Lecture 4

Developing Sustainable Local Energy Systems

Speaker: Prof Antonello Monti

Institute Director ACS / Chair holder Automation of Complex Power Systems

RWTH Aachen University, Germany

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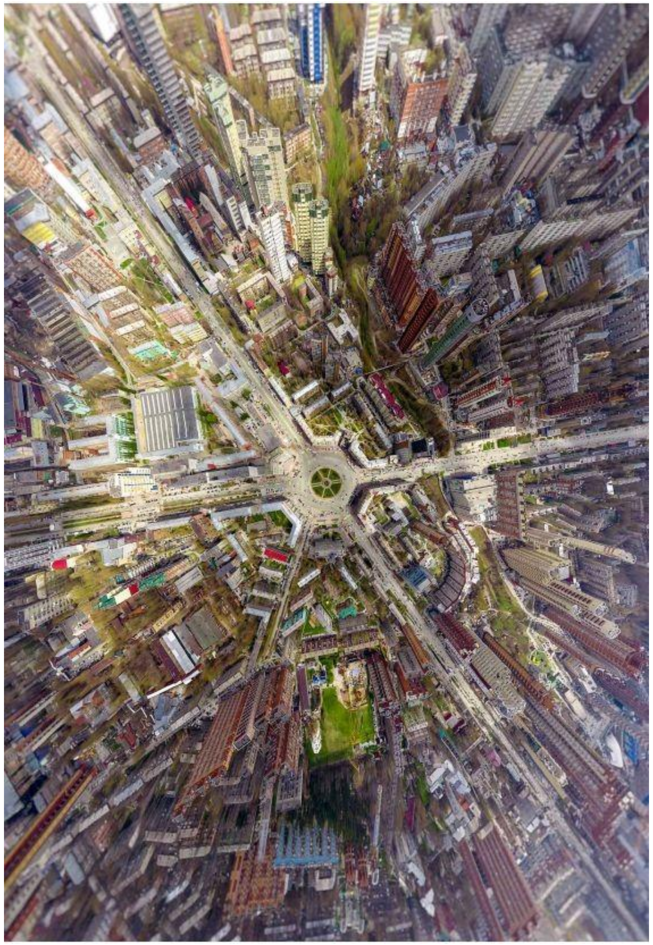
Climate Combat Lab

Developing Sustainable Local Energy Systems

Univ.-Prof. Antonello Monti, Ph.D.

The impact of urban energy systems

- Cities in Europe
  - host ~ 75% of EU population
  - cause 60-80% of global energy consumption and CO_2 emissions
- Climate change →→ cities
- Other challenges: housing, pollution, mobility, health, aging, social segregation, …
- Directions
  - More renewables
  - More resilience
  - More efficiency
  - Less emissions
  - Sustainability
  - Circularity



The Future of Cities, JRC Report
EUR 29752 EN

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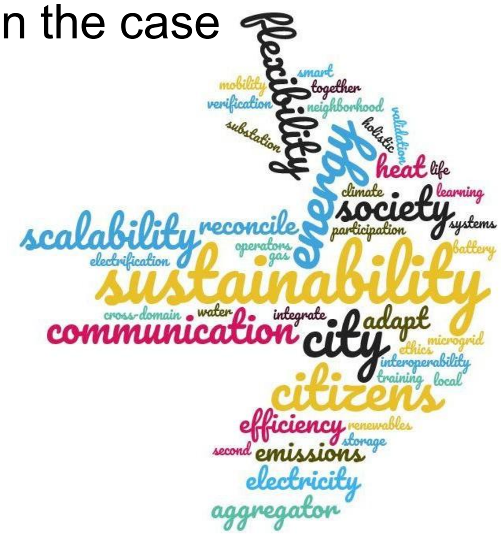
The complex world of urban energy systems

- Energy used in many forms, like
  - Electricity
  - Heat, Gas, Oil..
- … and for many uses, in
  - Residential and commercial buildings
  - Industry
  - Mobility
  - Communication

https://setis.ec.europa.eu/system/files/citizens_summary.pdf

- Infrastructures are coupled, like in the case of:
  - Electricity&gas
  - Electricity&mobility
  - Electricity&water

  And also of:
  - Waste management, recycling,..



and above all coupled with **society and people**

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The electrical levers and their potential

- Innovation for energy positive buildings and districts
- Peer-to-peer energy management and storage solutions for grid flexibility
- e-mobility integration into smart grid and city planning
- Citizen-driven innovation for co-creating smart city solutions
- Use of local renewable generation, flexibility
- Maximum self-consumption, less emissions
- Fast fault location and service restoration, bottom up black start, quality of service of electricity

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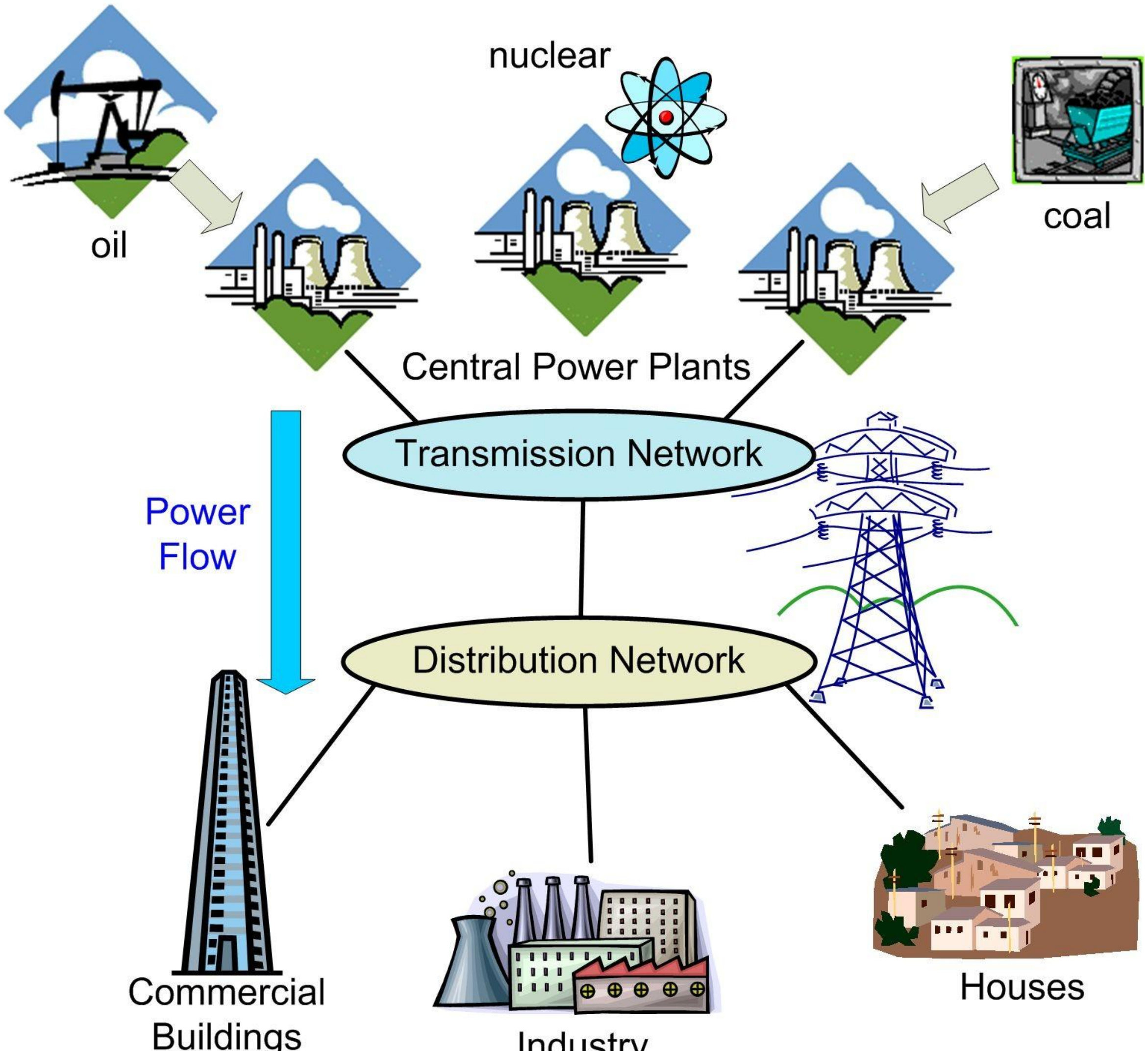
Traditional Power System



Courtesy of Alborg University

Characteristics of the classical Power System

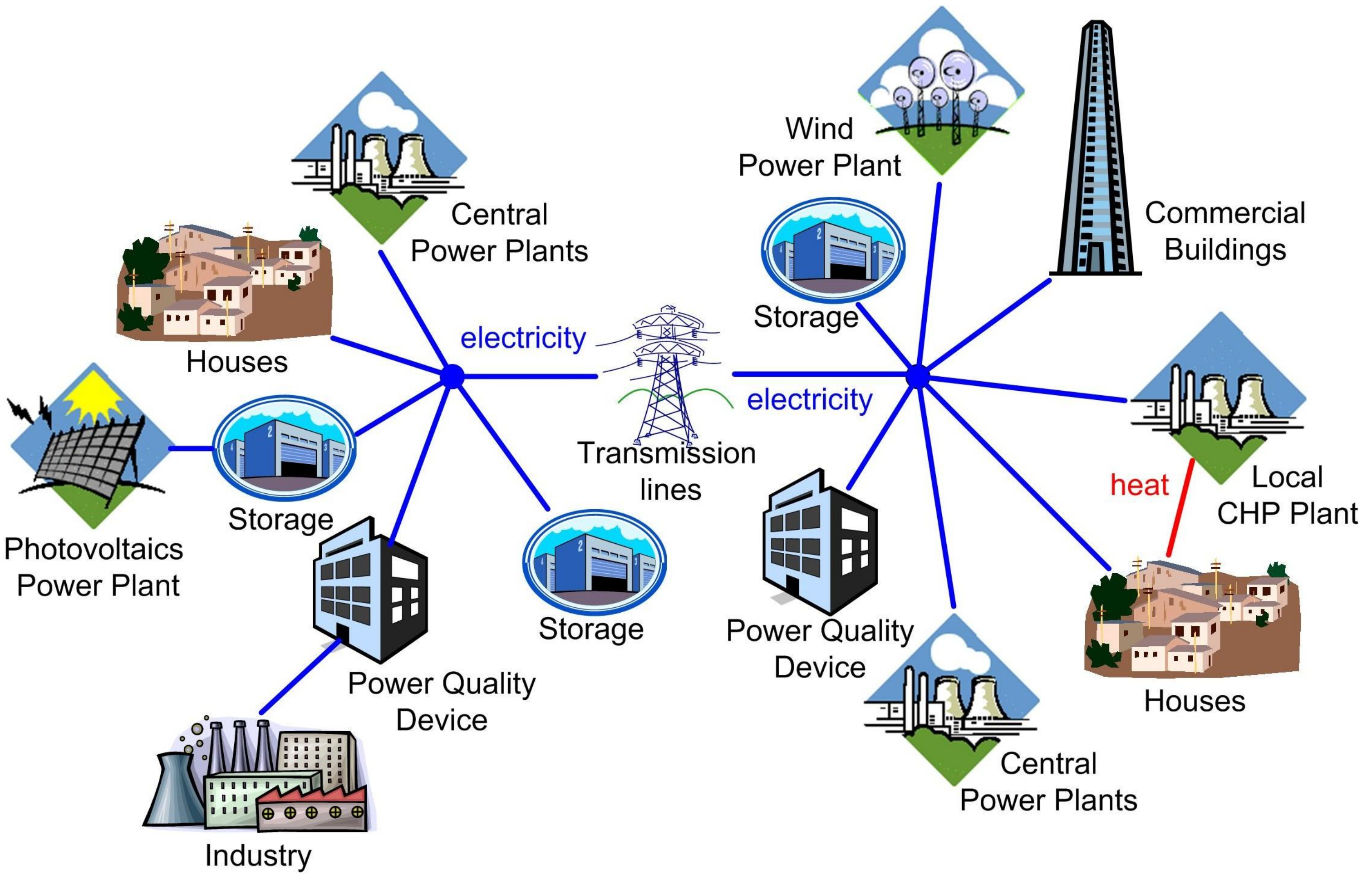
- Generation highly concentrated
- System is quasi-static
- Generation is “totally” under control
- Loads are statistically predictable
- Flow of energy from transmission to distribution is unidirectional
  - Distribution is a totally passive system

After more than 100 years .....

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

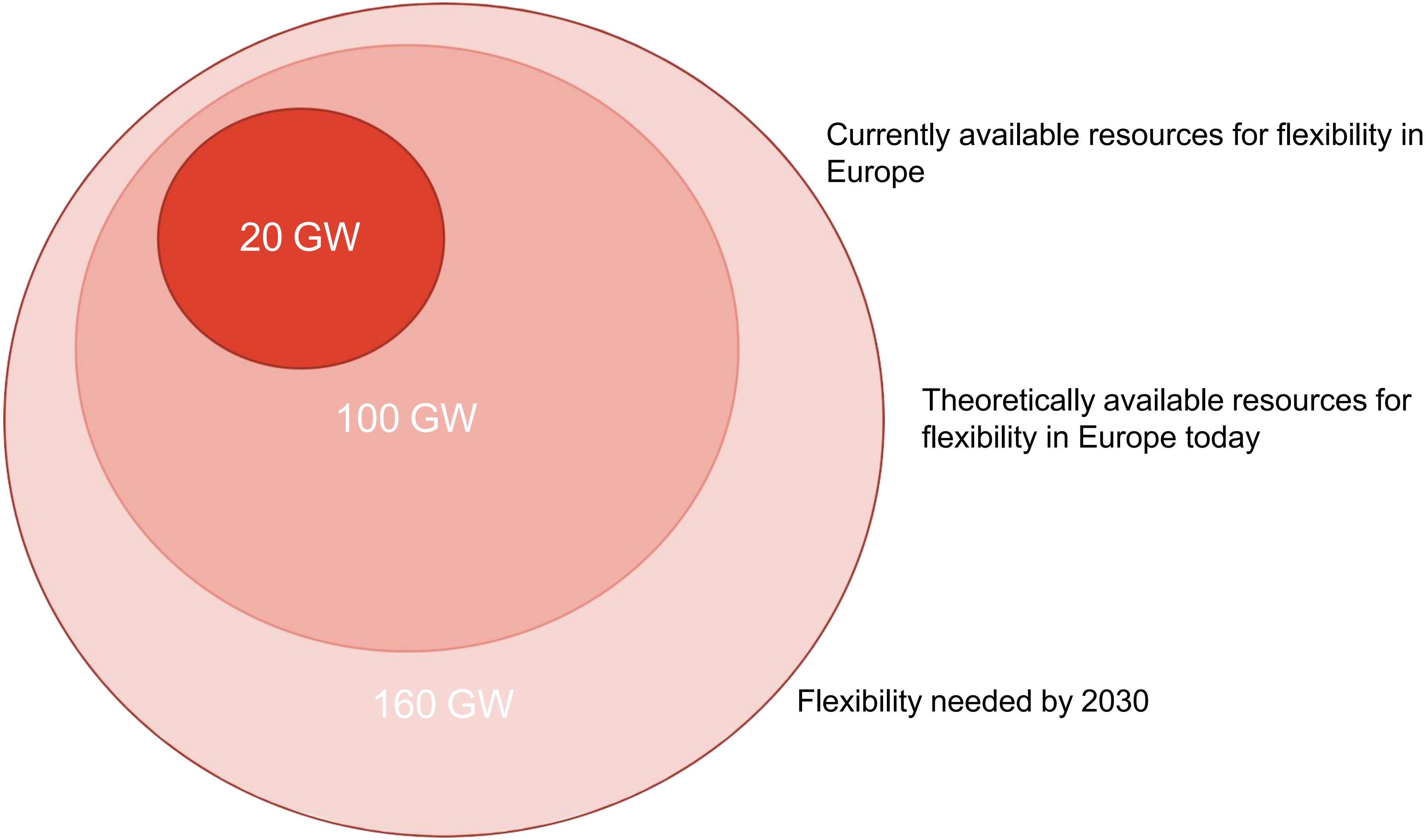
- More distributed generation
- Renewable sources are not totally predictable (uncertainty) and not under our control
- Power injection happens also at distribution level
- The system is characterized by higher dynamics
  - E.g. wind puff

