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DEMAND SIDE FLEXIBILITY APPLIED TO WATER ELECTROLYSIS

GANADOR PREMIO A LA EXCELENCIA EMPRESARIAL EN ARAGÓN 2006
GRANDES EMPRESAS

AENOR Empresa Registrada UNE-EN ISO 9001 ER-0532/1998
AENOR Seguridad Información UNE-ISO/IEC 27001 SI/014/2009 DataCenter INYCOM
AENOR Gestión Servicios TI UNE-ISO/IEC 20000-1 STI-0002/2014
AENOR Gestión Ambiental UNE-EN ISO 14001 GA-2009/0053 O.C.ZARAGOZA

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Inycom is a Spanish technology company headquartered in Zaragoza.

Founded in 1982, Inycom has a long recognized experience thanks to its success based on business excellence guiding principles.

700 employees

▪

9 offices in Spain

1 office in Ecuador

▪

33,5 M€ turnover 15/16

71 M€ turnover 16/17

INFORMATION AND COMMUNICATION TECHNOLOGIES

LABORATORY AND DIAGNOSTIC EQUIPMENT

ELECTRONIC TEST AND MEASUREMENT INSTRUMENTATION

RESEARCH, DEVELOPMENT AND INNOVATION

- **Flexibility**:
  - *On an individual level, flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. [EG3 REPORT SMART GRID TASK FORCE]*
  - *Flexibility can be provided by both supply and demand on a large scale, for example by CCGT plants, industrial and commercial consumers, aggregated smaller household load, distributed generation, and energy storage. [EG3 REPORT SMART GRID TASK FORCE]*
- **Water electrolysis (WE)**: potential to provide flexibility to the grid as a load

KPI 4	H2 production electrolysis, flexibility with a degradation < 2% year (refer to KPI 3)	5% - 100% of nominal power	5% - 150% of nominal power	0% - 200% of nominal power	0% - 300% of nominal power
KPI 5	H2 production electrolysis, hot start from min to max power (refer to KPI 4)	1 minute	10 sec	2 sec	< 1 sec
	H2 production electrolysis, cold start	5 minutes	2 minutes	30 sec	10 sec

[Multi annual working plan, FCH 2 JU 2014]

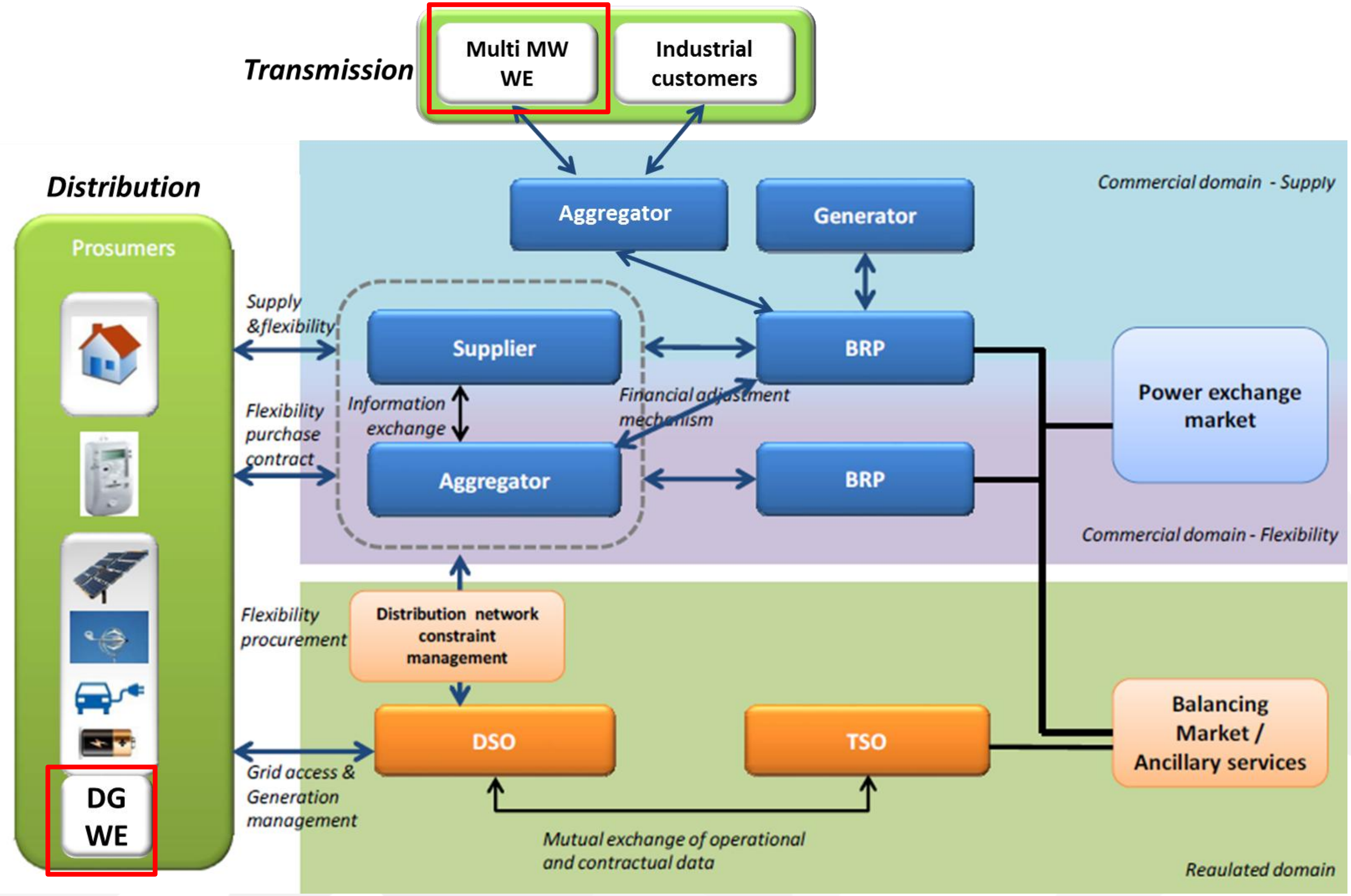
INTRODUCTION

- **Flexibility**:
  - *On an individual level, flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. [EG3 REPORT SMART GRID TASK FORCE]*
  - *Flexibility can be provided by both supply and demand on a large scale, for example by CCGT plants, industrial and commercial consumers, aggregated smaller household load, distributed generation, and energy storage. [EG3 REPORT SMART GRID TASK FORCE]*
- **Water electrolysis**: potential to provide flexibility to the grid as a load

2017	ALK	PEM
Load range	15-100% nom. load	0-160% nom. load
Start-up	1 - 10 minutes	1 sec - 5 minutes
Ramp-up	0,2 - 20 % /s	100% /s
Ramp-down	0,2 - 20 % /s	100% /s
Shut down	1 - 10 minutes	Seconds

[Study On Early Business Cases For H2 In Energy Storage And More Broadly Power To H2 Applications, FCH 2 JU 2017]

- Interrelation between actors towards business models based on flexibility of WE:



[Adapted from EG3 REPORT SMART GRID TASK FORCE]

- **Key actor: Aggregator.**

Benefits of aggregation of several loads:

- Different types of loads with varying characteristics which provide backup (e.g. when one is unavailable)
- Reduction of risk and increased robustness
- A pool of loads is seen as a single consumer -> capacity to negotiate large contracts and decrease costs
- Aggregation of loads adds value as generators do and is proven in Austria, Belgium, Finland, France, Ireland and Great Britain

Barriers:

- Technical prequalification is complex
- Great knowledge on each load behaviour and advanced capabilities for interconnection (need for sophisticated central IT system)

- **Possible grid services accesible to flexible WE**:

