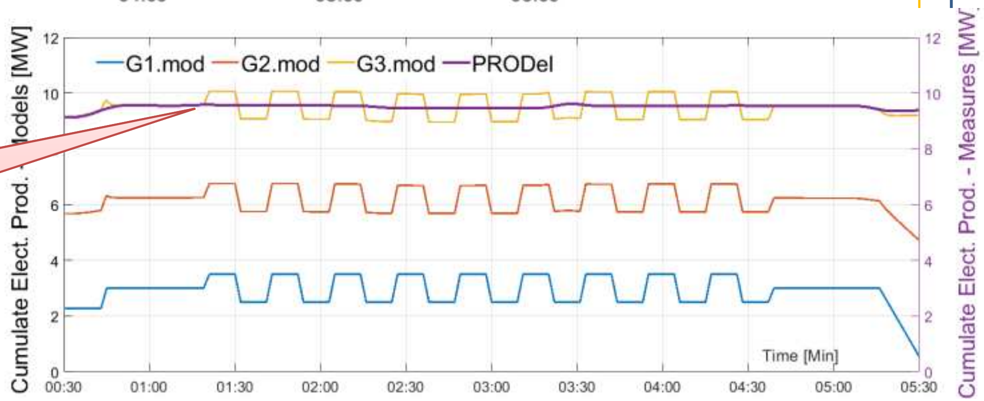
The modelling step: service provision - aFRR



The service aFRR shaped for the simulation

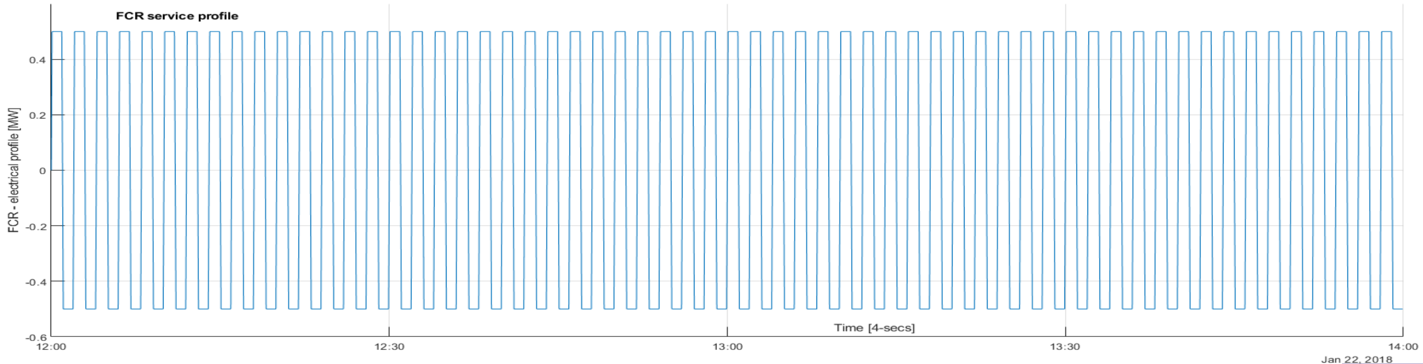


The CHP electrical and heat output profiles during the aFRR service provision



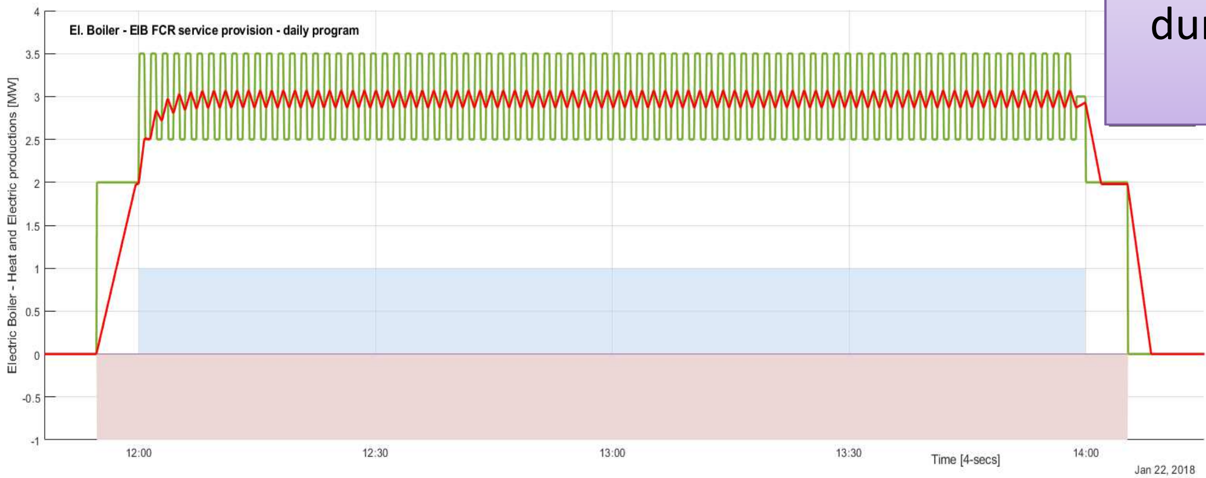
The service aFRR as appears on the plant electrical network

The modelling step: service provision - FCR



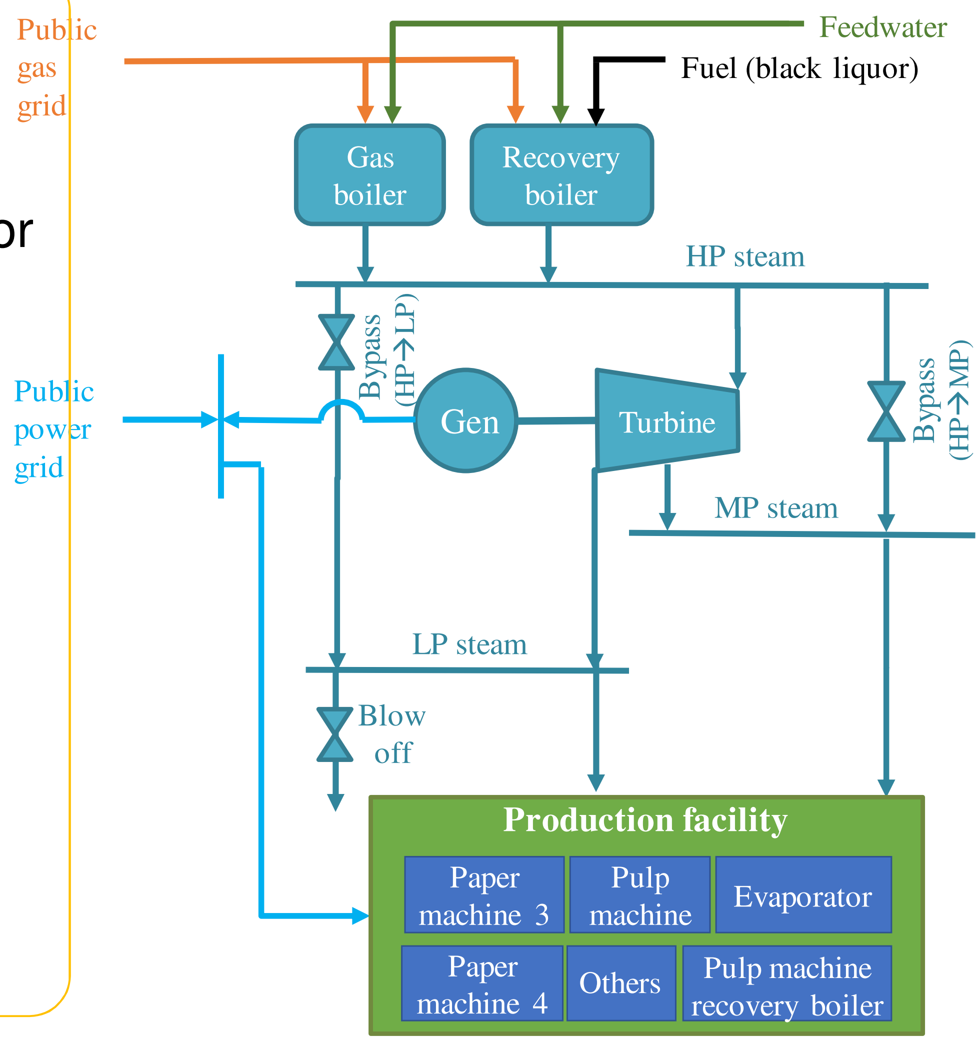
The service FCR shaped for the simulation

The El. Boiler heat output profile and electrical absorption during the FCR service provision



Mondi case study: an integrated paper mill

- **Feed water:** 100 bar, 104 °C.
- **Steam generators**:
  - Natural gas boiler, 40 t/h
  - Recovery boiler (black liquor + gas), 26 t/h
- **Turbine:** Extraction back-pressure turbine, 10.5 MWe
- **HP steam:** 72 barg, 505 °C
- **MP steam:** 12 barg, 210 °C.
  - By-pass from HP available
  - No blow off.
- **LP steam:** 3.5 barg, 190 °C
  - By-pass from HP available
  - Blow off available.



Model description

Input

- Steam demands
- Blow-off steam
- By-pass steam
- Steam flow of recovery boiler
- Black liquor flow
- Electricity demand
- Flexibility demand

Steam and electricity generation system model

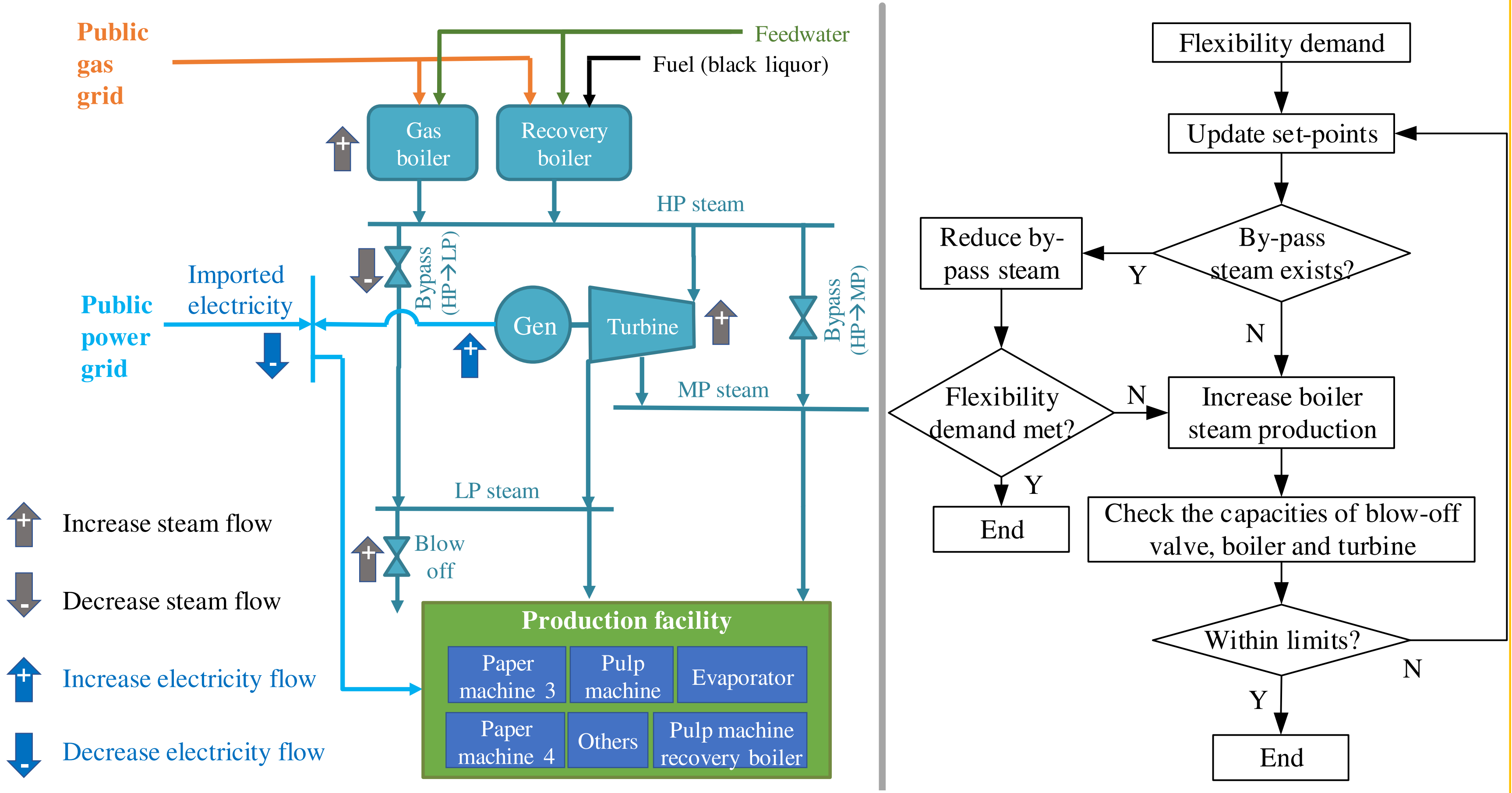
Output

- Electricity generation
- Imported electricity
- Imported gas
- Variations of by-pass steam
- Variation of blow-off steam
- Loss of feed-water

