Energy flexibility in smart grids, homes and cities

Developments and standardization

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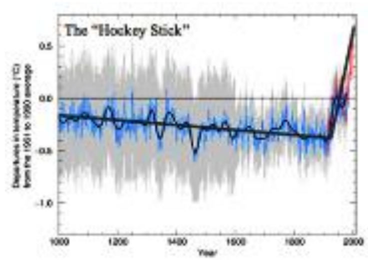
Contents

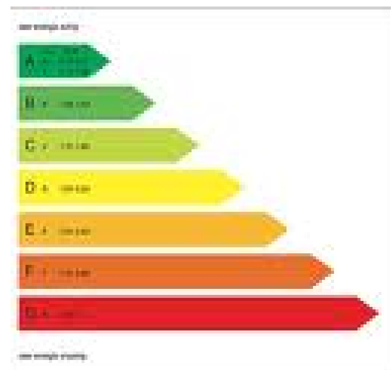
1. Observations in the energy domain
2. Flexibility for solving balancing problem
3. Smart grid energy management
4. Flexibility and home energy management
5. Standardization of energy flexibility
6. Challenges with IT in the smart grid

Observations in the energy domain

Energy transition: the need for change

- Climate change
- CO2 reduction
- Al Gore
- More efficient use of energy
  - Saving of natural resources
  - Sustainable resources
  - Efficient use of resources.





From Consumer to Prosumer

- Increasing amount of "own" (RES) energy supply of households
- Surplus of energy supply of households provided to smart grid

Uncertainty of Renewables

- Weather conditions determine amount of energy
- Uncertainty in weather pattern
- Uncertainty in energy supply from RES has to be taken into account

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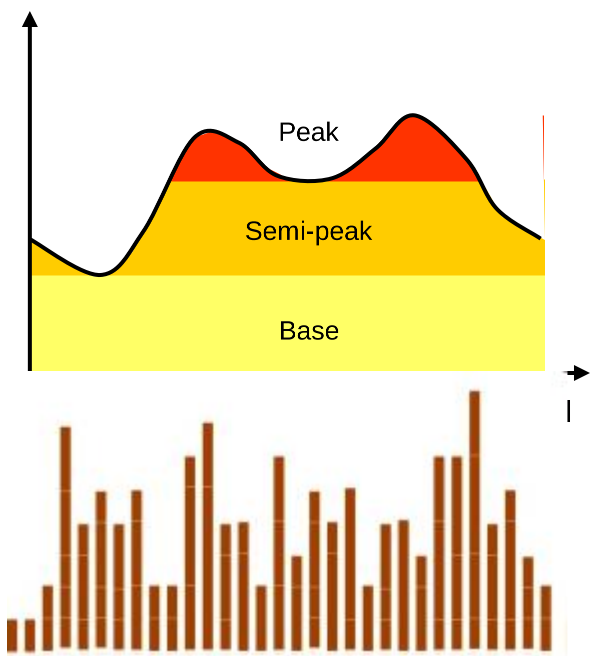
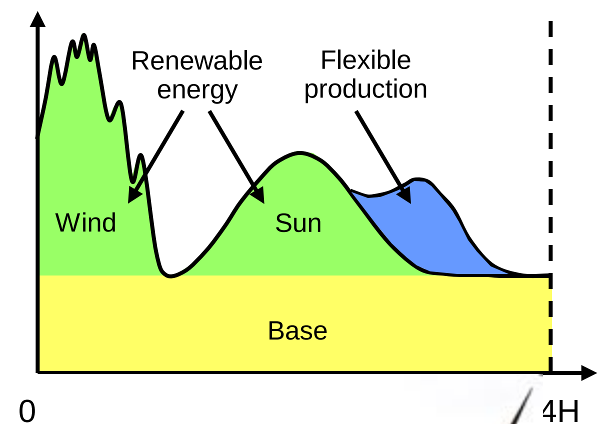
Sustainable resources:
A paradigm shift in energy networks!