Grid service	Description	Function	User offering the service	End user requiring the service
Peak shifting	Capture energy during off-peak periods and sell during peak periods to reduce peak power requirements and the need for higher cost energy	• Long term congestion management. • Portfolio optimization • Generation capacity adequacy	• Aggregated (or individual) industrial and commercial users • Aggregated domestic customers	DSO BRP TSO
Demand adjustments	Changes in energy usage by end-use customers (domestic and industrial) from their current/normal consumption patterns in response to market signals, such as time-variable electricity prices or incentive payments, or in response to acceptance of the consumer's bid, alone or through aggregation, to sell demand reduction/increase at a price in organized electricity markets	• Short term congestion management • Portfolio optimization • Generation capacity adequacy	• Aggregated (or individual) industrial and commercial users • Aggregated domestic customers	DSO BRP TSO
FCR, FRR, RR balancing (frequency adjustment) services	Provision of additional active power (or a decrease in demand) to face frequency changes demanded by the system	• Frequency control	• Aggregated or individual industrial and commercial users • Aggregated distributed generation	TSO

- **Possible grid services accesible to flexible WE**:

Grid service	Description	Function	User offering the service	End user requiring the service
Biogas injections	Injection of biogas (e.g. hydrogen) in the natural gas grid	• Long term congestion management • Portfolio optimization	• Distributed generation	DSO TSO BRP
Curtailment products	Increasing demand to accommodate surplus energy from RES avoiding curtailment	• Short term congestion management	• (Aggregated) distributed generation • (Aggregated) industrial and commercial users • Aggregated domestic customers	DSO TSO
Reactive power	Variation in reactive power from generators to stabilize voltage	• Voltage control	• (Aggregated) distributed generation	DSO TSO

INTRODUCTION

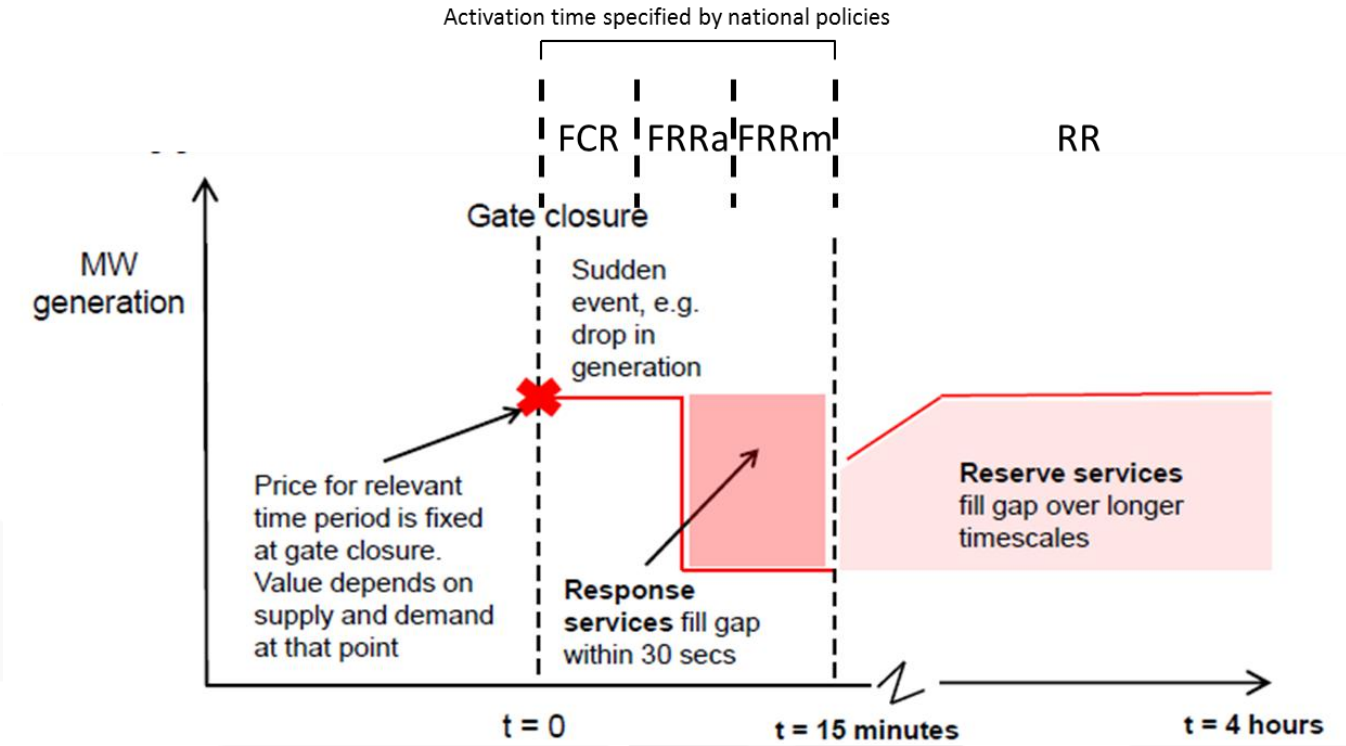
- **Greatest potential for WE: transmission level**
  - Multi MW WE present lower CAPEX/OPEX values per unit of power/energy
  - The ratio BOP consumption over stack consumption decreases -> More efficiency
  - Competition with electrochemical batteries is not a problem (as it is in several to ~100 kW systems) and this size is also far from large hydro pump stations (~100 MW to several GW)
  - Support from EC through the FCH 2 JU:
    - Pioneering projects on grid balancing through WE:
      - DEMO4GRID project (alkaline technology, IHT, largest stack in the EU)
      - H2FUTURE project (PEM technology)

Cost-competitive hydrogen generation

- Transmission level: frequency adjustment grid services

FREQUENCY ADJUSTMENT GRID SERVICES

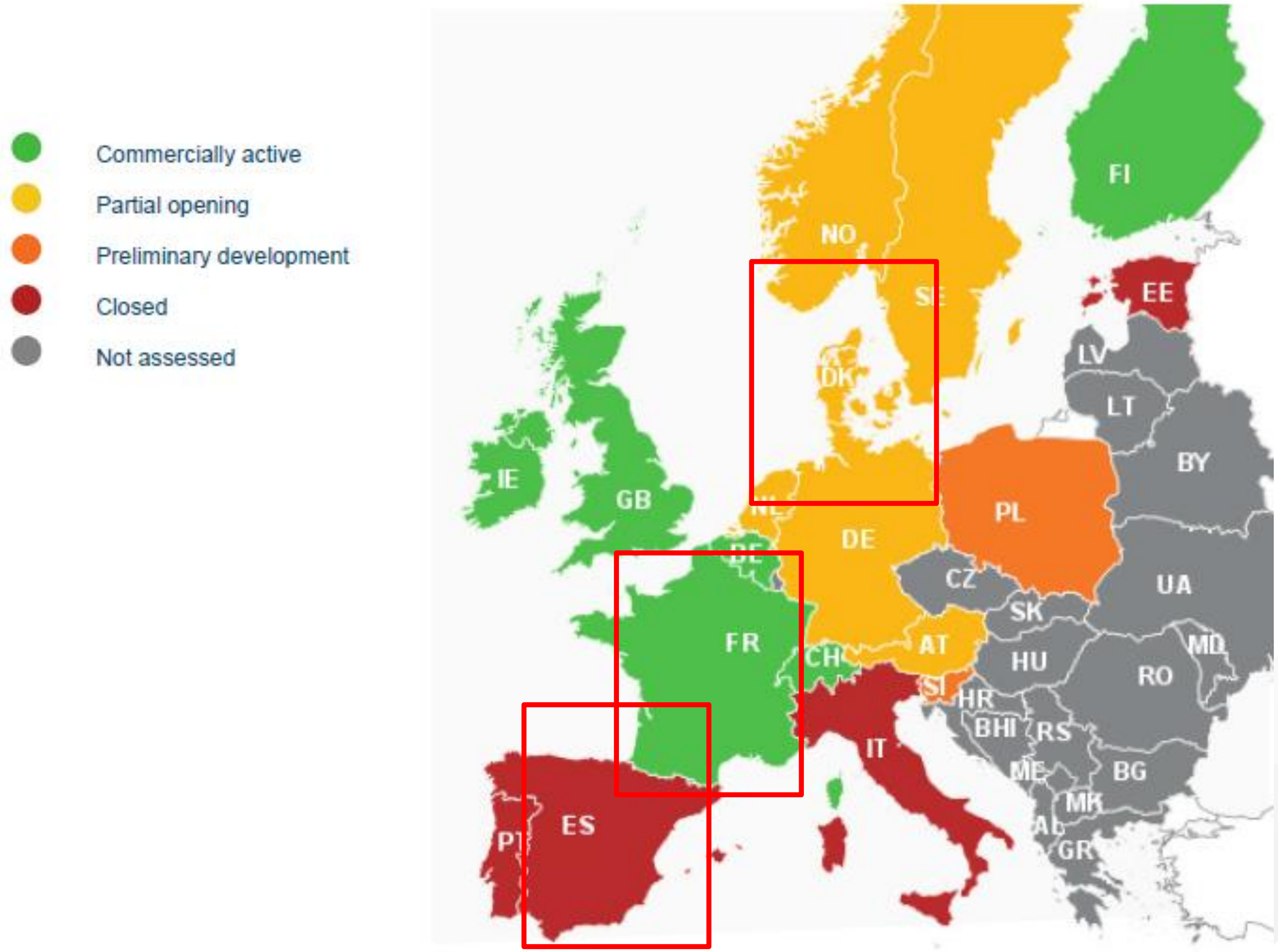
- **Very wide and varied terminology across the EU:**



