The Digital Energy Revolution

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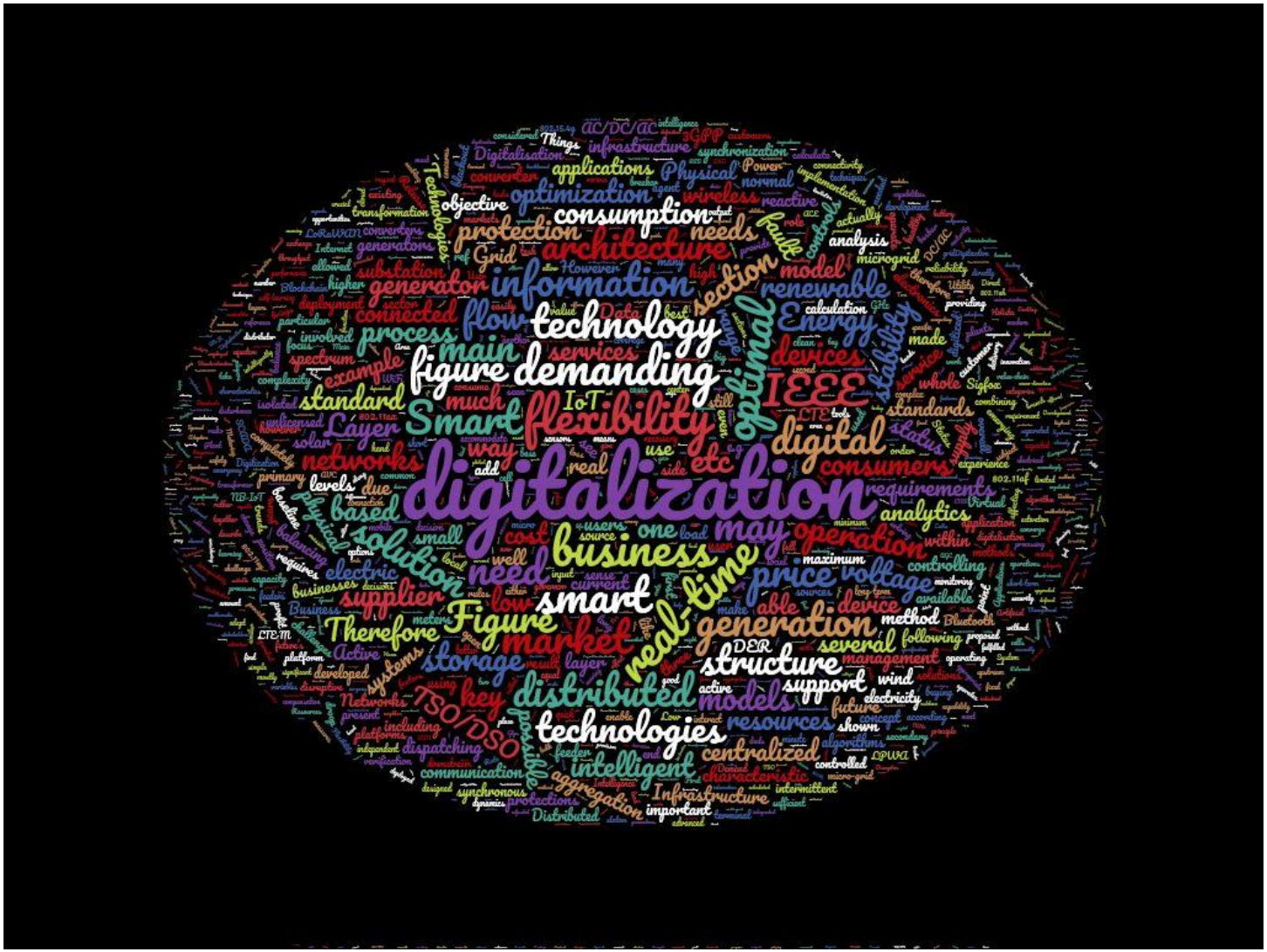
ACS | Automation of Complex Power Systems
E.ON Energy Research Center
RWTH AACHEN UNIVERSITY

In the beginning it was Smart Grid



What is the meaning of this change?

- ***Digitali*** gital
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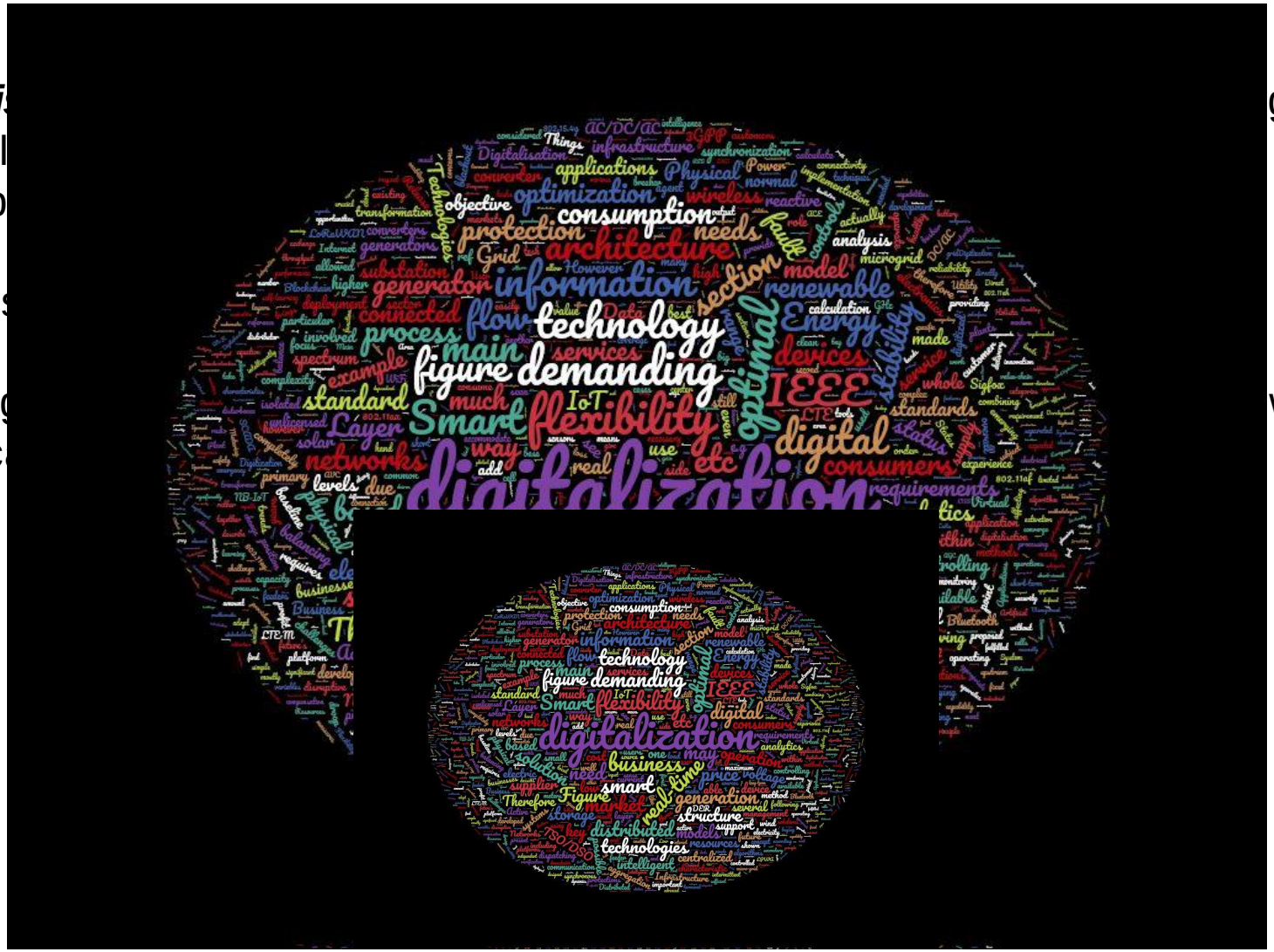
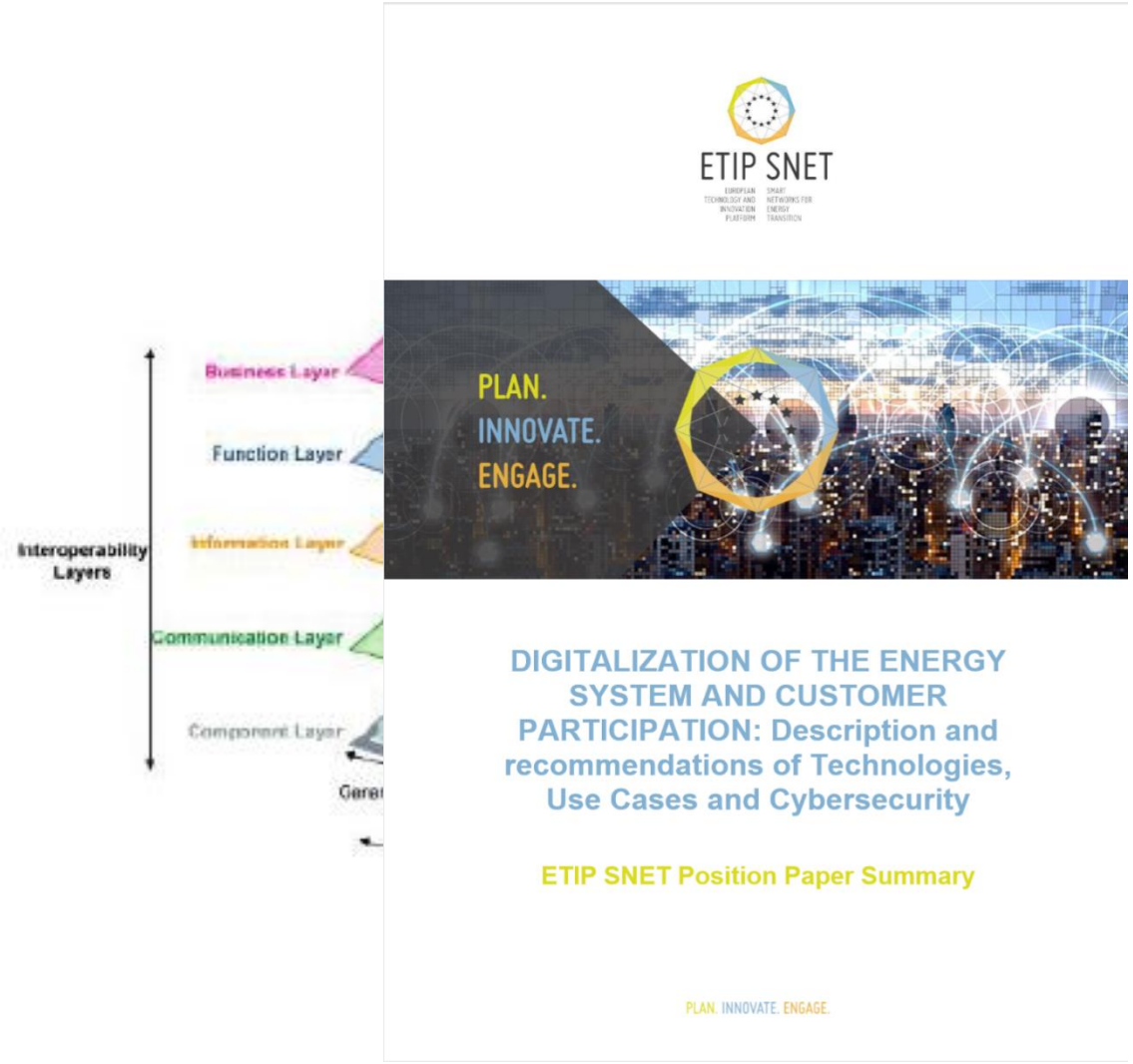


ETIP SNET WG4 TF1: A Layered Approach



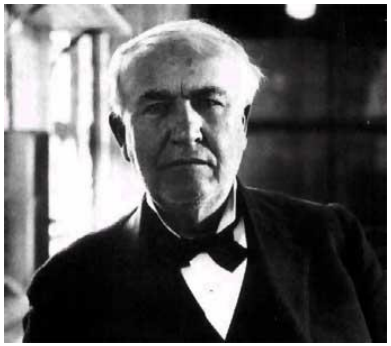
Business Layer

Infrastructure Layer

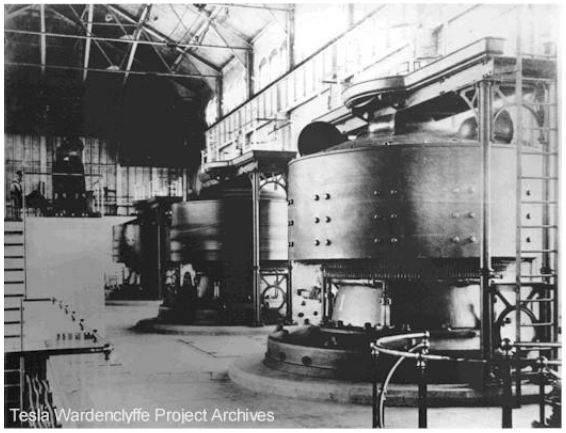
Physical Layer

https://www.etip-snet.eu/publications/etip-publications

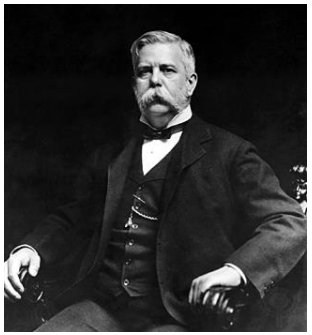
Looking back at the beginning …



Thomas Edison

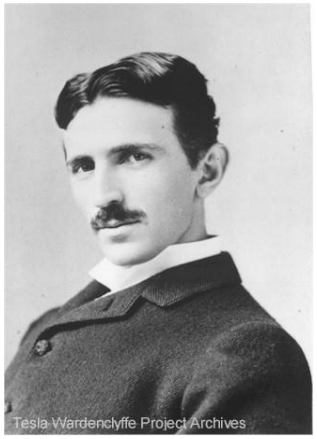


Hydro-electric power plant Niagara



George Westinghouse

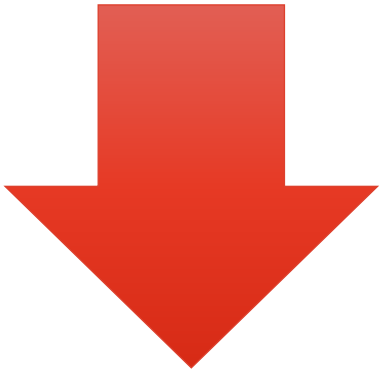
- DC Current:
  - Small Plants
  - Low Voltage
  - Distributed Generation