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



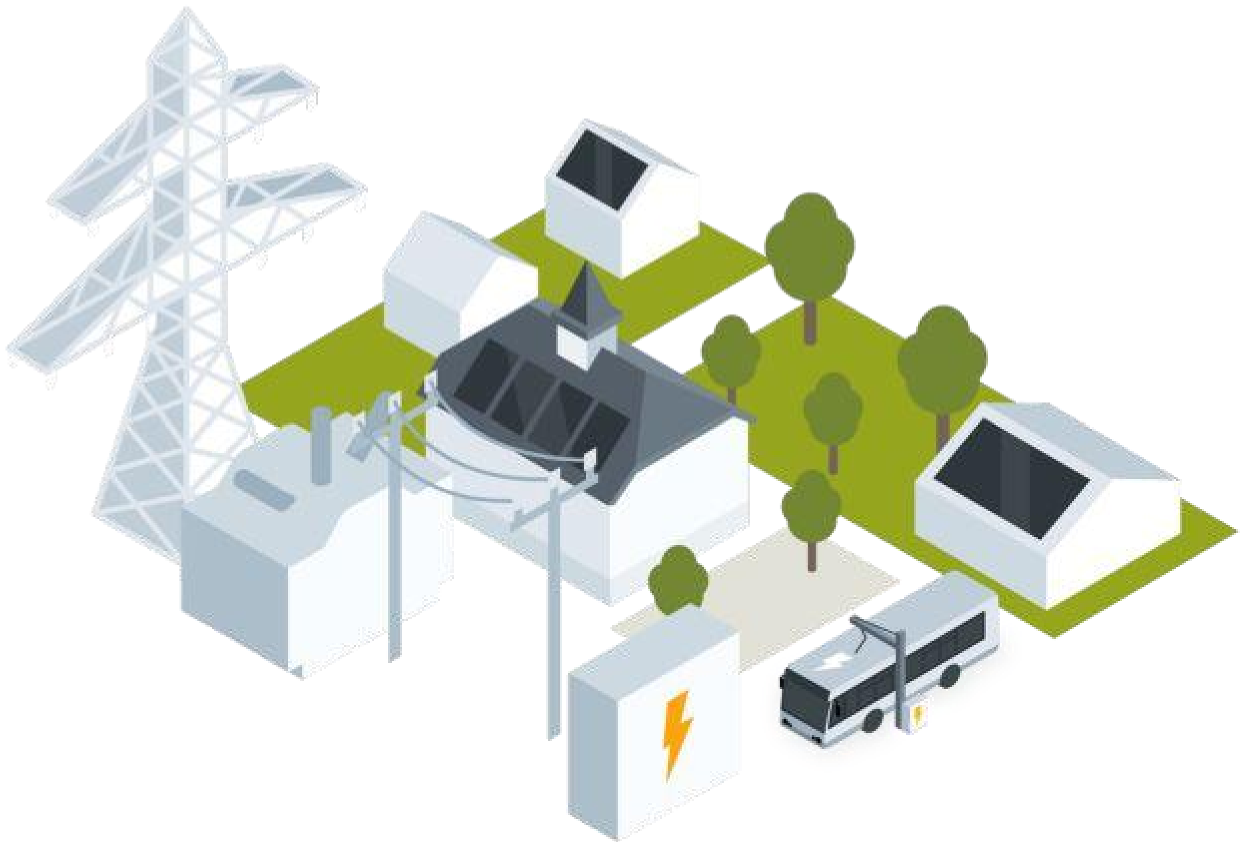
Energy transition – the grid edge and the grid

- 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

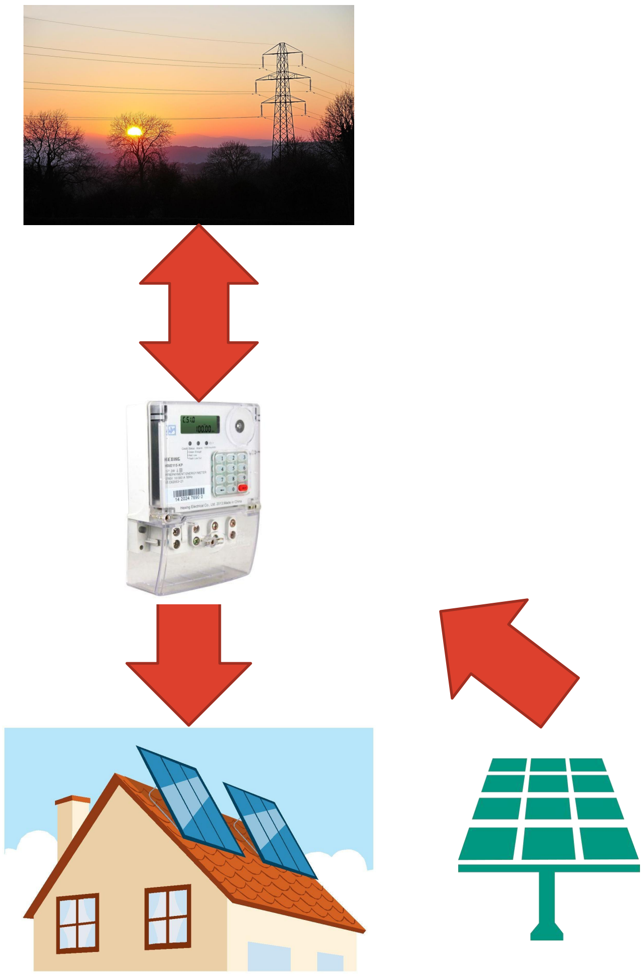
A brief history of customers: the beginning

- 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

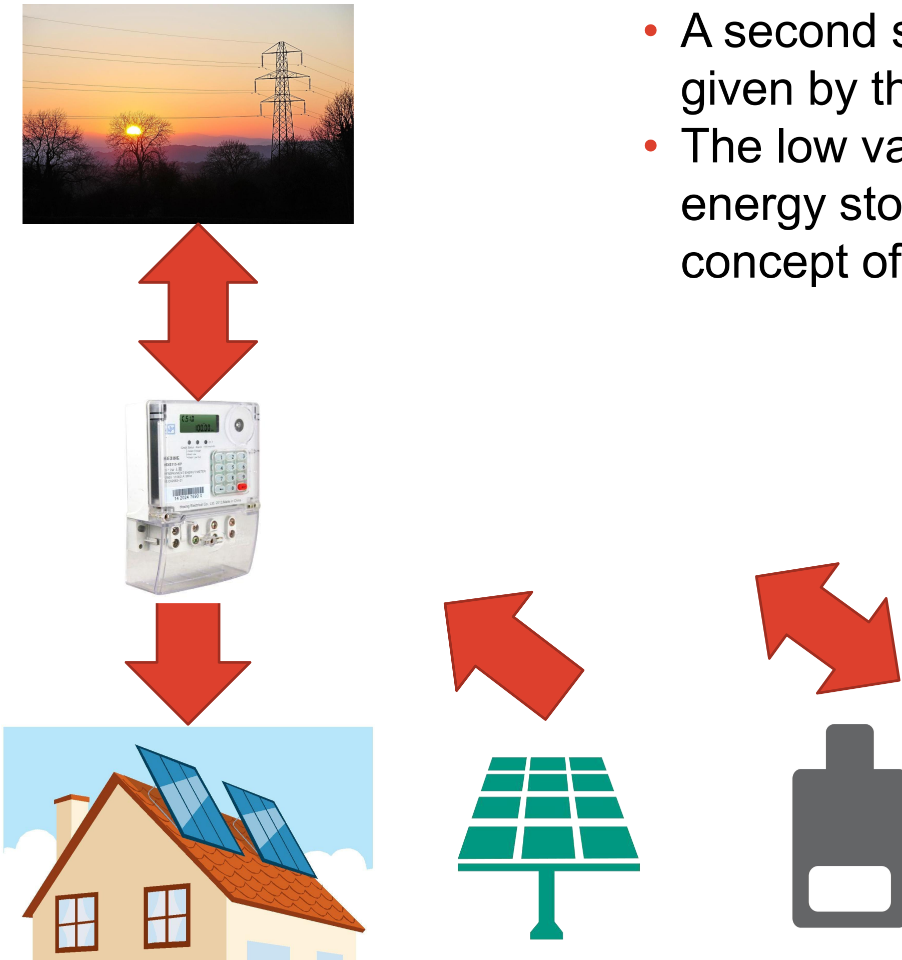
- Smart Meters introduce the concept of communication with the customer
- New options are open in terms of tariffs
- The deployment of the infrastructure is anyway very slow because of the lack of a clear business case
- Few countries are an exception. First adopters are Italy and Sweden for different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

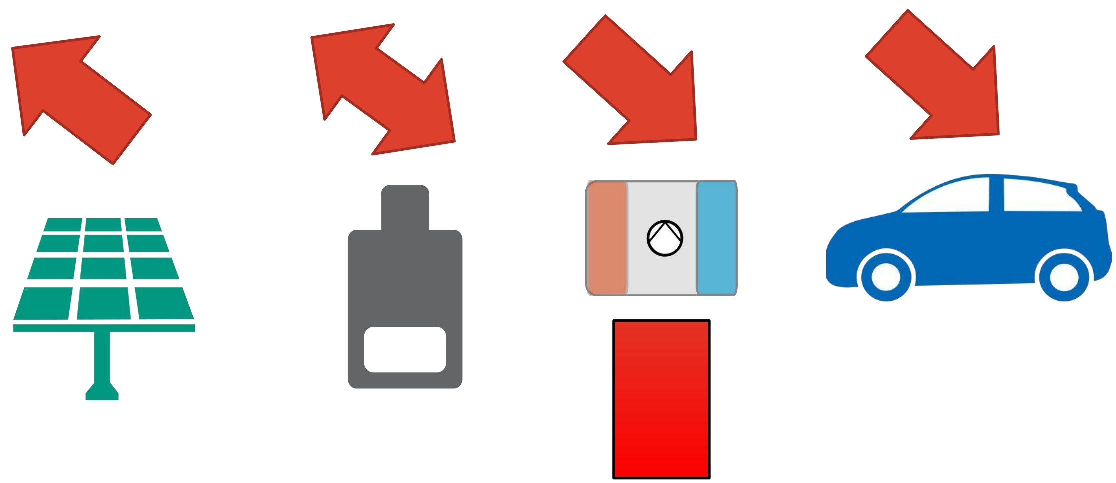
A brief history of customers: storage



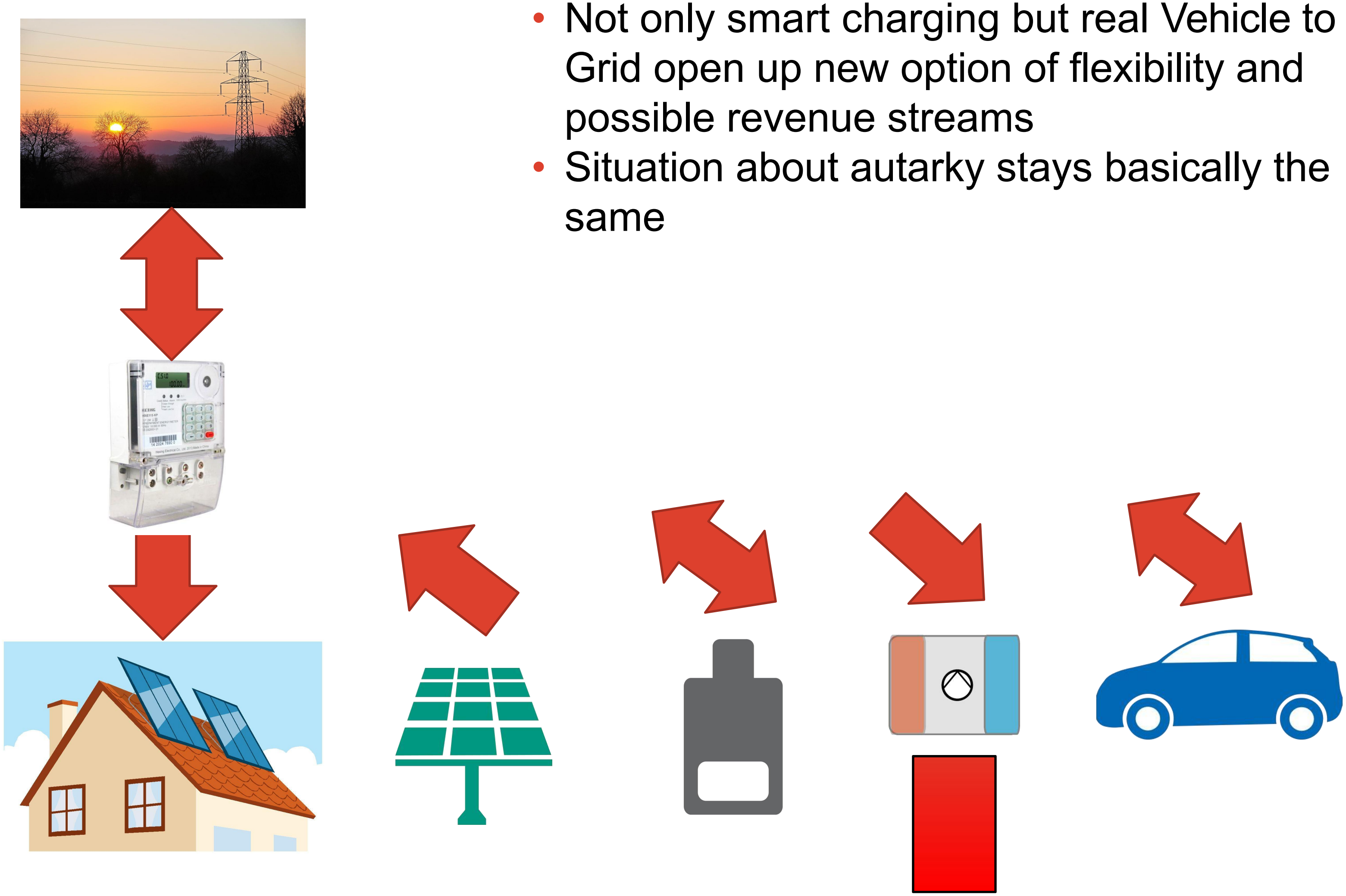
- A second step in the deployment of PV is given by the reduction on the feed-in tariff
- The low value of feed-in tariff makes energy storage convenient pushing the concept of self consumption