- Frequency Containment Reserve (**FCR):** balancing within seconds.
- Automatic Frequency Restoration Reserve (**aFRR**) automatic short term balancing of frequency deviations
- Manual Frequency Restoration Reserve (**mFRR**), manually activated if deviations are continuing.
- Furthermore, some countries contract the Replacement Reserve (**RR**), which follows in order to replace capacities if an outage is continuing further on.

FREQUENCY ADJUSTMENT GRID SERVICES

- Different opportunities in the EU:



Proven with some technologies

FREQUENCY ADJUSTMENT GRID SERVICES

Frequency adjustment grid services - FRANCE

ENTSO-E's terminology	TSO's terminology	Tot. Capacity Contracted[89]	Demand Response Access & Participation	Aggregated Demand Response Accepted	Aggregated Generation
FCR	Primary Control *(Réglage Primaire de Fréquence)*	600 – 700 MW	✓ (≈60MW) *though FCR cooperation*	✓ *though FCR cooperation*	✓ *through FCR cooperation*
aFRR	Secondary Control *(Réglage Secondaire de Fréquence)*	600 – 1000 MW	✓ Q3-Q4 2016, for around 10 MW	✓ *via **secondary** market*	✓
mFRR	Fast Reserve *(Réserves rapides)*	Max. 1000 MW	✓ (480 MW)	✓	✓
RR	Complementary Reserve *(Réserves complémentaires)*	Max. 500 MW		✓	✓
DSR - RR	Demand Response Call for Tender* *(Appel d'Offres d'Effacement)* **New Status in 2017*	2014: max. 850 MW 2015: 1200 to 1800 MW 2016: max. 2100 MW 2017: 750 to 1400 MW[90]	✓	✓	🚫

- **Frequency adjustment grid services - FRANCE**

Product	Minimum size (MW)	Notification Time[111]	Activation	Triggered (max. times)
Primary Control (FCR)	1 MW	< 30 s	automatic	Triggered continuously
Secondary Control (aFRR)	1 MW	< 400 s	automatic	Unlimited
Fast Reserves (mFRR)	10 MW	13 min	manual	Unlimited
Complementary Reserves (RR)	10 MW	30 min	manual	Unlimited
DR Call for tender (DSR – RR)	1 MW	2 h	manual (ongoing works on automation)	Up to 40 days/year

FREQUENCY ADJUSTMENT GRID SERVICES

- **Frequency adjustment grid services - FRANCE**

Product	Availability payments	Utilisation payments	Access
Primary Control (FCR)	According to bid	According to spot price	Weekly tender together with AT, DE, NL & CH TSOs (from 17 January 2017)
Secondary Control (aFRR)	160k€/MW/y for obligations. Free deals on secondary market.	Spot price	Obligation to provide (or contract a substitute) for generators, DSR participation through secondary market only; pro rata activation
Fast Reserves (mFRR)	24 k€/MW (2017)	Free bid price	Merit order based (energy)
Complementary Reserves (RR)	16 k€/MW (2017)	Free bid price	Merit order based (energy)
DSR-RR	12-20 €/MW/year[114]	100 €, 150 € or 200 €; or spot price based formula (min. 65 € and max. 500 €/MWh)	Merit order based (energy)
Balancing Mechanism	*Not available*	Free bids	Merit order based

FREQUENCY ADJUSTMENT GRID SERVICES

- **Semi-centralised production for mobility applications in Albi (France)**

[Study On Early Business Cases For H2 In Energy Storage And More Broadly Power To H2 Applications, FCH 2 JU 2017]

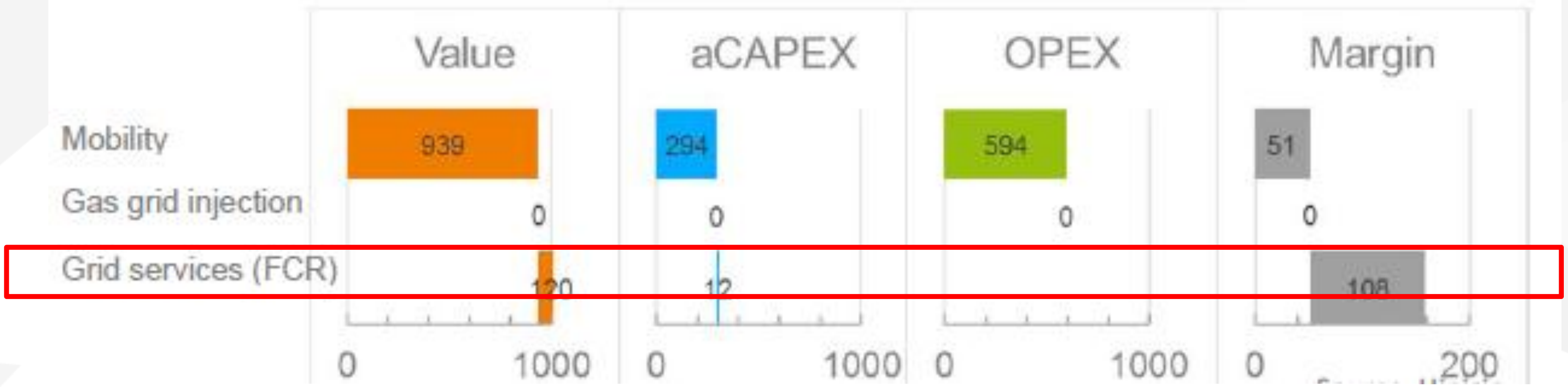
Parameters	2017	2025
Daily and annual H2 demand	740 kg/day 270 t/year	2600 kg/day 950 t/year
H2 price to end-user (@700 bar)	9-10 €/kg	9-10 €/kg
H2 price to HRS (@200 bar)	7 €/kg	6 €/kg
HRS distance	20 km one-way (city scale)	
Nb. tube-trailers equivalent	7 trailers	21 trailers
Grid fees, taxes, levies and GO	13 €/MWh (incl. partial exemption because of electro-intensive status)	
Grid services value	18 €/MW/h (symmetrical FCR)	
Gas grid injection tariff	90 €/MWh LHV	

FREQUENCY ADJUSTMENT GRID SERVICES

- **Semi-centralised production for mobility applications in Albi (FRANCE)**

[Study On Early Business Cases For H2 In Energy Storage And More Broadly Power To H2 Applications, FCH 2 JU 2017]

Results	2017
Primary market size	2 MW
Unit sizing	100%
Technology	PEM
Peak power	160% Pnom
Op. time and total elec. price (prim.)	95% @ 44 €/MWh
Levelized cost of H_2	6.7 €/kg
Net Margin	159 k€/MW/year
Payback time w/o grid services	11 years
Payback time w/ grid services	8 years



However, **adding grid services triples profitability** by generating additional revenues at low costs. The system payback time is fast tracked by 3 years with grid services revenues, reaching 8 years.