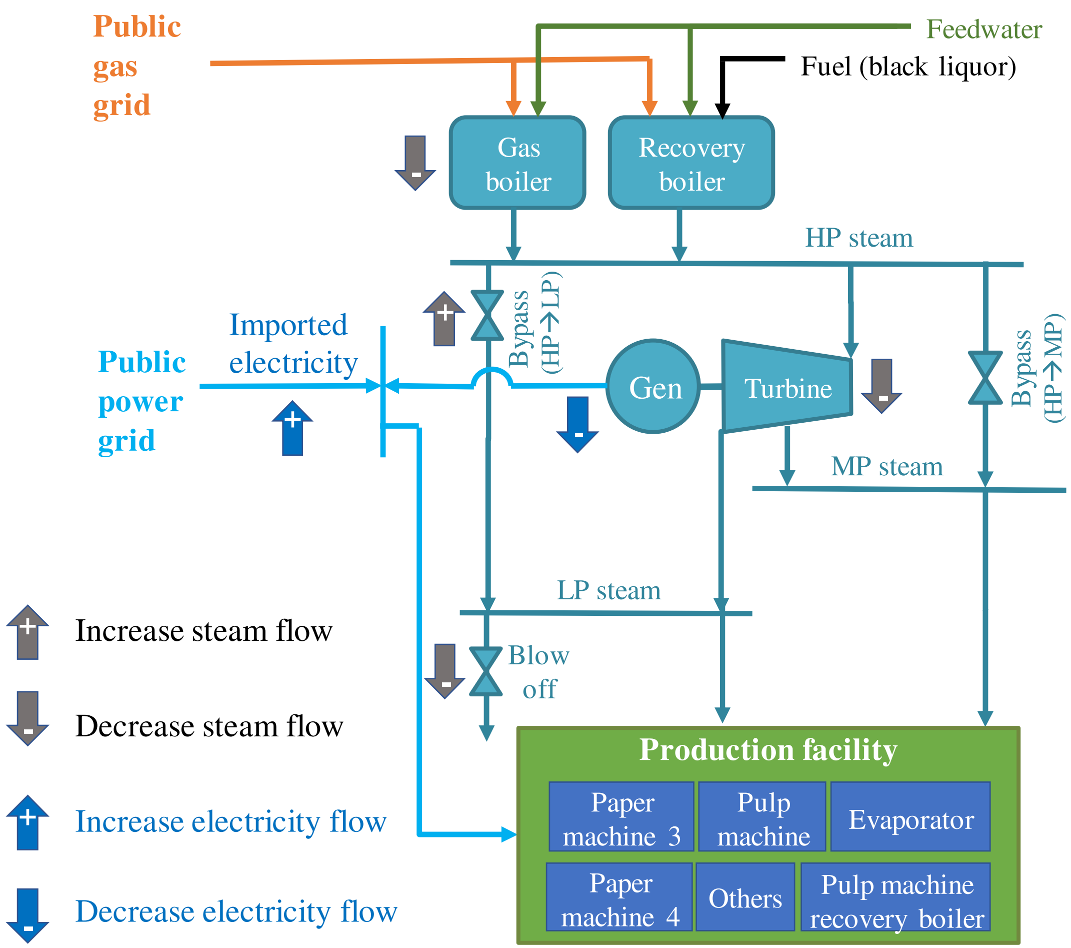
Parameters

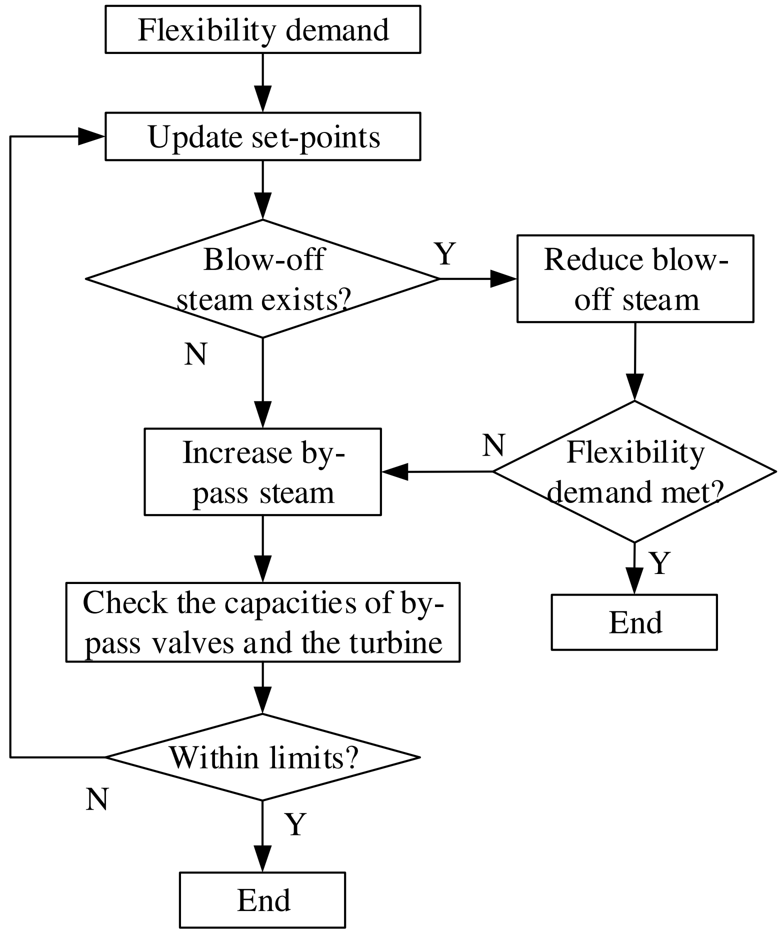
- Water supply (temperature & pressure)
- Boiler (efficiency & capacity)
- Turbine (efficiency & capacity)
- Steam system (temperature & pressure)
- Reduction station capacity
- Blow-off and fresh water preparation limits

Upward Regulation (decrease imported electricity)



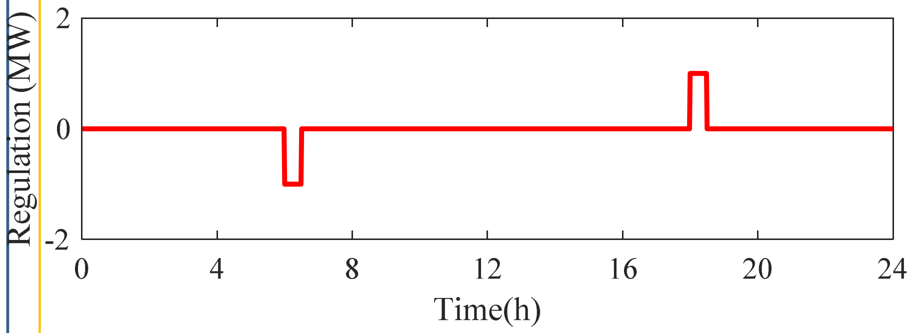
Downward Regulation (increase imported electricity)

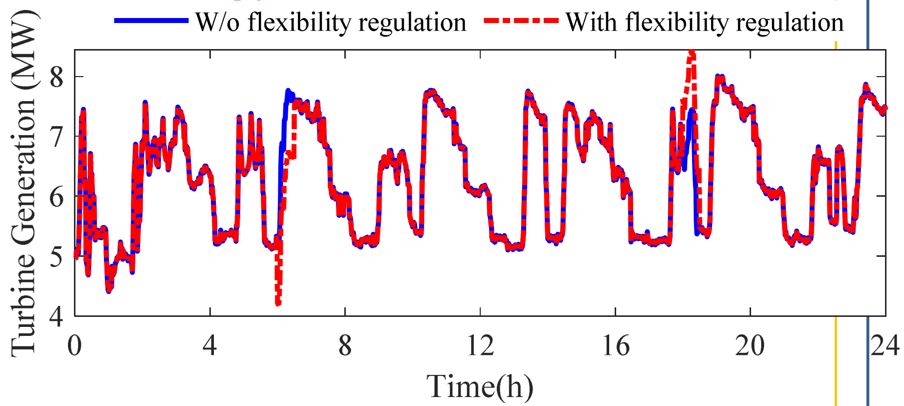


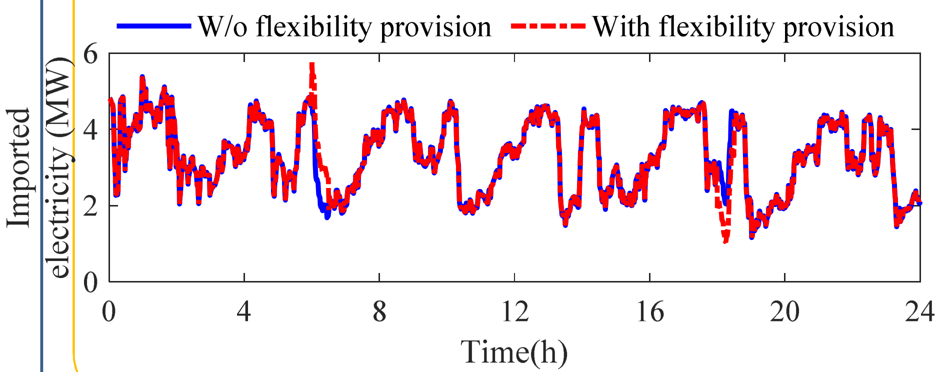


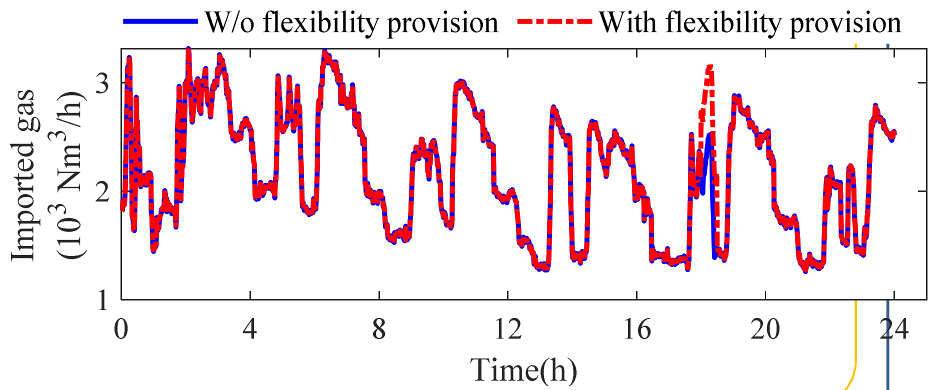
Simulation results

- Downward regulation (1MW more imported electricity): 6:00 to 6:30.
- Upward regulation (1MW less imported electricity): 18:00 to 18:30.