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

New approaches for customer engagement

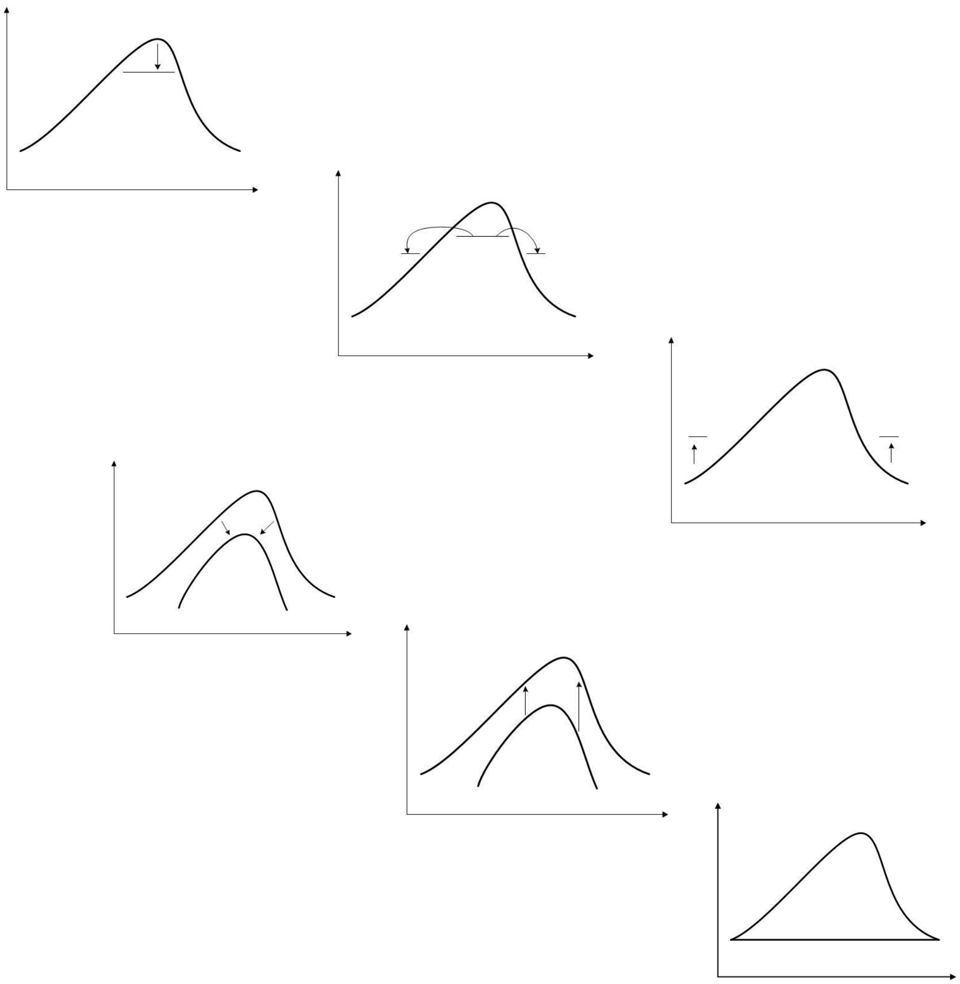
- Load Management: Demand/Response – Demand Side Management
- Load Management: Aggregation
- Load Management: Virtual Power Plant
- Load Management: Local Energy Systems
- Moving towards a service oriented approach: no more kWh

Load Management Methods: DSM

- Definition of Demand Side Management (DSM)*
  - *"DSM is the planning, implementation, and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e., changes in the time pattern and magnitude of a utility's load"*
- Goals
  - Load shifting: load profile should match generation
  - Minimization of the energy consumption, especially peak consumption
- Characteristics
  - Concept was first presented in the 60ies
  - Only actions which influence the user behavior and/or consumption
  - Actions triggered by the energy provider to avoid grid extension and expensive peaks
  - Top-down approach

Load Management Methods: DSM*

- Load management
  - Peak clipping
  - Load shifting
  - Valley filling
  - Strategic conservation
  - Strategic load growth
  - Flexible load shape



* *Source*: Gellings, C.W.; , "The concept of demand-side management for electric utilities," *Proceedings of the IEEE* , vol.73, no.10, pp. 1468- 1470, Oct. 1985

Load Management Methods: DR

- Definition of Demand Response (DR)*
  - Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time
  - Incentive payments designed to induce lower electricity use at times of high wholesale market prices or when the system is jeopardized
  - Includes all intentional modifications to consumption patterns of electricity of end-use customers, intended to alter the timing or level of instantaneous demand or the total electricity consumption
  - Bottom-up approach

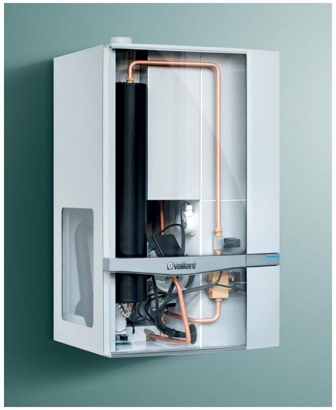
* *Source*: IEEE

Load Management Methods: DR

- Goal: to reduce electricity consumption in times of high energy cost or network constraints by allowing customers to respond to price or quantity signals
  - Manual: they see prices, for example on a display, and decide to shift their consumption
  - Automated: their consumption is shifted automatically through technical signals and based on an agreement established with the supplier. For instance, customers could agree to shift part of their consumption to times when prices are at a certain level

Load Management Methods: Aggregation

- Distributed Energy Resources (DER) are small-scale power generation and storage technologies, (typically in the range of a few kWe to tens of kWe) located close to the customer side
  - Micro-combined heat and power system (µCHP)
  - Electric energy storage
  - Photovoltaics, wind turbines
  - Active demand: HVAC, HEMS, freezers, dish washers, etc



Source: Vaillant

- Concerns
  - Non-dispatchable (PV, wind) and partly dispatchable DER (µCHP) require additional regulating power to assure the system stability
  - Bidirectional power flow
    - Protection schemes are challenged
    - Not connected to SCADA systems
    - Difficult to be monitored and controlled
  - Transient voltage variations and harmonic distortions
    - Power quality concerns

Source: 3M

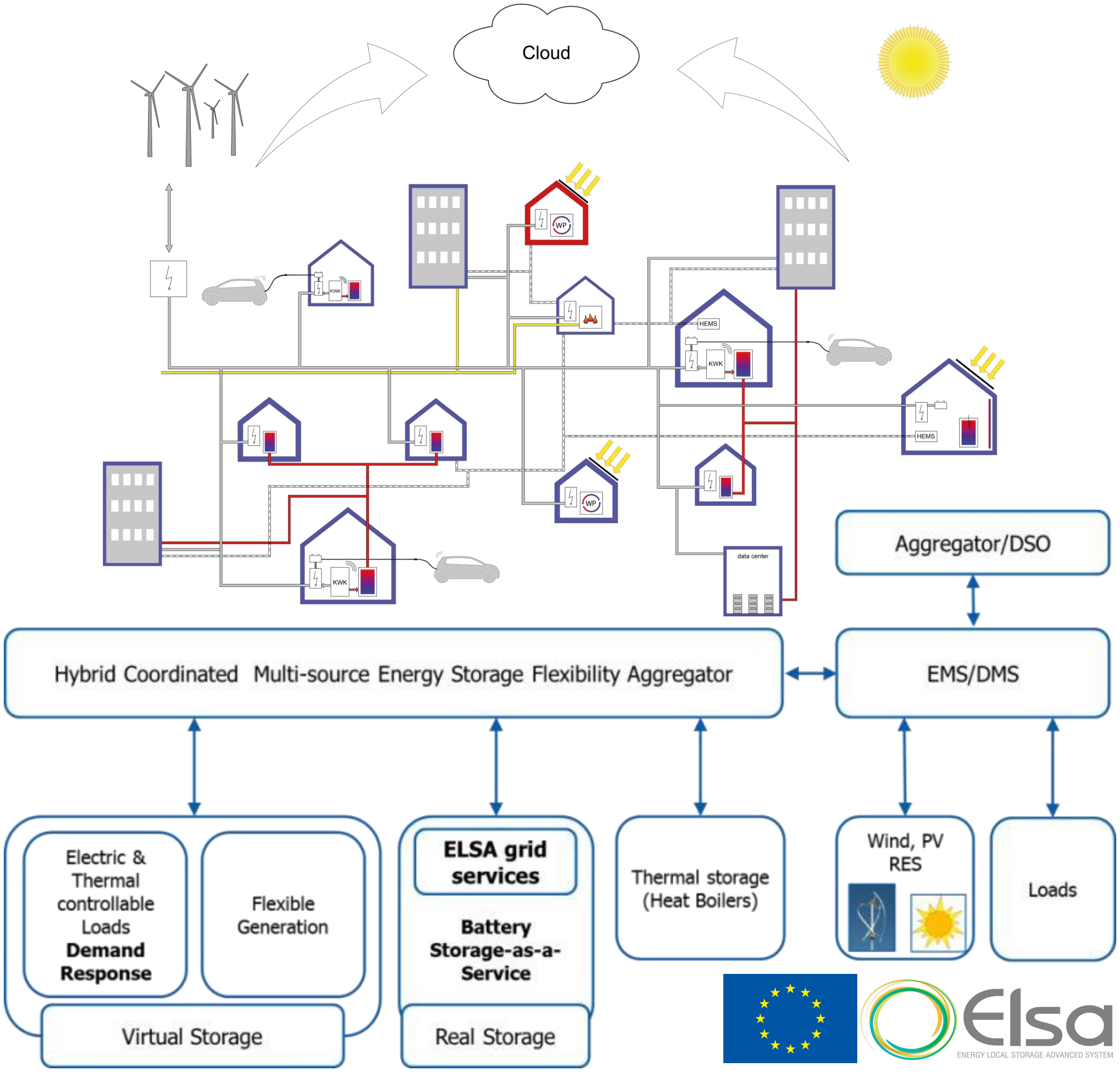
Load Management Methods: Aggregation

- Aggregation: "*The process of linking small groups of industrial, commercial, or residential customers into a larger power unit to make them visible from the electric system point of view*" *
  - DER units have to provide the flexibility and controlability to support the system operation
  - DER units are too small and too numerous to be addressed individually
  - Aggregation can involve distributed resources and/or distributed generation
    - Load or generation profiles of individual consumers and/or small generators appear as a single unit to the electric system
  - DER aggregation enables aggregators to operate DER and to provide services to the power system, e.g. system balancing
  - DER aggregation helps implementing smart grids concepts by reaping some of its benefits to integrate DER units more efficiently

* *Source*: Hashmi, M.; Hanninen, S.; Maki, K., "Survey of smart grid concepts, architectures, and technological demonstrations worldwide"

District energy management system
Example

- Potential: self-consumption, peak-shaving, load-shifting, support to grid operators, integration of wind generation…
- Among the tech objectives
  - Use second life batteries
  - Multi-physics, multi-energy carrier (thermal-electrical)
  - ICT energy management for storage-building-grid (cloud implementation, open source platform)
  - Local services for optimization and demand response



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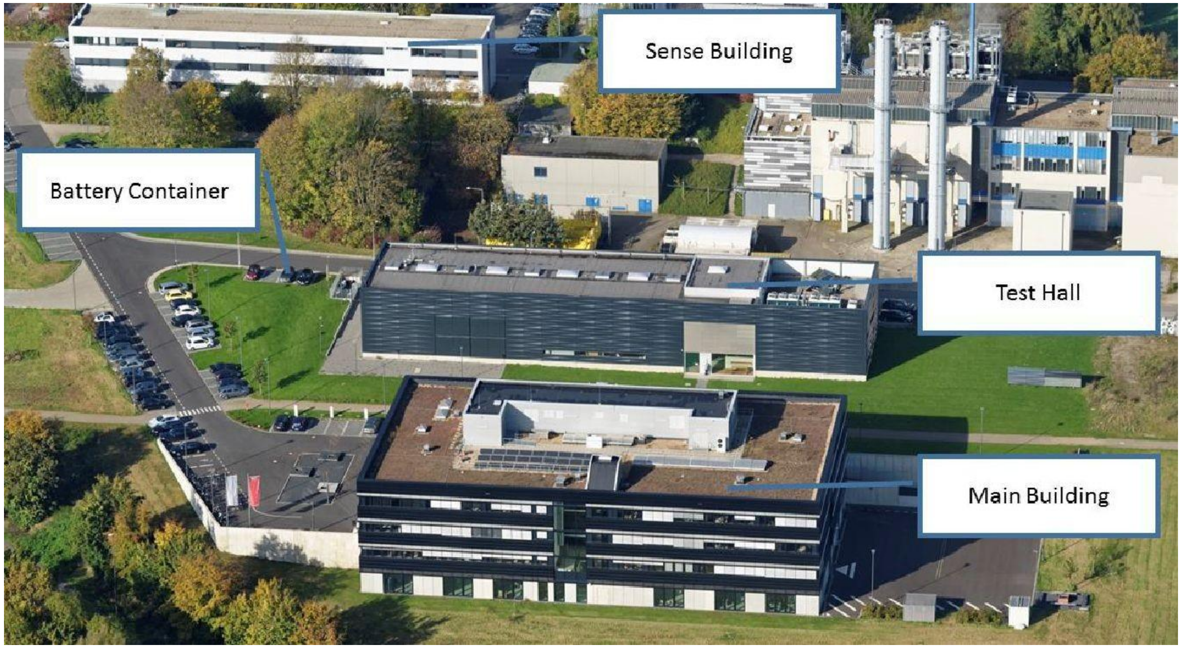
District energy management system
Demo site in Aachen