Frequency adjustment grid services - DENMARK

ENTSO-E's terminology	TSO's terminology	Tot. Capacity Contracted	Demand Response Access & Participation	Aggregated Demand Accepted	Aggregated Generation
FCR	Primary Reserve (DK1)	23 MW	✔	✔ (23 MW[44])	✔
aFRR	Secondary Reserve (DK1)	≈100 MW	✔	✔	✔
FCR-N	Frequency-controlled normal operation reserve (DK2)	≈22 MW	✔	✔	✔
FCR-D	Frequency-controlled disturbance reserve (DK2)	37 MW	✔	✔	✔
mFRR	Tertiary (Manual) Reserve (DK1 and DK2)	≈868 MW	✔	✔	✔
RR		0 MW	✔	✔	✔

FREQUENCY ADJUSTMENT GRID SERVICES

Frequency adjustment grid services - DENMARK

Product	Minimum size (MW)	Notification Time	Activation	Triggered (max. times per day)[49]
Primary Reserve (DK1)	0,3 MW	30 sec	automatic	~10-20%
Secondary Reserve (DK1)	1 MW	15 min.	automatic	~0,2%
Frequency-controlled normal operation reserve (DK2)	0,3 MW	150 sec	automatic	~0,1%
Frequency-controlled disturbance reserve (DK2)	0,3 MW	50% in 5sec, 50% in additional 25 sec	automatic	~10-15%
Tertiary (Manual) Reserve (DK1 and DK2)	10 MW (5MW Q2 2017)	15 min	manual	N/A. Heavily dependent of the price of the submitted bid. If low (competitive) the DR-asset is expected to be activated on a daily basis, if high only few times a year.

FREQUENCY ADJUSTMENT GRID SERVICES

- **Frequency adjustment grid services - DENMARK**

Product	Availability payments	Utilisation payments	Access
Primary Reserve (DK1)	Range: 50,000 to 200,000 DKK/MW per month	Part of imbalance	Daily auction
Secondary Reserve (DK1)	Long term contract with Norway	NO	Long-term tender (5 years) Auctions if more is needed
Frequency-controlled normal operation reserve (DK2)	Range: 50,000 to 250,000 DKK/MW per month	Regulating power-price	Daily auction
Frequency-controlled disturbance reserve (DK2)	Range: 20,000 to 80,000 DKK/MW per month	Part of imbalance	Daily auction
Tertiary (Manual) Reserve (DK1 and DK2)	DK1 approx. 10,000 DKK/ MW per month DK2: Long term contract with five different retailers	Both: Regulating power price.	Daily auction

FREQUENCY ADJUSTMENT GRID SERVICES

- Frequency adjustment grid services - DENMARK

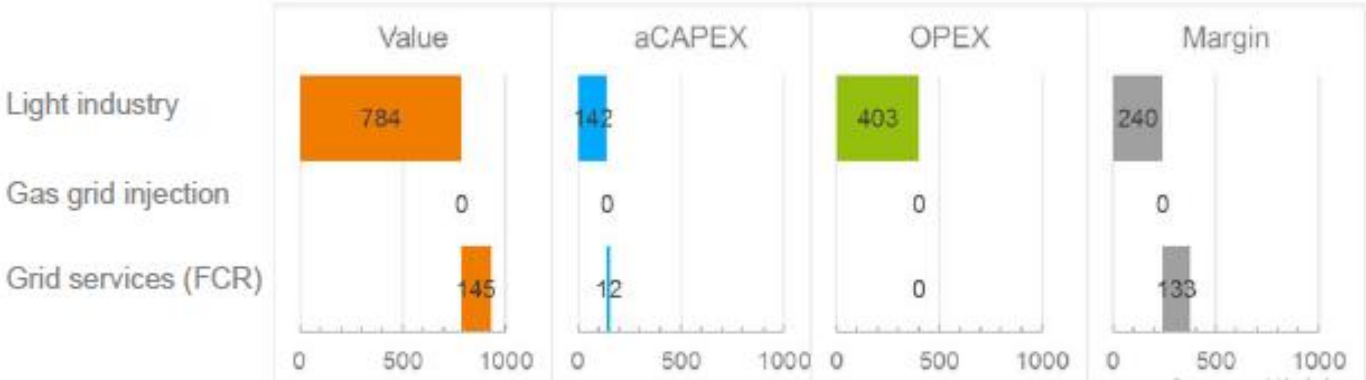
Parameters	2017	2025
Annual H2 demand	900 t/year	
H2 price sold to industry	5 €/kg	
Grid fees, taxes, levies and GO (DK)	11 €/MWh	
Grid services value	17 €/MW/h (asymmetrical FRR)	
Gas grid injection tariff	90 €/MWh LHV	

FREQUENCY ADJUSTMENT GRID SERVICES

- **Frequency adjustment grid services - DENMARK**

Adding grid services enhance net margin by 55%. Danish FCR (DK-West) allows for asymmetric capacity. **Asymmetric grid services favours ALK electrolysers** as they are cheaper than PEM and can still make use of the whole electrolyser nominal capacity for grid services. The grid services contribution allows to fast track the system payback time to 3.4 years.

Results	2017
Primary market size	6 MW
Unit sizing	100%
Technology	ALK
Peak power	100%
Op. time and total elec. price (prim.)	95% @ 38 €/MWh
Levelized cost of H_2	3.5 €/kg
Net margin	373 k€/MW/year
Payback time w/o grid services	4.6 years
Payback time w/ grid services	3.4 years



FREQUENCY ADJUSTMENT GRID SERVICES

Frequency adjustment grid services - SPAIN

Product		Minimum size	Notification Time	Activation	Triggered
Interruptible Contract (Mainland)	5 MW blocks	Blocks of 5 MW	Three options: (1) Instantly execution, no notification, (2) Fast execution, 15min, (3) Hourly execution, 2h[326].	Automatic	Max 240 h/year and 40 h/month
	90 MW blocks	Blocks of 90 MW		Automatic	Max 360 h/year and 60 h/month
Interruptible Contract (Islands)		0,8 MW	Five options, from 2 hours to instantly	Automatic	Max 120 h/year

- Spanish TSO REE is studying the possibility of achieving flexibility with loads and making them participate in primary, secondary and tertiary frequency regulation
- Only opportunity: Interruptibility grid service