- AC Current:
  - Big Plants
  - High Voltage
  - Lumped Generation

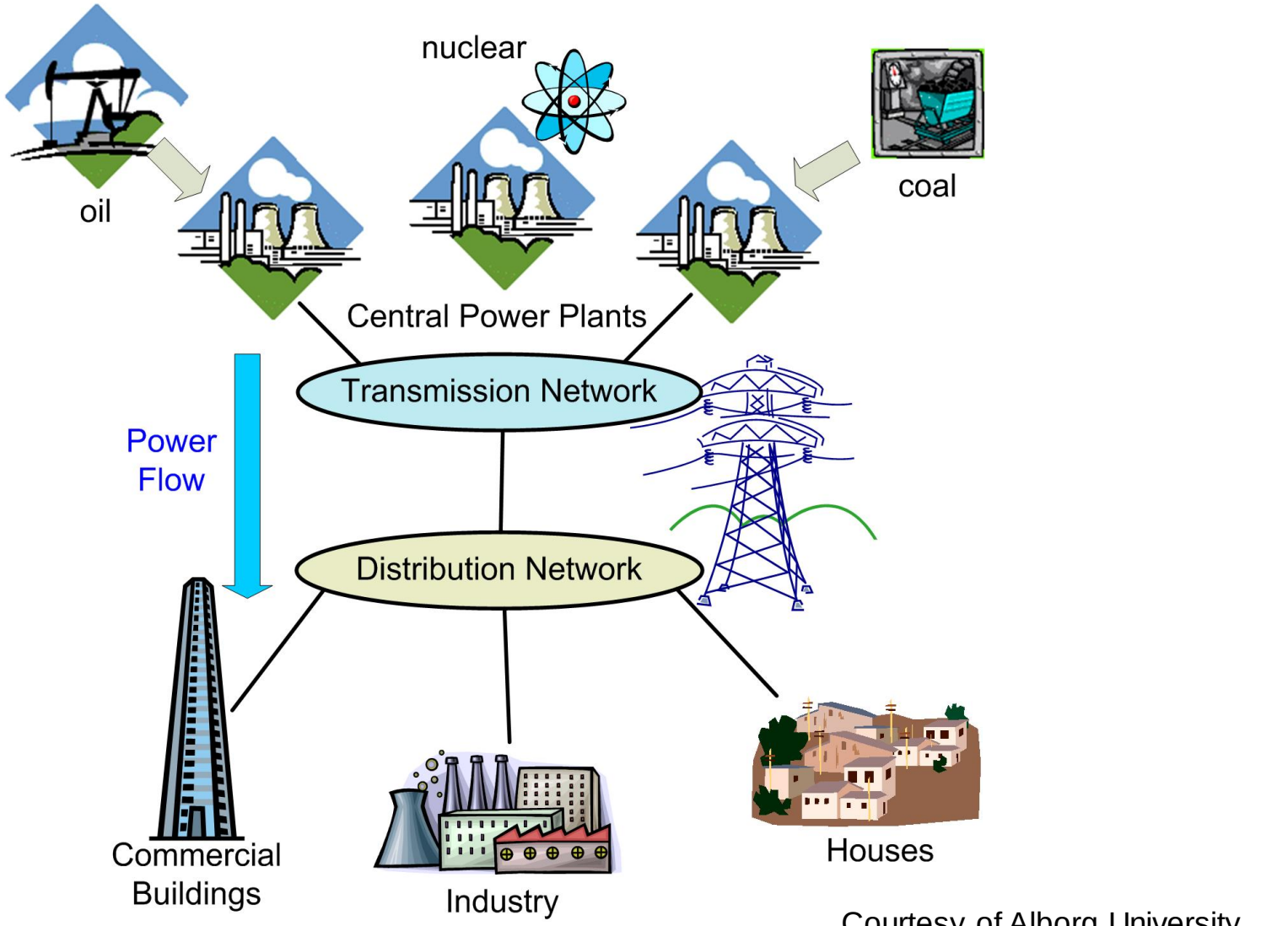
What we can learn from history

- The main reason AC was selected is because of the transformer. There was no efficient way at the time to convert DC in high voltage and back
- The following focus on thermal power plants pushed for lumped generation characterized by significant rotating masses able to smooth transients
- Reliability brought to design the system as interconnected as possible



We developed the most complex infrastructure built by human beings around the concept of synchronous operation and based on an extremely efficient communication channels: frequency

Traditional Power System



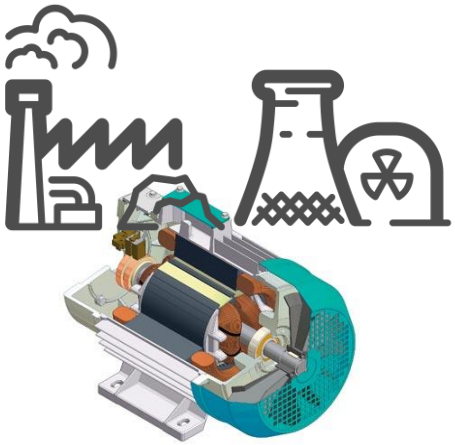
Courtesy of Alborg University

Characteristics of the classical Power System

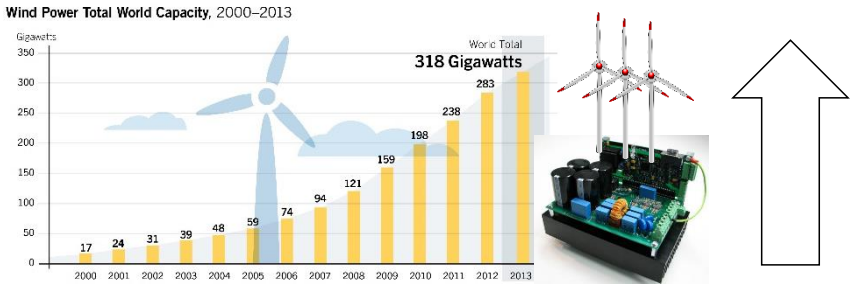
- Generation highly concentrated
- System is quasi-static
- Generation is “totally” under control
- Loads are statistically predictable
- Flow of energy from transmission to distribution is unidirectional
  - Distribution is a totally passive system

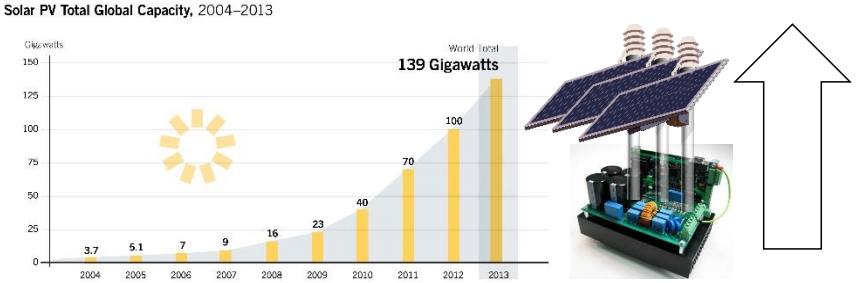
After more than 100 years .....

Non rotational generation



- Classical networks based on electromechanical systems -> Inertia
- Modern Distributed Energy Resources based on Power Electronics



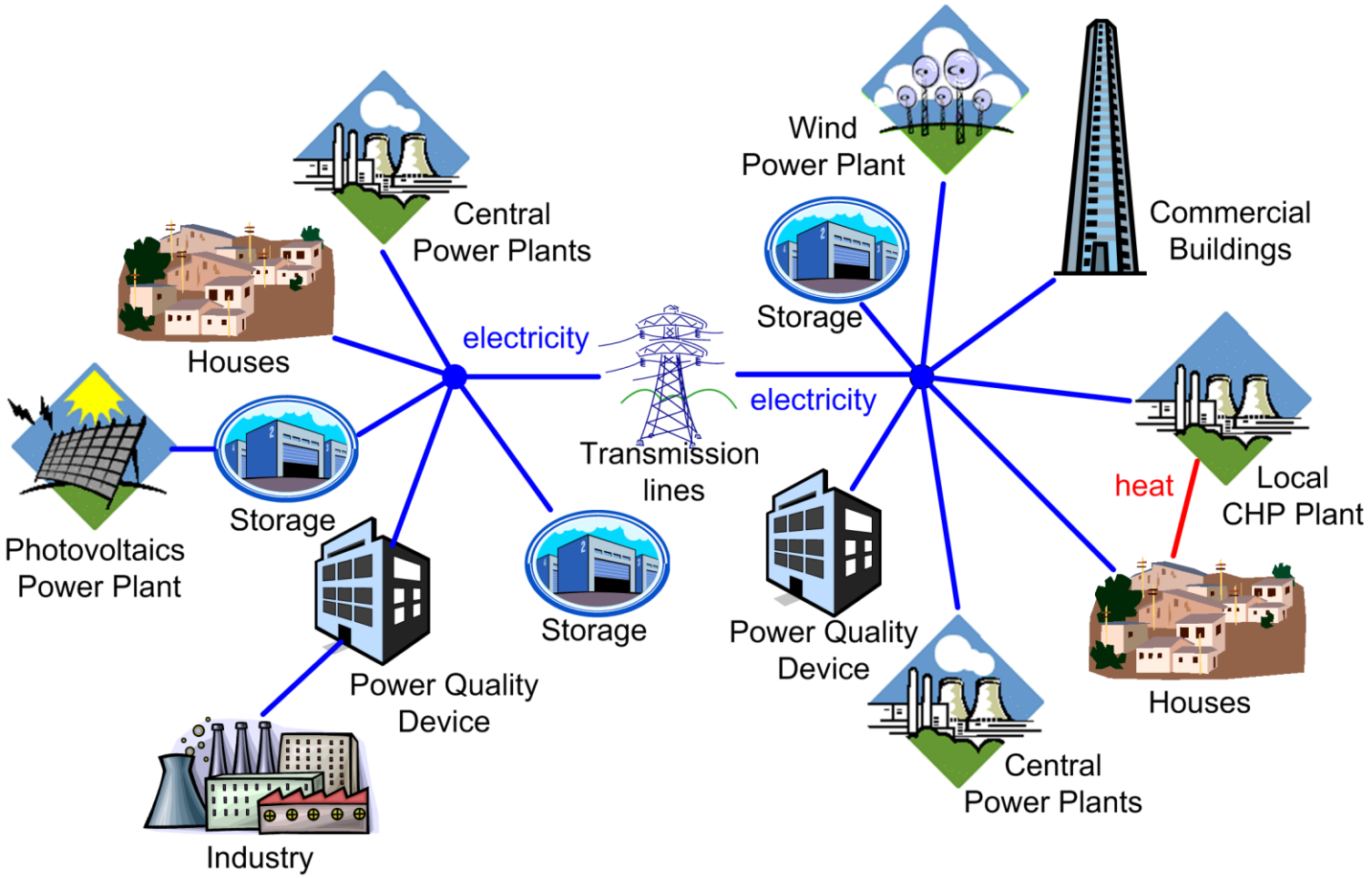


Renewables 2014 Global Status Report

Some numbers about Germany today

- Total contribution from renewable reached about 40% last year
- During operation already it already happened to have an in-feed from renewables over 100%
- In summer, during a sunny weekend, it happened to have more than 50% in feed from PV in low voltage

Power Systems Today



Courtesy of Alborg University

Characteristics of Today's Power System

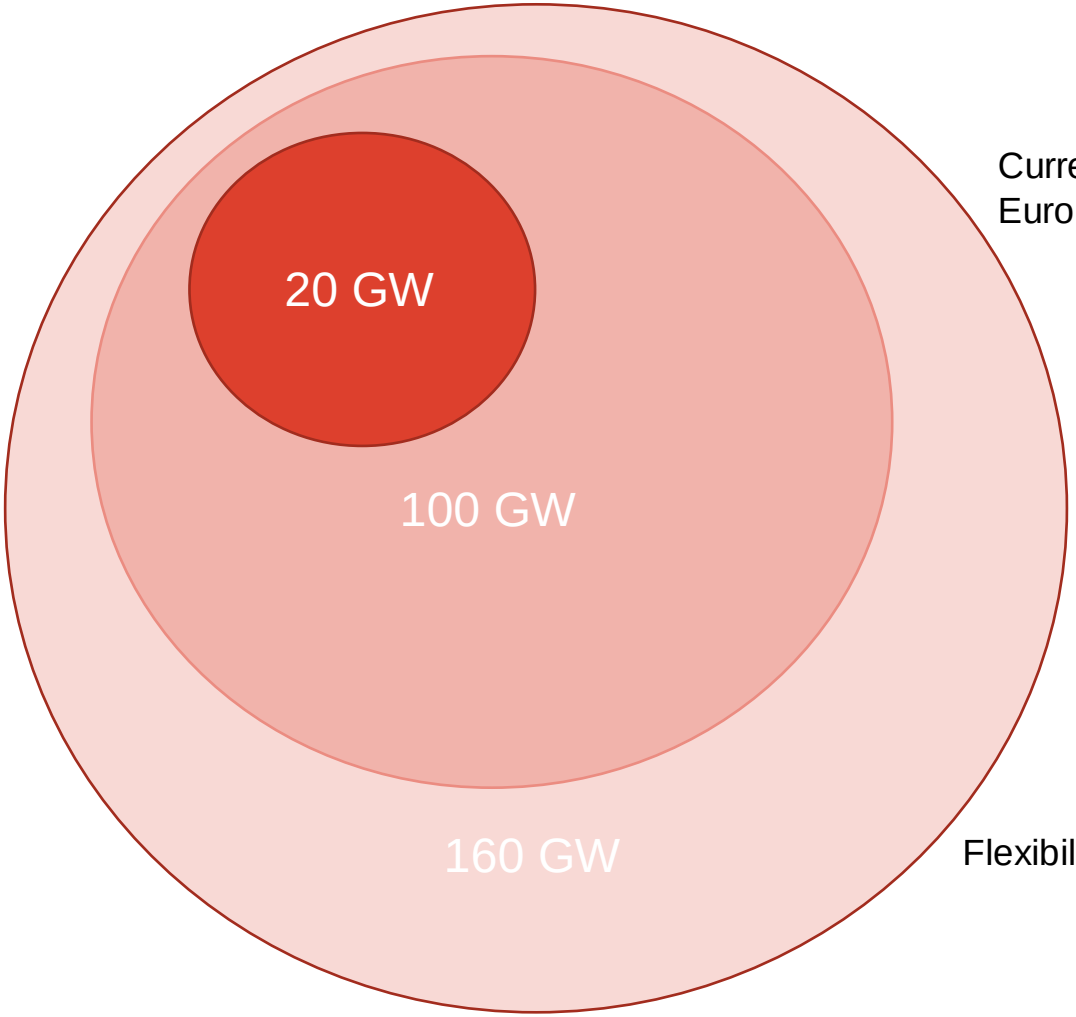
- More distributed generation
- Renewable sources are not totally predictable (uncertainty) and not under our control
- Power injection happens also at distribution level
- The system is characterized by higher dynamics
  - E.g. wind puff

Balancing the grid

Classical Grid is based on real-time balancing.

Does it make sense in a renewable driven grid?