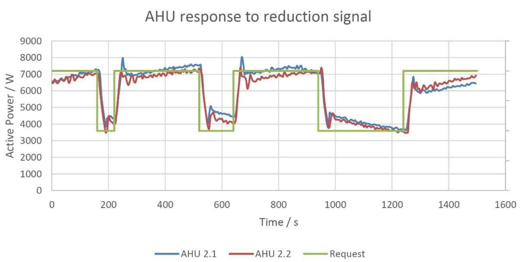
- Daily power range 150kW-220kW, yearly average 180kW
- Among the advancements
  - Local ICT
    - Interfaces for buildings, aggregators, grid operators
  - Central cloud SCADA
    - Interconnection of sites
  - Two-level optimal scheduling of cluster of heating systems

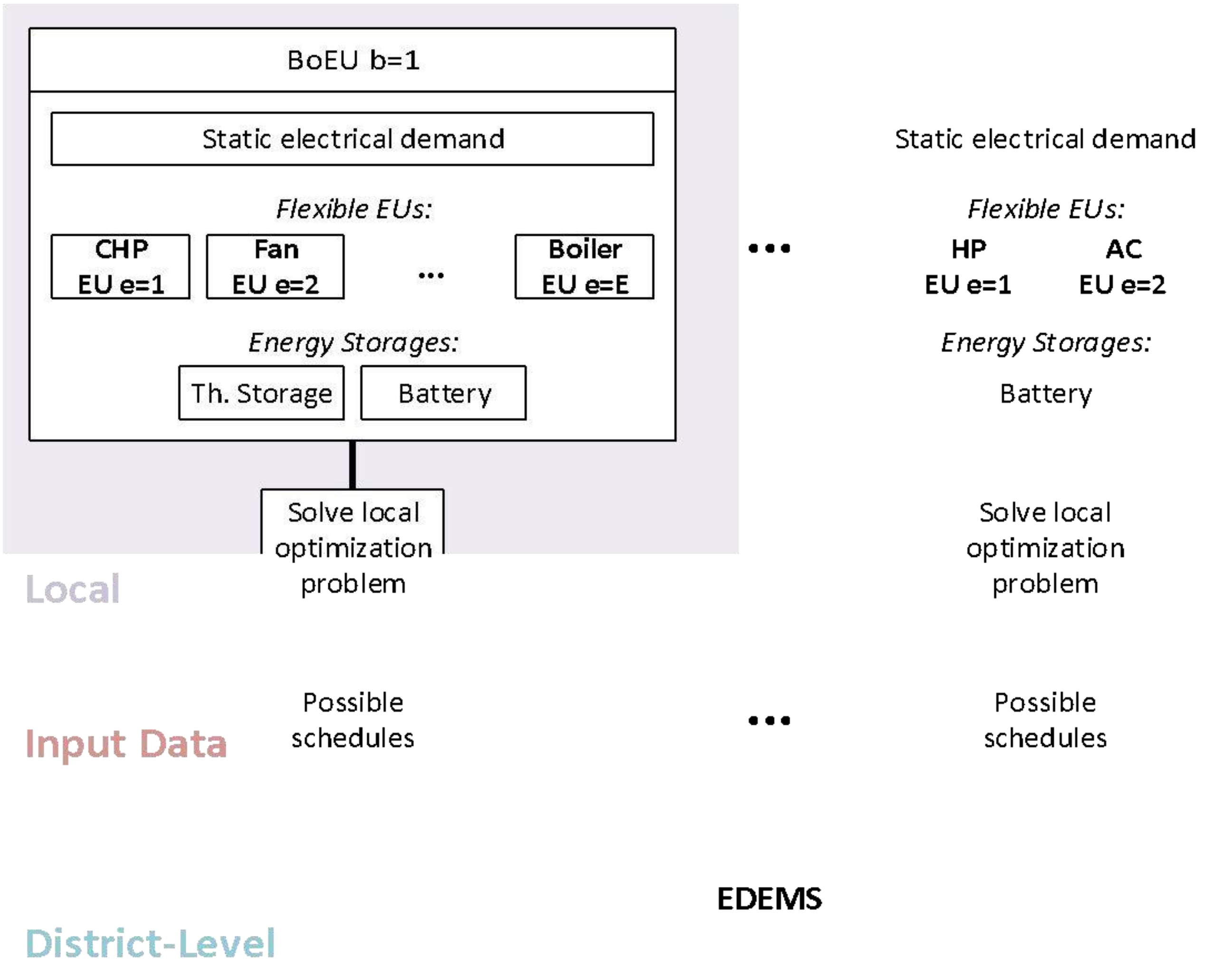


Elsa
ENERGY LOCAL STORAGE ADVANCED SYSTEM

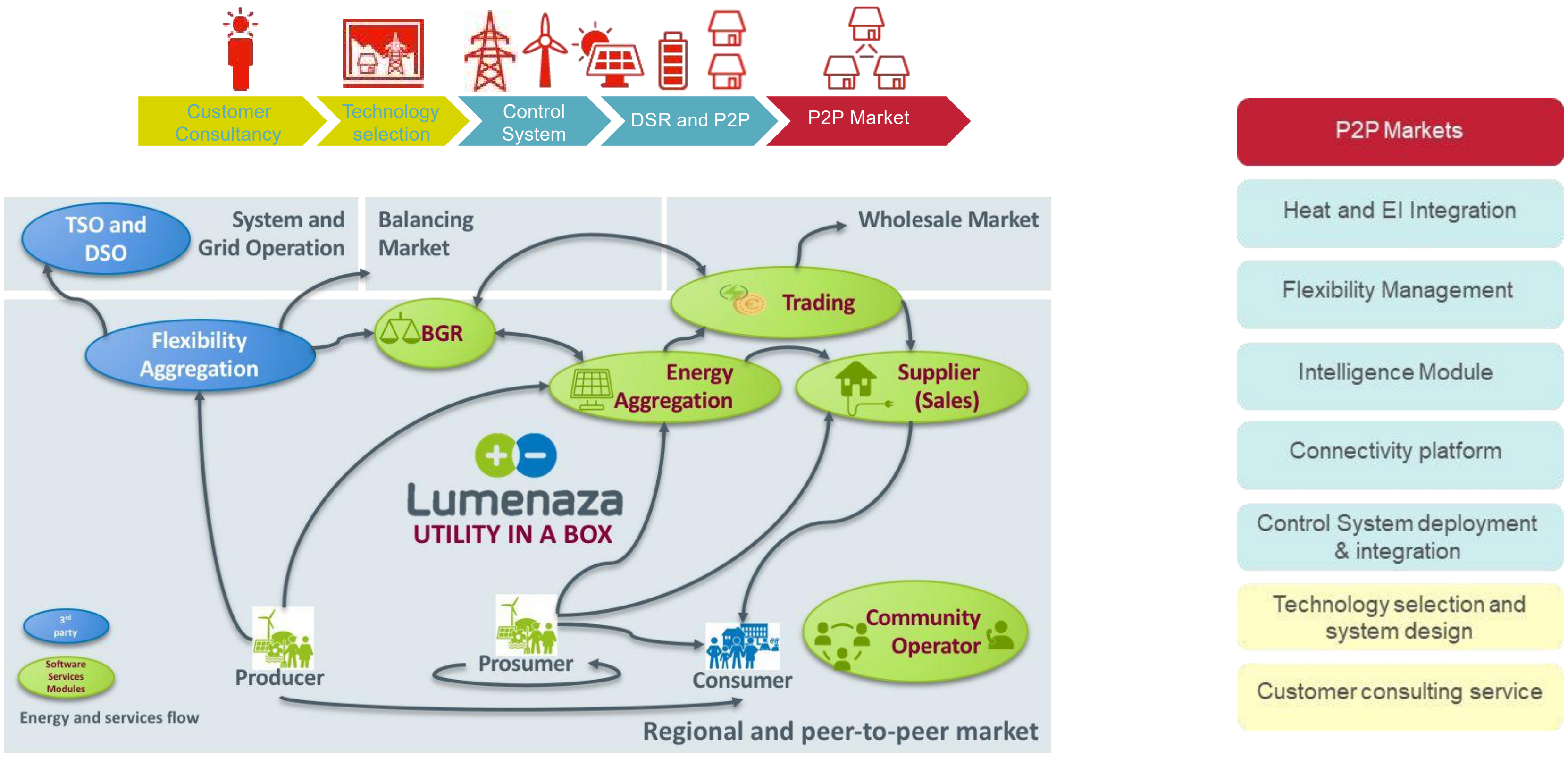
District energy management system
Demo site in Aachen – a closer look

- Each building has its own energy system, goals, local optimum, acceptable schedules
- Shared battery storage, own other storage





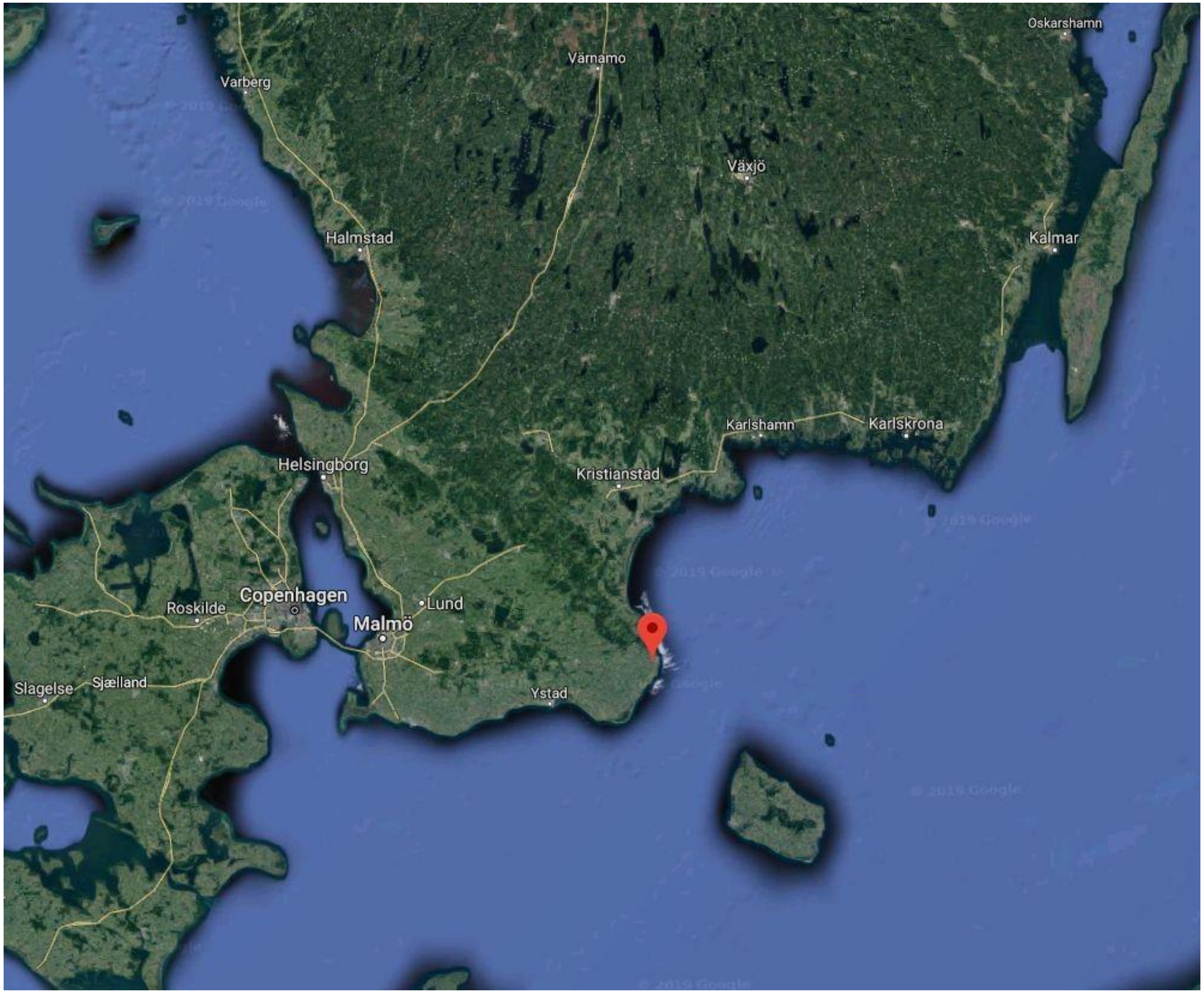
Local Energy Systems
Bird's eye view



- Increase consumer engagement
- Strengthen community links
- Maximise self-consumption
- Prevent unnecessary grid expansion
- Enable p2p market

Source: EON.SE

Local Energy System Pilot in Simris, Sweden



Local Energy System
Simris, Sweden

Installed

- Advanced Control Systems
- Back-up Generator
- Battery
- Wind and PV

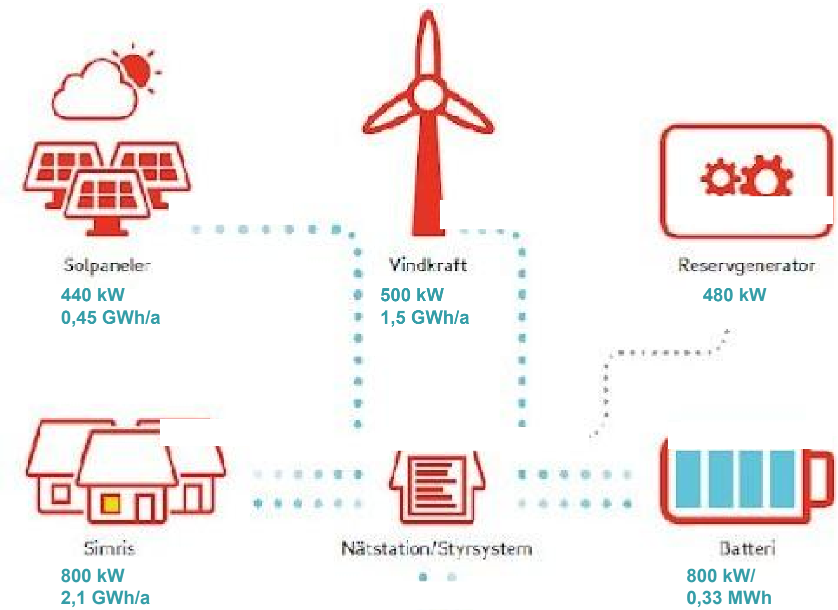
Customer Engagement

- Steerable assets e.g. heat-pump, PV+battery, heat water boiler
- Installed control units of customer assets (by E.ON)
- Compensation for used kWh

Steerable Assets 37

- Existing HP 16
- Existing HTWB 10
- New PV+Bat 9
- New HP 2

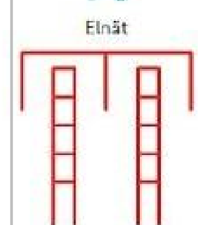
LES Simris - *eon.se/simris*



Facts of Simris

•App. 145 house holds– thereof about 40% summer houses
•High average age
•Environmentally engaged

Customers were able to engage until **May 2018**



Facts of Balancing

Full island operation during periods (ca 10 weeks spread over the year).