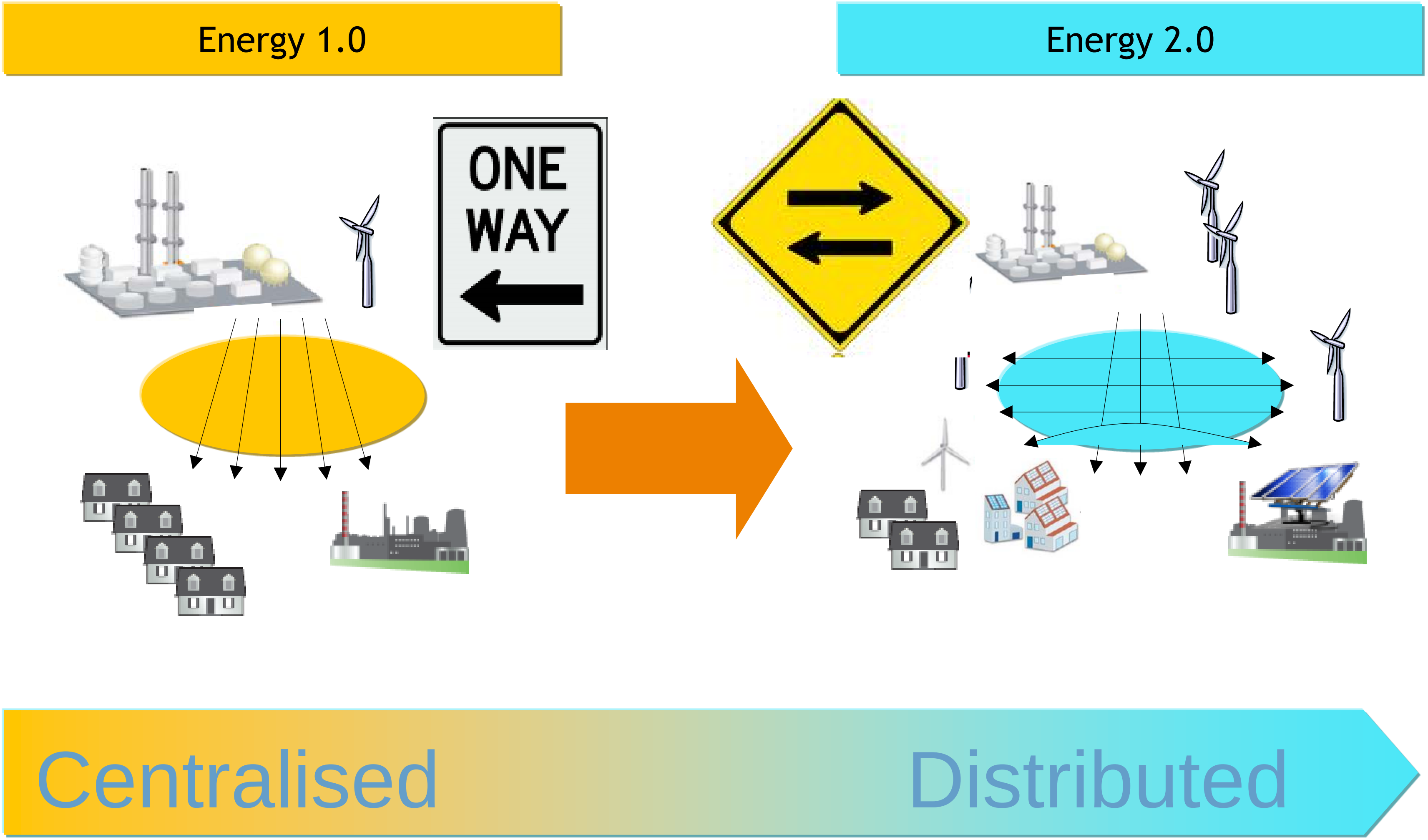
Production follows demand

Demand follows production





The internet of energy: Smart Grid
Balancing the network?



Flexibility for solving balancing problem

Distributed generation and consumption

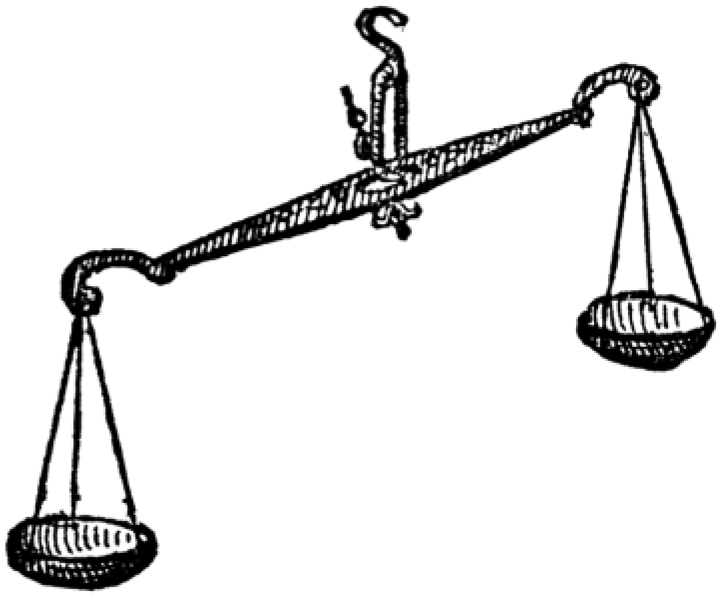
Requires (Active) load balancing between supply and demand (and storage)

- **Centralized**
  - central knowledge and control

  -> DSO/TSO distribution system operator
- **Decentralized**
  - decentral knowledge and control

  -> LSO local system operator

  = one of the scenarios (but with the biggest impact)



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Local balancing requires control

Control of generation

Who is in control?

Control of consumption

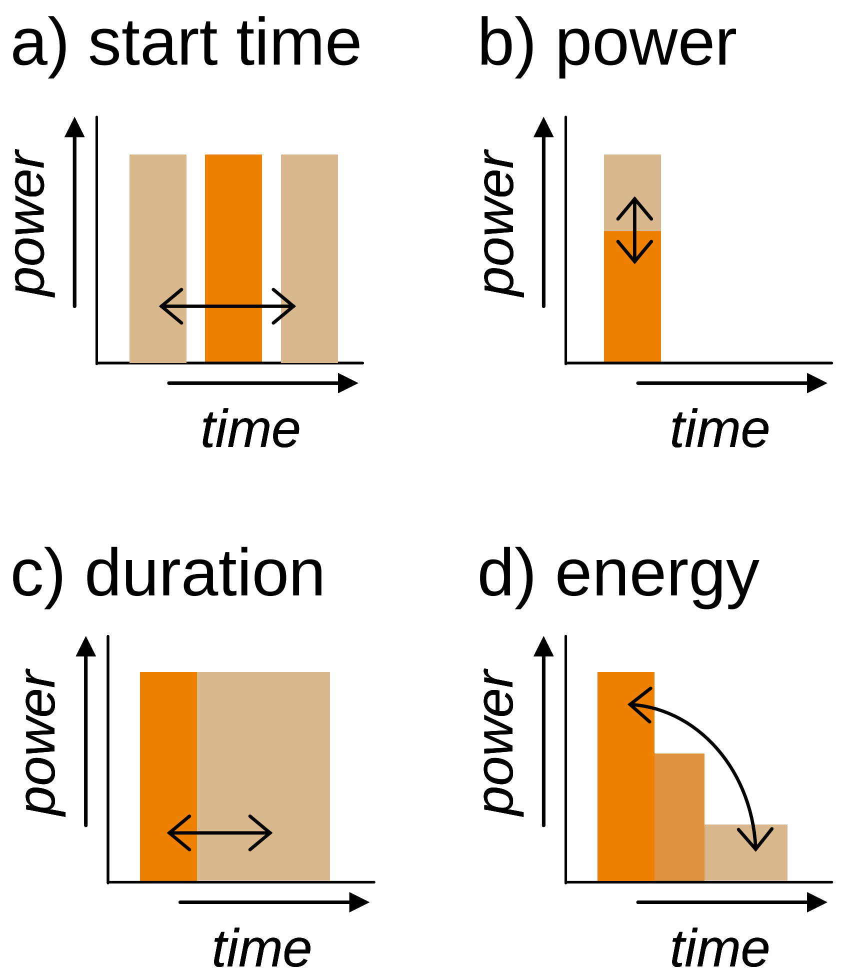
Control of storage

Flexibility can help!!