Current and future needs of flexibility

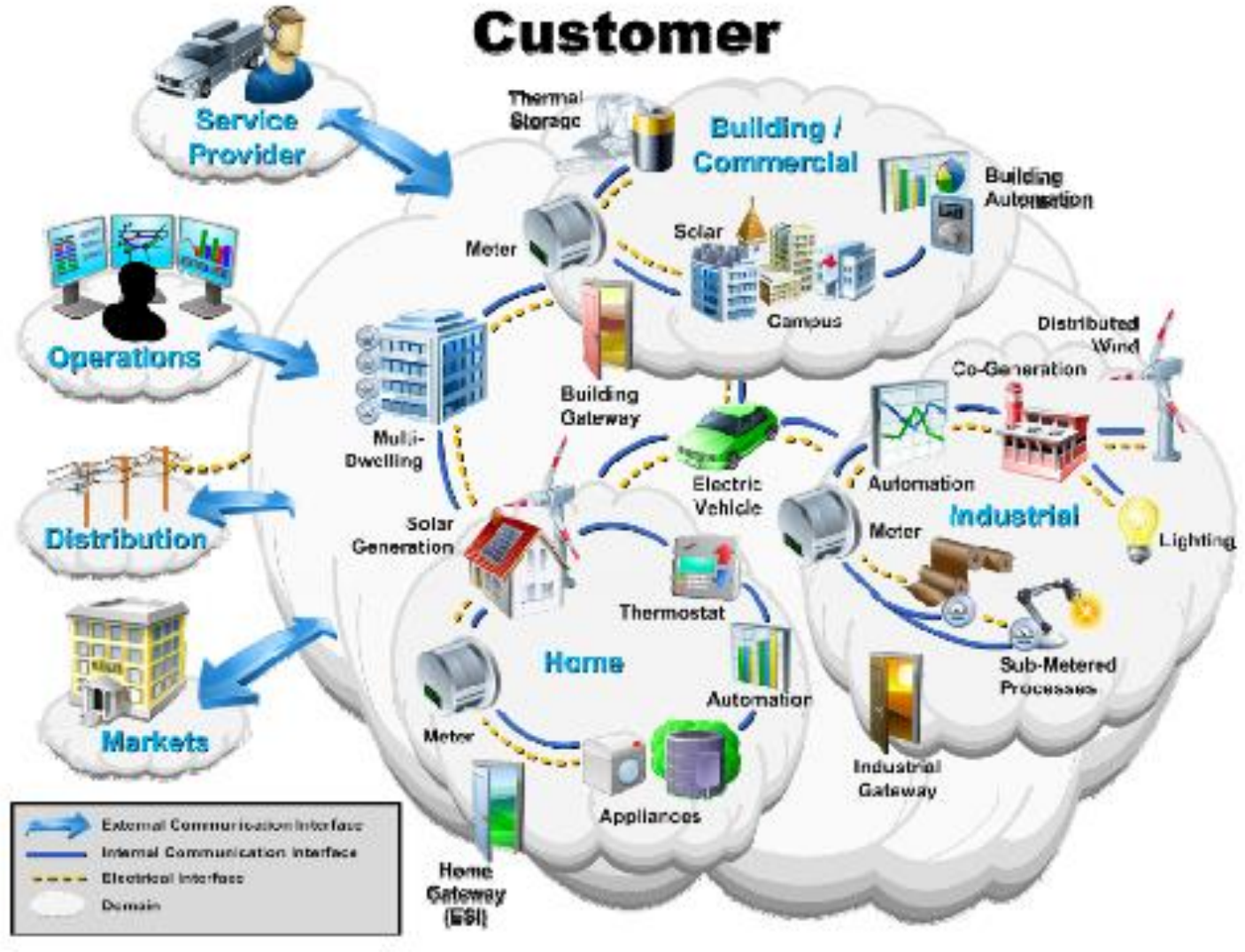


Currently available resources for flexibility in Europe

Theoretically available resources for flexibility in Europe today

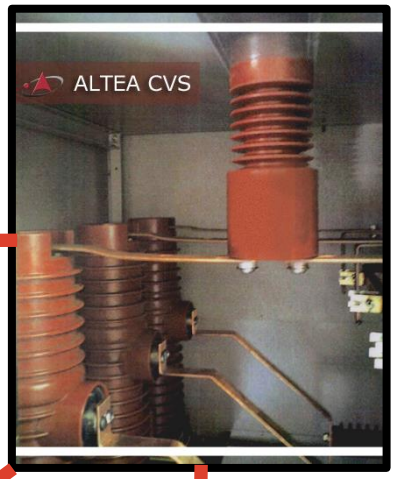
Flexibility needed by 2030

Flexibility = Customer Involvement



Source: NIST

Key Ingredients



Energy transition – the grid edge and the grid

- Grid Edge, now where the consumers, the prosumers and the communities are
- Pushing intelligence and action to the customer
  - Changes the business models, mobilizes investments
  - Requires management and grid interaction solutions
- Edge Technologies for the customer
  - Optimization, analytics, data platforms,…
  - peer-to-peer trading, e.g. blockchain
- Technologies for the grid
  - Monitoring, control, data platforms

https://new.siemens.com/global/en/company/topic-areas/smart-infrastructure/grid-edge.html

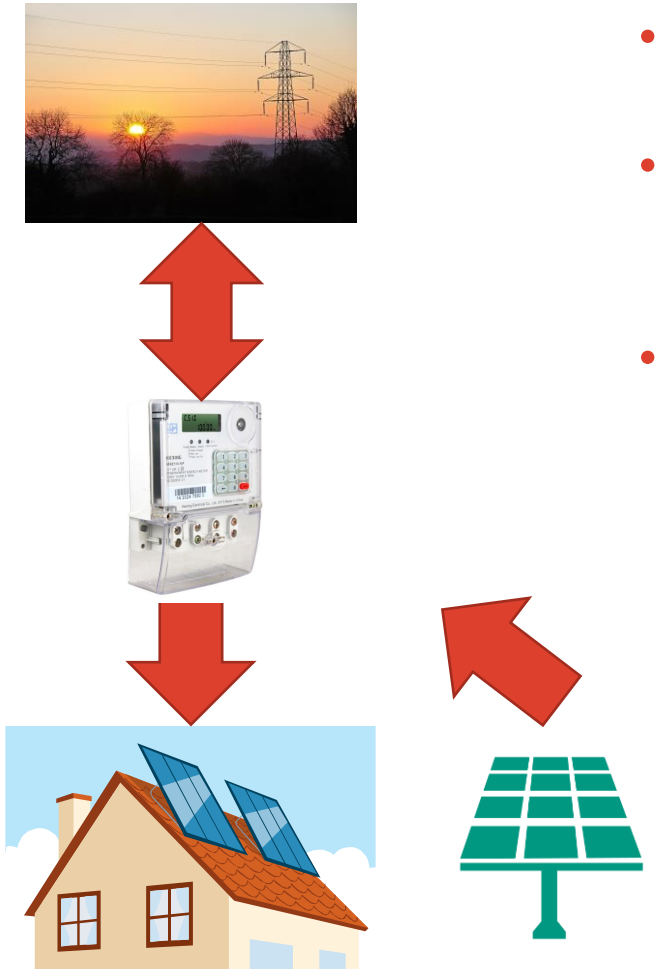
A brief history of customers: the beginning

- The customer has no role in the energy system
- Only interaction is given by the energy bill
- No communication is supported
- This is still the situation for the majority of citizens in Germany!!!

A brief history of customers: the birth of the smart meter

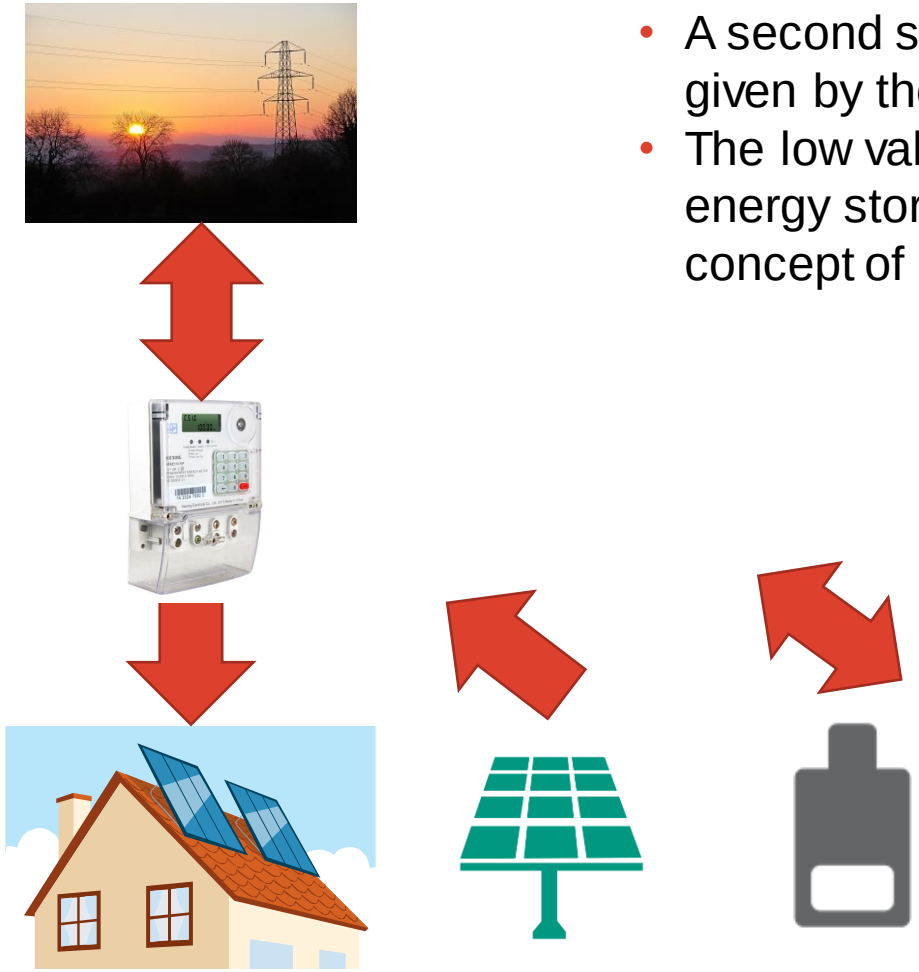
- Smart Meters introduce the concept of communication with the customer
- New options are open in terms of tariffs
- The deployment of the infrastructure is anyway very slow because of the lack of a clear business case
- Few countries are an exception. First adopters are Italy and Sweden for different reasons

A brief history of customers: the customer becomes active



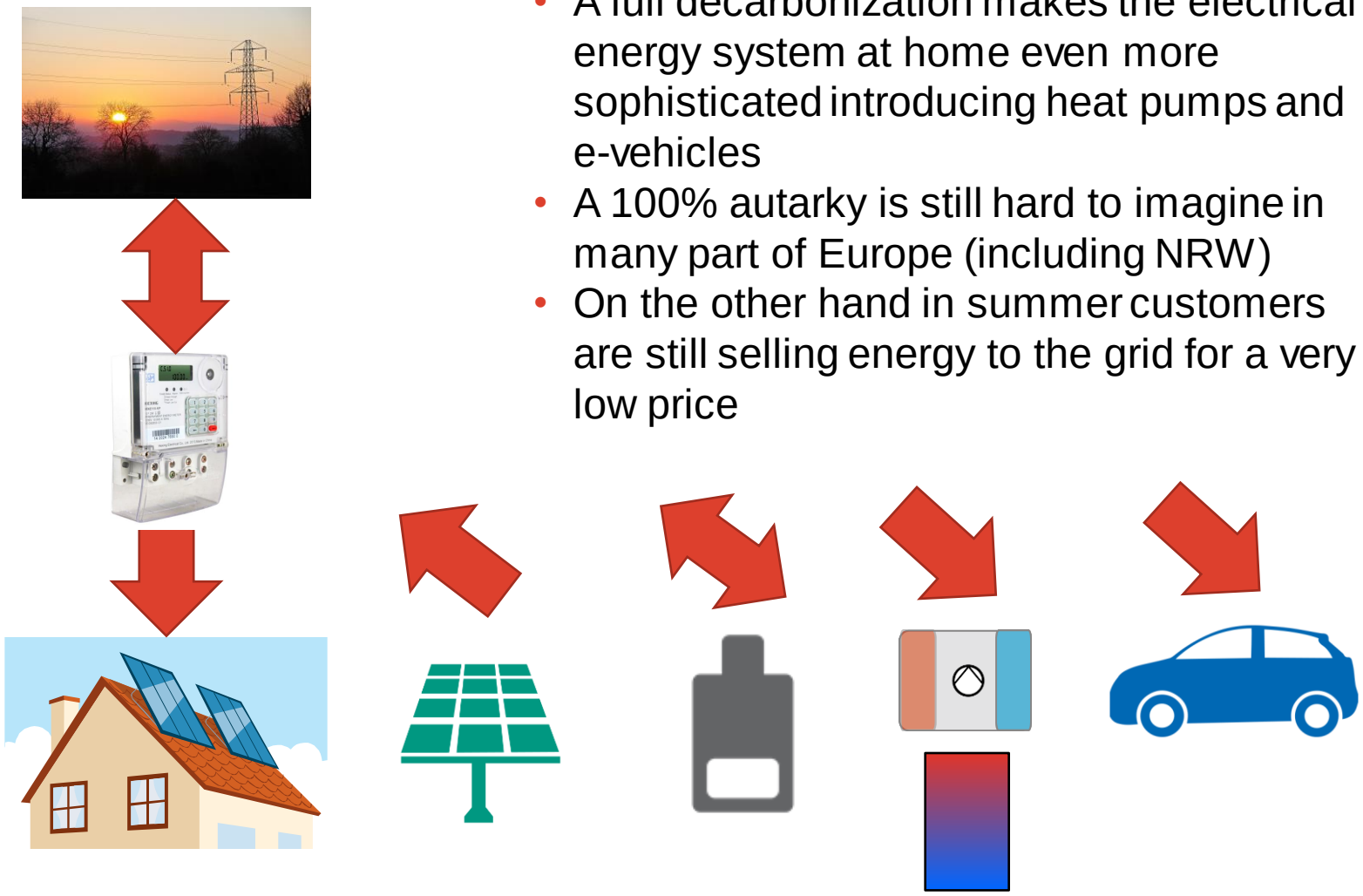
- Different types of incentive schemas supported the growth of PV
- Germany among the most active proposing very convenient options for the customers
- Feed-in tarif as main element driving the process. In the early days it was equally convenient to use or to sell energy to the grid

A brief history of customers: storage



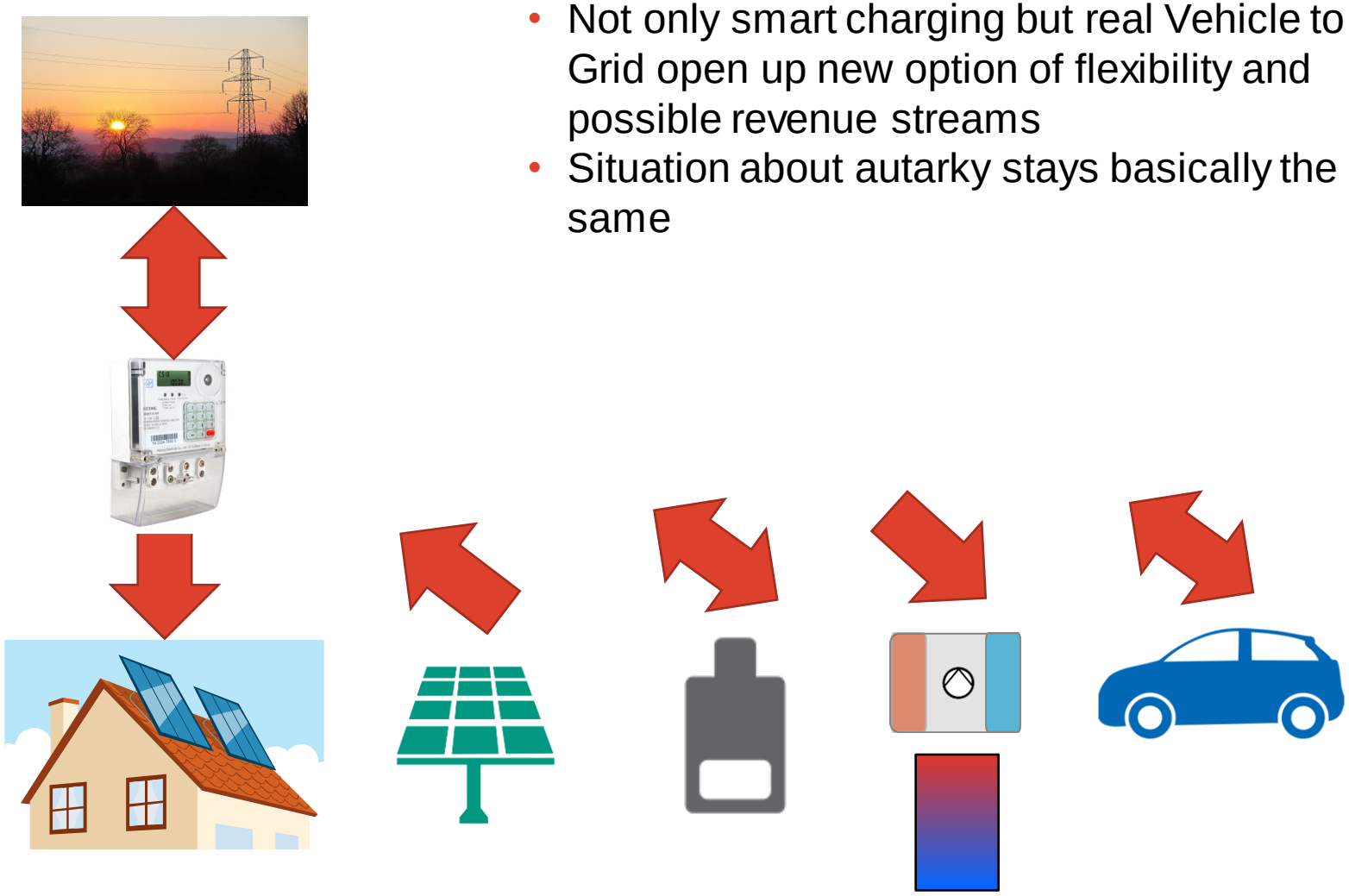
- A second step in the deployment of PV is given by the reduction on the feed-in tariff
- The low value of feed-in tariff makes energy storage convenient pushing the concept of self consumption