The battery can source Simris for 30 min with maximum load

Source: EON.SE

Local Energy Systems as Microgrids

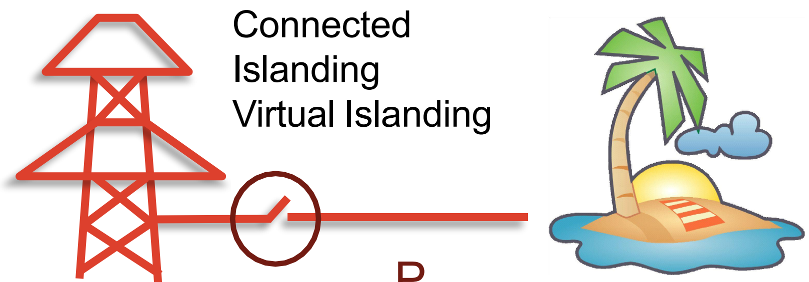
- Local group of energy generators, storage and loads on distribution level
- Allocation and collective control of this limited group of resources
- Connected to the main grid at the point of common coupling (PCC)

Advantages

- Local usage of energy resources
- Feasible size for optimal control
- Isolation possible in failure scenario

Problems

- Active control with additional intelligence
- Many uncertain parameters
- Interaction with higher control levels



Microgrid (MG) as an independent island

Evalute the potential islanding time (PIT) under different operational strategies

Grid Connected Energy Management System Strategies

Case (a)
Economic value

Minimize operational cost

Maximize revenue from services

Case (b)
Local use of Energy

Minimize Power Exchange with the main grid

Minimize energy import

Case (c)
Max potential Islanding time

Primary:
Maximize PIT

Secondary:
Minimize cost

Energieplattform Twistringen

Energy Communities in Distribution Grids

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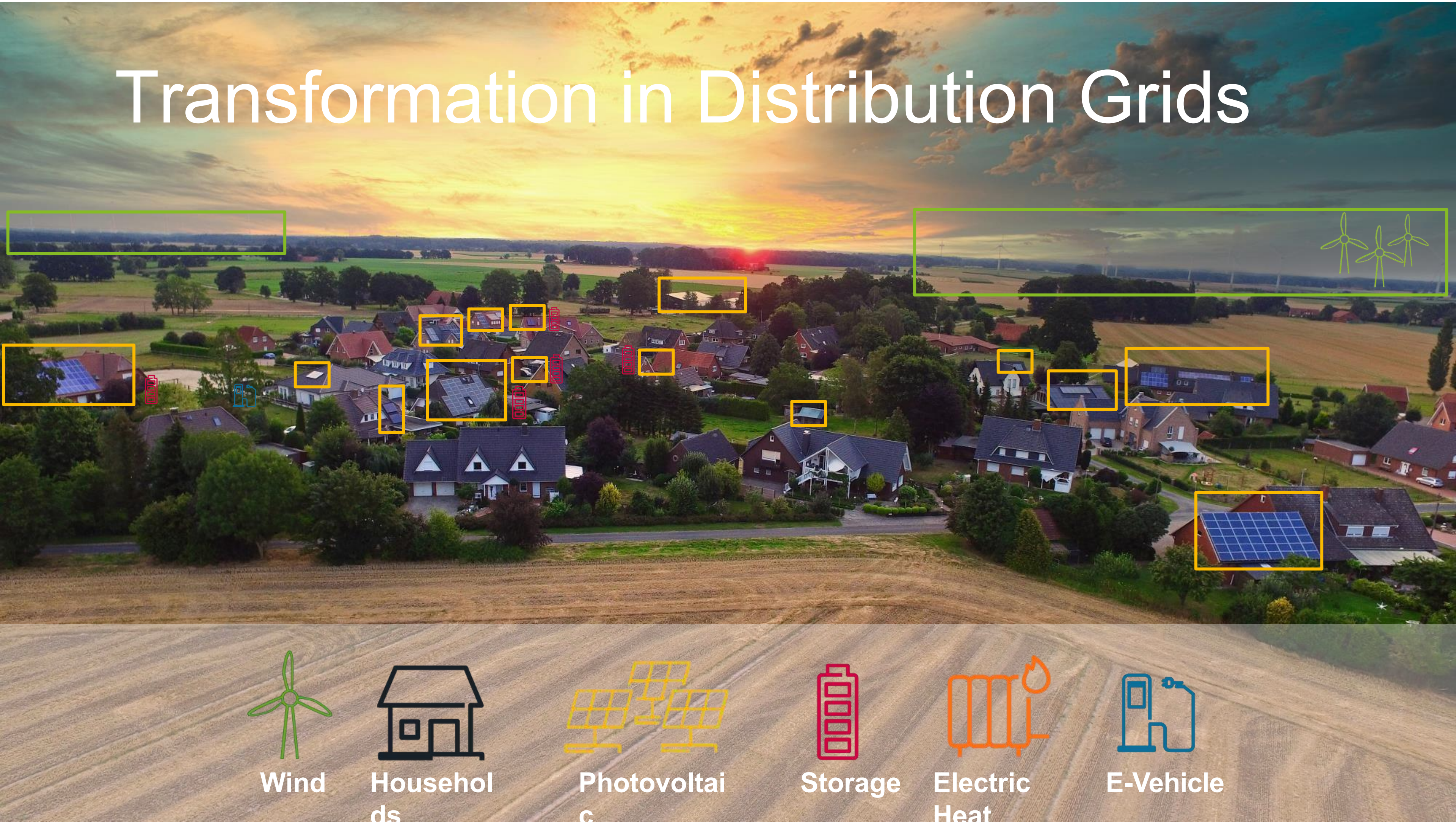
mtu A Rolls-Royce solution

B.A.U.M.

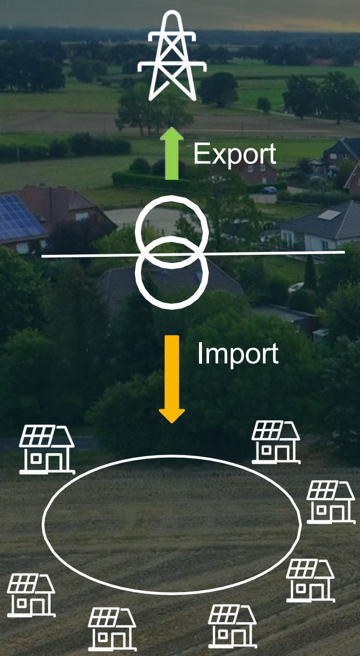
ENGINEERING

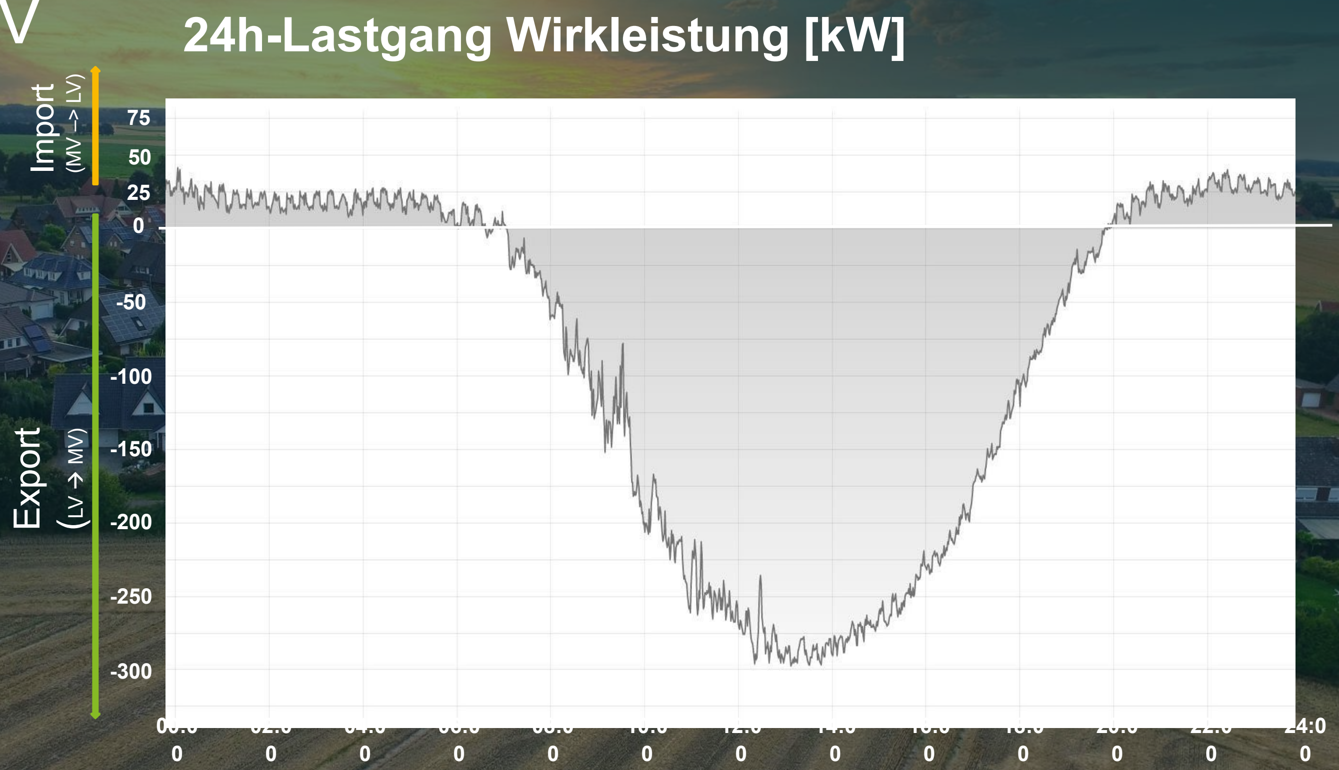
RSE Ricerca Sistema Energetico

Transformation in Distribution Grids



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





Energy Management System in Distribution Grid | Platone – Energieplattform Twistringen

Changing load demand characteristics due to changing grid customer needs

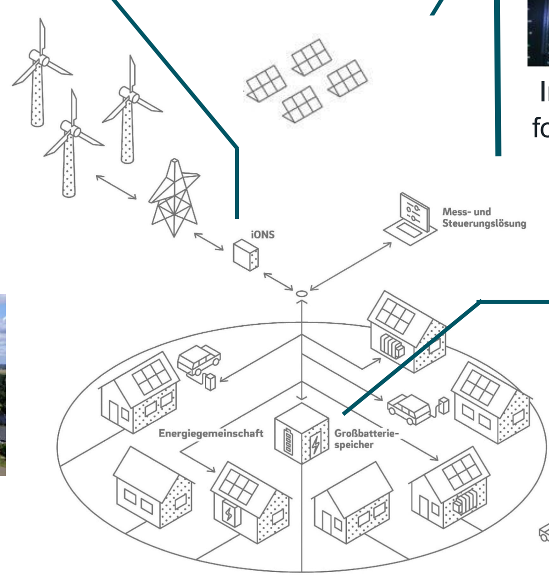
Energieplattform Twistringen – Energy Management Systems in Distribution Grids

Digital Substation

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

Community Abbenhausen

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



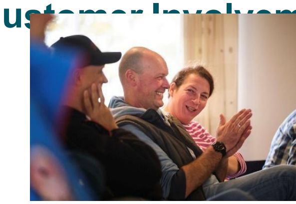
Energy Management

Implementation of monitoring, forecasting and local balancing features

Battery Storage

Provision flexible power and storage capacity

Customer Engagement & Customer Involvement



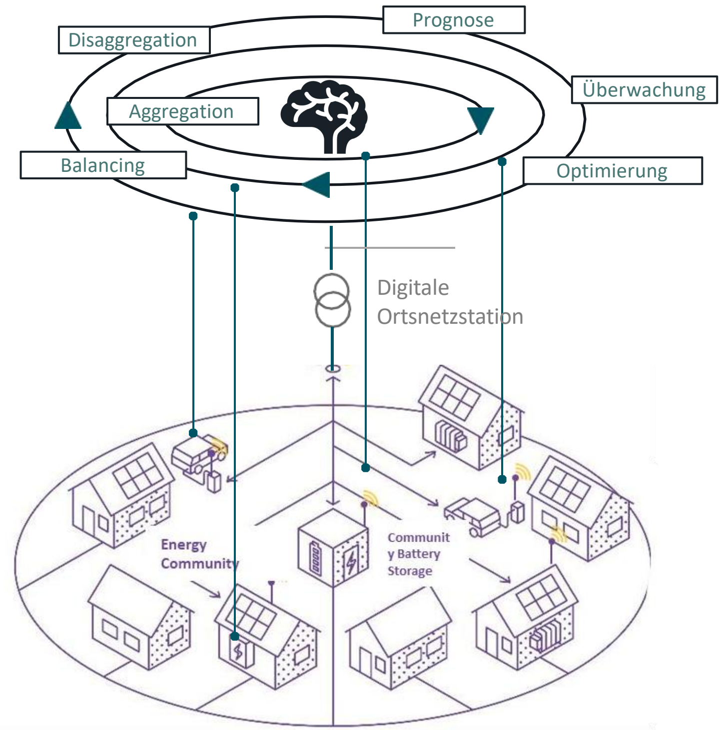
- 21 responses with interest for participation
- Equipment of 5 Households and implementation of 1 Prototype System

Energy Management System in Distribution Grid | Platone – Energieplattform Twistringen

Local Energy Management Features

Features	Target
Monitoring	• Observation of generation and consumption in low voltage grids (total and net) • Determination of status and availability of flexibility • Visualization
Forecasting	• Prediction of PV generation and load demand of households (t+24h) • Prediction of low voltage grid net load and net energy demand (t+24h)
Balancing	• Control of small scale batteries and flexible loads • Implementation Measurement-Control-Cycles (15-Minutes) • Forecast-based control and forecast based control with optimization
Optimization & Coordination	• Maximization of load peak-reduction at MV/LV while putting respect to the limits of available flexibility (kW and kWh) • Implementation of prioritization rules in case of time overlapping requests

Use Cases



Energy Management System in Distribution Grid | Platone – Energieplattform Twistringen