FREQUENCY ADJUSTMENT GRID SERVICES

Grid service implemented: **Interruptibility grid service from REE**

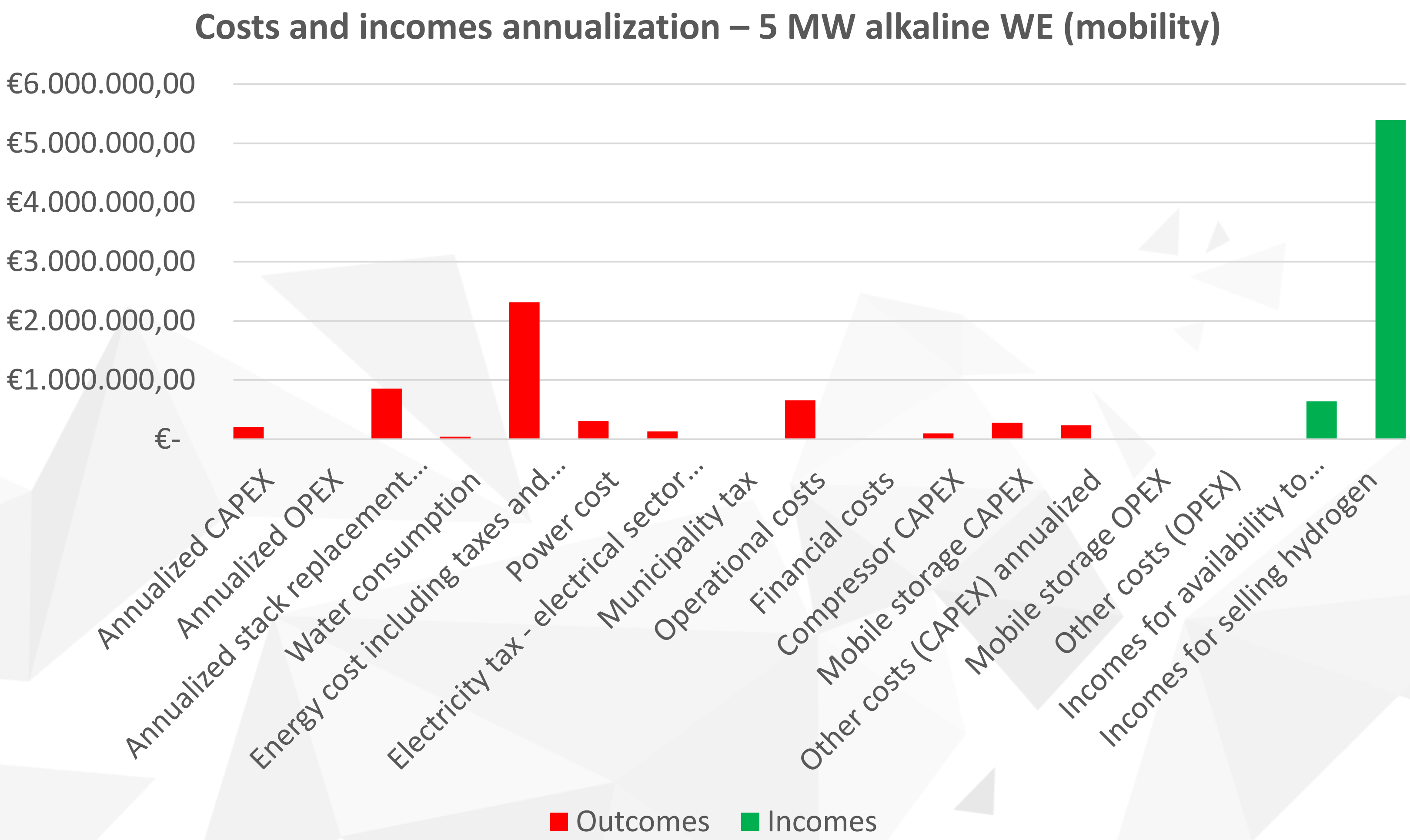
Order IET/2013/2013 overview

- The procedure of assignation of interruptibility service is done through tenders managed by the system operator (REE) – **yearly** basis
- For each tender, there are two products:
  - **5 MW** reduction packs
  - 90 MW reduction packs
- Each product has **three execution options** in relation to response time:
  - Instantaneous execution (A): without pre-order
  - Fast execution (B): minimum pre-order of 15 minutes
  - Hourly execution (C): minimum pre-order of 2 hours
- The maximum hours in per year in the execution of reduction orders are:
  - 240 hours per year for the 5 MW product, with a maximum of 40 hours per month. – **Almost unused. Remuneration for large consumers in Spain**

Availability: > 95% of time (per year)

FREQUENCY ADJUSTMENT GRID SERVICES

- Interruptibility: only feasible for mobility (6 EUR/kg H2, supposing a demand for 5 MW electrolyser, which means great amount of FCEVs)



- Injection in gas grid/industrial uses: not feasible (Price optimization better)

DISTRIBUTION LEVEL: P2P SMARTEST

- **Distribution level:**
  - Low size WE imply greater BOP/stack consumption -> less efficiency
  - Higher CAPEX/OPEX per unit of power/energy
  - Competition with other energy storage systems

To make WE more attractive: new business models to enable consumers to become prosumers and be able to participate in energy markets as well as sell energy

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P2P-SMARTEST FACTSHEET

- **Topic:** P2P-SmartTest project investigates and demonstrates a smarter electricity distribution system integrated with advanced ICT, regional markets and innovative business models. It will employ Peer-to-Peer (P2P) approaches to ensure the integration of demand side flexibility and the optimum operation of DER and other resources within the network while maintaining second-to-second power balance and the quality and security of the supply.
- **Duration:** 1.1.2015-31.12.2017
- **Total PM:** 528
- **Budget:** total costs 3 866 215 €, EU grant 3 496 141 €
- **Partners:** University of Oulu - Finland (PC), University of Bath – UK, Cardiff University – UK, Fundacion CENER-Ciemat – Spain, Centre Tecnologic de Telecomunicacions de Catalunya – Spain, Instrumentacion Y Componentes SA – Spain, Katholieke Universiteit Leuven – Belgium, Regenera Levante SL – Spain, ENDESA SA - Spain

P2P-SMARTEST OBJECTIVES

Objective 1: To investigate and develop **alternative business models** for DSOs, MNOs, Aggregators, ESCOs, Suppliers and Consumers for **P2P energy trading** to capture the whole supply chain value while maintaining second-by-second power balance, **maximizing Demand Response and DER utilization** and ensuring supply security. The magnitude of benefits from introducing P2P energy trading is quantified and the required changes in technical, commercial and regulatory arrangements will be identified.

Objective 2: To evaluate **existing ICT technologies and new ones for (a) the optimized, stable and robust P2P** energy trading and balancing within a MicroGrid, a CELL (a defined set of microgrids), and intra MicroGrids and CELLs while considering the new business models, (b) active electricity network management, demand/response, load balancing and forecasting, congestion management and capacity calculation, and (c) optimum, secure and stable operation of a MicroGrid and a CELL during normal/abnormal operating conditions. While the focus is on investigating the last-mile technologies which support inter- and intra-MicroGrids operation, also the backbone telecom infrastructure is considered, which is critical for intra CELLs operation and data exchange with transmission network operators.