Flexible Energy Demand

- Dishwasher and washing machine can flexibly run overnight
- Electric vehicle can be charged flexibly during parking interval

Energy Profile Flexibilities



- Flexibilities are expressed in terms of constraints on an energy profile.
- Profile elements can have constraints on their power, energy and time.

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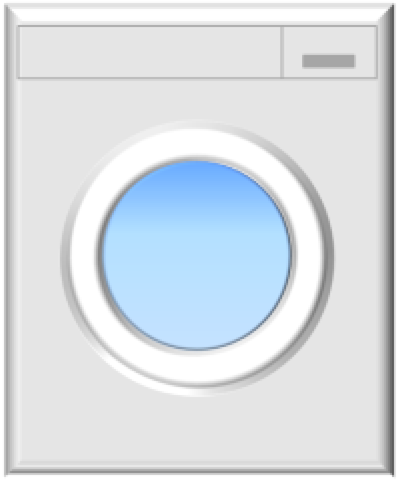
Timeshifter category

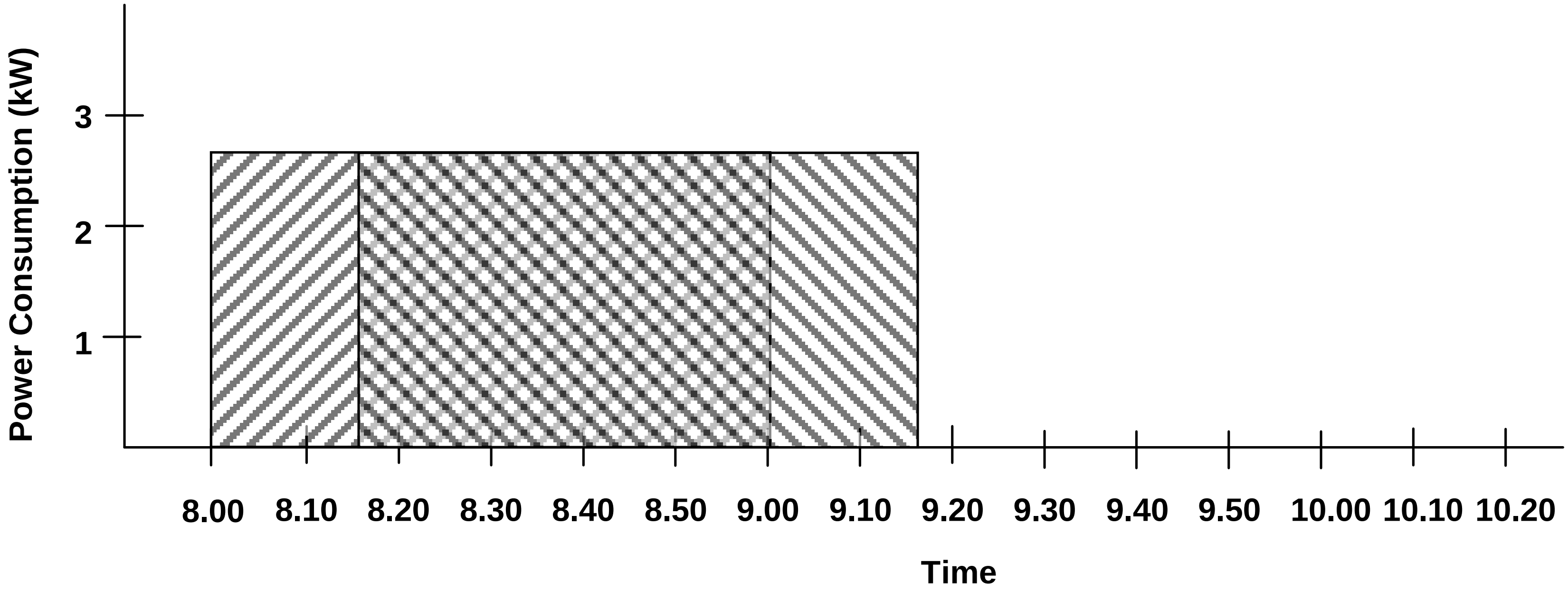
- Timeshifters consume/produce energy according to a predetermined energy profile, the start time of this profile can be shifted in time
  - Examples: washing machine, dish washer



- Timeshifter control space parameters
  - Energy profile (array of Wh)
  - StartAfter
  - StartBefore