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

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

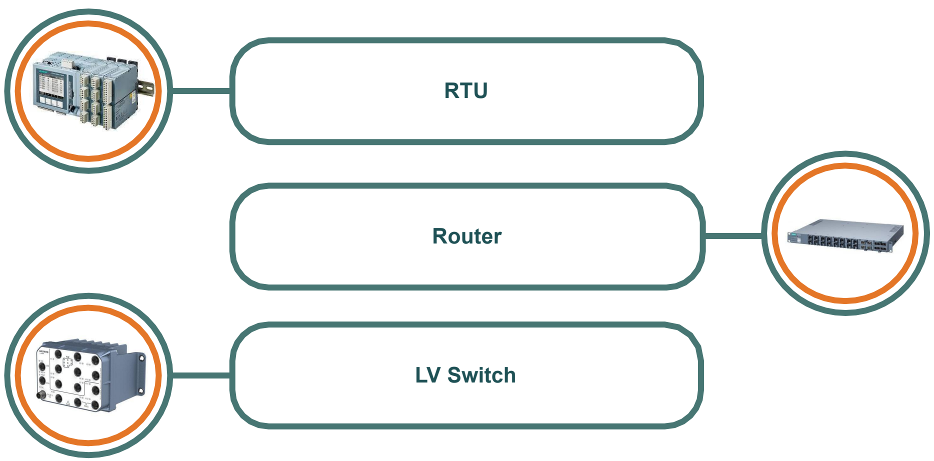
*The Smart Park areti is equipped with several electric charging stations**

*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*

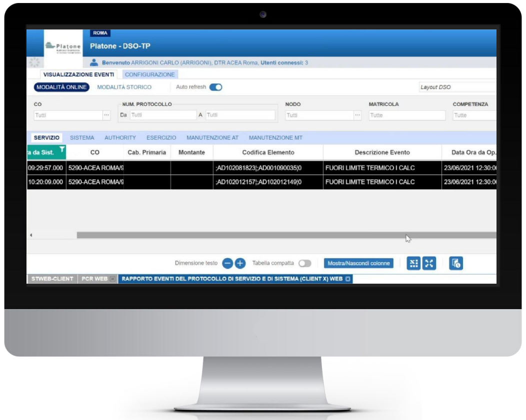
Hardware on the Field

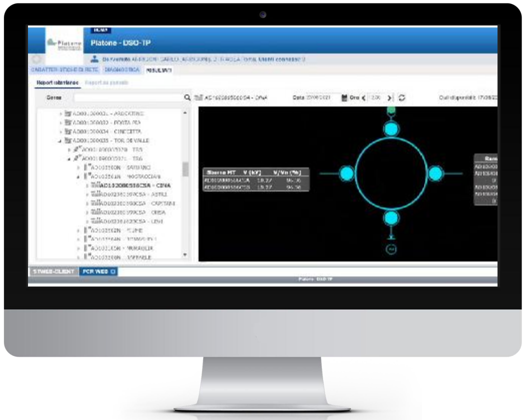
Several secondary substations already equipped with technological devices that enable the interaction with areti's central systems, started to communicate with Platone ecosystem and its platforms. Thanks to these kind of devices, grid issues detection will be improved.



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

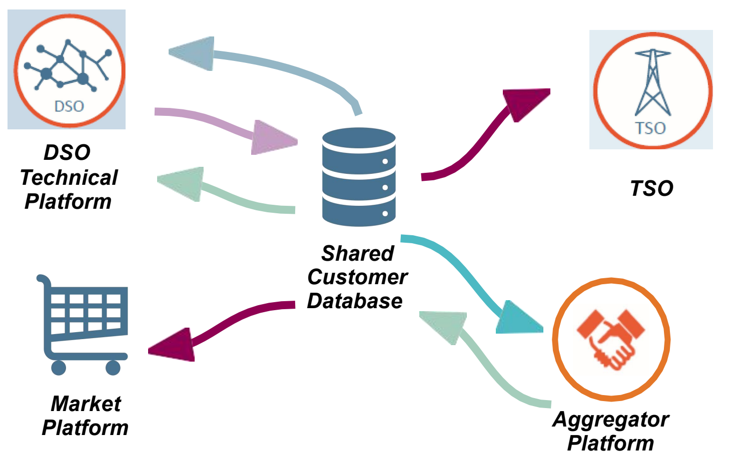
Enabling to the evalaution and certification of the Chain2full

Preparation and Flexibility Products

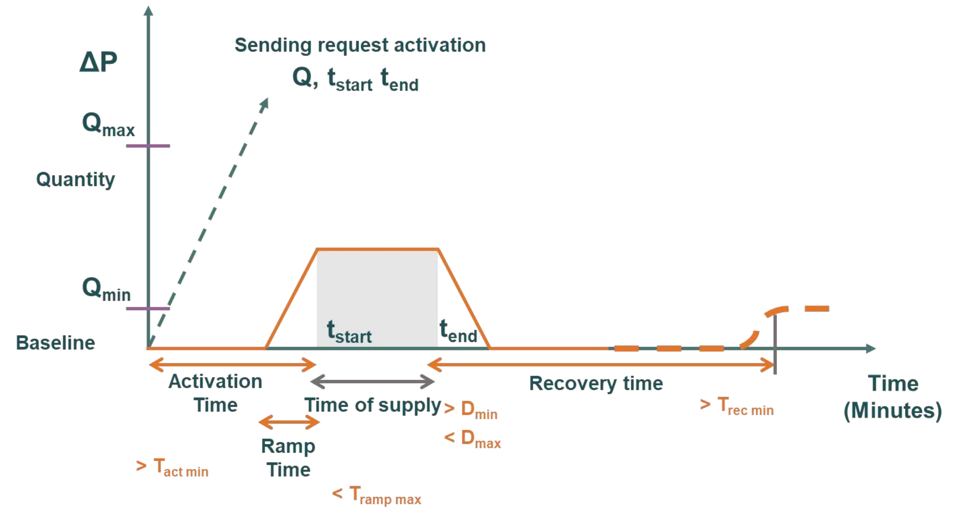
Preparatory activities

Data Flow Chart

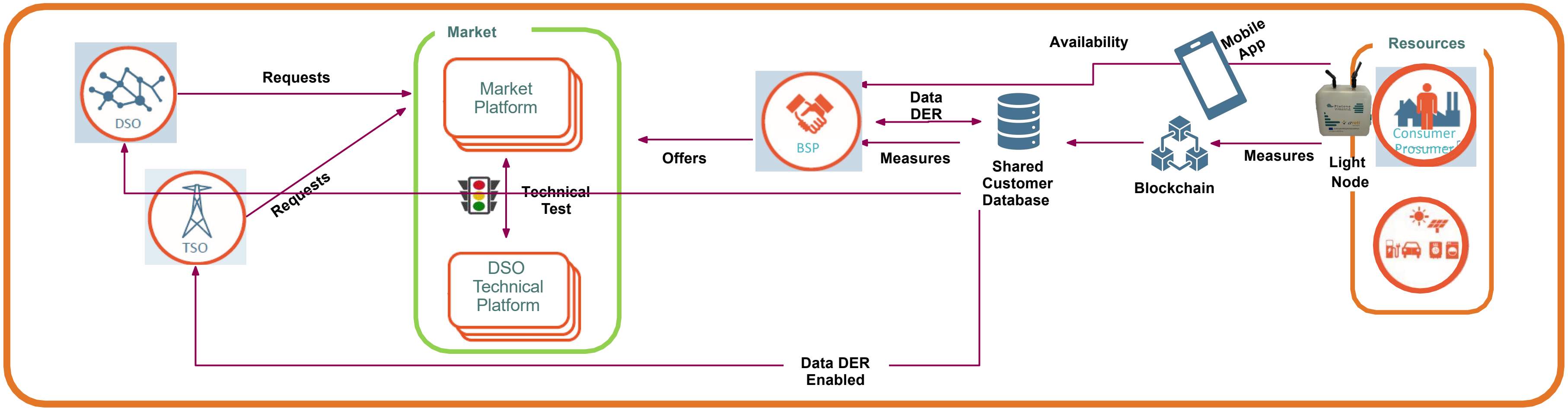
- 0: PoD Registration
- 0A: PoD Association
- 0B: PoD Flexibility Data
- 1: Acquiring of customer data (Baseline)
- 1A: Acquiring of customer data (Observability)



Flexibility products



Activation and Use

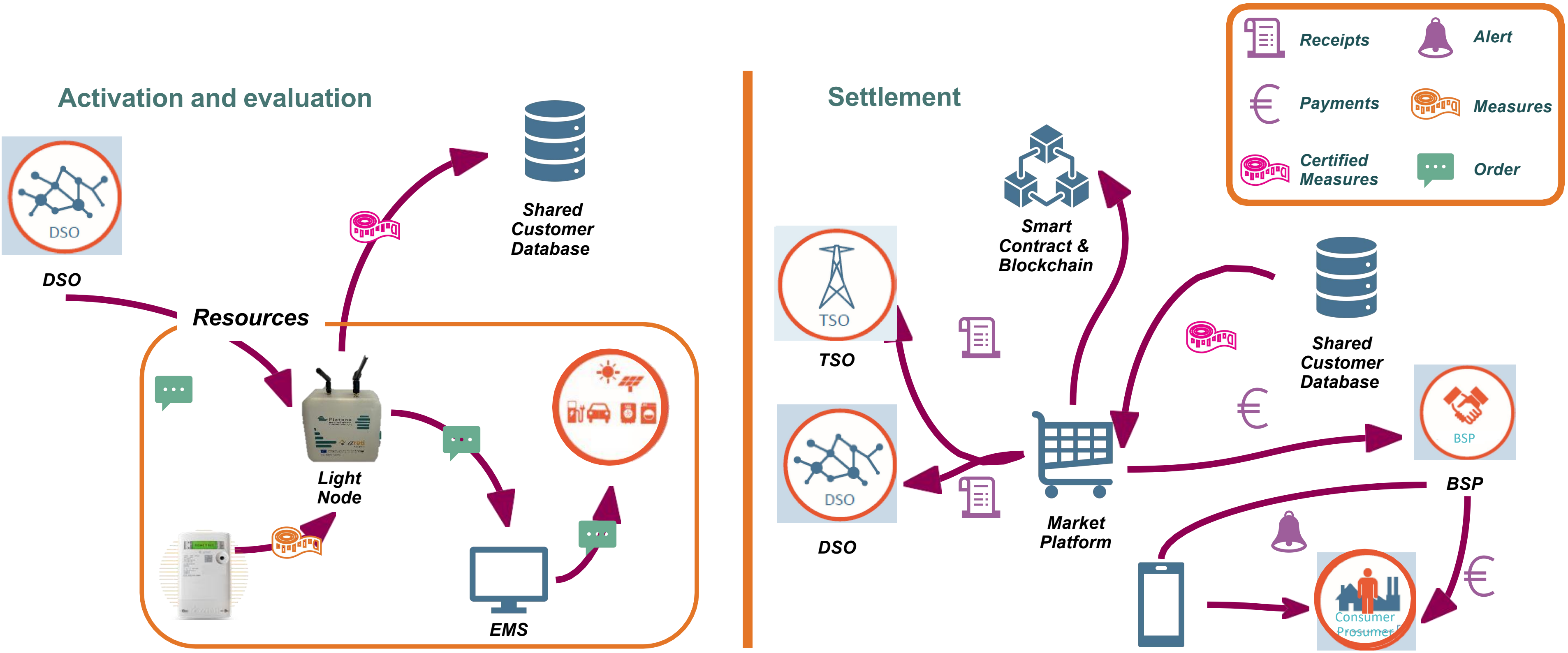


Market Platform

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

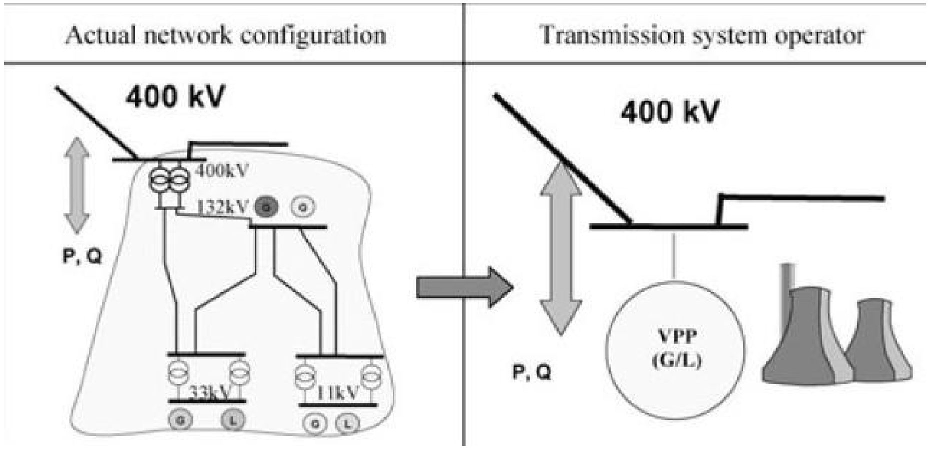
InfraDay: 6 sessions each covering the services to be provided during the 4 hours of the day following the session day

Measurement and Settlement



Load Management Methods: Virtual Power Plant

- Virtual Power Plant (VPP)
  - Management of a large group of microgenerators with capacity comparable to a conventional power plant
  - Power plant with geographically located generation assets which are interconnected through the virtually existing communication channels
  - Software-dependent, using advanced ICT technologies
- Function
  - Independent power producer based on the aggregation of DER
  - Energy supplier based the aggregation of prosumers
  - Energy management system, where the VPP is a software based application which can be used by any parties



Source: Pudjianto, D: "Virtual power plant and system integration of distributed energy resources"

Load Management Methods: Virtual Power Plant

- Advantages
  - Higher efficiency
    - Reduced energy losses during electricity transmission and distribution
    - Savings for primary energy
    - Reduction in the emission of pollutants
  - Higher flexibility
    - More suitable for the compensation of fluctuations
- Disadvantages
  - Lower stability reserves

Load Management Methods: Energy Communities

- Energy communities are groups of individual actors who voluntarily accept certain rules for the purposes of a common objectives (only or also) relating to energy; that is:
  - Purchasing energy as collective groups, and/or
  - Managing energy demand and supply, and/or
  - Generating energy, and/or
  - Providing energy-related services