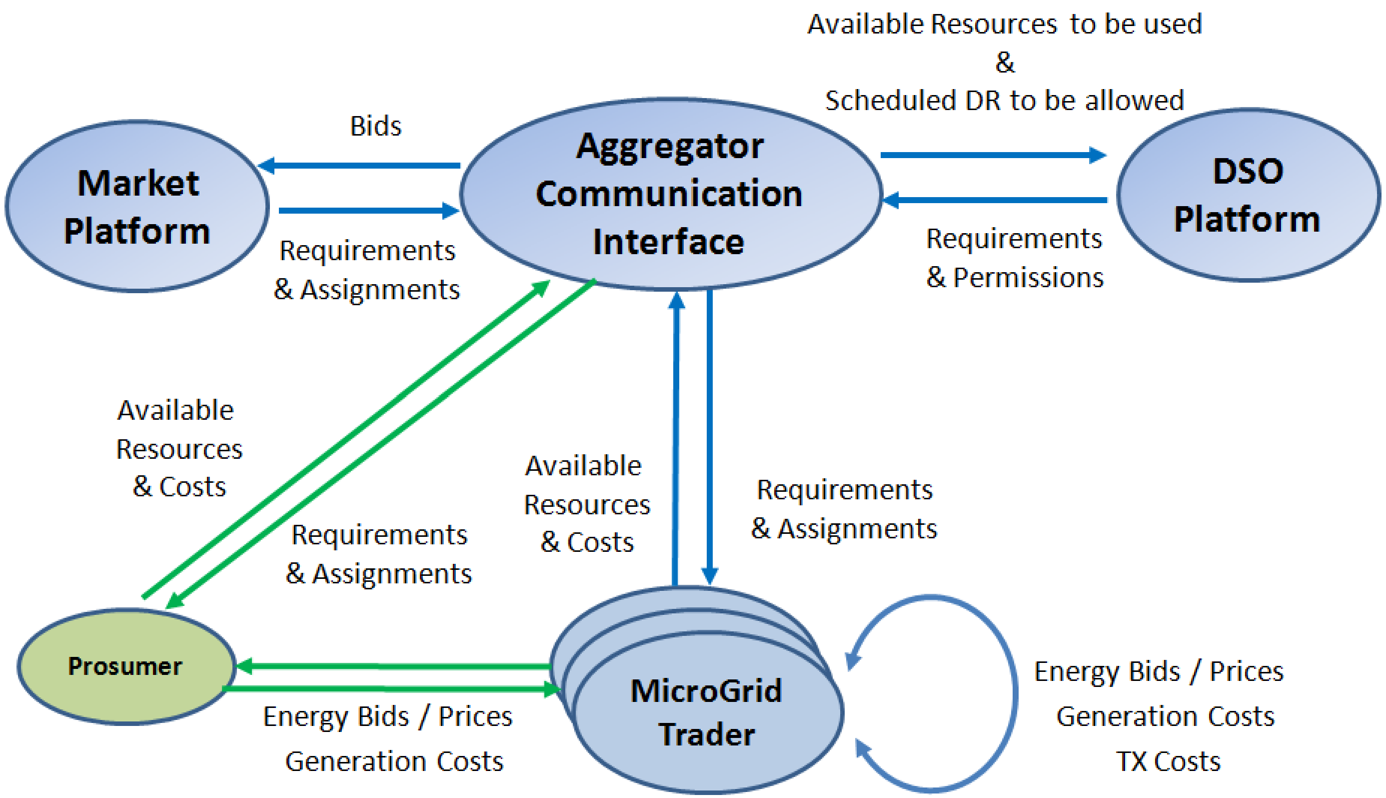
Objective 3: To develop **P2P advanced optimization techniques to provide efficient P2P energy market trading**, while considering the new business models and ICT technologies. In order to fulfil a real integration of the flexibility of demand and DER management using P2P, the whole market domain will be explored including products/services to be traded and certification mechanisms to be implemented.

Objective 4: To develop **alternative P2P based control paradigm of distribution networks**, integrate probabilistic and predictive control functions to enable and facilitate the P2P based energy trading and better network operation under extremely dynamic and uncertain conditions, and model of dynamic demand for operational functions of P2P smart distribution networks.

MARKET INNOVATION – TRADING TARGET MODEL

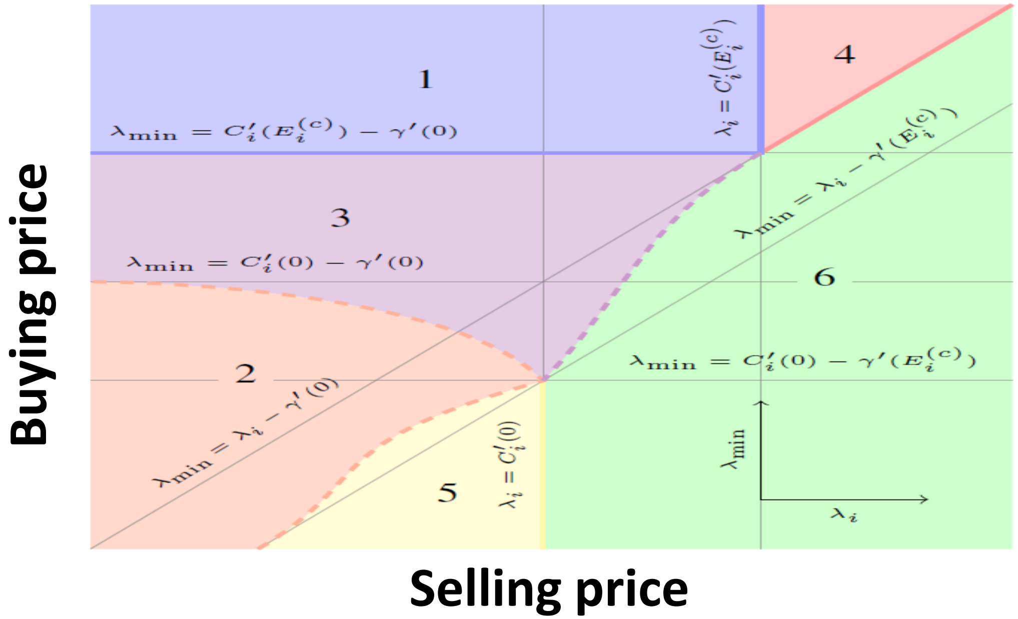
Commercial relations supported

- Microgrid Trader – Microgrid Trader
- Microgrid Trader – Prosumers
- Microgrid Trader – Aggregator
- Prosumers – Aggregator
- Aggregator – DSO & Wholesale market



MARKET INNOVATION 2 - Design of P2P Energy Trading Algorithms

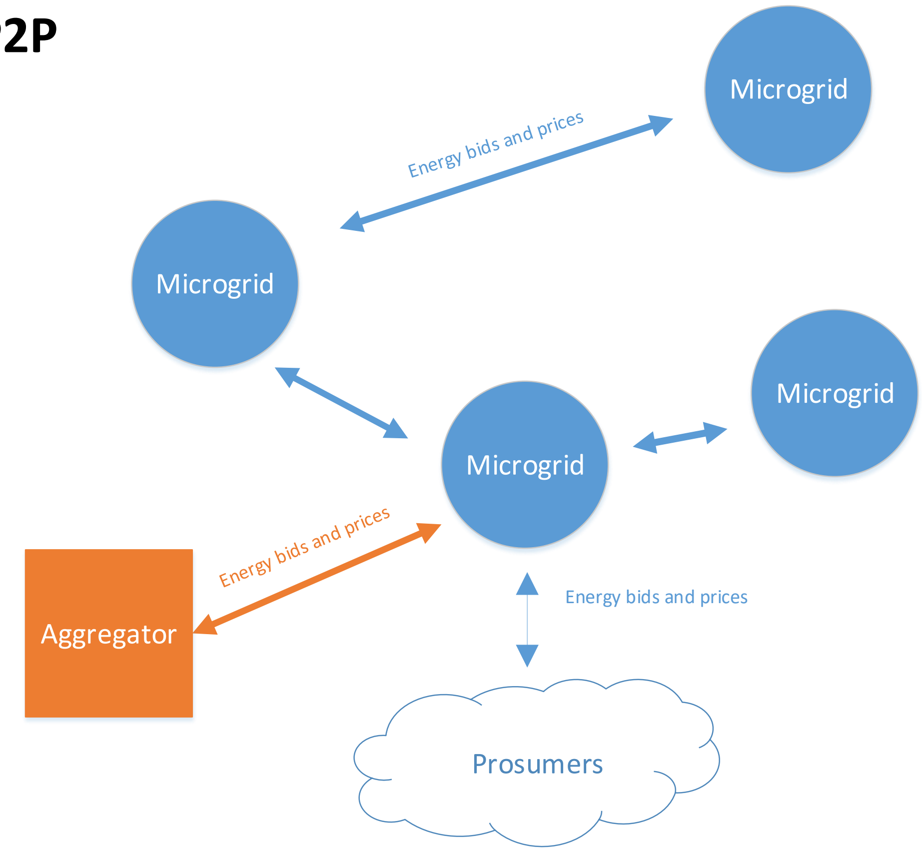
- Each microgrid decides on its action (buy, sell and generation) based on its local cost:
- Local cost = generation cost - sales + purchases + transportation costs
- Energy bids are exchanged between trading parties
- Energy prices are updated (market clearing process) to match sales and purchases and exchanged between parties.
- The process is repeated until agreement (start again from step 1)