Washing machine

- Total shift in time of start and end time



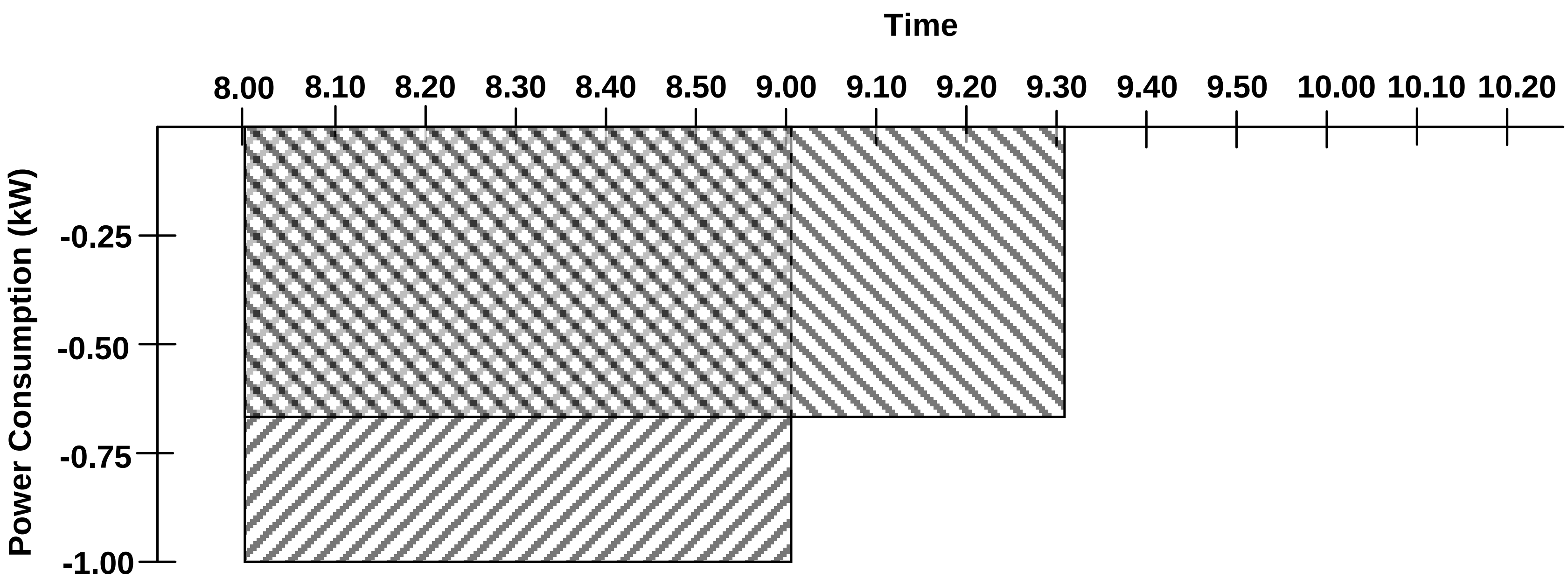
Buffer category

- Buffers can consume/produce more or less energy (within certain operational constraints) according to the needs of the household
  - Examples: fridges, freezers, heating

- Buffer control space parameters
  - Capacity (Wh)
  - State of Charge (%)
  - Target State of Charge (optional)
  - Target Time (optional)
  - Charge speed (W)
  - Self Discharge (W)
  - Minimal switch on period
  - Minimal switch off period

Combined heat power system

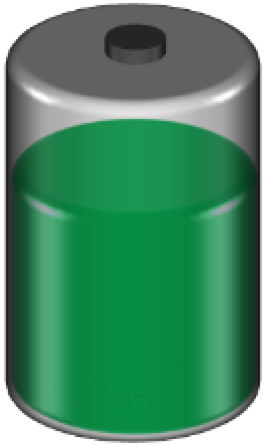
- 2 options: 70% and 100% operating
- Total amount of power x time must be equal



Storage category

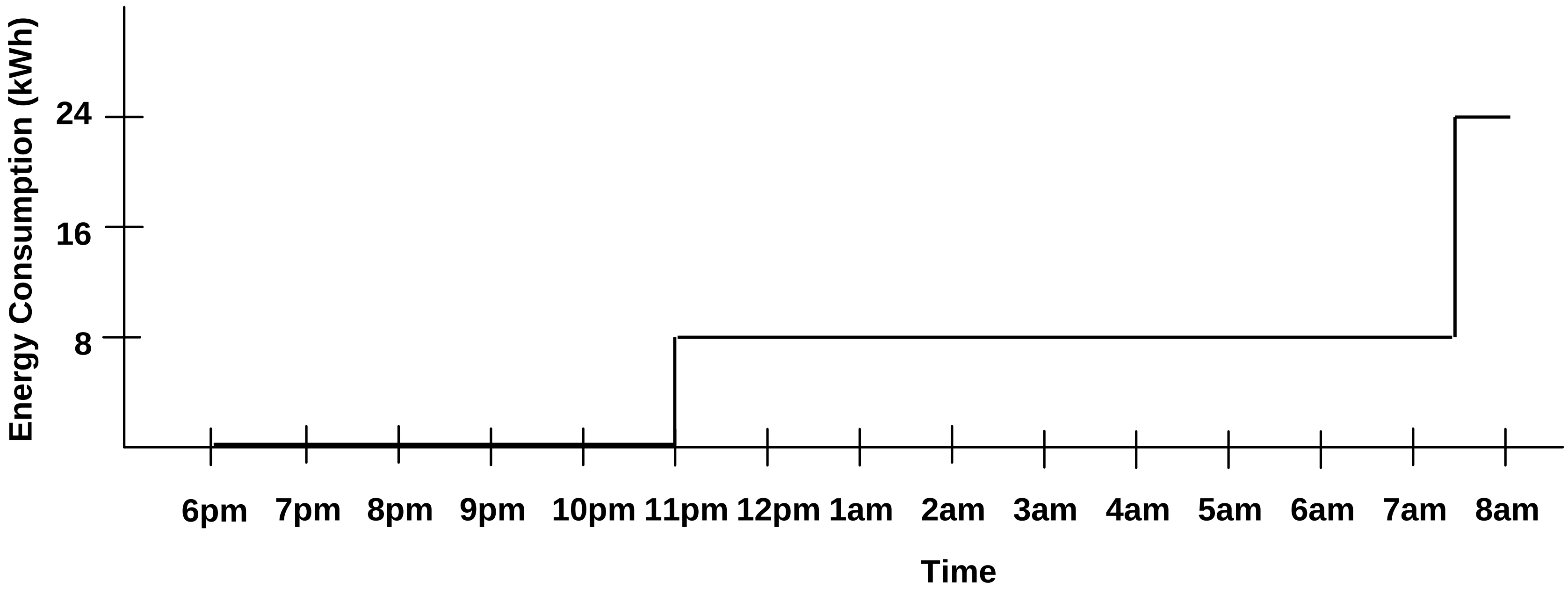
- Storage device can store electricity and release it when required
  - Examples: EV, battery

- Storage control space parameters
  - Inherits all parameters of the buffer category
  - Discharge Speed (W)
  - Charge Efficiency
  - Discharge Efficiency