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

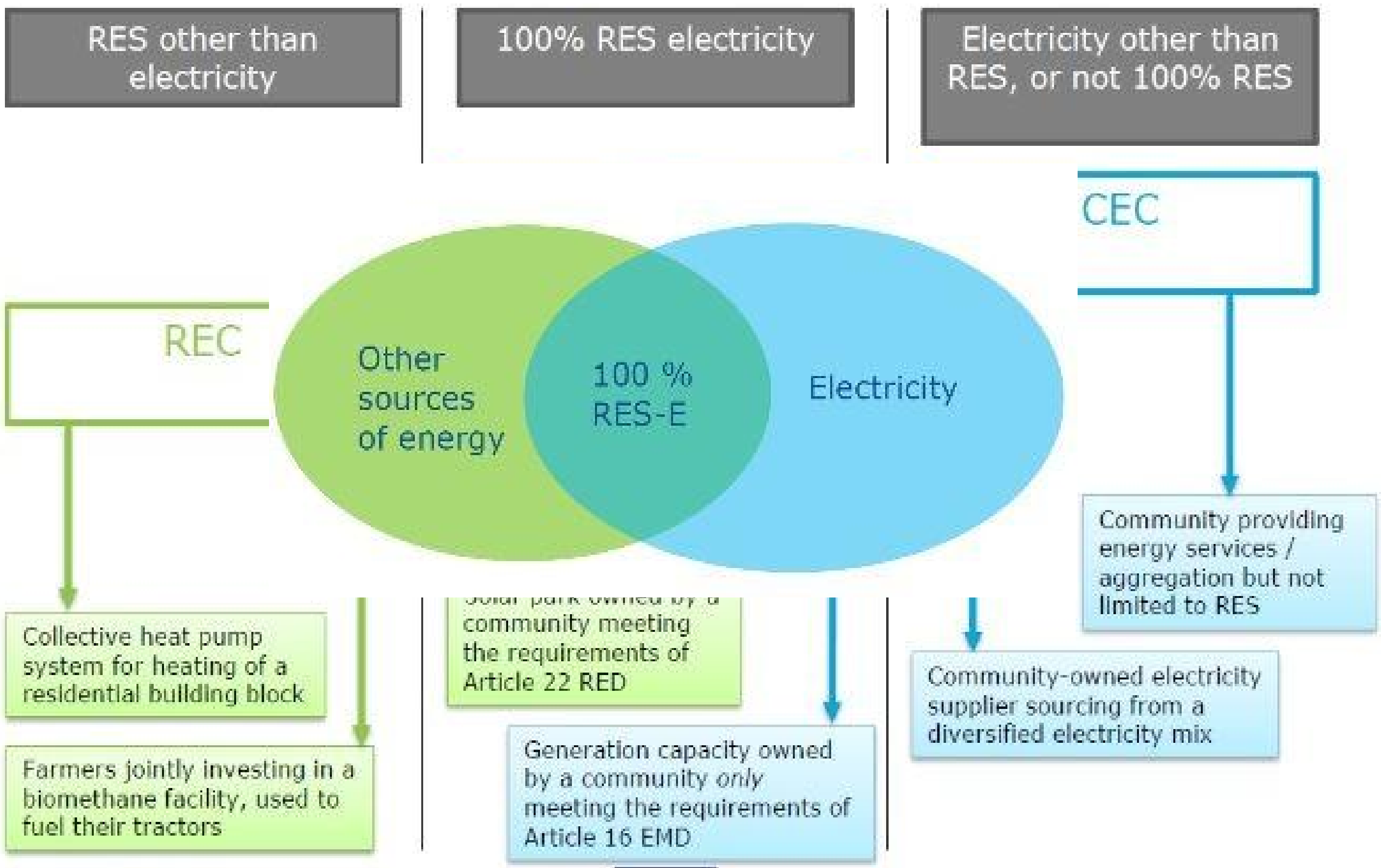
Load Management Methods: Energy Communities

- 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

REC		CEC	
Participation and Governance	only non-professional actors, control remains with members located in proximity	Participation and Governance	open to all kinds of entities, but control remains with non-professional actors
Active policy	Promote and facilitate the development of RECs Elimination of barriers	Charges, taxes and fees	Respect for the Member States' autonomy
Role in support schemes	Member States to take specificities of RECs into account when designing support schemes	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

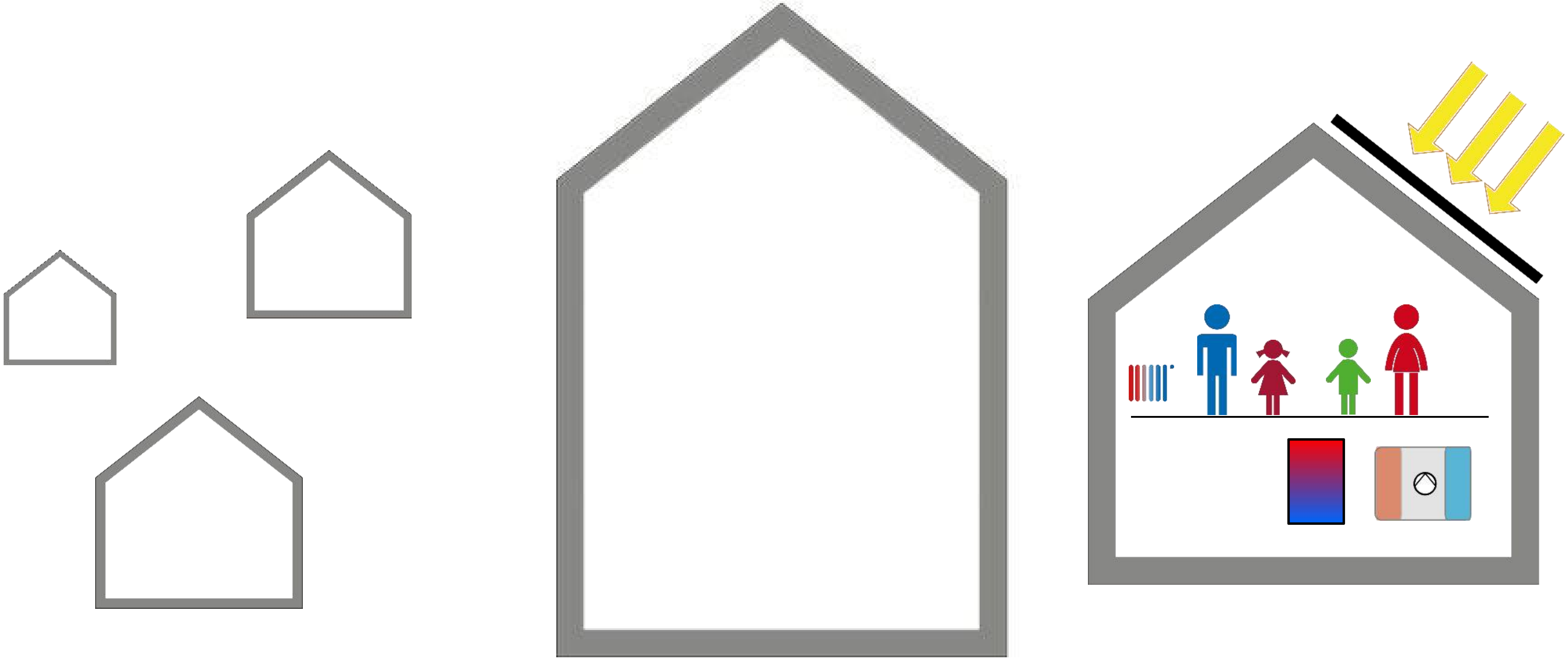
Load Management Methods: Energy Communities

- "Open and voluntary" and "Effective control"
  - CEC
    - All kinds of persons or organisations can be a member or a shareholder
    - "Effective control" * is attributed to shareholders or members who are natural persons, local authorities, including municipalities, or small enterprises and microenterprises (not: medium and large enterprises)
  - REC
    - Member and shareholder can be natural persons, SMEs or local authorities, including municipalities
    - Effectively controlled by shareholders or members that are located in the proximity

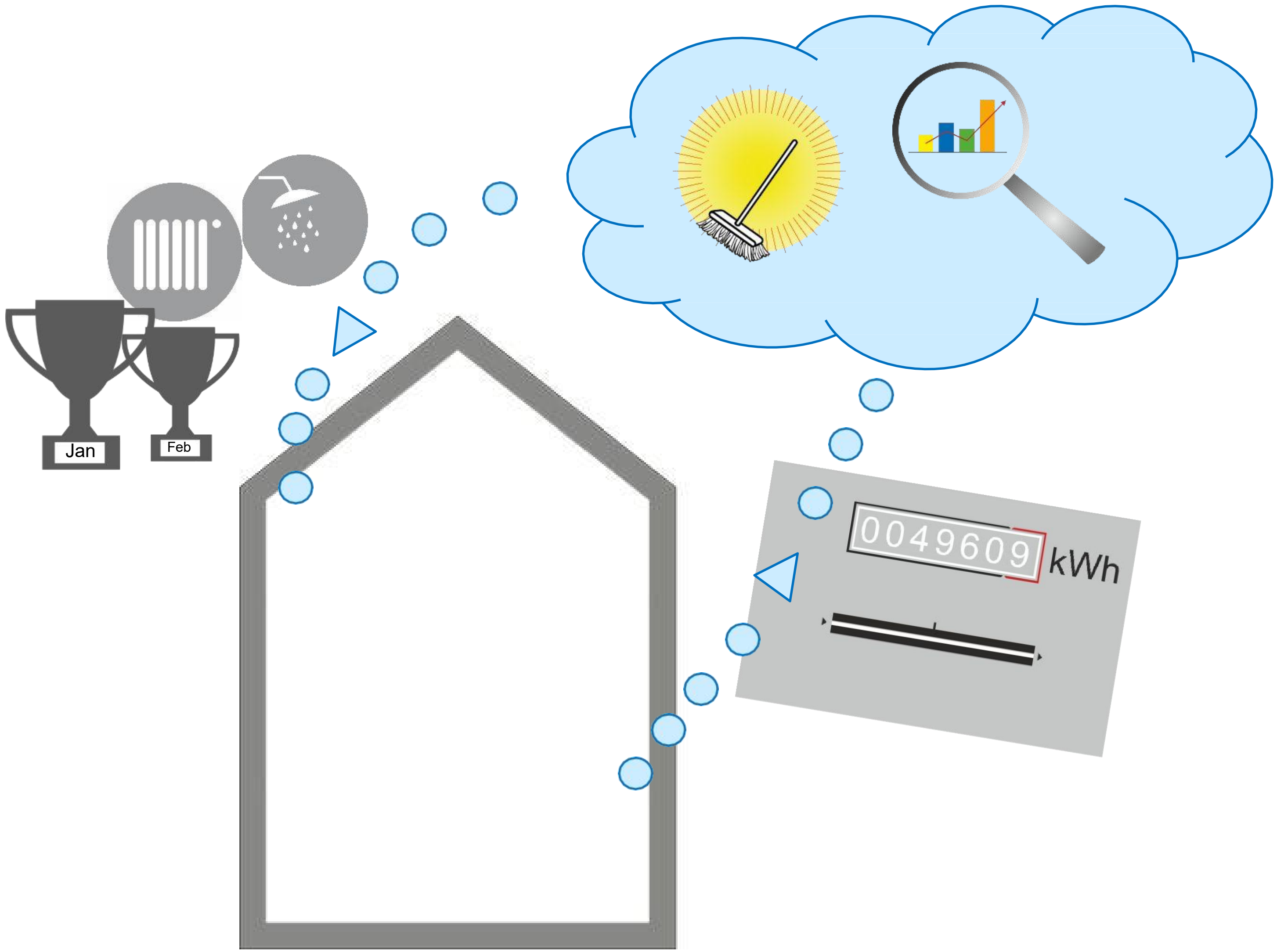
* "*Control*" (*EMDII*): Possibility of "**exercising decisive influence** on an undertaking, in particular by **(a) ownership** or the **right to use** all or part of the **assets** of an undertaking; (b) rights or contracts which confer **decisive influence on the composition, voting or decisions of the organs** of an undertaking"