- Case 1: Generate
- Case 2: Only buy
- Case 3: Generate and buy but do not sell
- Case 4: Generate and sell but do not buy
- Case 5: Sell and buy but do not generate
- Case 6: Sell, buy and generate

MARKET INNOVATION 2 - Design of P2P Energy Trading Algorithms

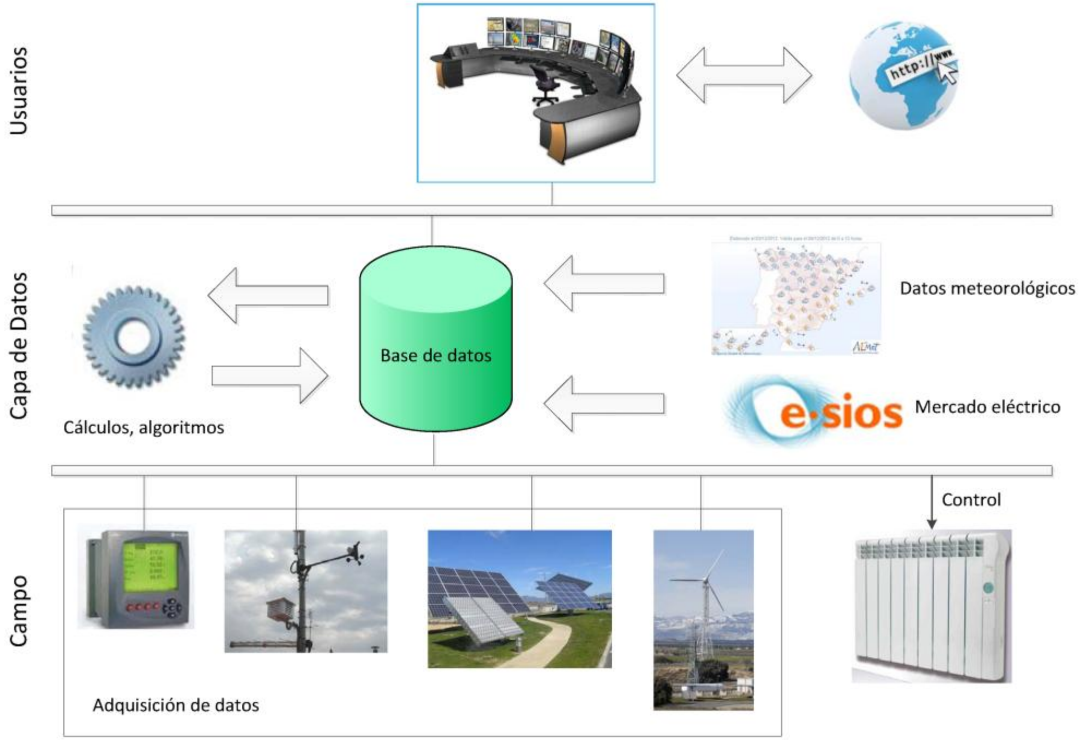
- Energy trading and Market Clearing in a **distributed P2P fashion**
- **Privacy** on cost functions
- **Flexible solution** (capable to account for multitude scenarios)
- Minimum **communication signalling**
- **Scenarios**:
  - Isolated microgrids trading
  - Interaction with the wholesale market
  - Demand elasticity and load curtailment