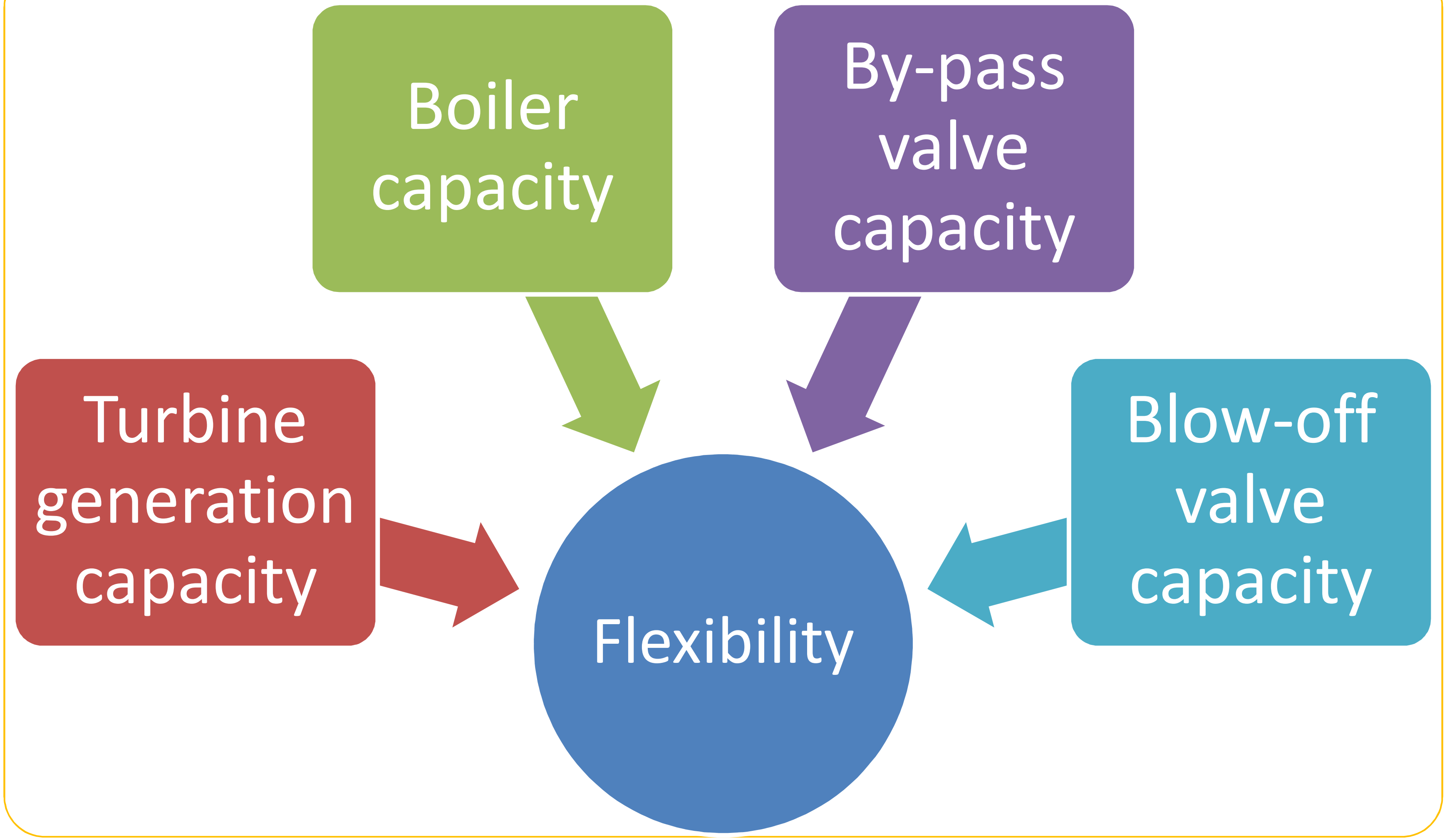






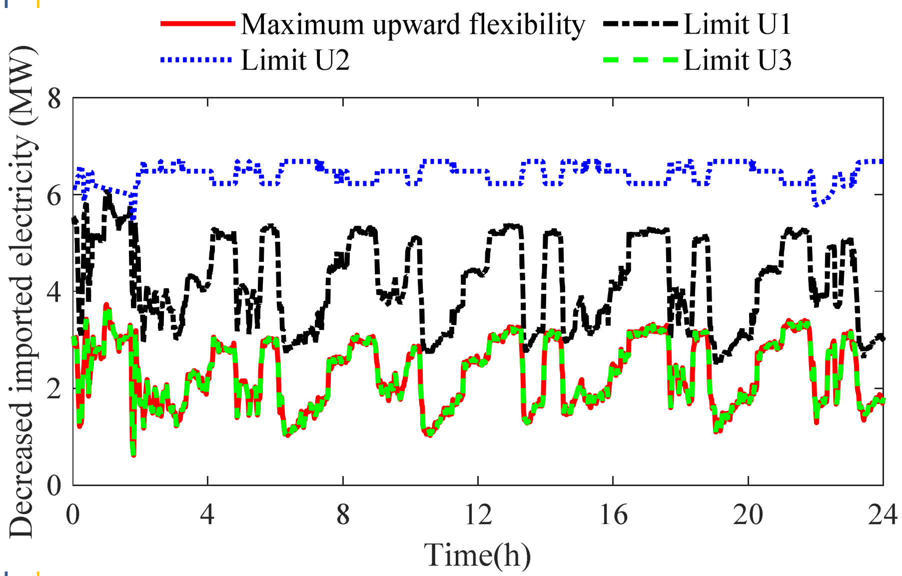


Flexibility quantification

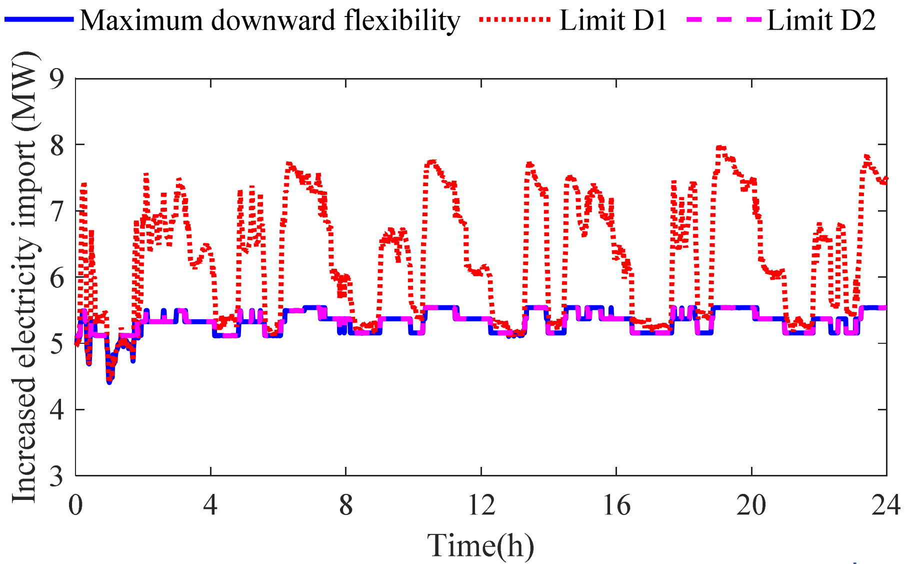


Flexibility quantification: results

Variation of maximum upward regulation



Variation of maximum downward regulation



Limit U1: rated electricity generation capacity of the turbine-generator

Limit U2: maximum blow-off steam flow rate

Limit U3: unused capacity of the boiler.

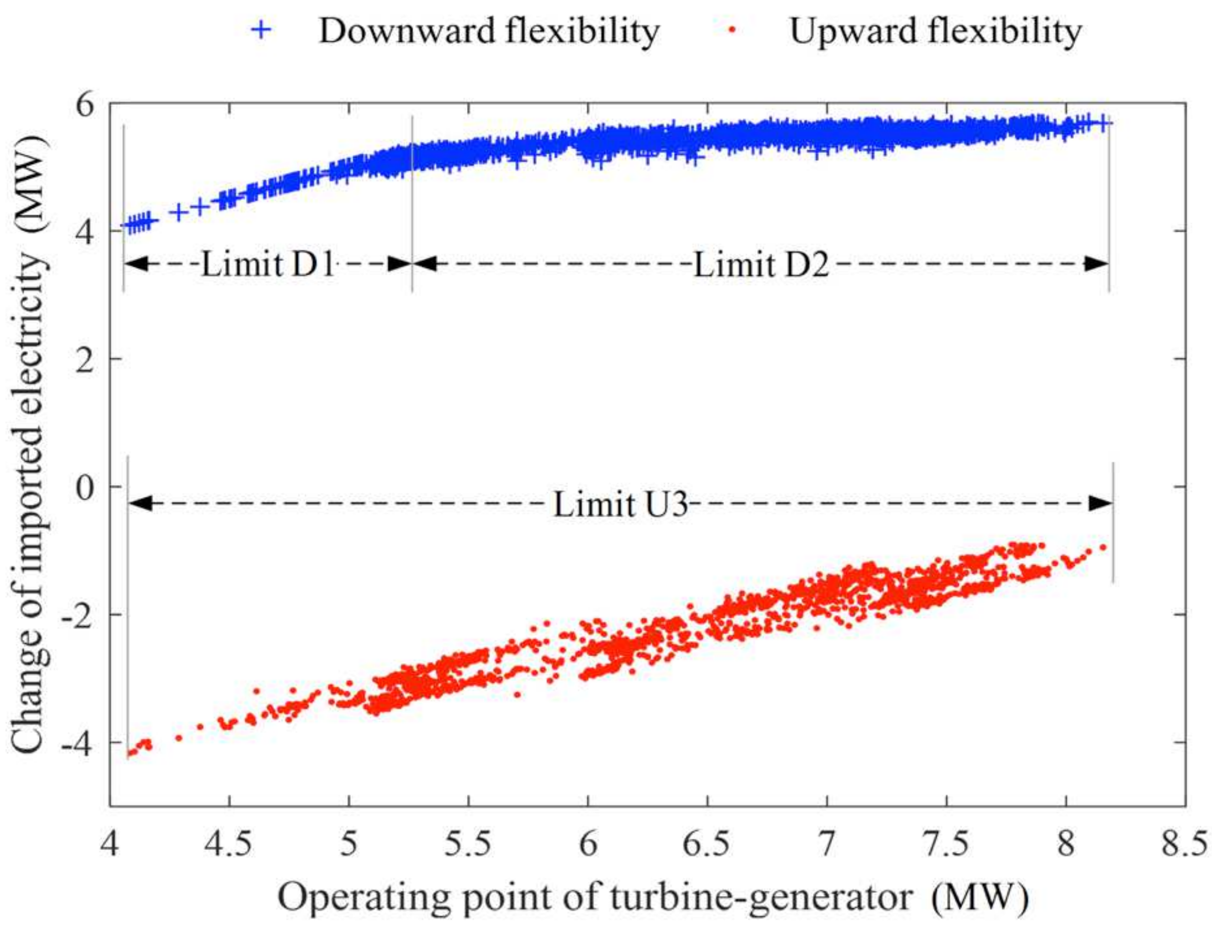
Limit D1: the minimum power output of the turbine generator.

Limit D2: Available capacities of by-pass valves.

Flexibility quantification: results

The boundaries for upward and downward flexibility in respect to the level of the operating point of the turbine-generator

- **Limit U3**: unused capacity of the boiler.
- **Limit D1**: the minimum power output of the turbine generator.
- **Limit D2**: Available capacities of by-pass valves.