Electric vehicle charging

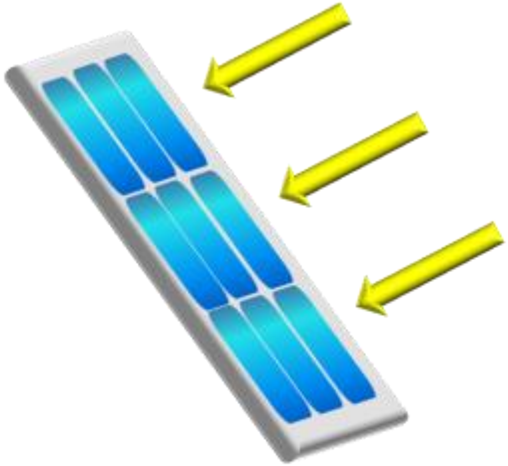
- Charging in steps
- First step towards 30% for emergency
- End level is 100% charged



Uncontrolled load/generation category

- These are devices that cannot be actively controlled
  - PV, Wind, lighting

- Control space parameters
  - Predicted Energy profile (array of Wh)
  - Confidence interval



Smart grid energy management

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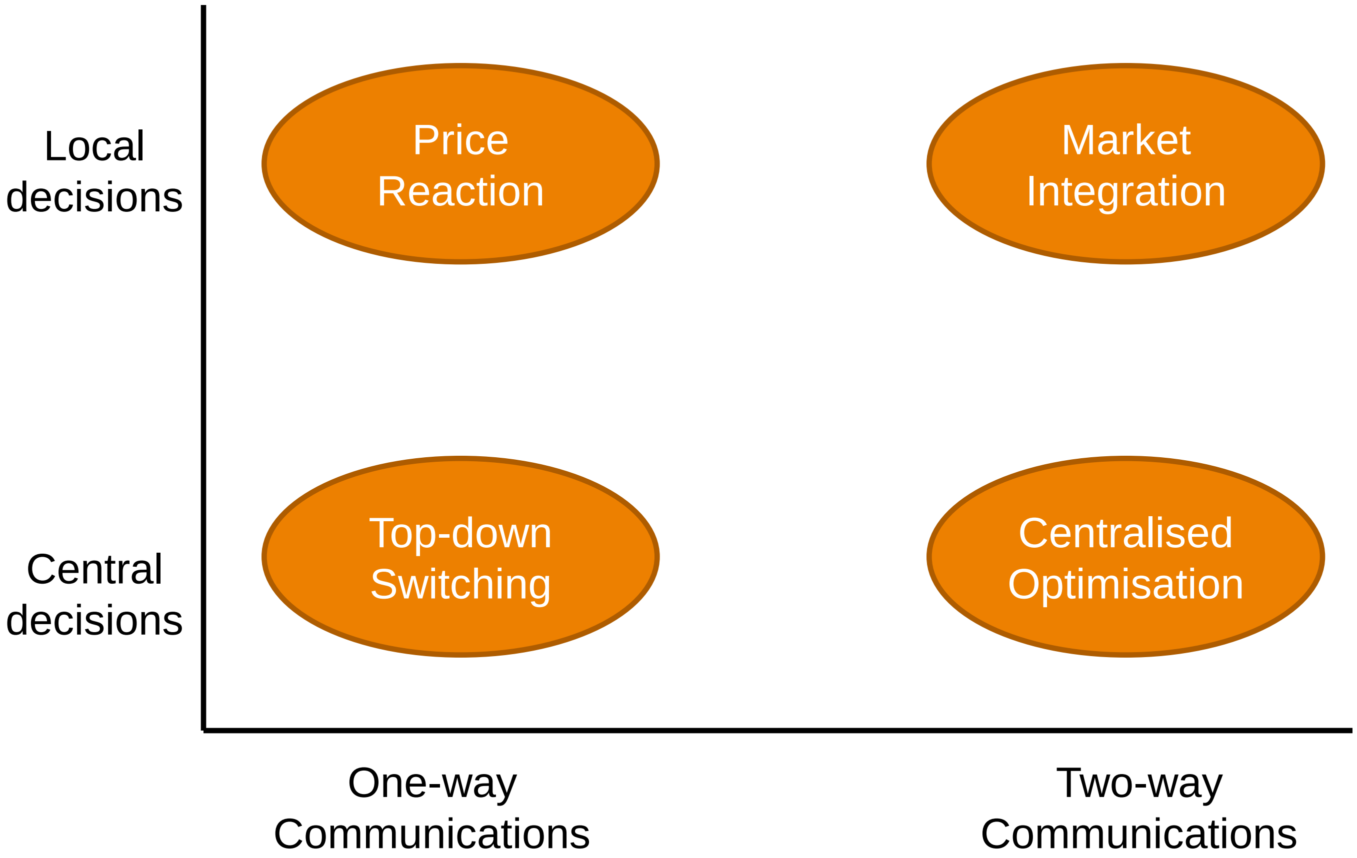
SEVENTH FRAMEWORK PROGRAMME

Different types of smart grid energy management



Top-down Switching

- Reducing peak loads by centrally switching devices on and off

- Example:
  - SmartAC program (PG&E)
    - Remote switching of AC units and heat pumps

- Pros
  - Easy to implement, instant reaction
- Cons
  - End user autonomy, not suitable for all appliances

Centralised Optimisation

- Flexibility of participants is collected at a central point
- Decisions on how to exploit flexibility are made centrally

- Example:
  - Virtual Power Plants

- Pros
  - Full use of flexibility potential, certain system reaction
- Cons
  - End user autonomy, privacy, complex for larger number

Price Reaction

- A dynamic price profile is sent to end users
- End users change their behaviour accordingly

- Example:
  - Meregio project by Energie Baden-Württemberg (ENBW)

- Pros
  - Scalable solution, privacy
- Cons
  - Uncertain system reaction

Wie funktioniert der dynamische MeRegio-Tarif?