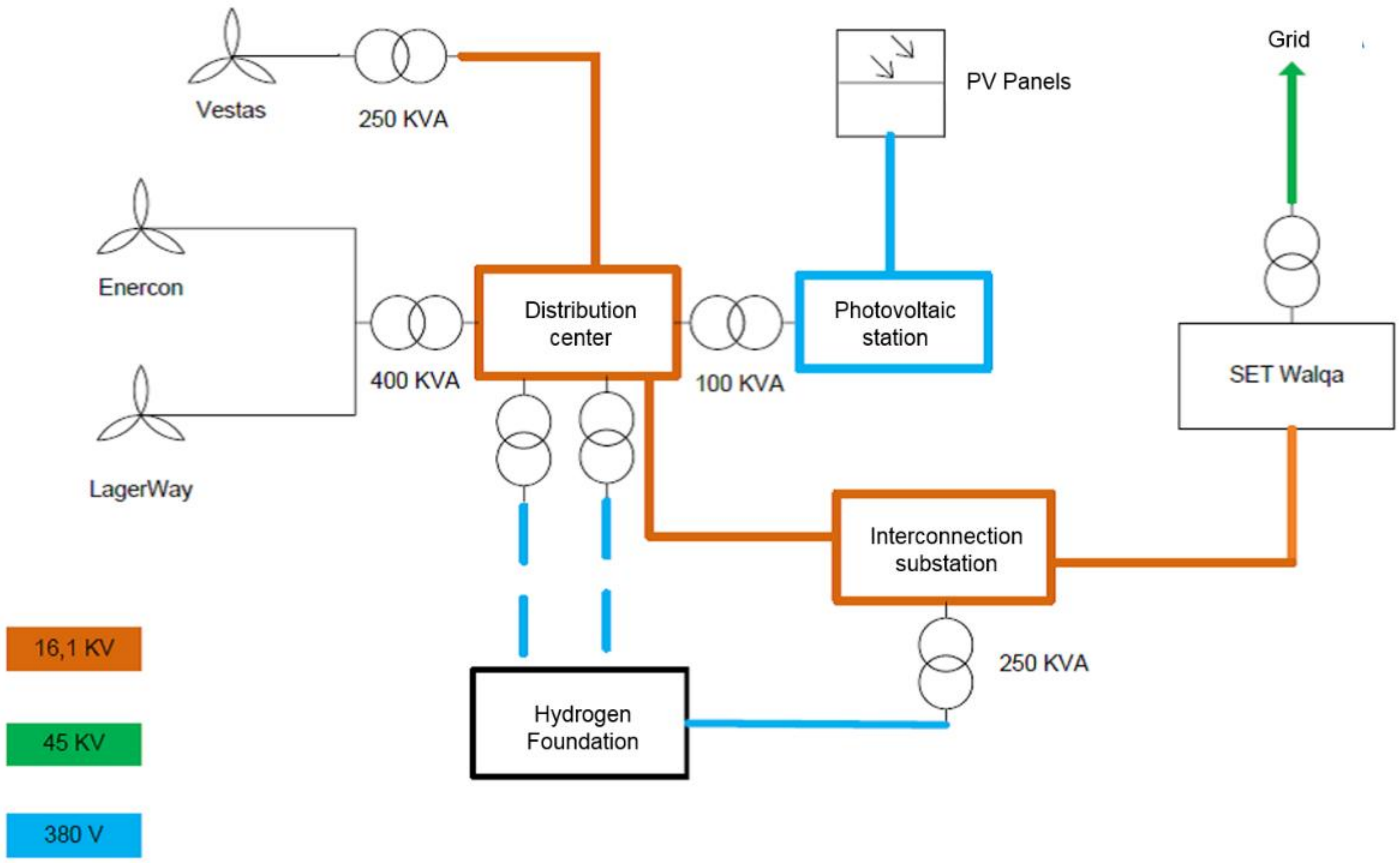
WALQA TECHNOLOGY PARK

WALQA INFRASTRUCTURE

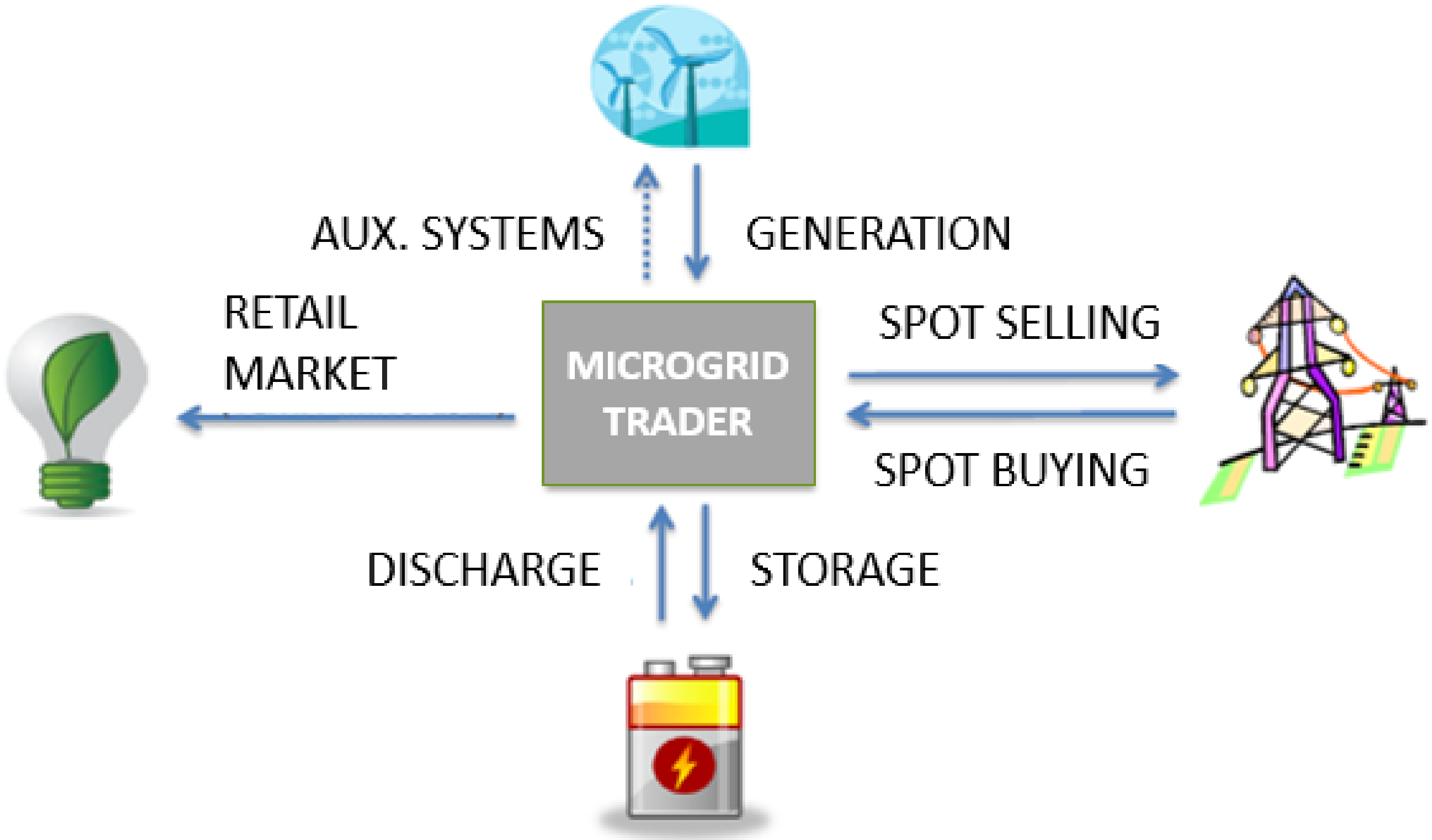
- Walqa Technological Park is an initiative run by Aragon General Government through the Aragon Institute of Development and Huesca City Council.
- Walqa is a microgrid including office buildings with up to 700 workers, wind power generation in 3 wind turbines (635 kw), solar FV (100 kw) and energy storage in batteries, hydrogen and super capacitors. There is also a small fleet of electric vehicles. All the loads and generation are currently being monitored through a web based system.
- Also prediction algorithms on power demand and electricity spot prices are available.



WALQA INFRASTRUCTURE



MICROGRID TRADER BUSINESS MODEL



P2P RESULTS TRADING AT WALQA

Item	Euros	Amortization
FV Panels	127.200	20 years
Wind turbines	889.000	15 years
Software/Licenses	12.000	5 years
Total	**1.028.200 €**	

Table 11 – Investments required to start the company.

Wind Generation	888.875	kWh/year
FV Generation	200.669	kWh/year
Consumption	2.517.010	kWh/year
2015 Mean Spot Price	5,038	€ cents/kWh
Wind Feed-in tariff	7,556	€ cents/kWh
Solar Feed-in tariff	38,828	€ cents/kWh

Yearly expenditure	Euros
FV Panels M&O	2.120
Wind Turbines M&O	14.585
Power Standing Charge	29.355
Wholesale Market Electricity Purchase	157.212
Self-Consumption distribution toll	127
Rent	10.000
Miscellaneous	5.000
Loan Interest	39.500
Total	**322.899,19 €**

Table 12 – Yearly expenses.

P2P RESULTS TRADING AT WALQA

- Scenarios enabled by P2P
- The main benefit is that now the microgrid trader has 2.526 MWh of electricity to sell to tenants as a retailer

Scenario	Total Energy consumption	Energy self-consumed	Energy bought in daily market	% FV energy sold to market	% Wind energy sold to market
With feed-in tariffs	2.526.205 kWh	7.699 kWh	2.518.505 kWh	100%	99%
No feed-in tariffs	2.526.205 kWh	762.328 kWh	1.763.876 kWh	15%	40%

Scenarios	Energy sold to tenants (kWh)	Wind Sold (€) to SPOT	FV Sold (€) to SPOT	Elect. Expenditure (€) (buying to SPOT)	Benefit (€)	Difference (€)	Aprox. Sales Margin (€)
Real	2.526.205	68.878	83.080	127.270 / 328.407	24.788		**-176.449**
P2P with feed-in tariffs	2.518.505	68.296	83.080	126.482	24.894	106	**352.900**
Self Consumption	1.484.708	-	-	74.800	-74.800		**253.607**
P2P without feed-in	1.763.876	18.331	1.562	88.864	-68.970	5.829	**259.436**

MICROGRID TRADER BUSINESS MODEL CONCLUSIONS

- Having a comprehensive management of the microgrid's power generation and consumption offers a benefit over a complete separate management, where the producer had to sell everything to the market and the trading company had to buy all the power needed for their clients.
- With feed-in tariffs for renewable energy, this profit is not very noticeable, but it grows as the feed-in tariffs are removed.
- If electricity prices are high in the wholesale market, the profit obtained with this model is higher than with low prices.
- Tariffs offered to customers are 10%-20% cheaper than current tariffs offered by retailers, even if the number of clients is much lower.
- Even if the overall efficiency of the system is improved reducing losses, transmission and distribution tolls have to be maintained when importing electricity from the power grid. When self-consuming the electricity generated on site, only 25% of the distribution toll can be removed.
- Energy storage is a further opportunity of revenue, but prices of batteries must fall as it has happened with PV panels.

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THANK YOU