Conclusions

- The presentation proposed a description of the basic notions MAGNITUDE project is going to use to model, simulate and optimize MES in order to quantify the flexibility they can provide to the electricity markets
- The presentation also gave a couple of perspectives, from two of the seven cases studies foreseen in MAGNITUDE, according to flexibility has been put on the run to be provided as market service to the market
- These two different ways to manage flexibility highlighted how they can cover both the planning phase, where a portion of the available flexibility is set to a specific electricity service, and during the re-balancing phase where for each other energy carrier is get a new equilibrium

Gabriele Fambri, Politecnico di Torino

AN ORCHESTRATION TOOL FOR THE OPTIMAL MANAGEMENT OF ENERGY EXCHANGE OVER THE NETWORKS: THE PLANET PROPOSAL FOR A NEW APPROACH TO THE SECTOR COUPLING

An orchestration tool for the optimal management of energy exchange over the networks

The PLANET proposal for a new approach to the sector coupling

Planning and operational tools for optimising energy flows & synergies between energy networks

Gabriele Fambri

Department of Energy, DENERG, Politecnico di Torino

10th October 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 773839

Outline

- PLANET project
  - General information
  - PLANET Objectives and Main Activities
  - Main use cases
- PLANET Decision Support System (DSS) Model
  - Orchestration module
  - Energy conversion storage technologies (P2H P2G)
  - The optimization module
  - Grid simulators
- First DSS prototype and Use Case development

Outline

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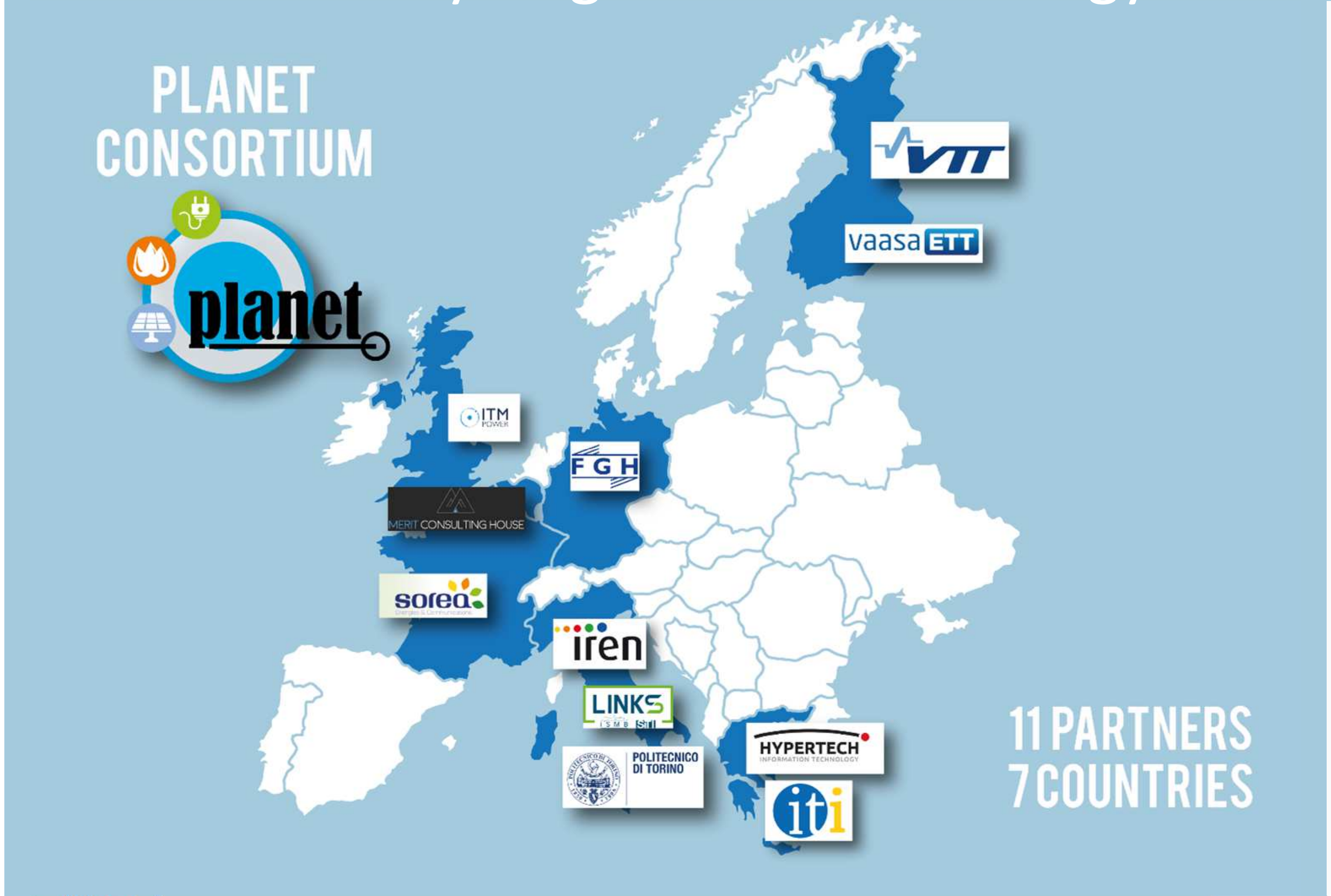
PLAnning and operational tools for optimising energy flows & synergies between energy NETworks



Project information

PLANET

Grant agreement ID: 773839

Status
Ongoing project

Start date
1 November 2017

End date
31 October 2020

Funded under:
H2020-EU.3.3.4.

Overall budget:
€ 3 999 695

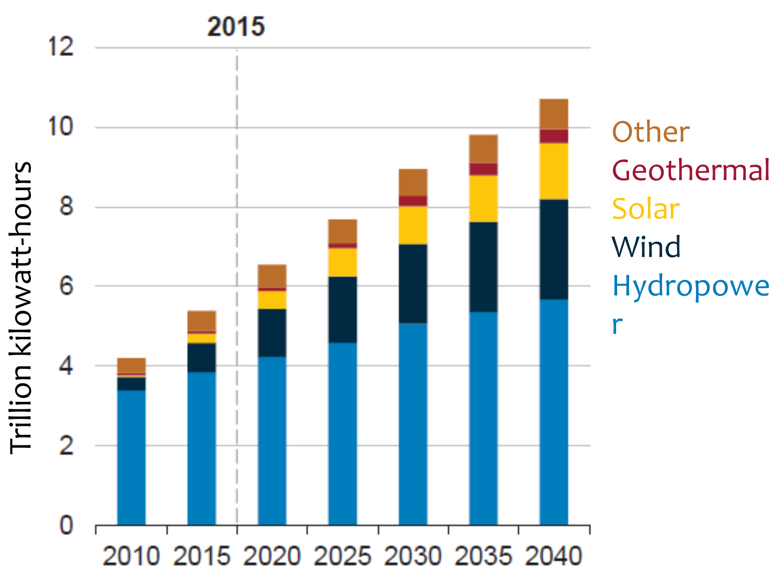
EU contribution
€ 3 999 695

Coordinated by:
POLITECNICO DI TORINO
Italy

Problem context

Non dispatchable Renewable Energy Sources are increasing in electricity network

- The World's mean temperature has risen by 0.8 °C due to the **anthropogenic greenhouse gas emissions**
- **Renewable Energy Sources** will play a fundamental role in order to limit the global warming



Source: Energy U.S., I.A., 2017. International Energy Outlook .

Problem context

Non dispatchable Renewable Energy Sources are increasing in electricity network

↓

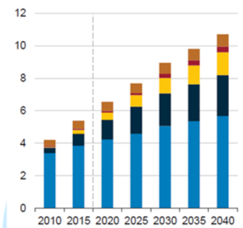
Relative uncertainties can generate electrical system reliability issues

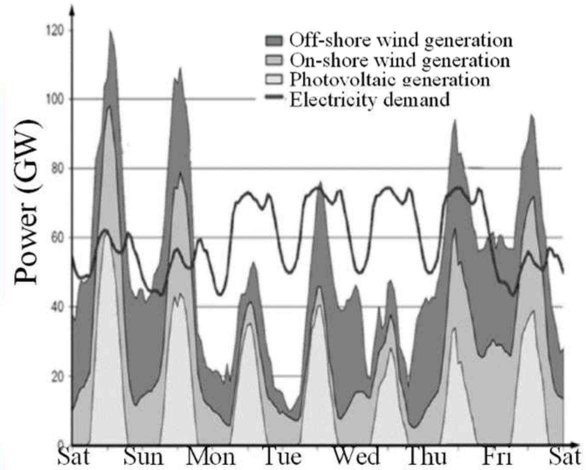
↓

Reverse Power Flow | Power Quality | Over Loadings

Renewable generation impact

- *Non usual operation, with network constraints verified.*
  - **Reverse power flow**: There is injection of power into the transmission system through the HV/MV transformer.
- *Operation with non-verified constraints.*
  - **Overloading**
  - **Over/under voltages**





Source: Siemens, 2015. Power to Gas – an economic approach?

Problem context

Non dispatchable Renewable Energy Sources are increasing in electricity network

↓

Relative uncertainties can generate electrical system reliability issues

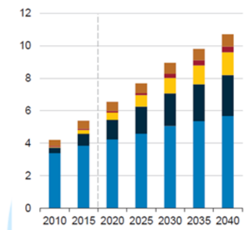
↓

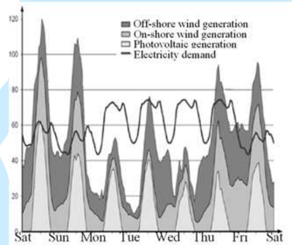
- Reverse Power Flow
- Power Quality
- Over Loadings

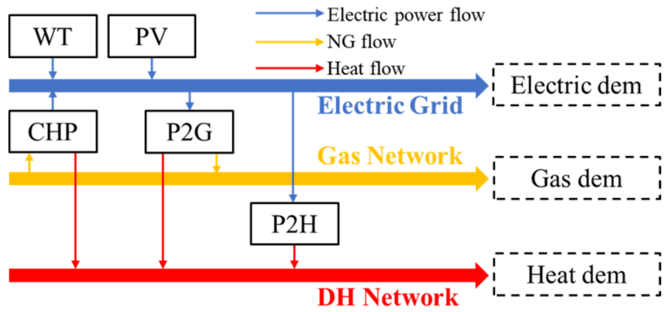
↓

Sector coupling can increase the flexibility of the global system and reduce these problems

Our solution







Problem context

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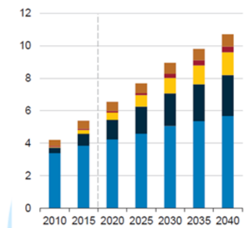
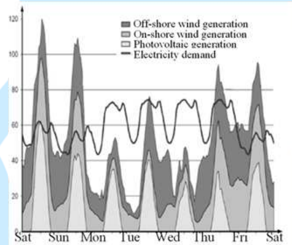
↓

PLANET Decision Support System

Our solution

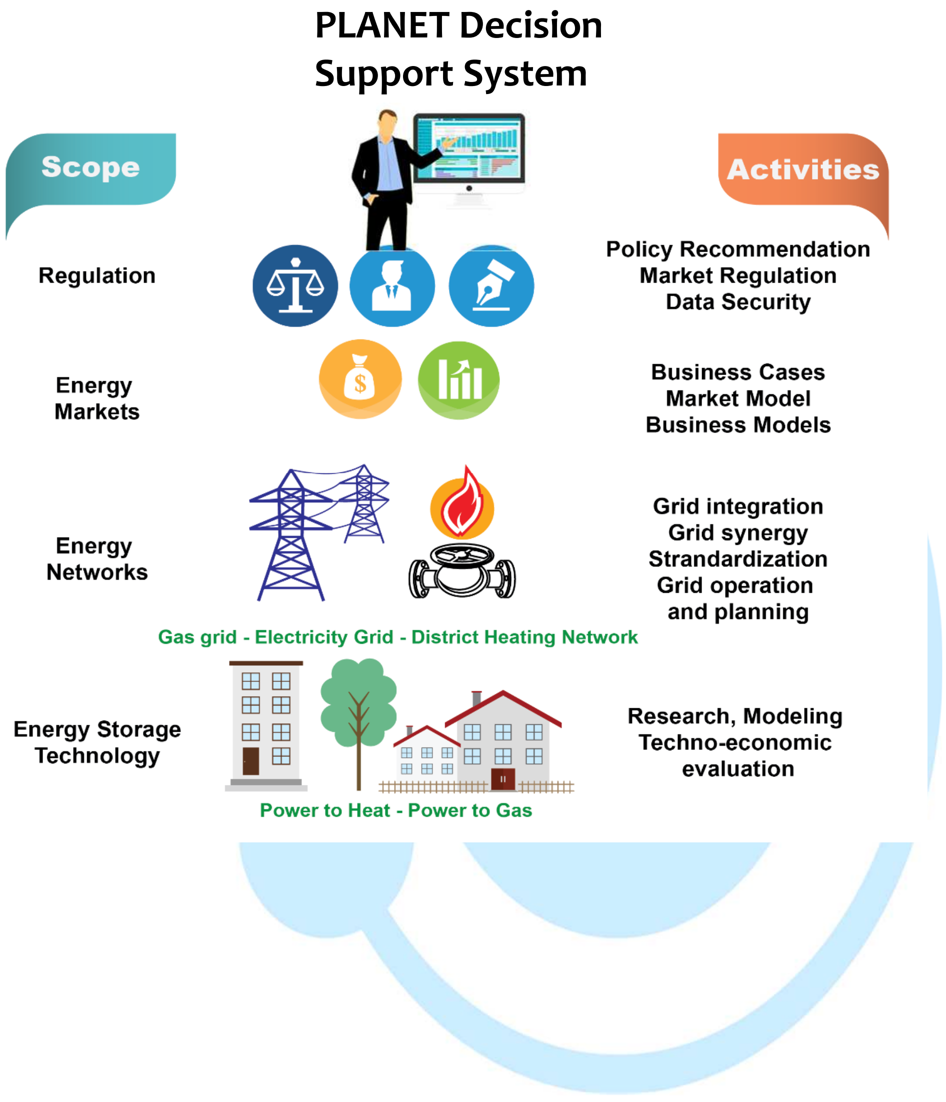




PLANET Objectives and Main Activities

Objectives:

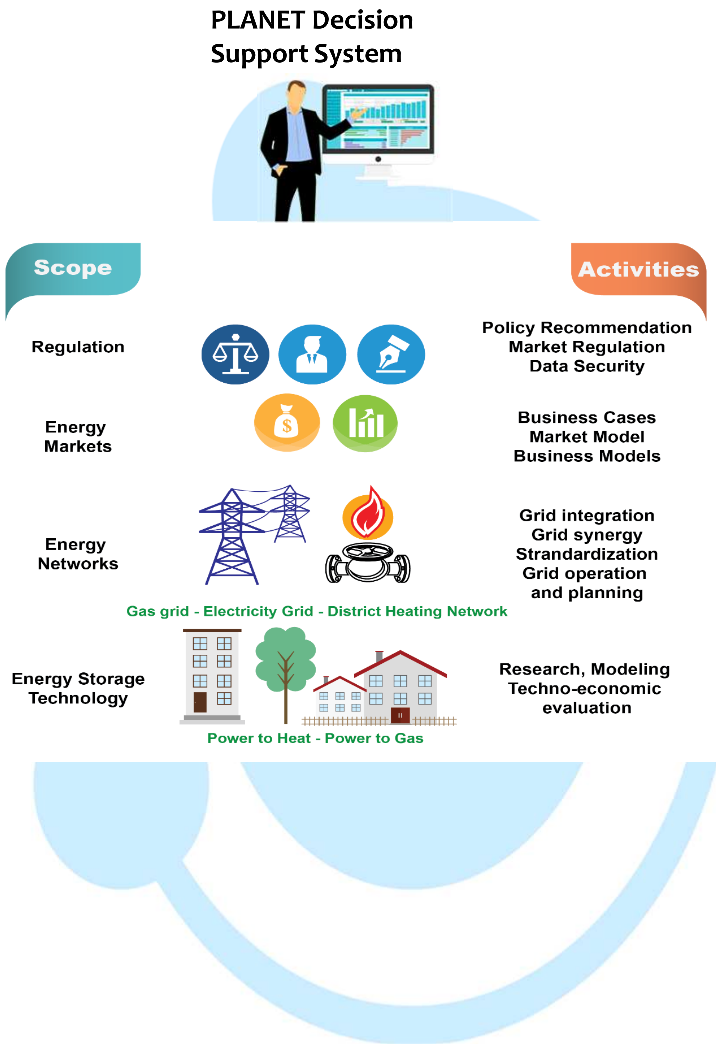
- Facilitate the **full integration of increasing renewable energies** in the electricity grid.
- Global **coordination of energy networks** (electricity, gas, heat) and assets with special focus on energy **storage** and **conversion** technologies.



PLANET Objectives and Main Activities

Main activities:

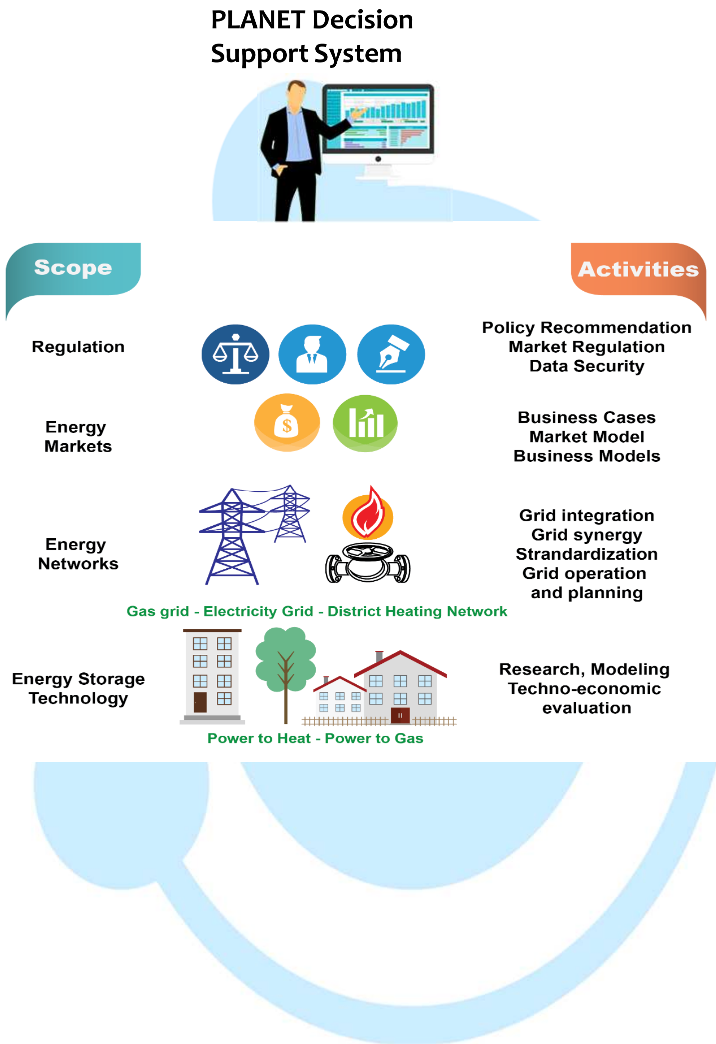
1. The **modelling of conversion/storage technologies** in order to properly take into account their expected impact in the field. These technologies include:
   - Power-to-Gas (**P2G**)
   - Power-to-Heat (**P2H**)
   - Combined Heat and Power (**CHP**)
   - Virtual Energy Storage (**VES**)



PLANET Objectives and Main Activities

Main activities:

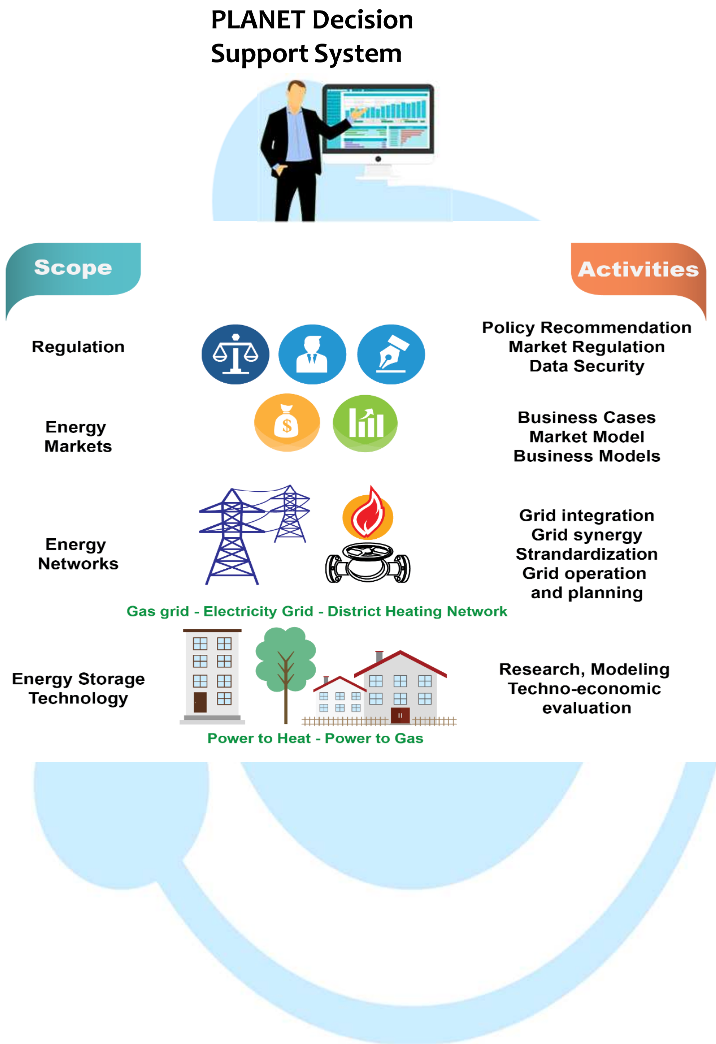
2. The **simulation of electricity, gas and heat networks**, and their integration with conversion/storage technologies models, in order to understand how these conversions can improve network stability, reliability and responsiveness



PLANET Objectives and Main Activities

Main activities:

3. The development of a holistic **Decision Support System (DSS)** that enables multi-grid operational planning and management taking into account synergies and energy flows between networks



PLANET DSS Main Stakeholders

- ***Distribution System Operators***
  - Evaluation of the added value of sector coupling in grid balancing with high presence of RES
- ***Policy makers***
  - Formulation of policies to encourage the use of conversion systems for energy system decarbonization
- ***Storage/Conversion asset owners***
  - Assessment of business viability of conversion system deployment in the energy system in terms of added value to the grid assets

PLANET Major Use Cases (1)

18 sector coupling scenarios have been investigated within PLANET project out of which the below ***major Use Cases*** have been identified including:

A. *P2G deployment for system control*

- The deployment of P2G conversion units in specific nodes of the MV electrical grid in high presence of RES for alleviation of reverse power flow and/or operational limits violation.
  - ***Seasonal Energy Storage, Elimination of RES curtailment w/o infrastructure upgrade***

B. *VES for congestion management via electricity demand shifting*

- The utilisation of theVES buildings flexibility for electrical grid balancing using local P2H technologies.
  - ***Peak-load management, Demand modulation, Congestion management***

PLANET Major Use Cases (2)

C. *Centralised heat-pumps for hot water storage in DH*

- Exploitation of the centralized P2H technologies for enhancing the thermal storage capacity connected to the DH network and ancillary service provision to the electricity grid.
  - ↳ ***Peak-load management, Elimination of RES curtailment w/o infrastructure upgrade, grid balancing.***

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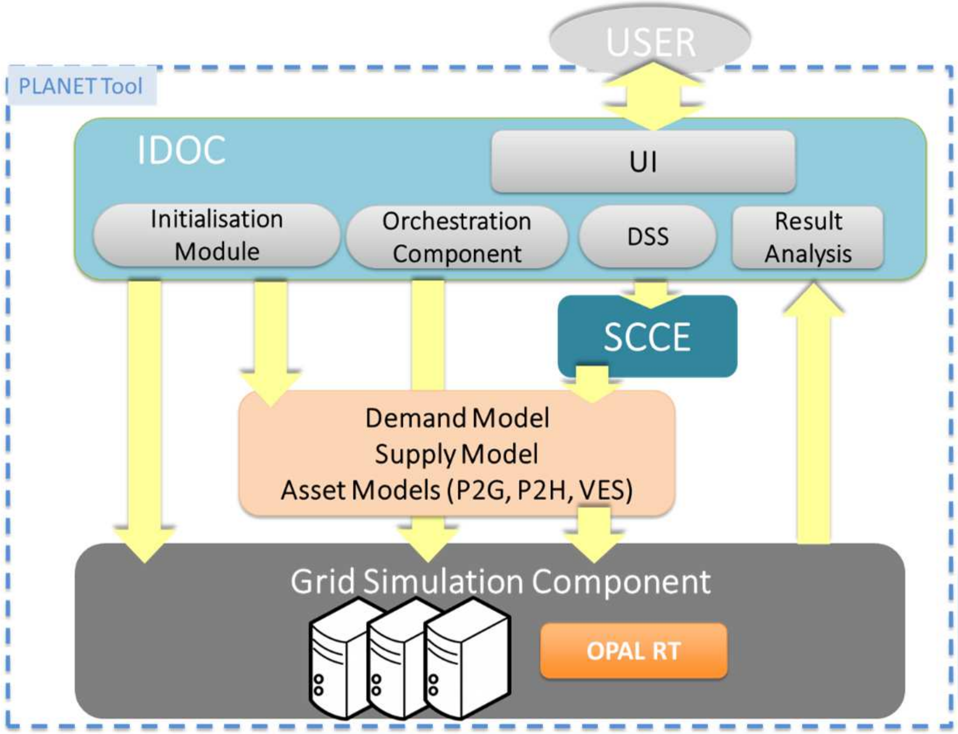
PLANET Decision Support System Architecture