A brief history of customers: full electric home



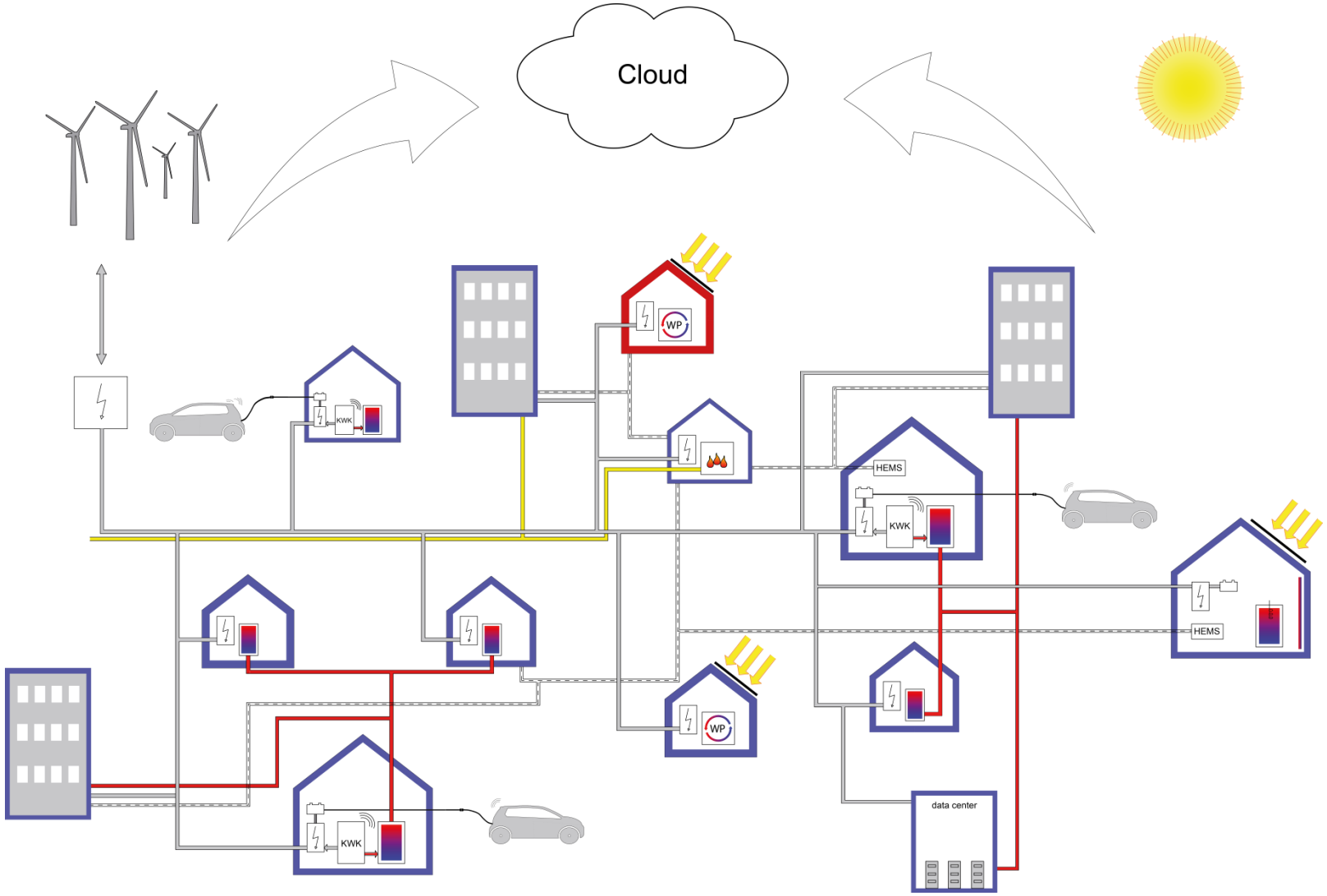
- A full decarbonization makes the electrical energy system at home even more sophisticated introducing heat pumps and e-vehicles
- A 100% autarky is still hard to imagine in many part of Europe (including NRW)
- On the other hand in summer customers are still selling energy to the grid for a very low price

A brief history of customers: full electric home 2.0



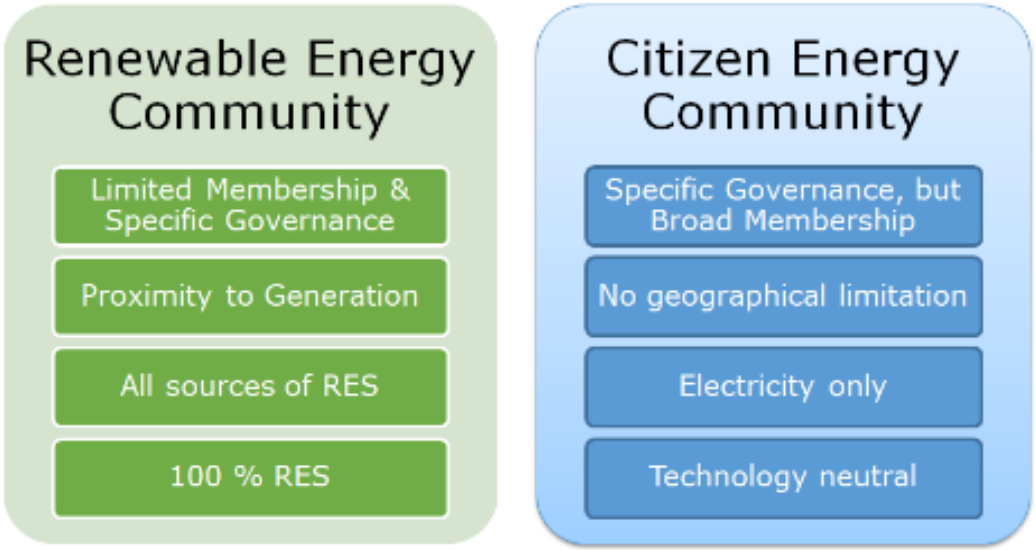
- Not only smart charging but real Vehicle to Grid open up new option of flexibility and possible revenue streams
- Situation about autarky stays basically the same

City quarter as key building block: breaking data silos to create a real data economy



Load Management Methods: Energy Communities

- Institutionalised Energy Communities as a part of EC's Clean Energy Package



Art. 22 of the Directive on the promotion of the use of energy from renewable sources on "Renewable Energy Communities" (RED), National transposition by June 30, 2021

Art. 16 of the Directive on the Internal Market for Electricity Directive on "Citizen Energy Communities" (EMD), National transposition by December 31, 2020

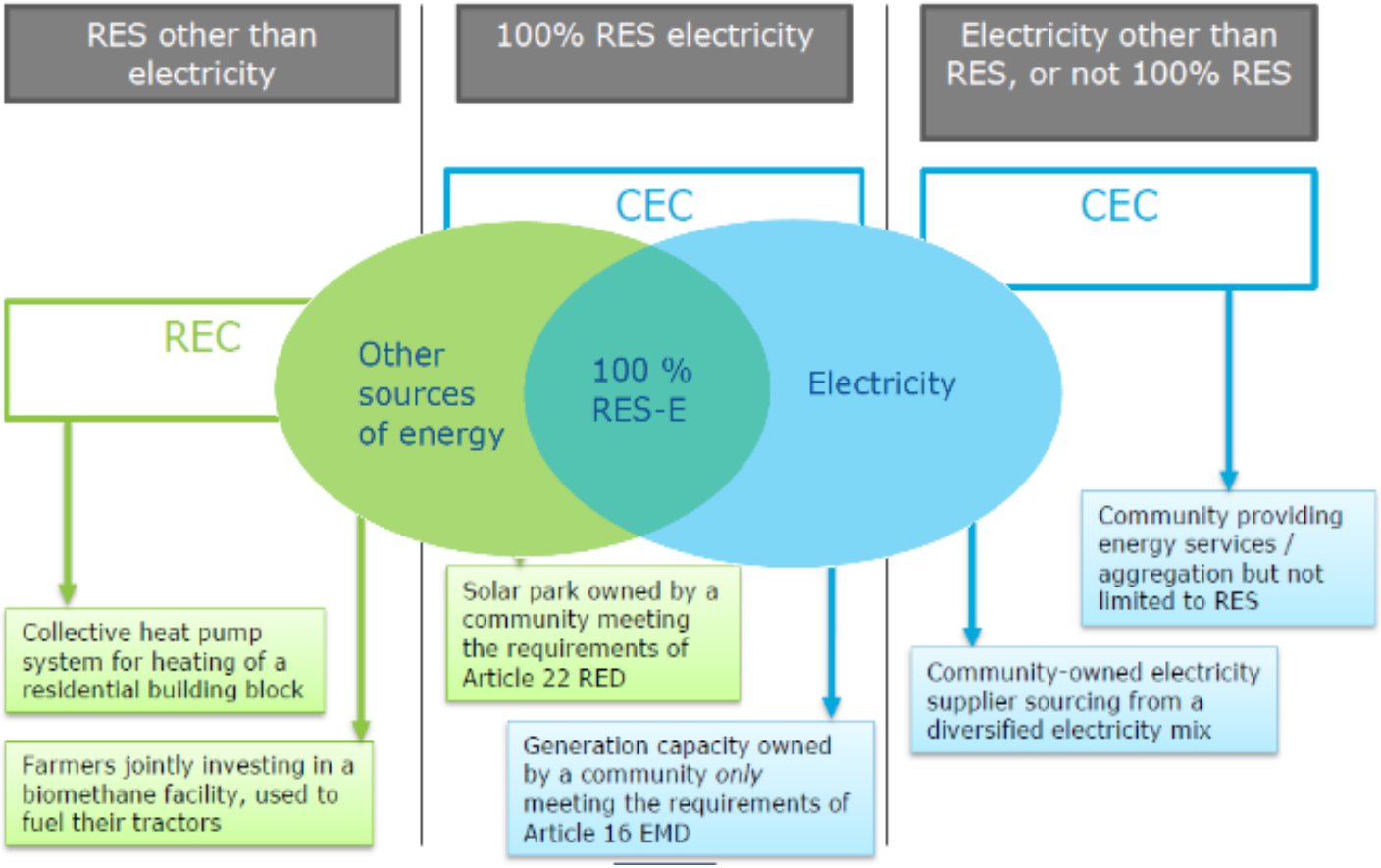
Load Management Methods: Energy Communities

- Objectives of Renewable (REC) and Citizen (CEC) Energy Communities
  - Provide environmental, economic or social community benefits for members or the local area by …
  - Empowering citizens
    - Tool to increase public acceptance of new projects
    - Tool to mobilise private capital for energy transition
    - A tool to increase flexibility in the market
  - RECs:
    - Favorable conditions and promotion for RES
  - CECs:
    - Recognition of new market actors
    - Level playing field and non discrimination

Source: Energy Communities and SWW Approach, L. Karg and G. Meindl

Load Management Methods: Energy Communities

- Relation of REC and CEC



Source: Energy Communities and SWW Approach, L. Karg and G. Meindl

Load Management Methods: Energy Communities

- Key characteristics of REC and CEC

Participation and Governance	only non-professional actors, control remains with members located in proximity
Active policy	Promote and facilitate the development of RECs Elimination of barriers
Role in support schemes	Member States to take specificities of RECs into account when designing support schemes

Participation and Governance	open to all kinds of entities, but control remains with non-professional actors
Charges, taxes and fees	Respect for the Member States' autonomy
DSO status	Member States may allow the DSO status, possibility of "closed DSO" status

Source: Energy Communities and SWW Approach, L. Karg and G. Meindl

Energieplattform Twistringen

Energy Communities in Distribution Grids

RWTH AACHEN UNIVERSITY

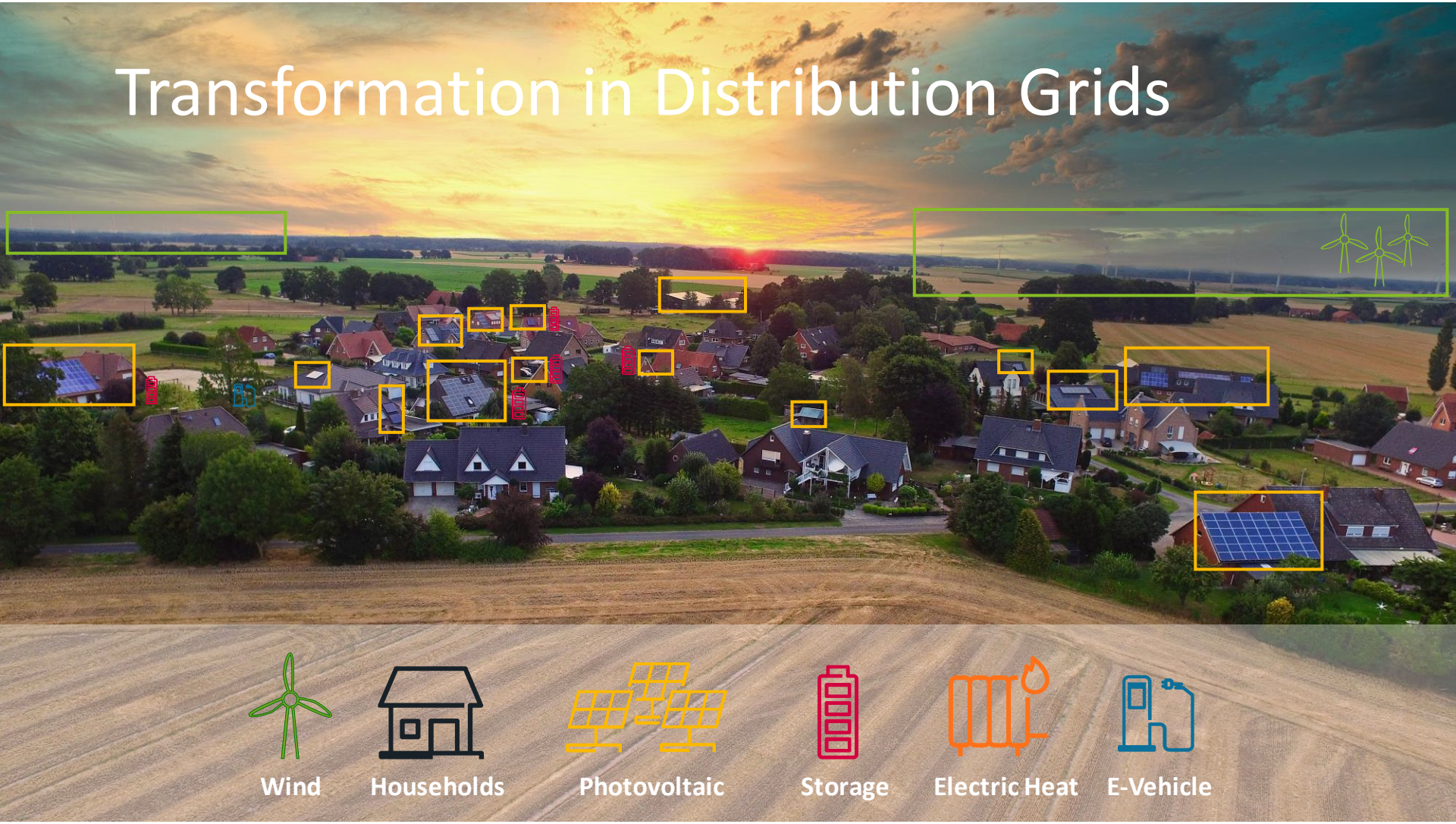
mtu A Rolls-Royce solution

B.A.U.M.