Preisanpassung Dynamische MeRegio-Tarifstufen – Neue Preise ab 1. April 2012

Dynamische MeRegio-Tarifstufen Preise ab 1. April 2012	brutto* Cent/kWh
Stufe 1 (ROT): **Peak-Strom** (Verbrauchspreis Spitzenlastzeit)	**90,00**
Stufe 2 (GELB): **Sparstrom** (Verbrauchspreis Mittellastzeit)	**28,00**
Stufe 3 (GRÜN): **Supersparstrom** (Verbrauchspreis Niedriglastzeit)	**18,00**

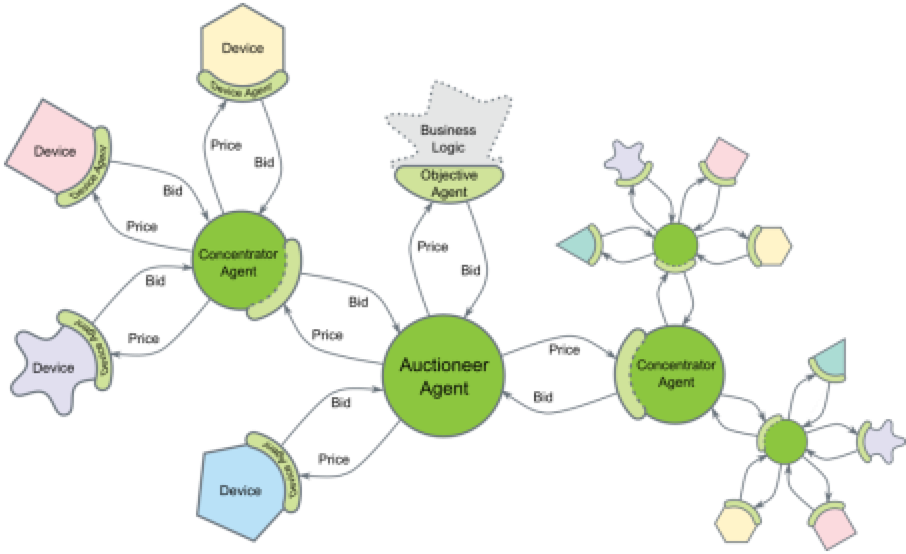
** Brutto inkl. Stromsteuer 2,05 Cent/kWh und 19% Umsatzsteuer*

Das Bonussystem des MeRegio-Tarifs

- Der dynamische MeRegio-Tarif besteht aus drei Tarifzonen, die im Abstand von 60 Minuten wechseln können. Ihre Tarifzonen kennen Sie bis zu 24 Stunden im Voraus.
- In Ihrem persönlichen Online-Portal werden alle Tarifzonen des MeRegio-Tarifs dargestellt und mit den Kosten des EnBW Intelligenten Stromzählers® verglichen (siehe Tabelle unten). So sehen Sie immer, was Sie mit dem MeRegio-Tarif im Vergleich zum Basistarif gespart haben.
- Ihre MeRegio-Ersparnis bekommen Sie jedes Quartal in Form einer Bonusvergütung ausbezahlt.
- Wie beim Intelligenten Stromzähler beträgt auch beim MeRegio-Tarif der monatliche Grundpreis 14,95 €. Sowohl die Höhe als auch die Anzahl der Tarifstufen können sich allerdings im Verlauf des Forschungsprojekts ändern.

Market Integration

- Creation of a market place for energy
- Example:
  - PowerMatching City
- Pros
  - Autonomy, privacy, certain system reaction, scalable
- Cons
  - Complex backoffice needed



POWERMATCHER smartgrid technology

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Appliance challenges

- Different functions
  - Washing machines, heating, fridges, freezers, electrical vehicles, etc.
  - Comfort should in principle always be maintained
- Different communication protocols
  - Zigbee, Z-Wave, PLC, WiFi, etc.
- Different datamodels
- Not mature yet

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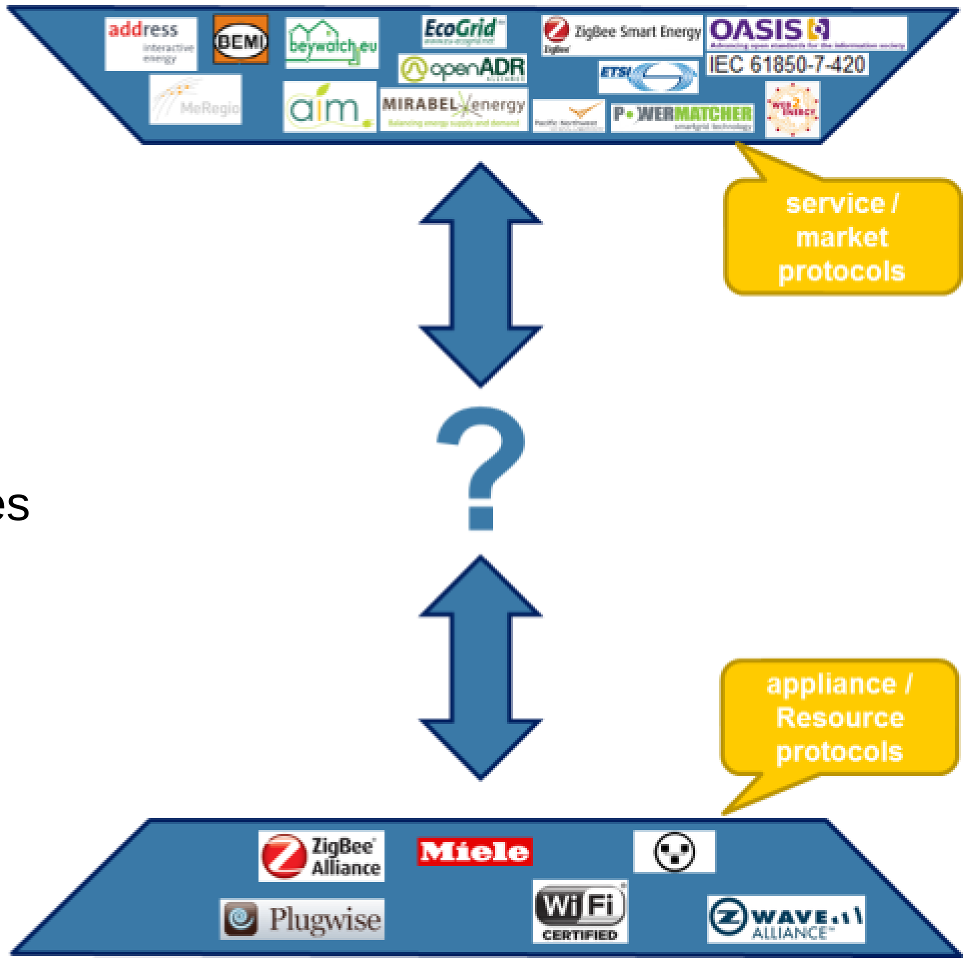
The challenge