- **The user interface and orchestration module:**
  Integrated **D**ecision Support System and **O**rchestration **C**ockpit (IDOC)
- **The optimization module:**
  Storage/**C**onversion and **C**oordination **E**ngine (SCCE)
- **Energy conversion systems:**
  - P2G: **P**ower to **G**as
  - P2H: **P**ower to **H**eat
  - VES: **V**irtual **E**nergy **S**torage
- **Grid simulator:**
  - Electrical Grid
  - Gas network*
  - DH network*

* Not implemented yet

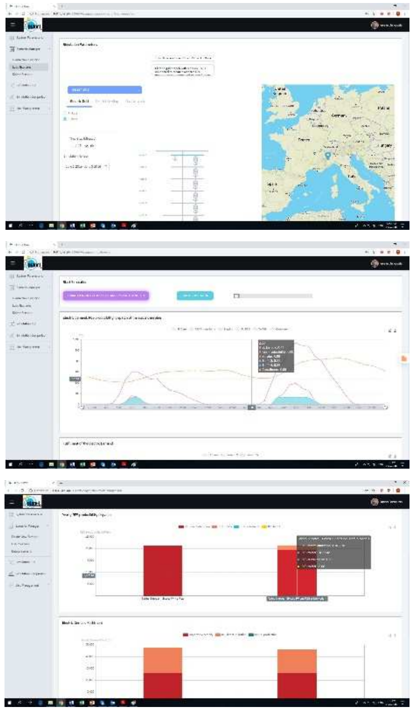


Web User Interface

Step 1: User registration and scenario creation

Step 2: Simulation of the scenario and result visualization

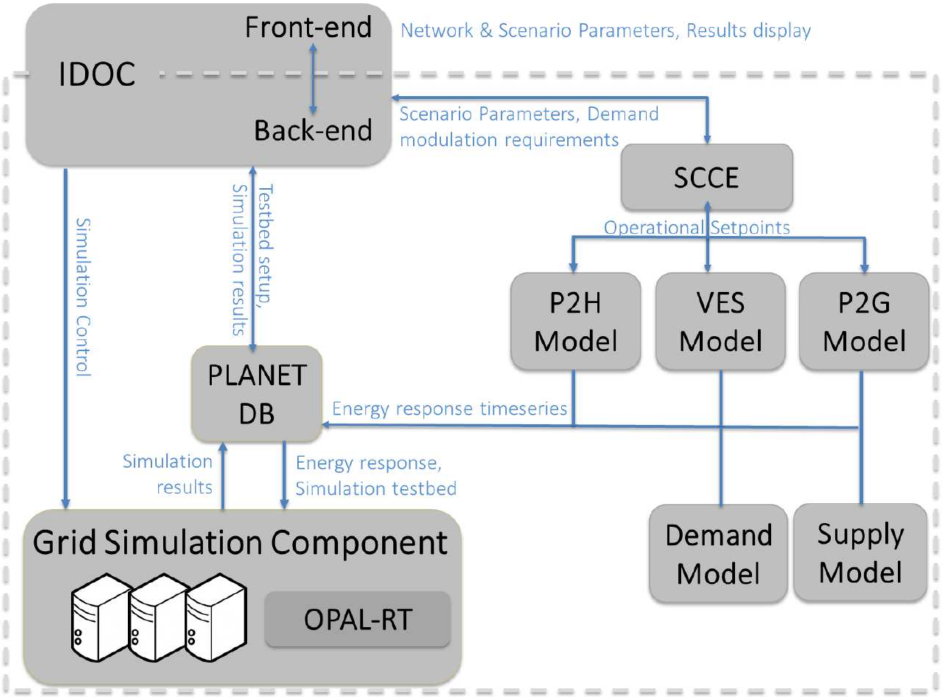
Step 3: Result comparison



- **Scenario initialization** (time horizon, grids, assets, economic, … input parameters)
- **Result visualization** (energy flows, LCOE, CO_2 emission etc)
- **Result comparison** with other scenarios

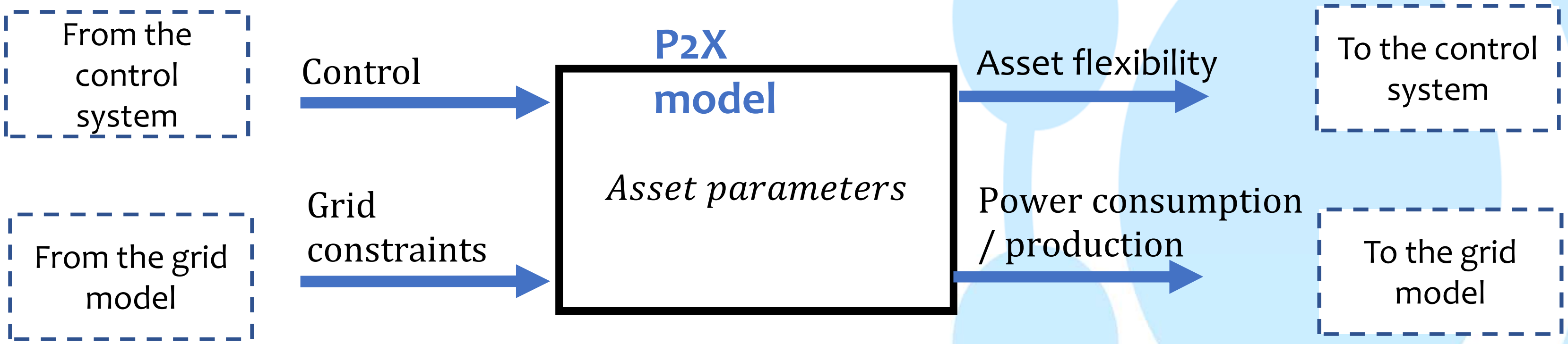
Orchestration module

- **Prepares the input data** for the simulation
- **Starts the simulator**
- **Coordinates** the data exchange between the modules
- **Retrieves the result** data.
- Organizes and **store data** in the PLANET DB



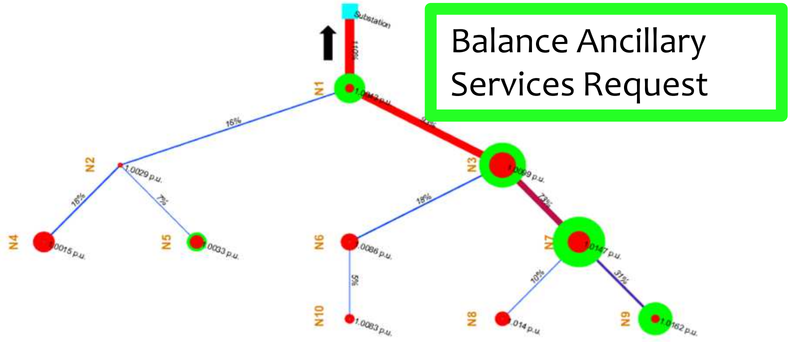
Energy conversion assets: P2X

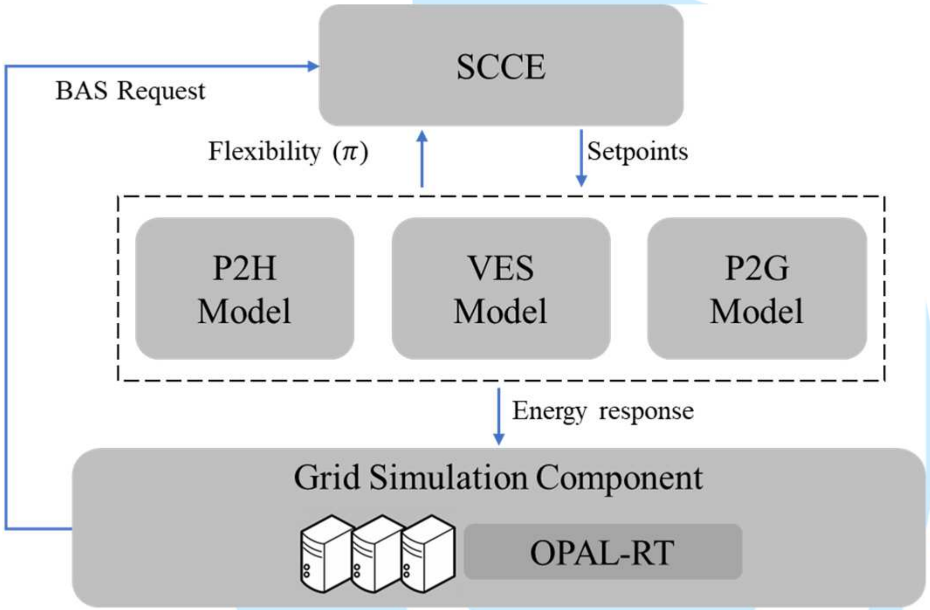
- Power to Gas (**P2G**)
- Power to Heat (**P2H**)
  - DH connected
  - Direct building connected (Virtual Energy Storage VES)
- Linking pin between energy networks: **sector coupling**
- Increasing of the system **flexibility**



SCCE: Flexibility dispatch

- A software component for **optimizing energy flow** in the feeders by the mean of **flexibilities** from Conversion Assets.
  - By defining the **optimal setpoint** of each asset



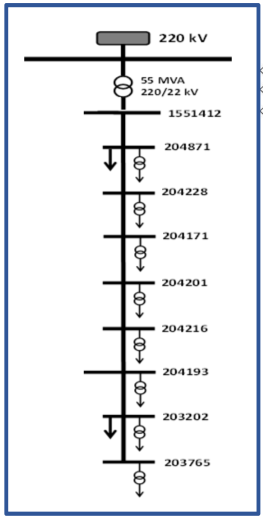


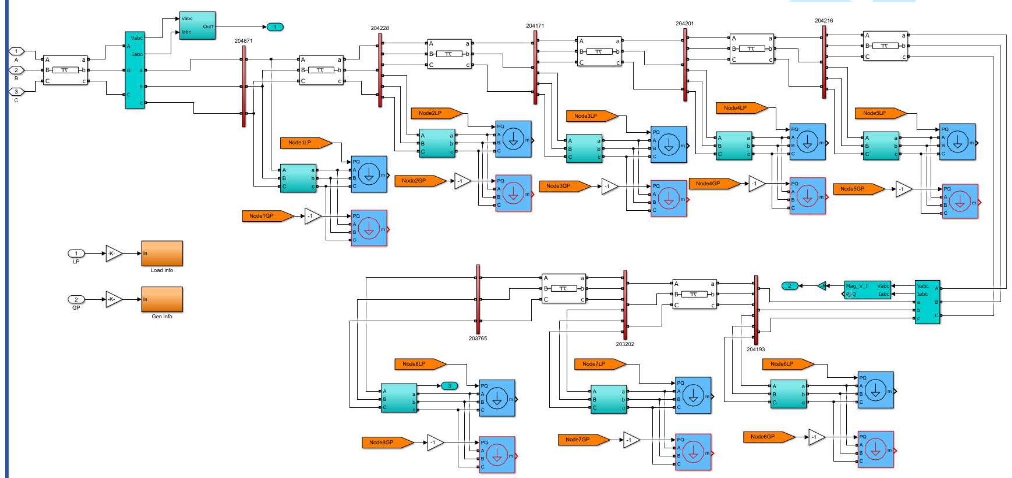
SCCE: Optimization solver

- The user can choose “offline” (all the time horizon) or “real time” (step by step) modes, by three main optimization solvers:
  - Metaheuristics: hybrid Genetic Algorithm plus Constraint Programming
  - Deterministic: Dynamic Programming as main routine
  - “Fast”: using Greedy algorithm for low computation scenarios.
- Objective functions:
  - Technical (e.g., minimization reverse power flow)
  - Maximization of Revenues for Assets’ holders
  - …

Electrical Grid Model

- The model is developed in RT-LAB with SimPowerSystem Simulink tool.
- The simulation solves the power flow in the electrical grid.