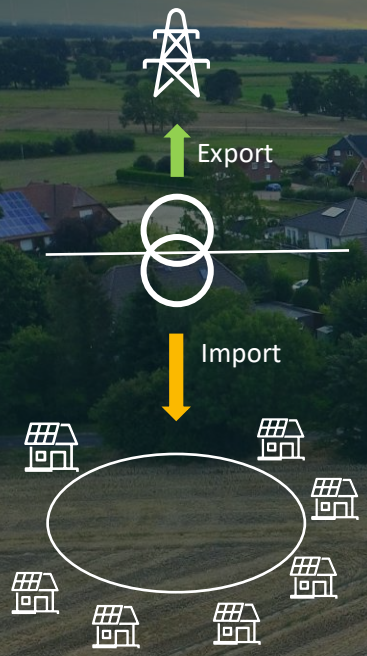
ENGINEERING

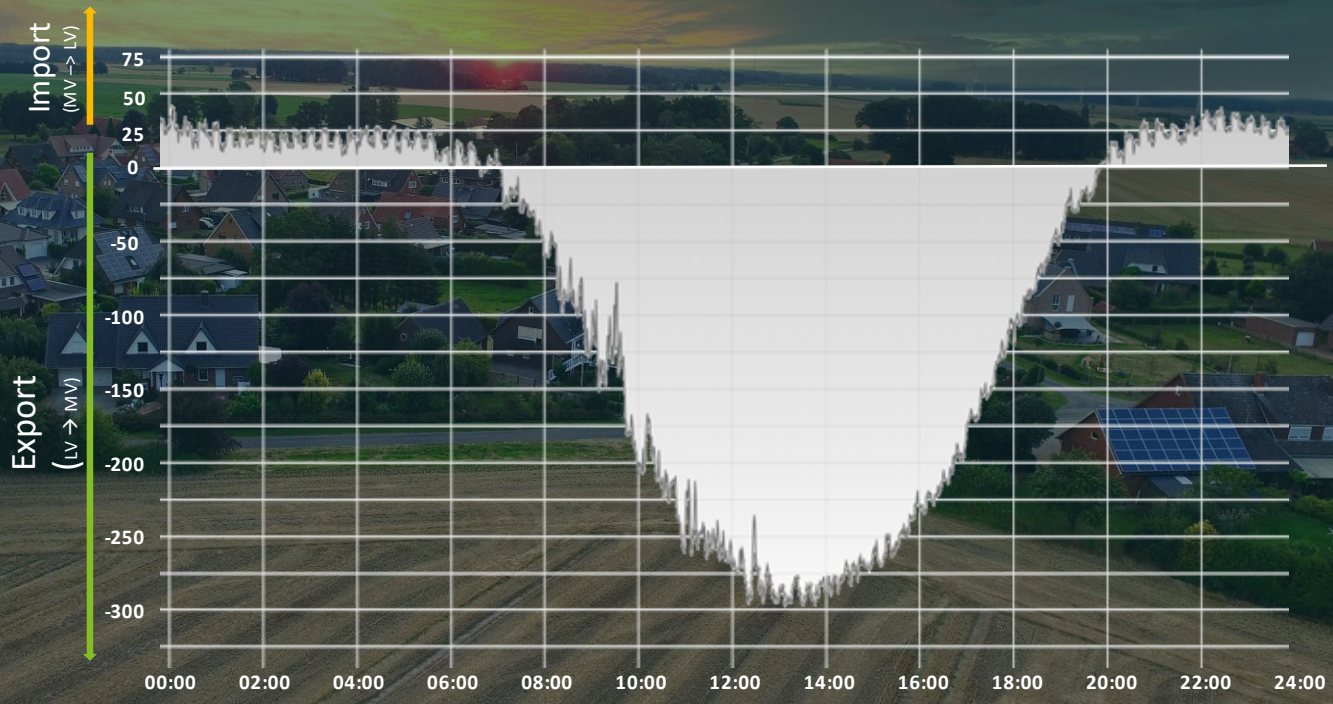
RSE Ricerca Sistema Energetico

Transformation in Distribution Grids



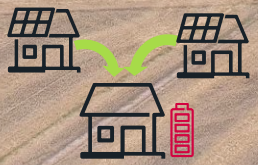
Load demand of rural low voltage grids with high share of PV





Changing load demand characteristics due to changing grid customer needs

PV – Self-Consumption



Collective Self-Consumption

Market Participation

Energieplattform Twistringen – Energy Management Systems in Distribution Grids

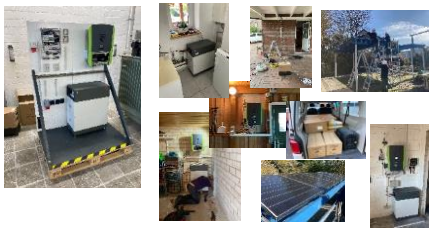
Digital Substation

Grid monitoring with on state-of-the-art sensors and communication devices

Energy Management System

Implementation of monitoring, forecasting and local balancing features

Customer Engagement & Customer Involvement



- 21 responses with interest for participation
- Equipment of 5 Households and implementation of 1 Prototype System

Community Abbenhausen

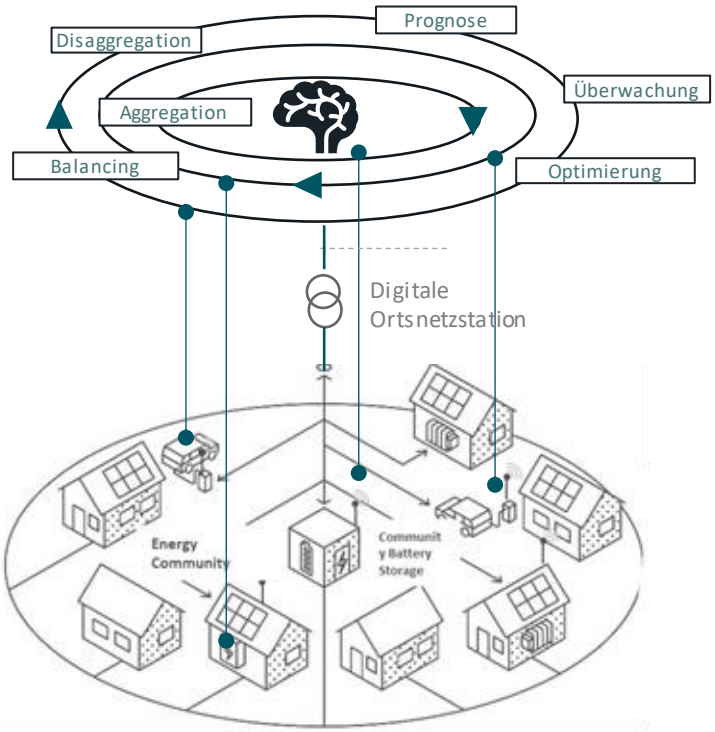
89 resident households with high share of roof-top photovoltaic systems

Battery Storage System

Provision flexible power and storage capacity

Energy Management System in Distribution Grid | Platone – Energieplattform Twistringen

Use Cases



UC 1 – Virtual Islanding / Collective Self-Consumption

Increase local consumption of PV generated energy and reduction of load peaks with:

- 15-Minute Control-Cycle
- Forecast-based control with optimization

UC 2 – Co-ordination von Flex-Request

Coordination of request through prioritization according to the BDEW traffic light rules

Application of local balancing schemes to battery system to achieve a constant requested value of power an the MV/ÖV grid connection point.

UC 3 – Ex-Ante Bulk Energy Import

- Forecast of net energy demand of lv grids (t+24h)
- Charging of batteries with energy from MV grid according to predicted energy deficits in the lv grid
- Discharging of batteries in times of load demand in MV grid to reduce stress

UC 4 – Ex-Post Bulk Energy Export

- Forecast of net energy demand/surplus of generation of lv grids (t+24h)
- Caching of surplus energy in local batteries
- Discharging of batteries in times of high demand or low generation in MV grid.
- Target: Minimization of load peaks in MV grid

Energy Management System in Distribution Grid | Platone – Energieplattform Twistringen

Italian Demo in H2020 Platone project

Energy community and participants to the trial have been equipped with technological devices

The Casaccia ENEA Smart Building has been involved in the trial

The cogeneration plant of Tor Di Valle has been equipped with an industrial Light Node

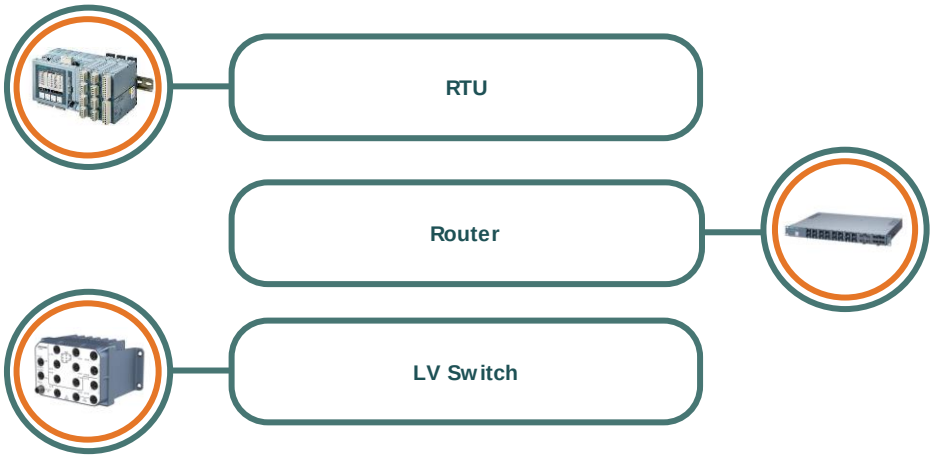
*The Smart Park areti is equipped with several electric charging stations**

*areti will start testing the italian demo solution on building blocks, promoting a model of collective self consumption**

**These type of users will be implemented in 2022 and 2023*

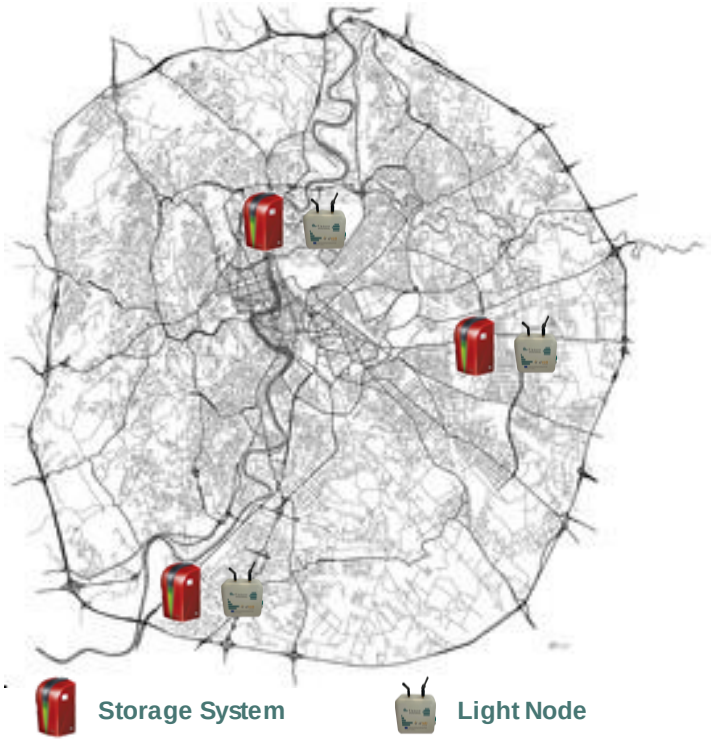
Hardware on the Field

Several secondary substations already equipped with technological devices that enable the interaction with areti's central systems, started to communicate with Platone ecosystem and its platforms. Thanks to these kind of devices, grid issues detection will be improved.



Platone

Rome



DSO Technical Platform of the Italian Demo

Thanks to the experience gained with the Platone solution regarding the exploitation of the DSO Technical Platform able to incorporate the functionalities of the ADMS, the functionalities necessary to manage the flexibility market and the demand-side response field (in the “system” point of view), areti decided to proceede with the reconstruction of its system in Open Source. Moreover, areti will consider the architecture and the Platone functionalities in the participation in public tenders.

Light Node

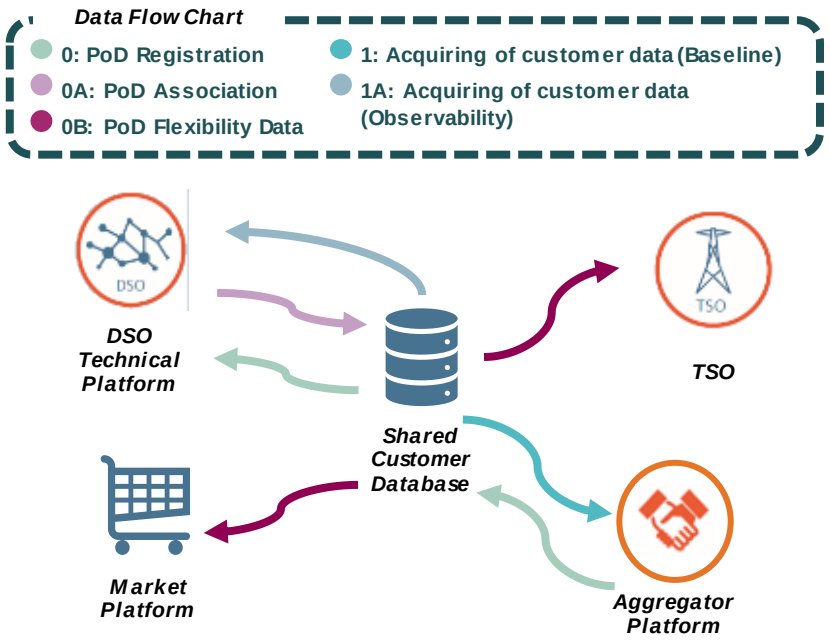
Collection of the measures coming from areti Smart Meter

Reception of the setpoint and activation of the customer to the flexibility

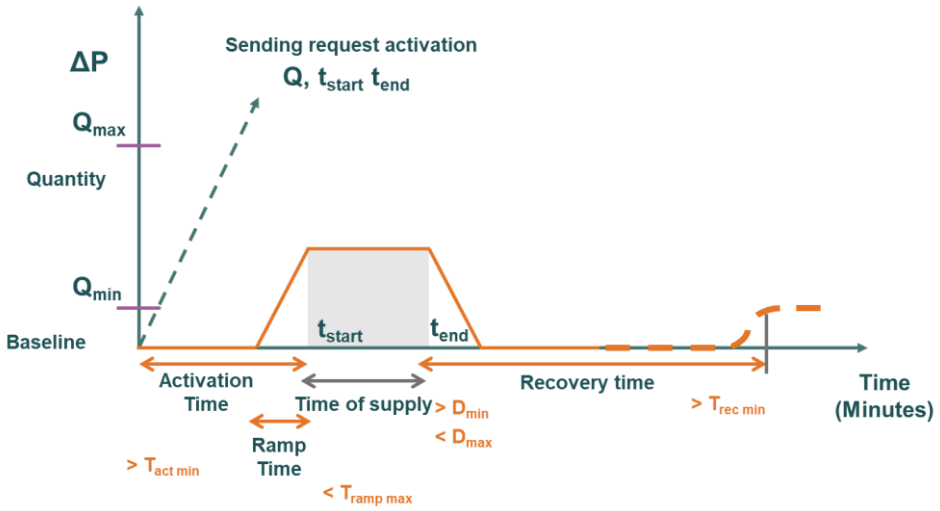
Enabling to the evalaution and certification of the Chain2full