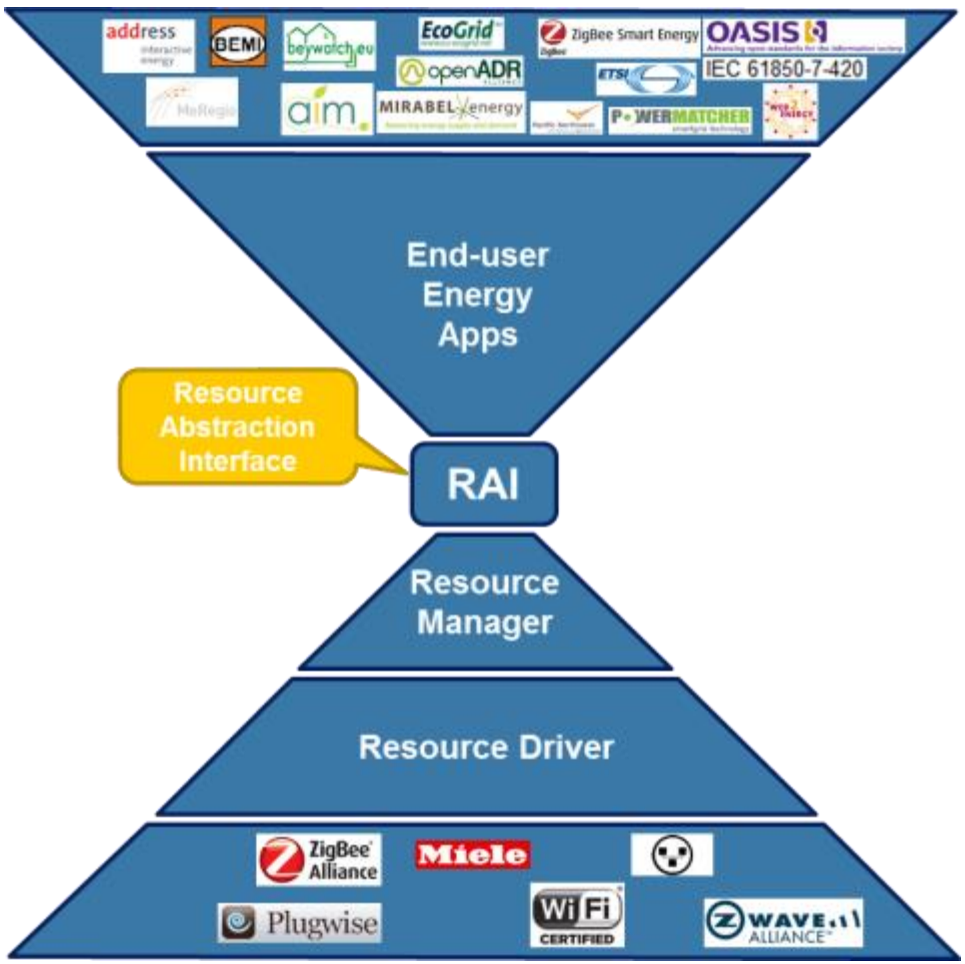
- Many different smart grid service/market approaches that can exploit flexibility
- Many types of appliances / resources that can deliver flexibility
- Many different protocols
  - Both for appliances and devices

How do we create interoperability in this heterogeneous context?