Measures per each node:

- Instantaneous current
- Instantaneous voltage
- Voltage p.u.
- Power

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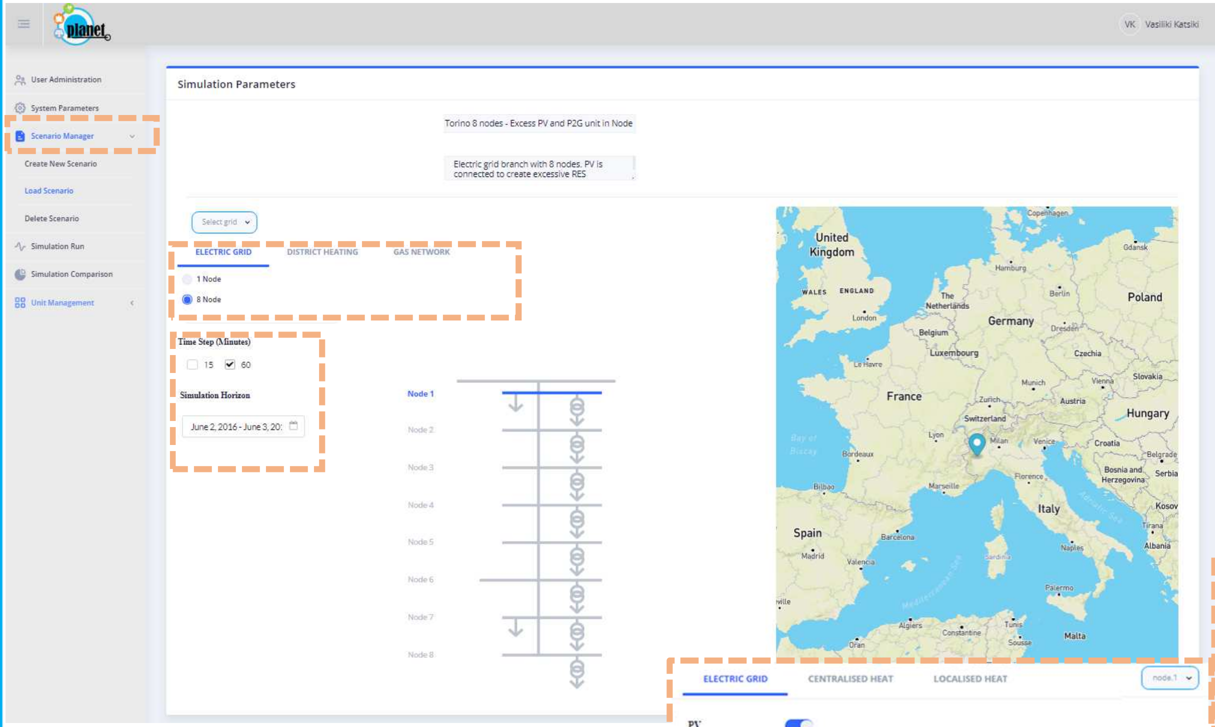
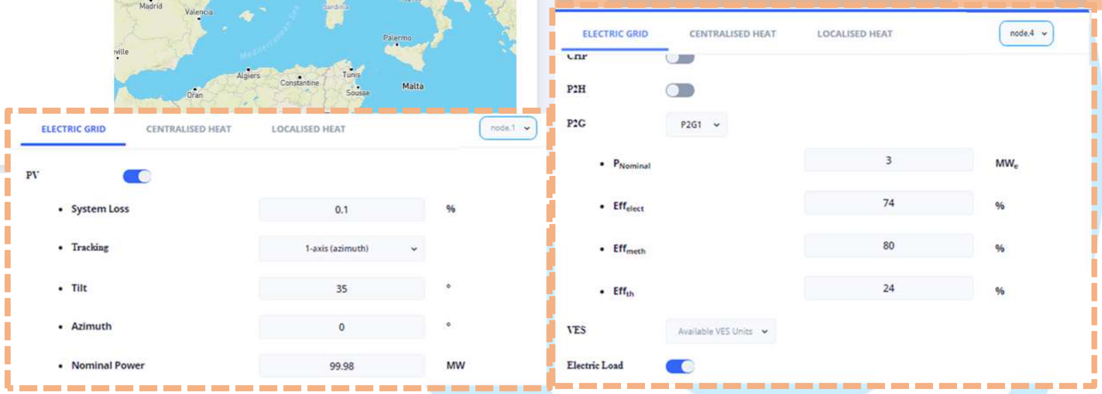
First DSS prototype (data input)



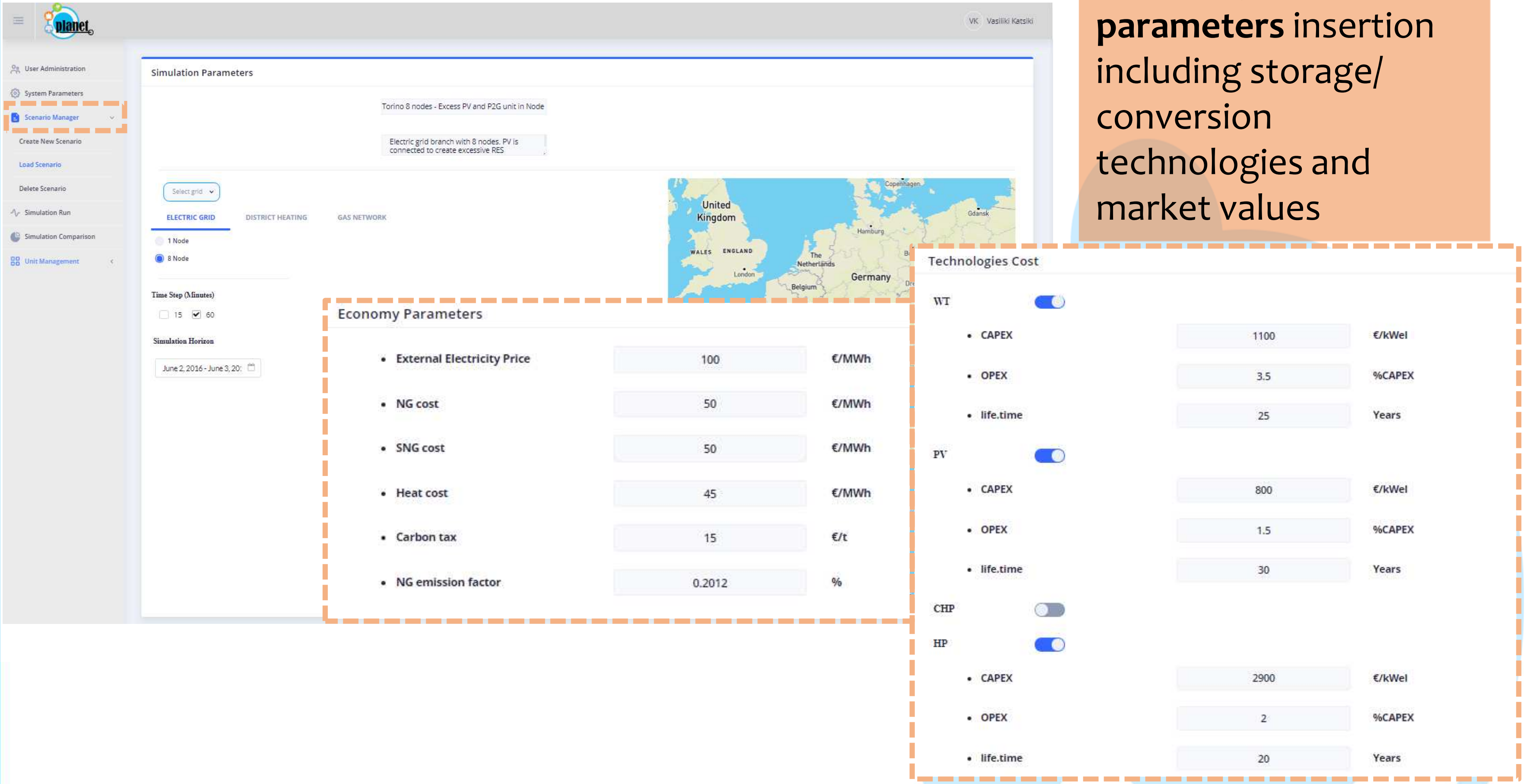
Simulation scenario configuration, incl.:

- Configuration of each energy network
- Configuration of time parameters of simulation
- Configuration of connected technology (RES and storage/converton tech.) to each node of the networks

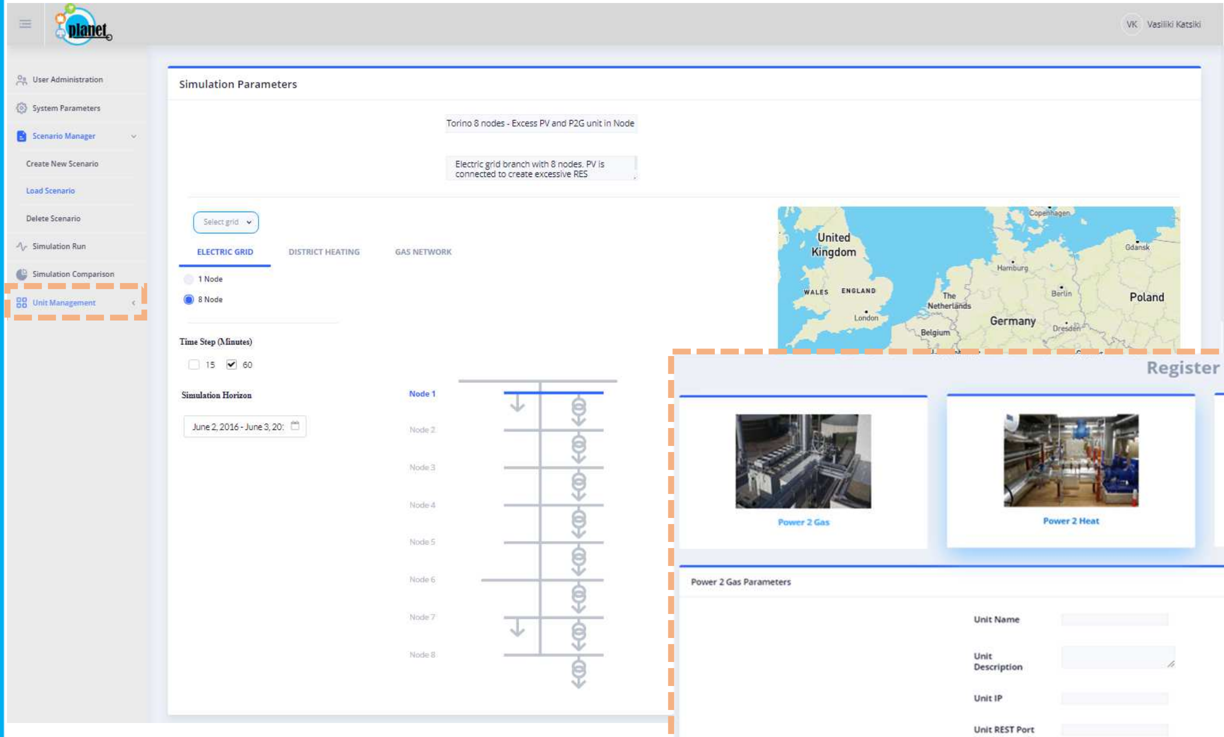


First DSS prototype (data input)

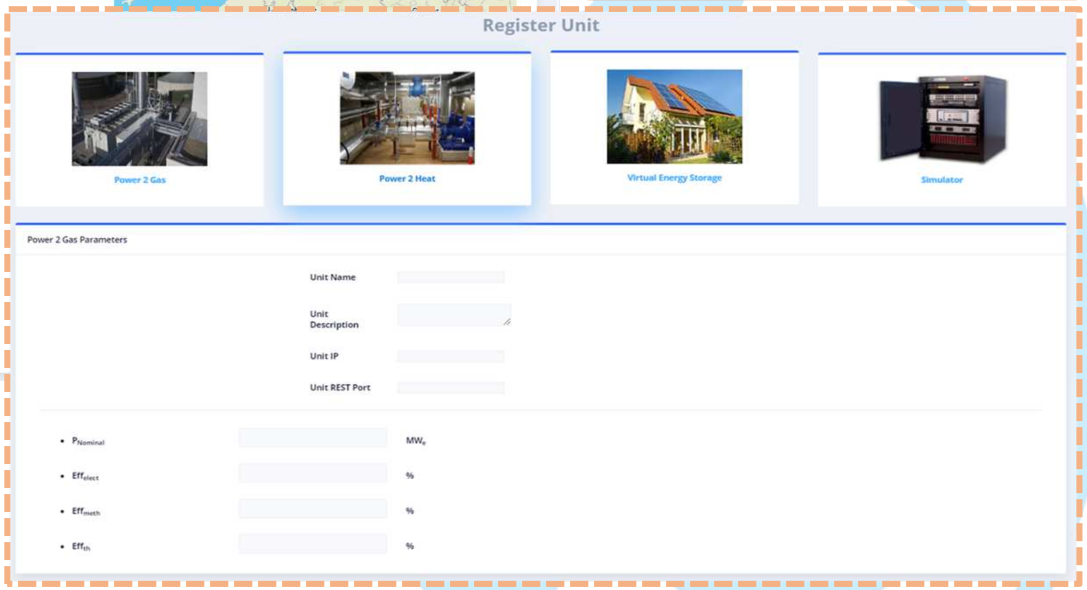
Possibility of **cost parameters** insertion including storage/ conversion technologies and market values