Preparation and Flexibility Products

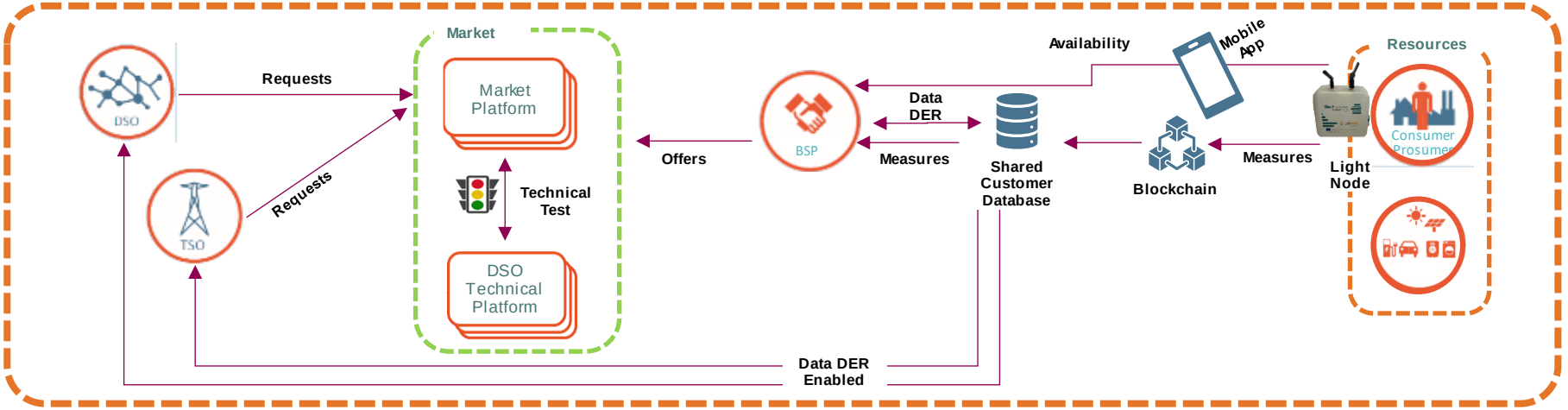
Preparatory activities



Flexibility products



Activation and Use

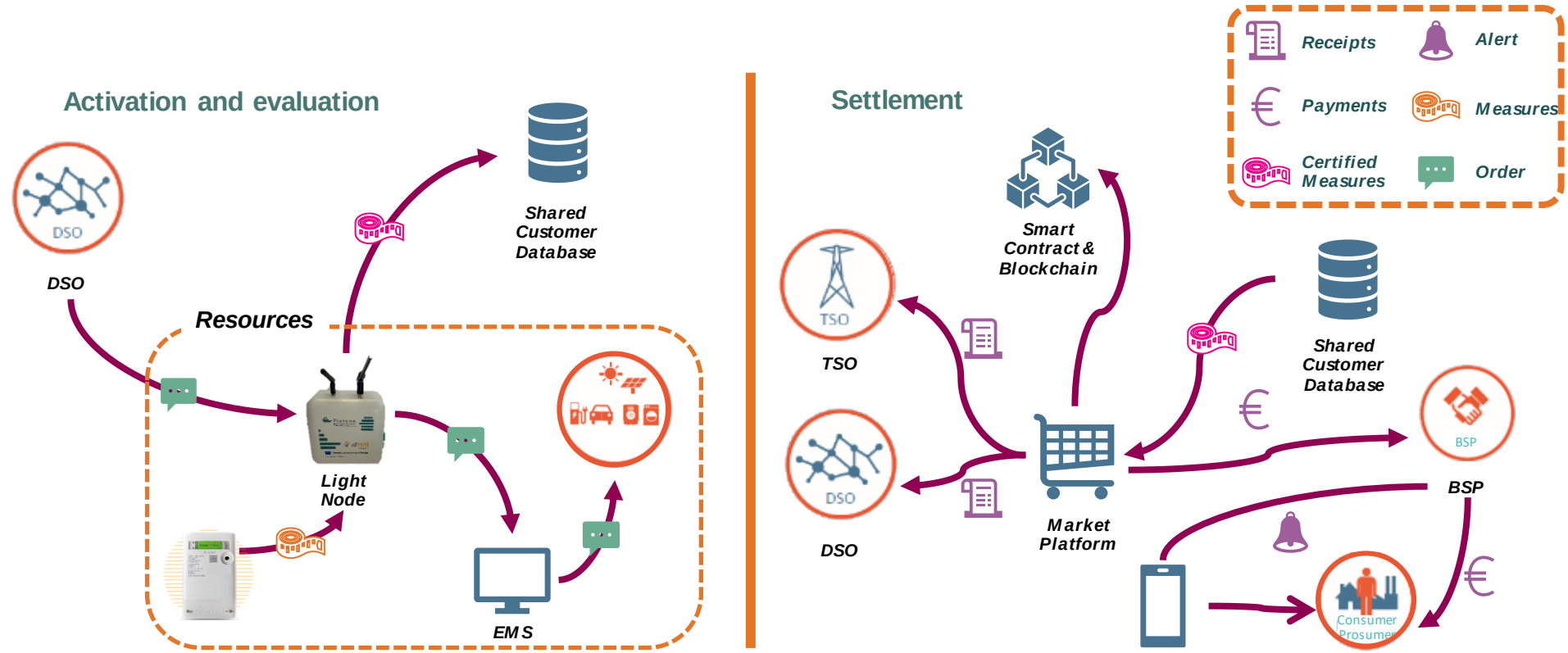


Market Platform

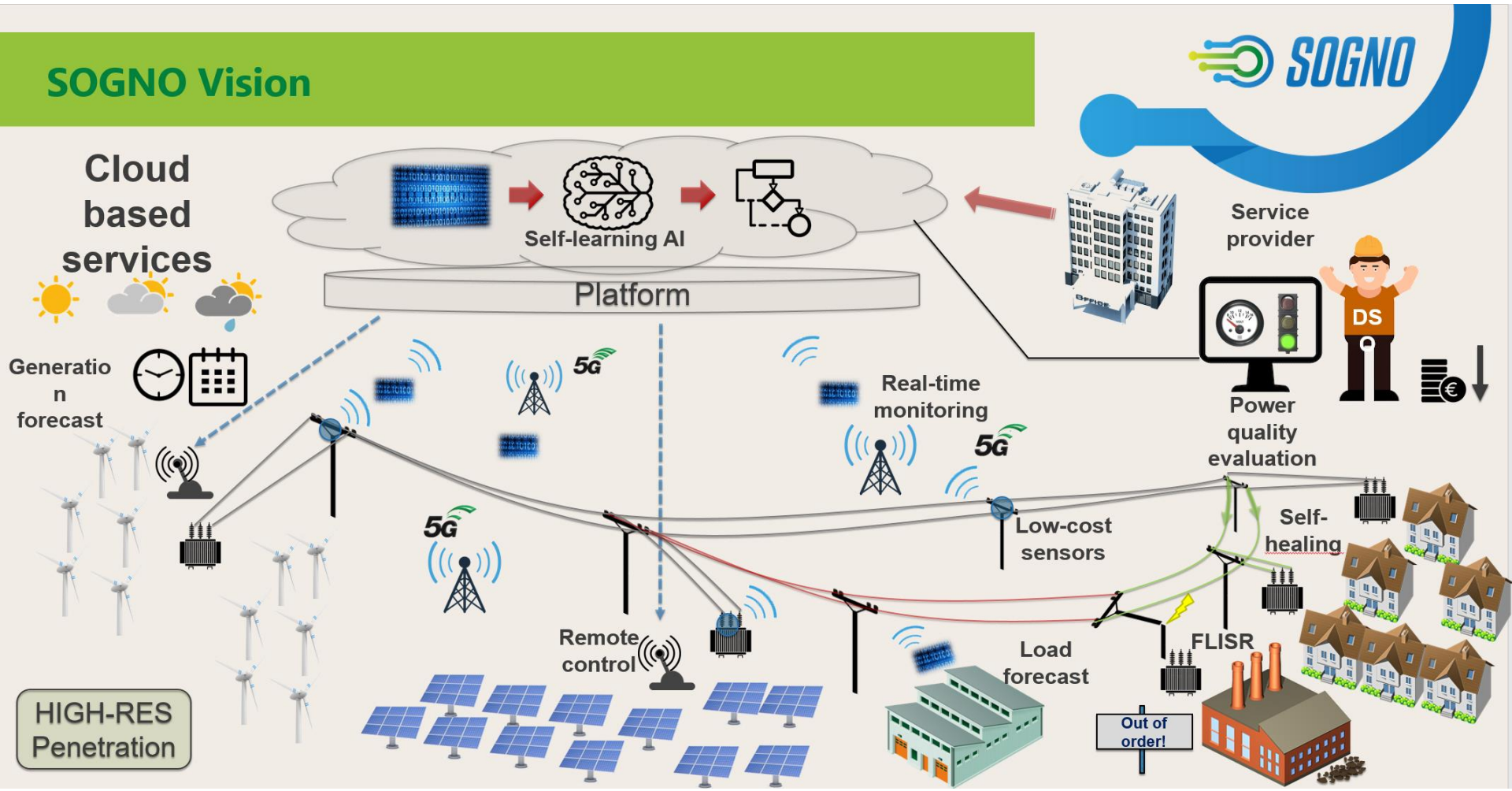
Day ahead: The only session relative to the services to be supplied in the 24h of the day following the negotiation day

InfraDay: 6 sessions each covering the services to be provided during the 4 hours of the day following the session day

Measurement and Settlement



H2020 SOGNO Vision



RWTH Smart Campus

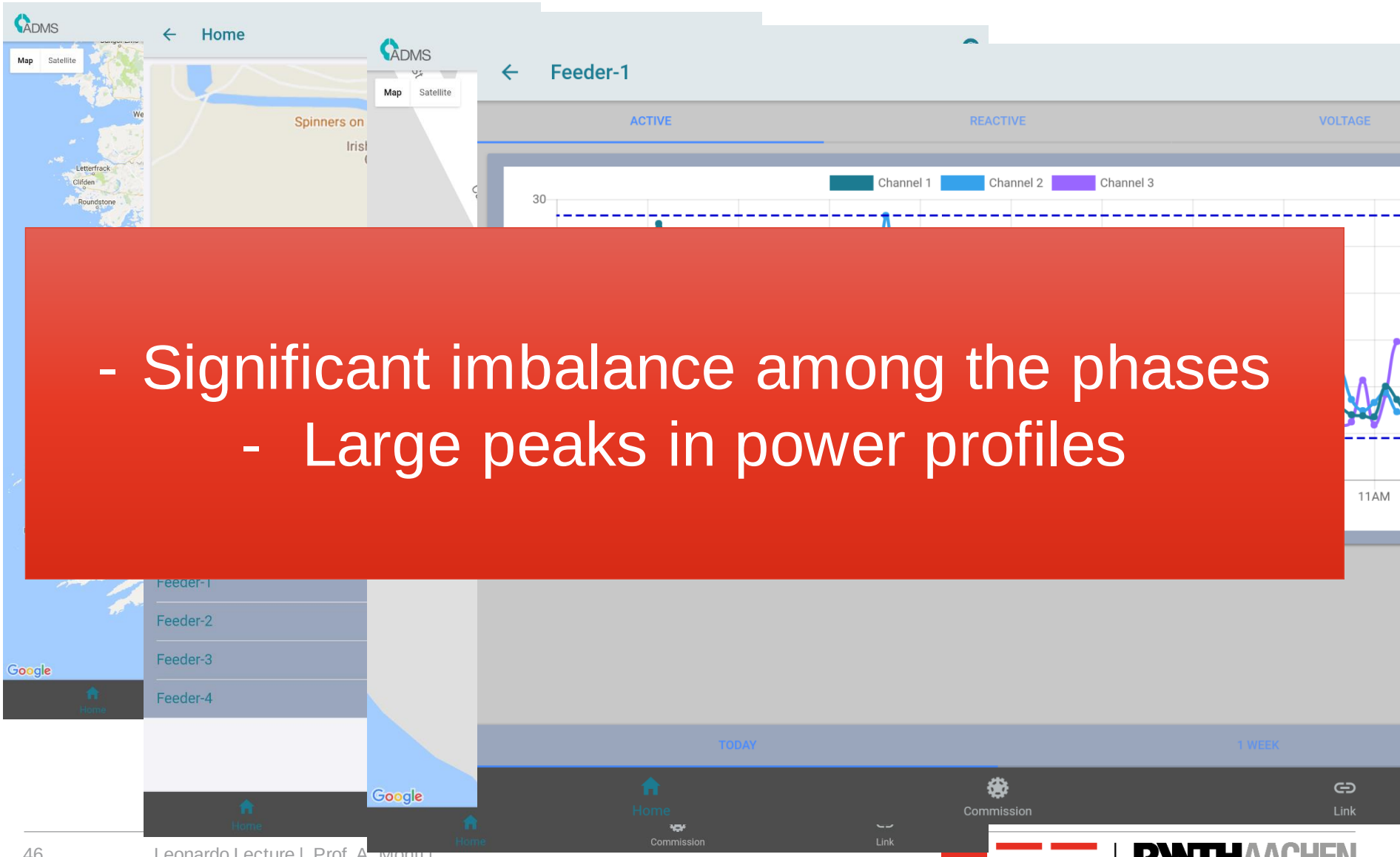
Smart Terminator ALTEA
Installed in an RWTH Substation
(no need of service interruption)

Enriching sensors with Smart Processing:
microPMU with cloud connection

Creating technology specifically for distribution instead of transferring products from transmission

Traveling to Ireland …..

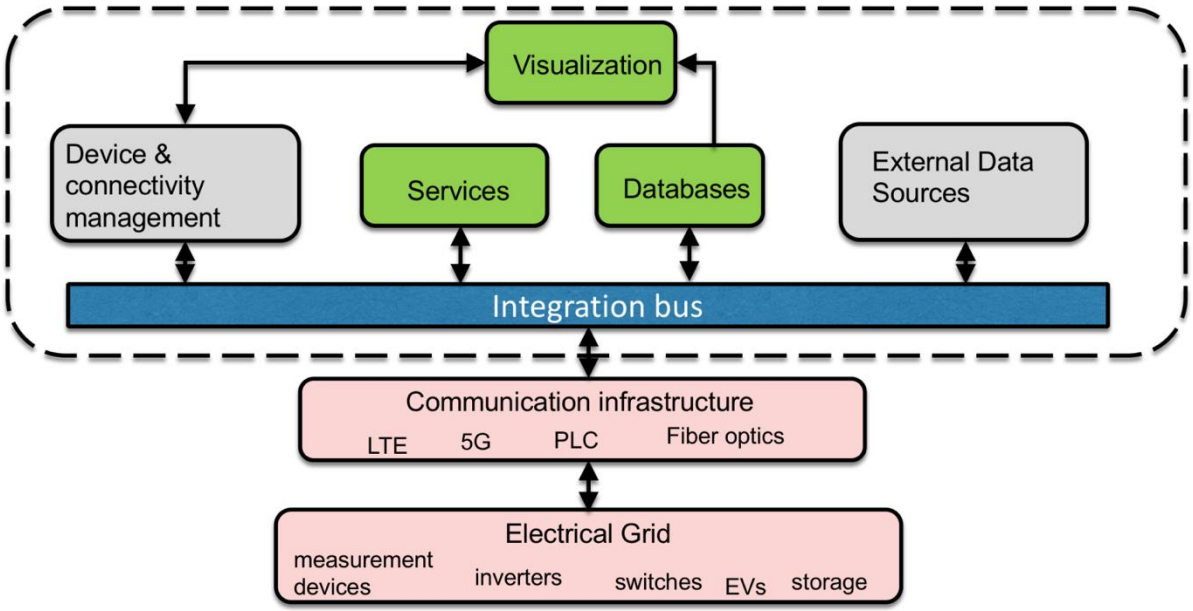
Learning what happens in the LV Grid ….