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

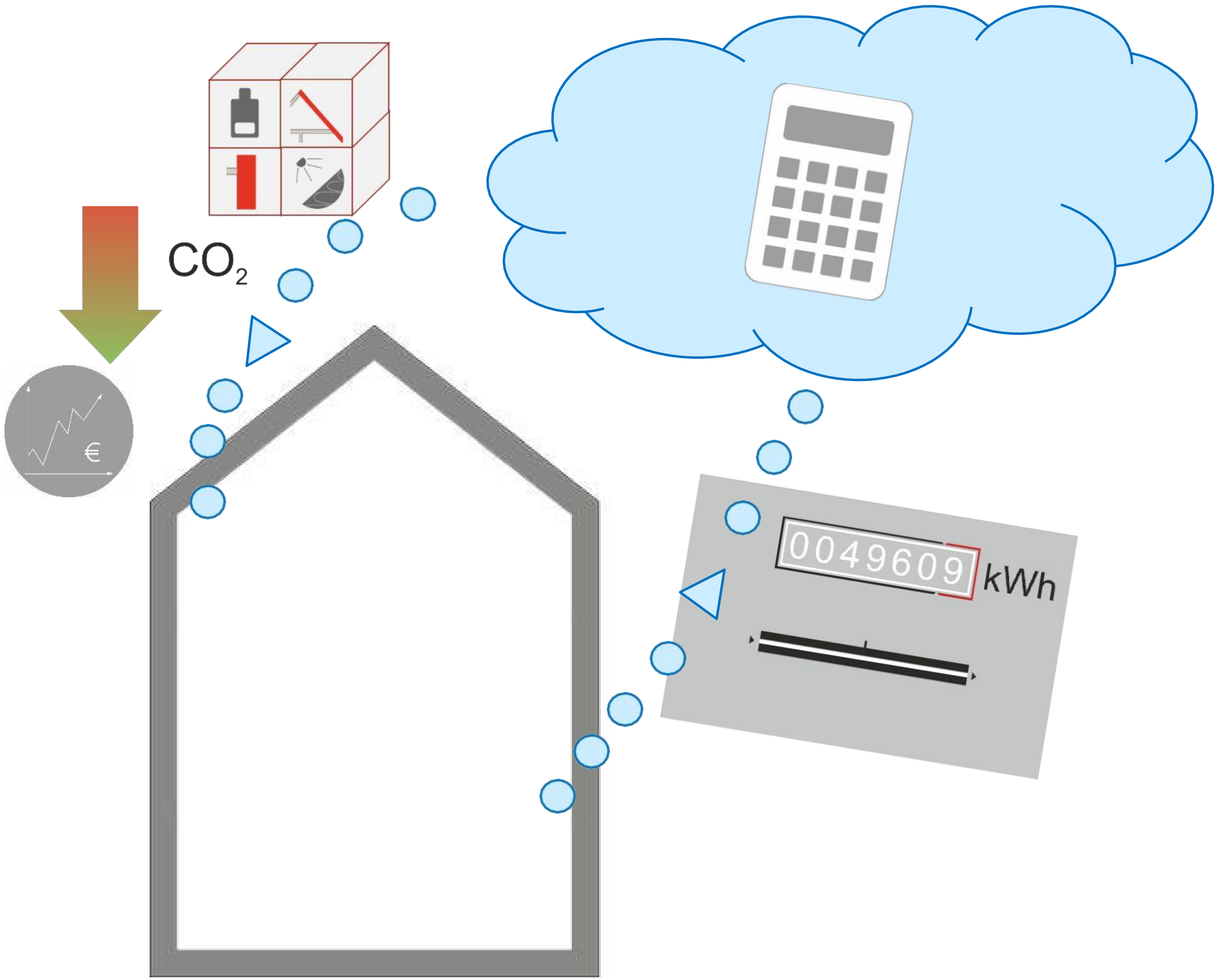
Services



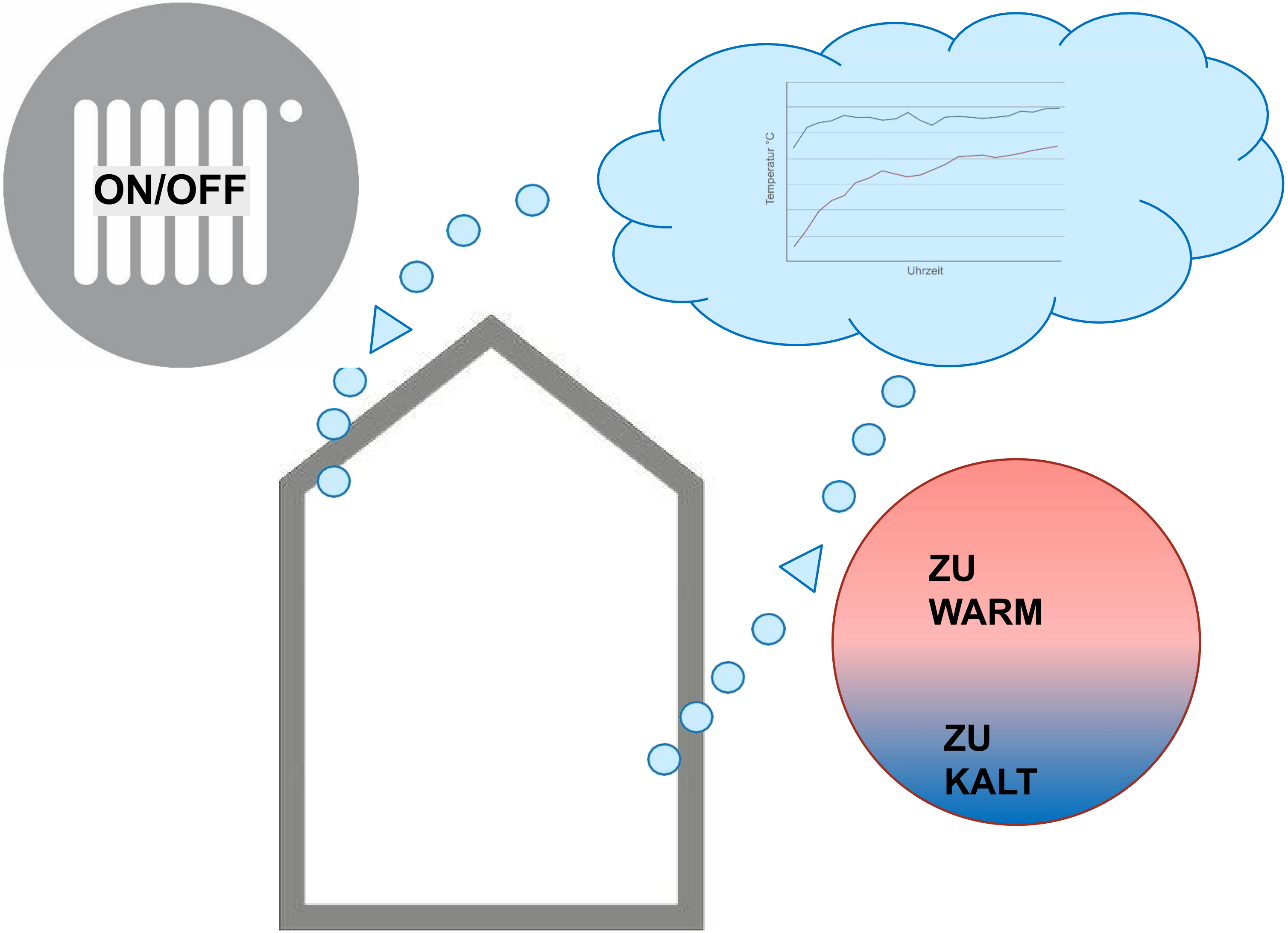
Service „Monitoring 2.0“



Service „Customer Advisement“

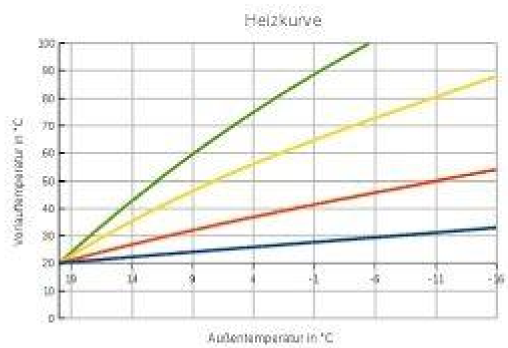


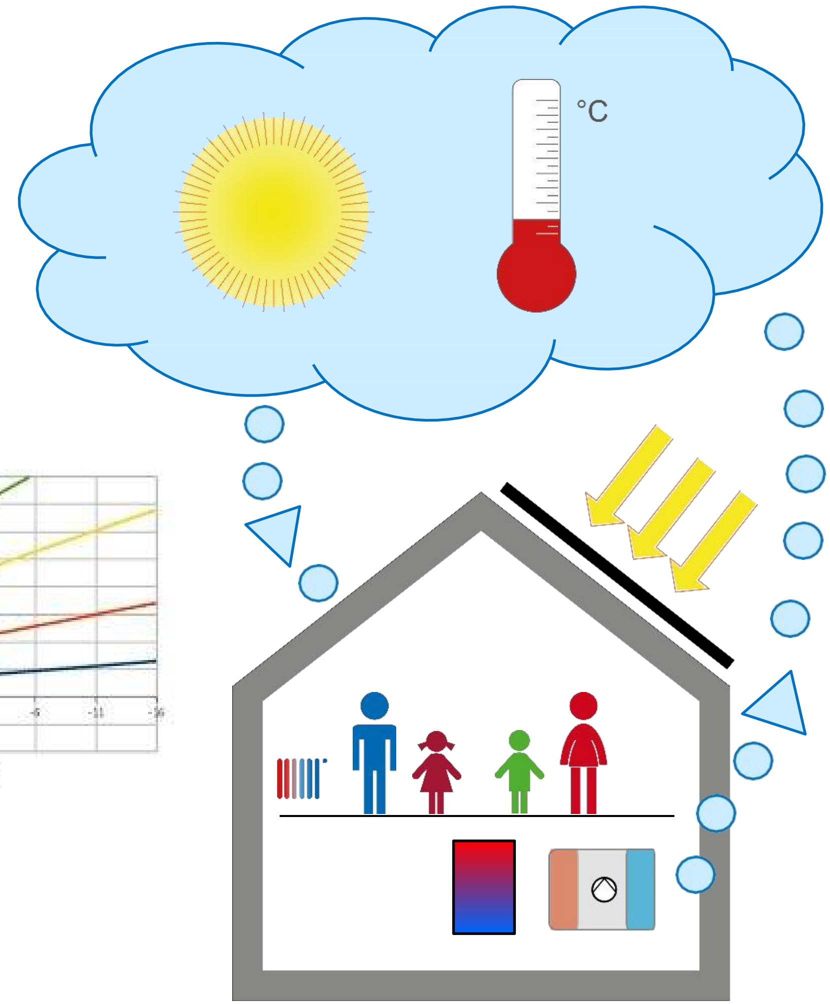
Service „Heating on Demand“



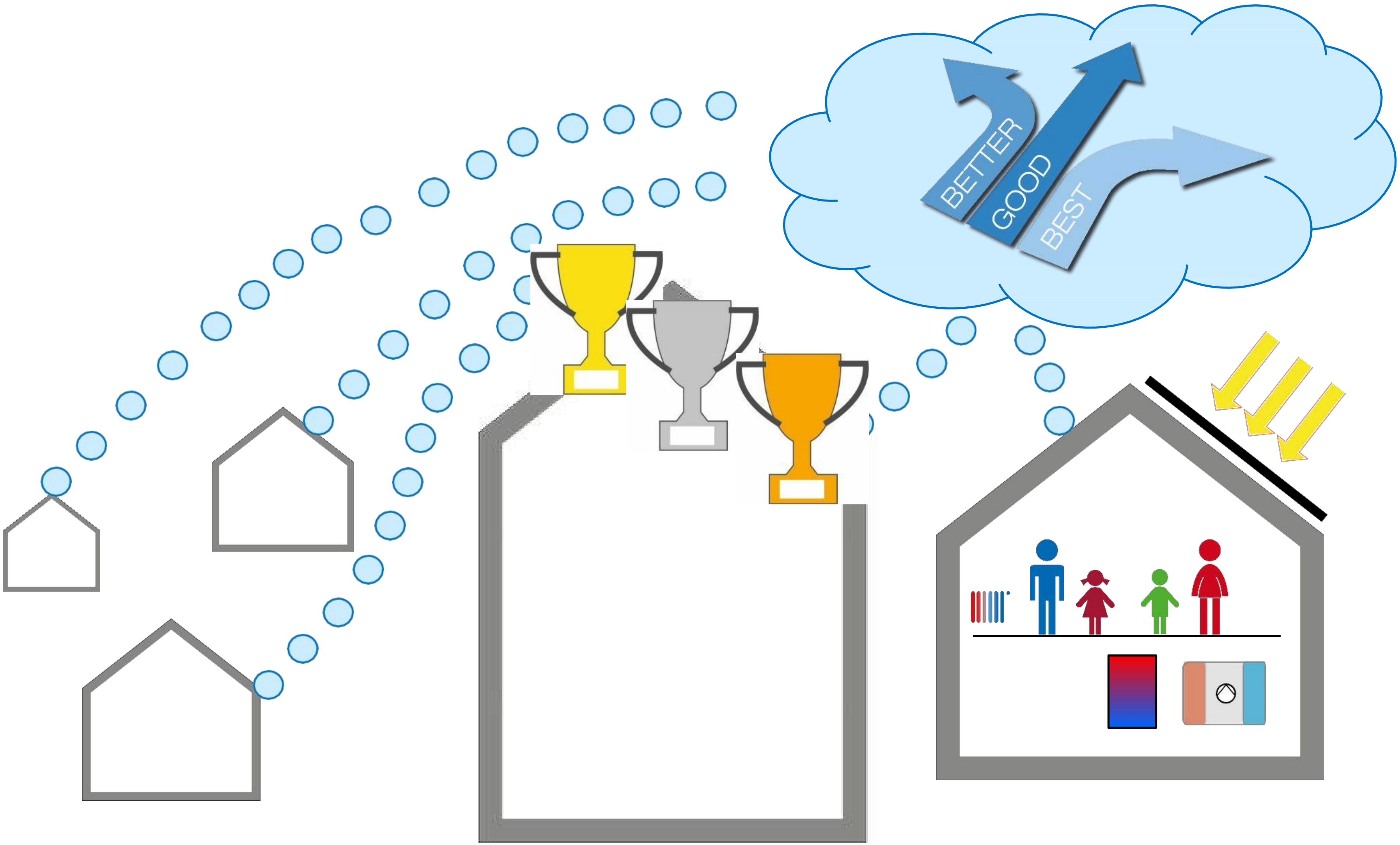
Service „My Comfort“

Service „Optimization of Heating Setting“



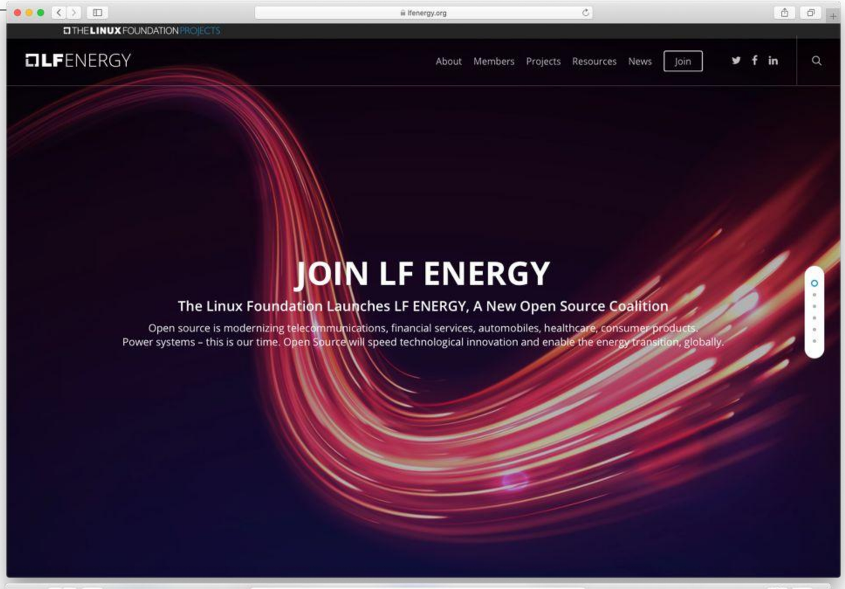


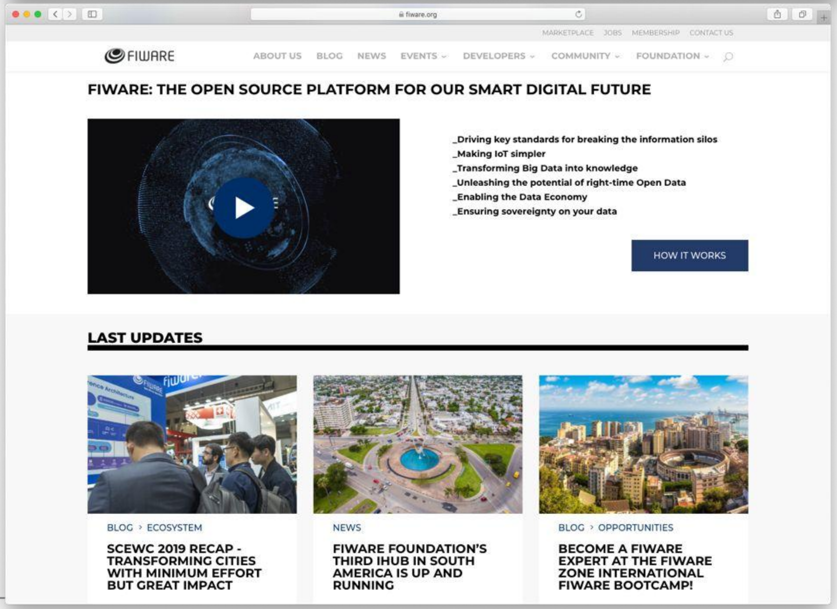
Service „Beat Your Neighbours“



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)





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
- The customers and their involvement is a key ingredient
- Open standards are key enablers for this process

Platone

Elsa
ENERGY LOCAL STORAGE ADVANCED SYSTEM

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