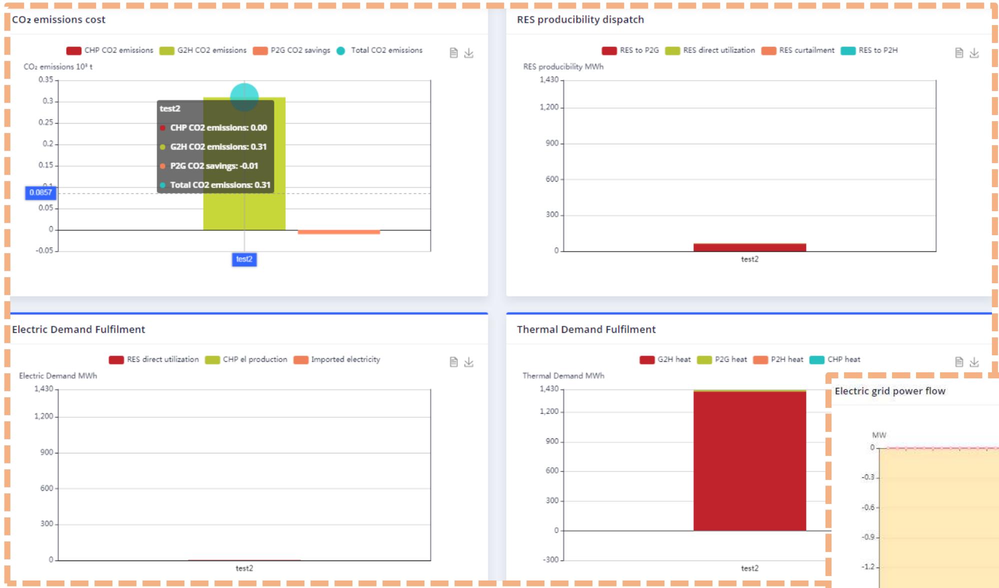
First DSS prototype: (unit registration)



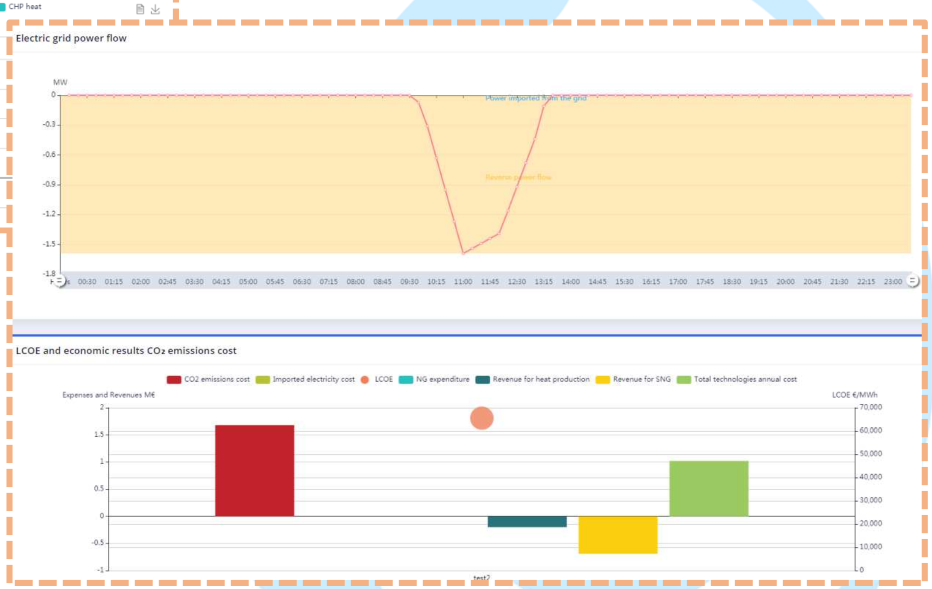
Unit Registration of all storage/ conversion technologies incl. P2G, P2H, VES, etc. for future utilization in PLANET system.



First DSS prototype (simulation results)



Result analysis and KPI assessment. Indicative indexes analyzed are reverse power flow, LCOE, Demand fulfilment, RES curtailment, etc.



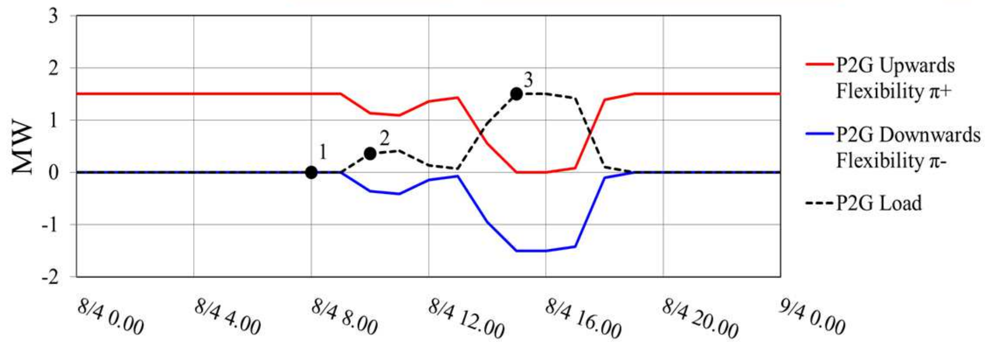
Use Case: P2G deployment for alleviating reverse power flow

- **Reverse Power Flow:** injection of power into the transmission system through the HV/MV transformer
- The analyzed scenario represents a typical future scenario characterized by a high penetration of renewables that could cause problems for the electric grid
- the **P2G flexibility** is used to absorb the RES over-production

The analysed scenario:

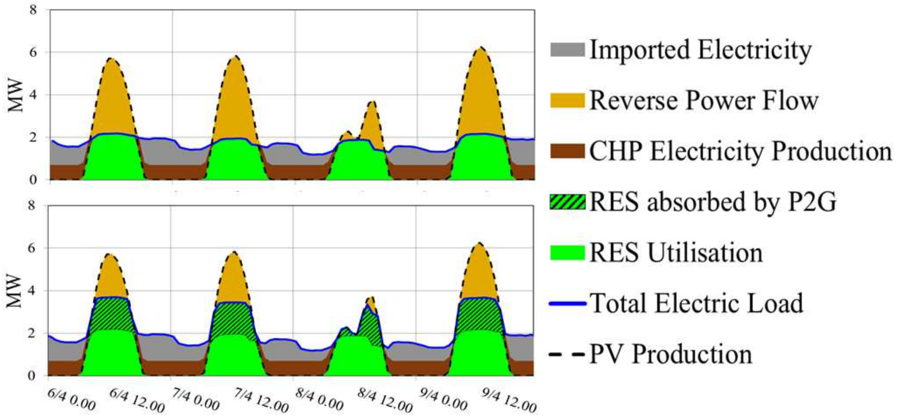
Grid Node	Electric peak load [MW]	PV nominal power [MW]	CHP - nominal power [MW]	P2G-nominal power [MW
1	0.3	1.0	-	-
2	0.2	2.0	-	1.5
3	0.5	-	-	-
4	0.5	1.0	0.4	-
5	0.4	2.0	-	-
6	0.2	1.0	-	-
7	0.3	1.0	-	-
8	0.6	-	0.3	-
tot	3.0	8.0	0.7	1.5

P2G flexibility evolution in time:

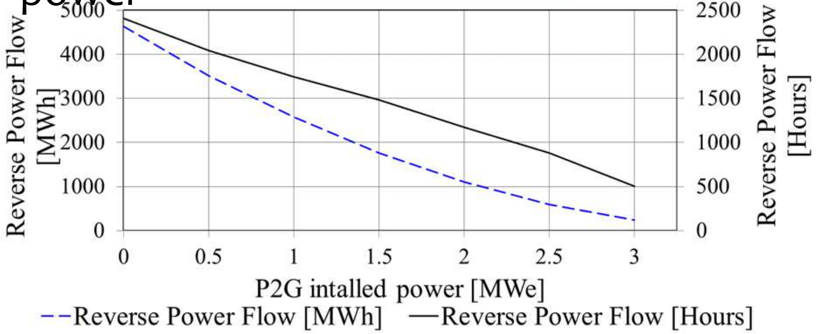


Use Case: P2G deployment for alleviating reverse power flow (Results 1)

Electricity production share for the case with and without P2G:



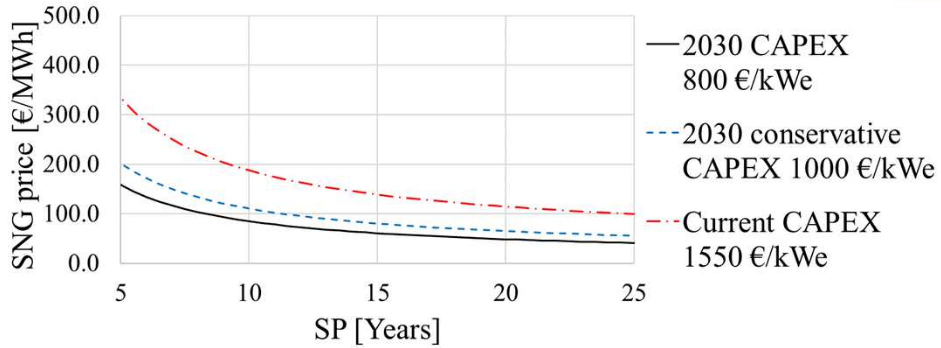
Reverse Power Flow reduction as a function of the installed P2G power



- With 1.5 MW of P2G, the Reverse Power Flow can be reduced by more than 60 % in terms of energy and by about 40% in terms of duration
- Even with a small amount of installed P2G of 0.5 MW (6.25% of the PV installed power), the effects on the Reverse Power Flow are remarkable

Use Case: P2G deployment for alleviating reverse power flow (Results 2)

SNG price and Simple Payback period
as functions of the P2G CAPEX



- Although this technology seems very interesting for balancing network flows, it may not be economically convenient due to the high investment costs and to the low full load hours of around 1900 per year

Conclusions

- PLANET will provide a useful Decision Support System tool for **optimize the energy exchange and synergies between energy networks**
- The tool will be useful for both **technical** and **business** decision makers' perspective
- Interested stakeholder:
    - **DSO**: grid planning, operational management
    - **Plant holders**: analyse the profitability of the plant
    - **Policy maker**: new regulation recommendations

THANKS FOR THE ATTENTION!

Planning and operational tools for optimising energy flows & synergies between energy networks

For more information, visit us at:
www.h2020-planet.eu
https://www.youtube.com/watch?v=gy4kxplMSZk

Follow us on social media
H2020 PLANET

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 773839

Discussion

Magnitude

Régine Belhomme, EDF

CONCLUSION & NEXT STEPS

More information?

https://www.magnitude-project.eu/

- Information on the project
- Public deliverables
- Publications
- Presentations… in particular the presentations of the workshop
- Events
- Etc.

What’s next?

- First **newsletter** with project results
- **Collaboration** with other European projects
- **Webinars** on specific topics
- **EMP-E** Conference
- Participation in conferences and journals
- And of course, **new results**…

Many, many thanks...

- To the session chairs
- To all the speakers, and presenters of posters and demos
- In particular to our guests from other projects (DHC+, FHP, FED, PLANET)
- To the ARTTIC team for the logistics: Elizabeth, Emma and Moran.

THANKS FOR YOUR ATTENTION

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