- Significant imbalance among the phases
- Large peaks in power profiles

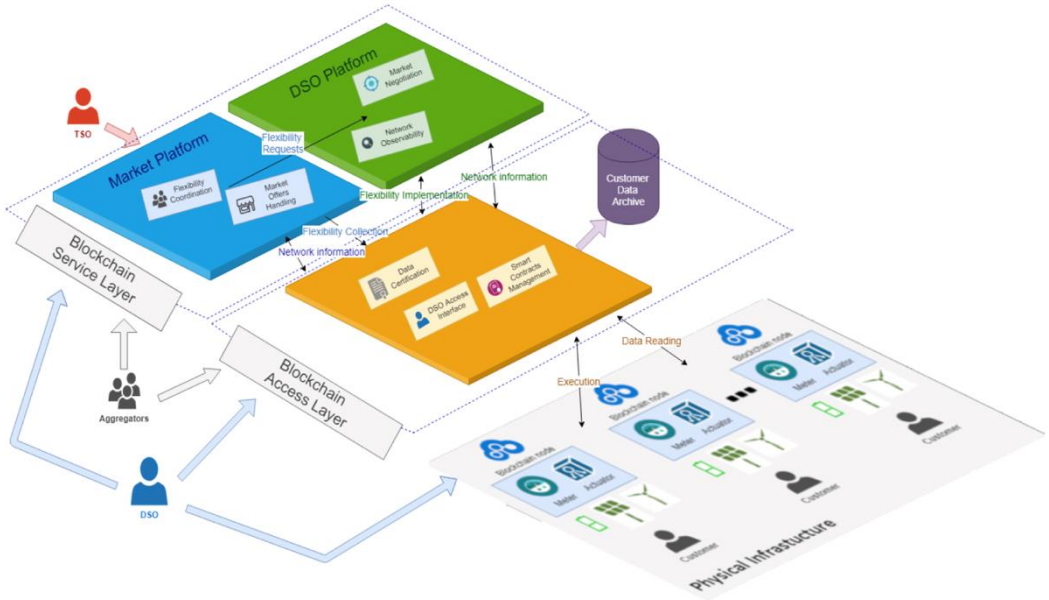
Open Source in PlatOne as a way to create a real open DSO platform

- Key components for an open platform:
  - Flexibility in data input
  - Integration bus for flexible integration of solution
  - Open API to external services



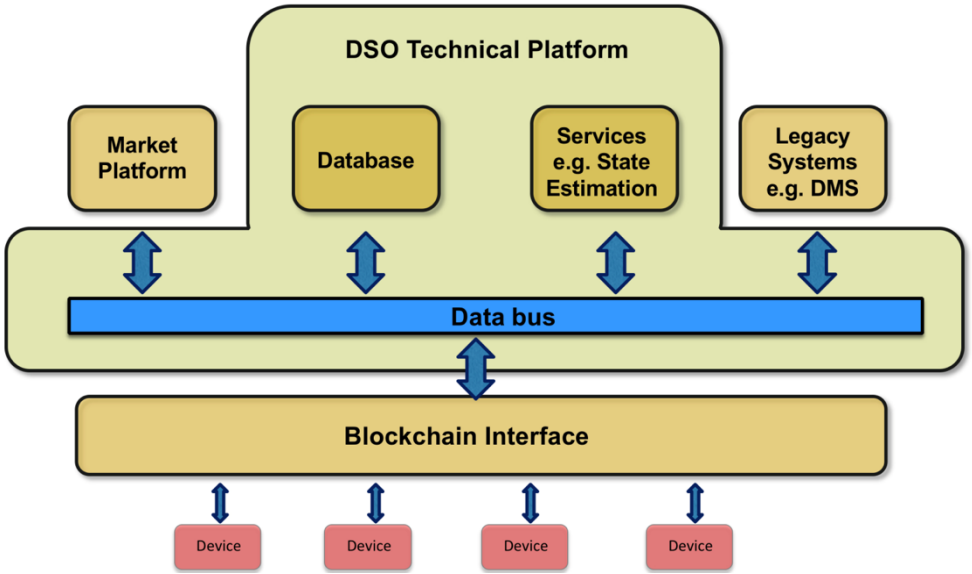
Open Source and dual use of data as key ingredient of an open platform

- Architectural proposal of H2020 PlatOne:
  - Blockchain access layer
  - Dual Use of data for market and technical services
  - Integration of legacy solutions



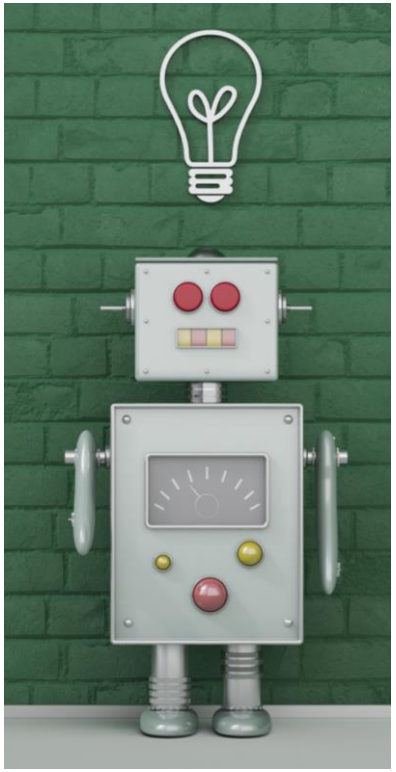
Putting all together to overcome limits of legacy solutions

- Combining the solutions envisioned in the previous architecture, here we have:
  - Secure data link thanks to blockchain
  - Integration of legacy DMS
  - Link to market for dual use of data
  - Integrated data bus for flexible integration of new services

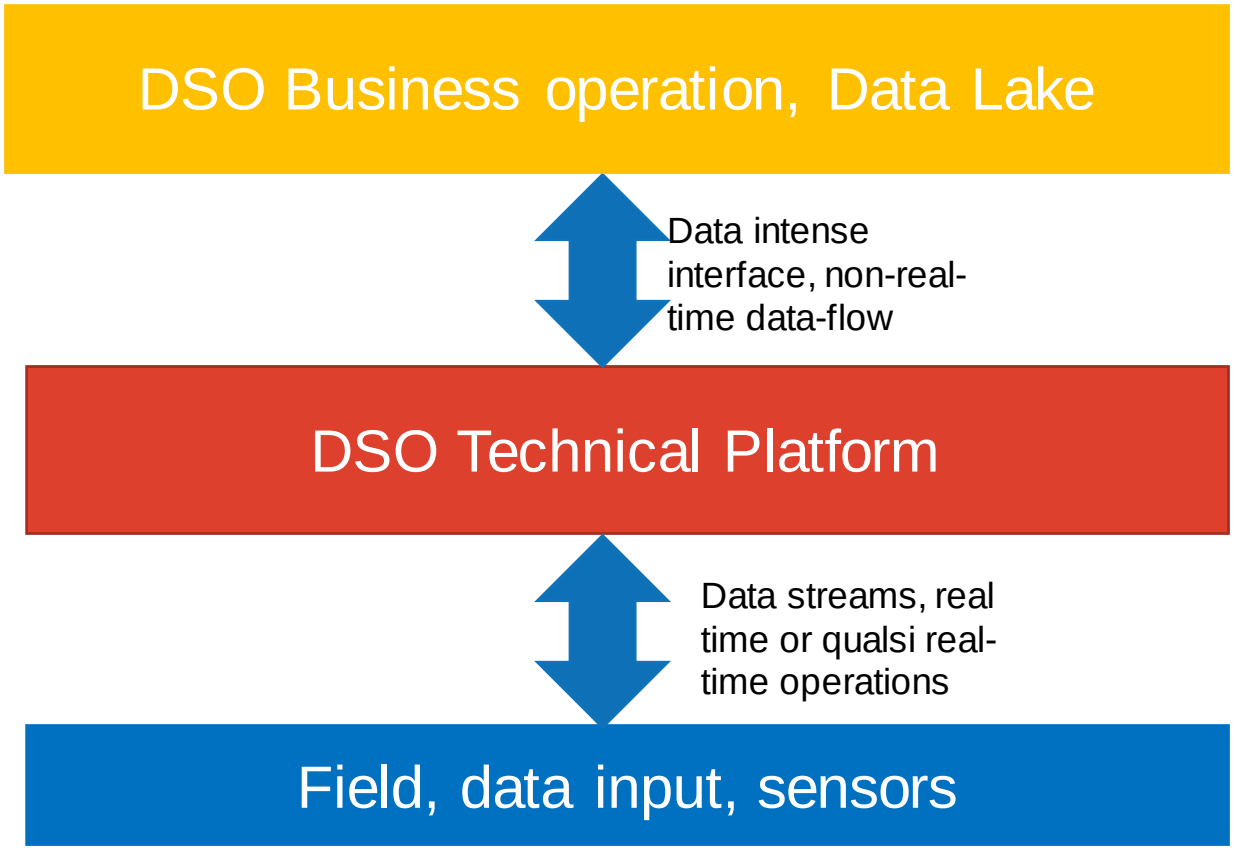


Building a requirement list for grid operation platforms

- Modularity
  - Different level of digitalization may bring to different selection of services
  - Different grid conditions may change priorities
- Scalability
  - Some services may require input from a massive and distributed amount of data sources
- Adaptability
  - Requirements may change with time
- Openness
  - It is hard to imagine that there is one solution that fits all
  - Rapid evolution requires open competition



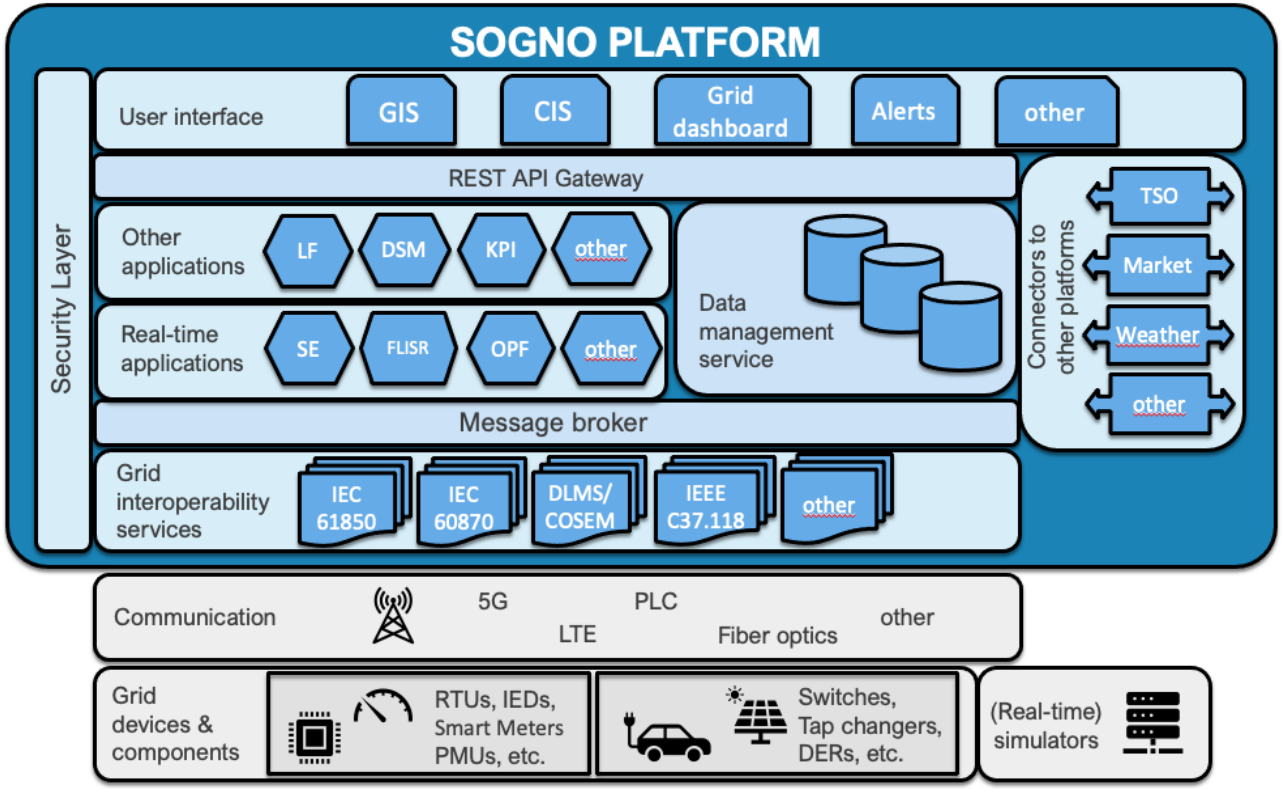
Different level of architectures



More generic and valuable platform already available as open solutions (e.g. FIWARE)

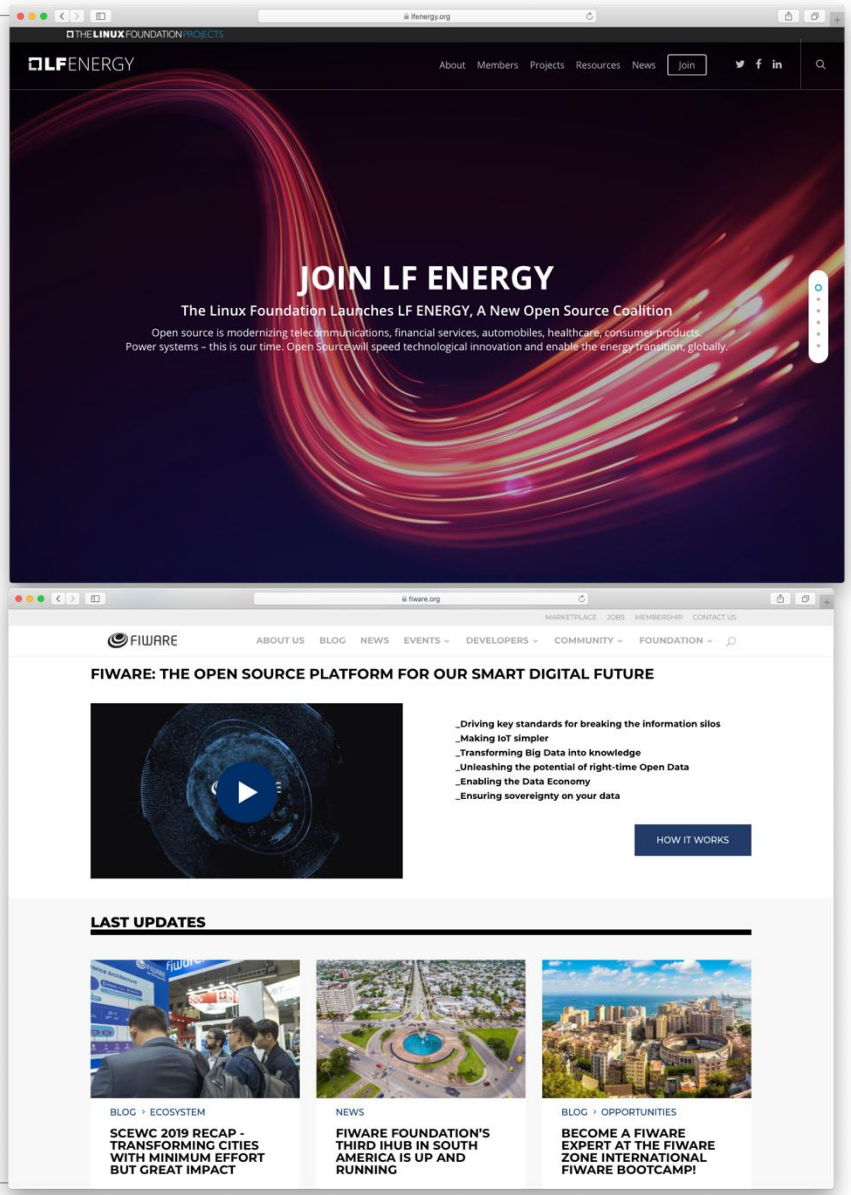
Significant set of domain-specific requirements, need for a DSO specific platform starting from standard data-stream approach and architectures

Generic architecture



Avoid closed solutions: Open Source

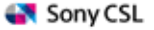
- Open Source has not been in the culture of grid operators
- Open source allows fast development and transparency
- Open source can be used to unlock new opportunities without compromising security
- Open source does not mean that there is no business model for SW (see Linux)



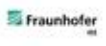
LF Energy Members

Strategic

General



Associate



LF Energy:

part of The Linux Foundation ecosystem of sustainable open source

THE LINUX FOUNDATION

For the last 16 years, The Linux Foundation has provided unparalleled support for open source communities through financial and intellectual resources, governance structure, IT infrastructure, services, events, and training.

Dedicated to building sustainable ecosystems around open source projects, The Linux Foundation is working with the global technology community to solve the world's hardest problems through open source and **creating the largest shared technology investment in history**.

The Linux Foundation is the umbrella organization for **more than 425 open source projects** accelerating open technology development and commercial adoption. Some of the game-changing initiatives hosted by The Linux Foundation include:

CLOUD NATIVE COMPUTING FOUNDATION

HYPERLEDGER
BLOCKCHAIN TECHNOLOGIES FOR BUSINESS

Zephyr Project

kubernetes

OpenSSF
OPEN SOURCE SECURITY FOUNDATION

ONAP
OPEN NETWORK AUTOMATION PLATFORM

LF NETWORKING

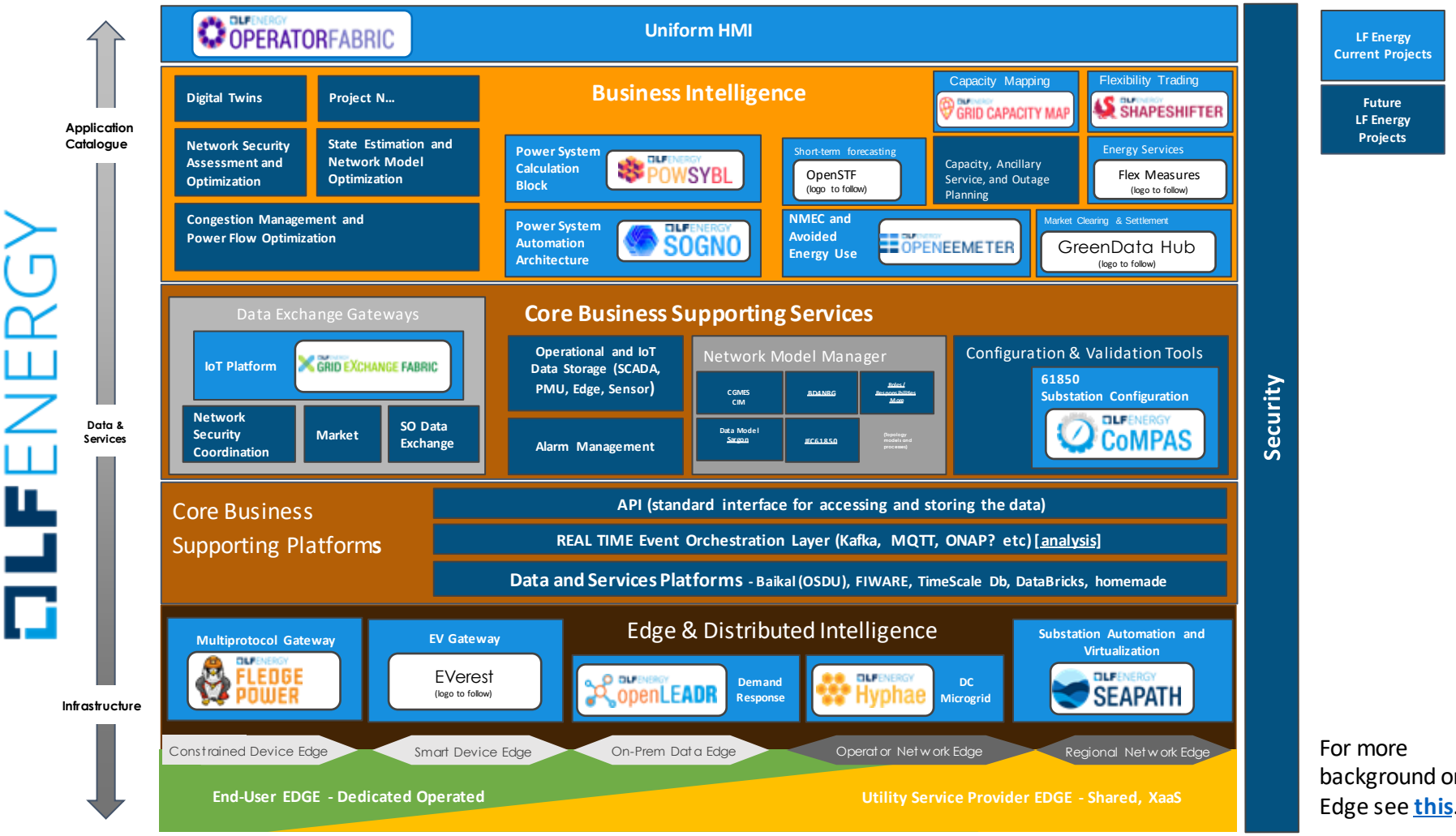
Let's Encrypt

RISC-V

node JS

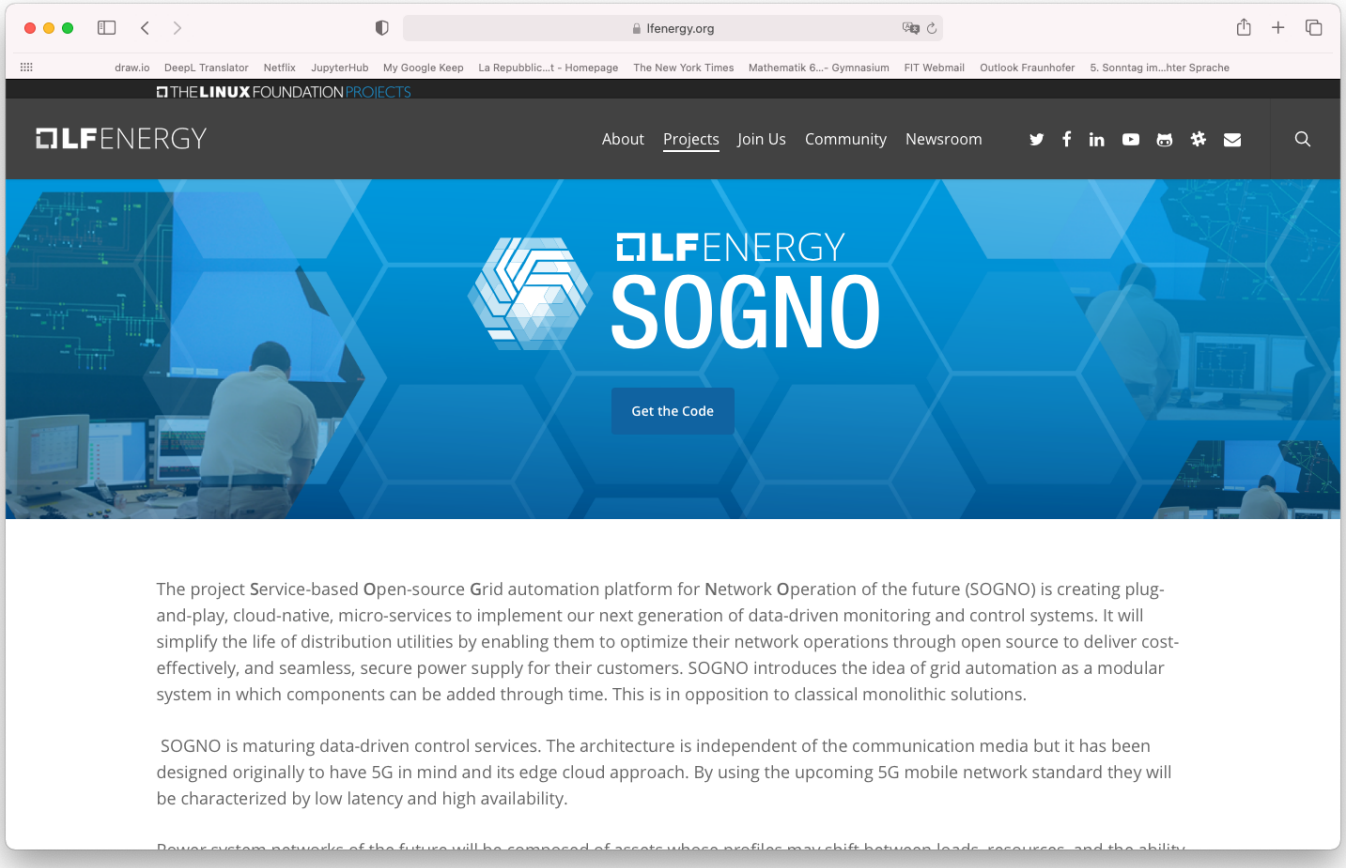
LF EDGE

FLEDGE



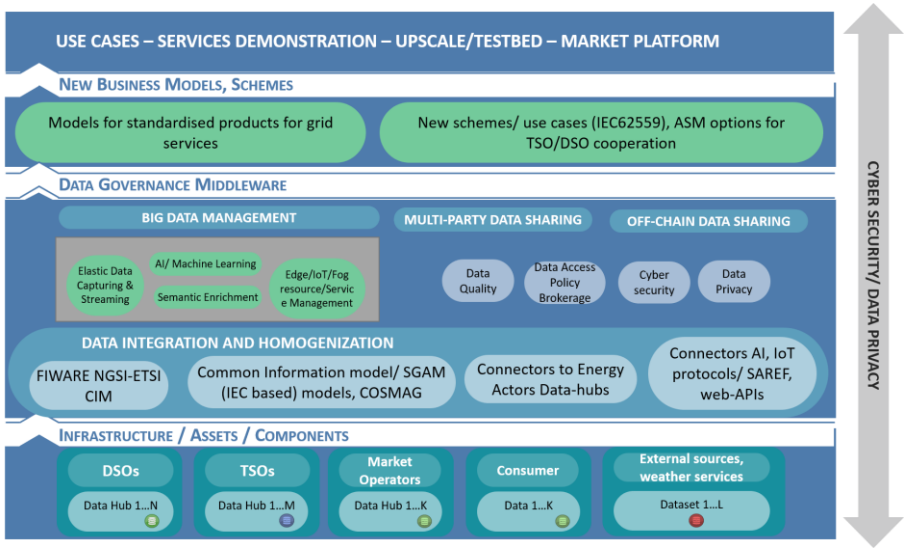
For more background on Edge see [this](#).

SOGNO as Linux Foundation Energy Project



OneNet Vision

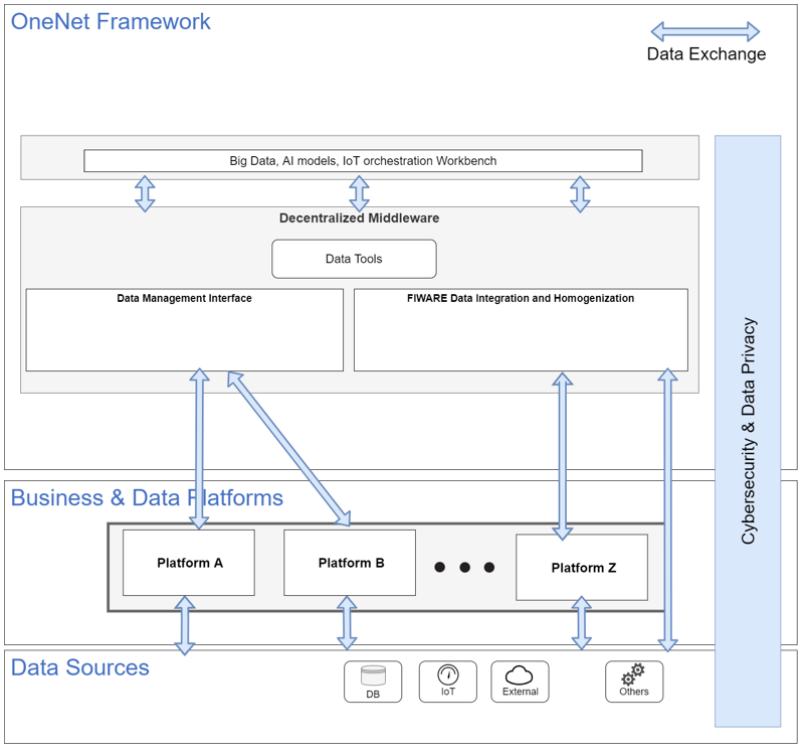
- To create a **fully replicable and scalable architecture** that enables
- the whole European electrical system to **operate as a single system** in which
- a **variety of markets** allows
- the **universal participation of stakeholders** regardless of their physical location – at every level from small consumer to large producers



OneNet Concept

OneNet Framework will focus on:

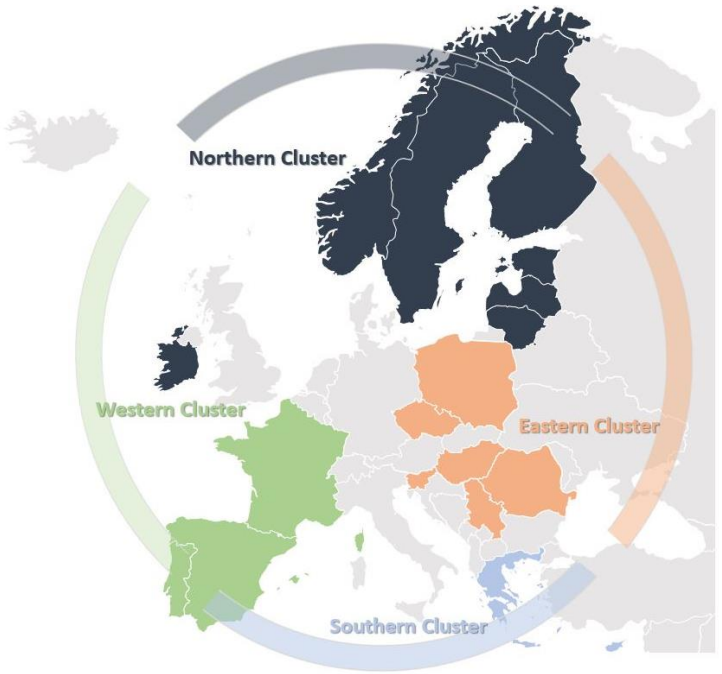
- the adoption of open standards and interfaces to allow the seamless participation of various users,
- data privacy control and data access according to regulations for each stakeholder,
- definition of standard models and protocols for data exchange,
- the provision of data management features like data harmonization, data quality assessment, semantic annotation,
- dataflow monitoring and logging,
- identification, authentication and authorization mechanisms for ensuring secure and trusted data exchange and platforms integration.



High Level OneNet Architecture

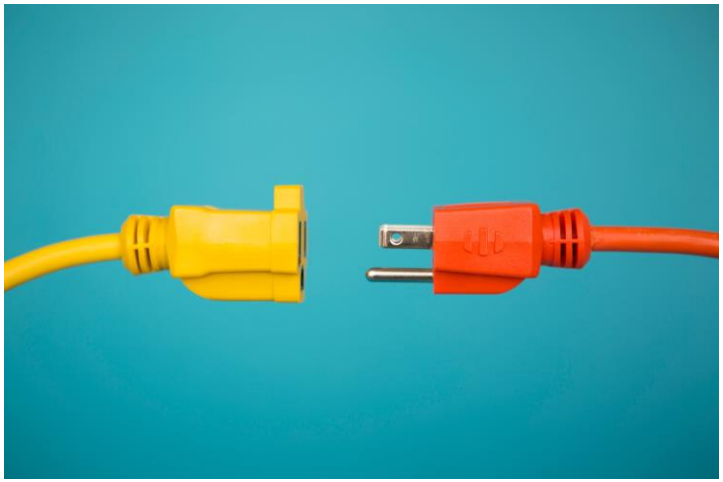
Demo clusters

- Several demos organized in 4 clusters covering the whole Europe
- Each cluster involving multiple DSO and TSO to implement completely new scenarios
- New market concepts tested in real life



Some key challenges/questions

- Are we doing the right use of the technology we have?
- What is the best way to build a data driven energy system?
- How can we ensure interoperability among data driven energy devices?
- How do we support the transition from the old to the new while preserving the continuity of service that we have today?



Conclusions

- Digitalization is completely transforming the energy sector
- New options and possibilities are open at every level
- Digitalization means also new concepts for operation that completely transform the way the grid is operated
- Open standards are key enablers for this process

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