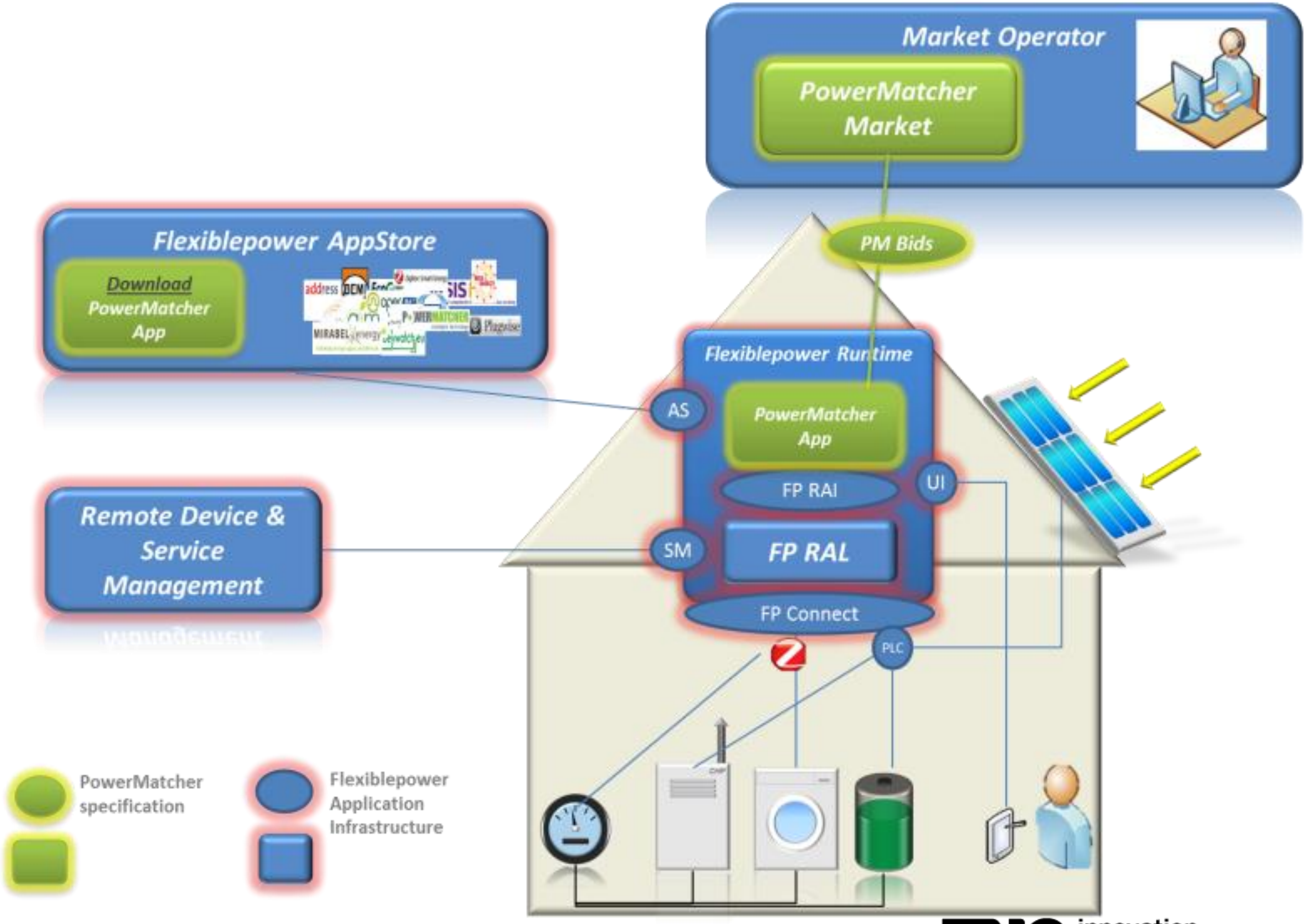
Our approach

- Introduction of a Resource Abstraction Interface (RAI) that only exposes energetic flexibility
- Abstracts from type of appliance/resource and specific protocols
- Energy apps are built on top of the RAI
- *Analogy with the Hardware Abstraction Layer (HAL) that sits between hardware and software on a computer*



Flexibility and Home Energy Management

FlexiblePower Suite



Home Energy Management System

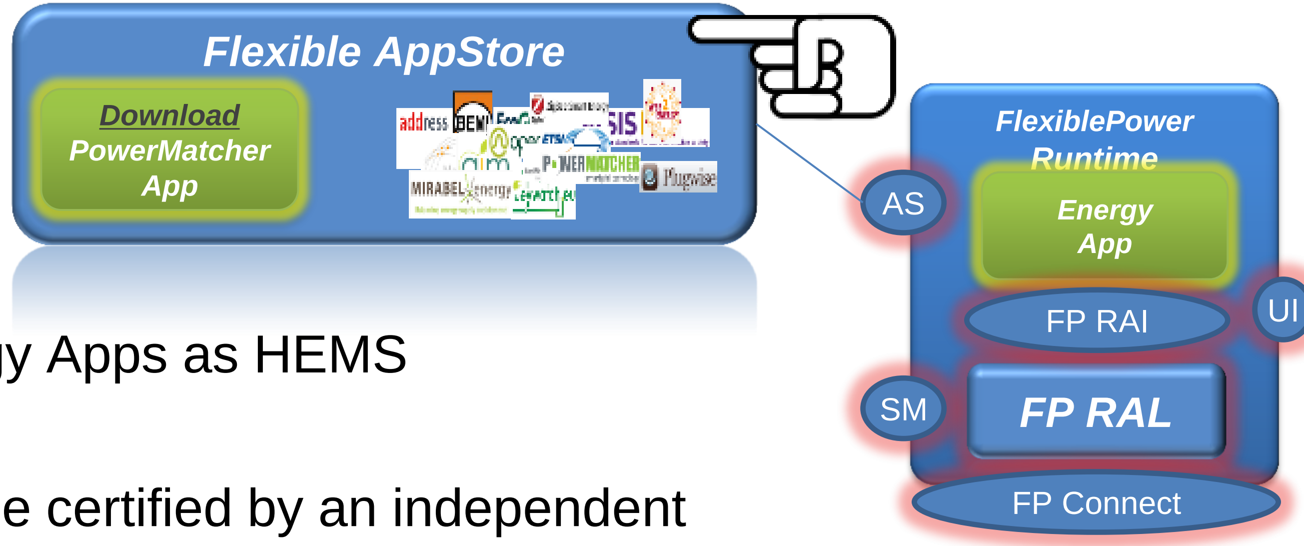
- A HEMS takes input from various sensors in the building and controls devices
- Tries to achieve an optimum between various objectives:
  - Usage of resources to minimize the import of electricity from the smart grid,
  - Maximize the use of the buildings own energy generation,
  - Maintaining the comfort level within the desired limits,
  - Reducing the cost of energy consumption.

- Local demand/supply adds new objective to HEMS:
  - Reducing cost of energy consumption through offering and negotiation of flexibility to be utilized by the smart grid such that smart grid balance is improved and penetration of intermittent renewable energy sources can be increased.

Use of flexibility in HEMS

- User sets his preferences for each device in the HEMS.
  - Example1: minimum and maximum level of an environment variable such as temperature that can be used as set-points for the control of a heating device.
  - Example2: indication whether or not a washing machine can be interrupted at certain fixed points within the washing programme, e.g. between washing and centrifuging (manufacturer must enable interruption at the various steps of these programmes)
- Data models are being developed to incorporate energy consumption and production information into existing Building Information Models (BIM).
- European projects: various information elements that can be used to express flexibility are defined.
  - HomeUsageProfiles, Scene, Comfort Setting and Load (which is shiftable) can be used to generate flex-offers towards the smart grid.

Energy Apps as HEMS



- Flexible Energy Apps as HEMS
- Apps should be certified by an independent party
- Provides a mechanism to remotely install an app on the runtime
- New business role

Standardization of energy flexibility

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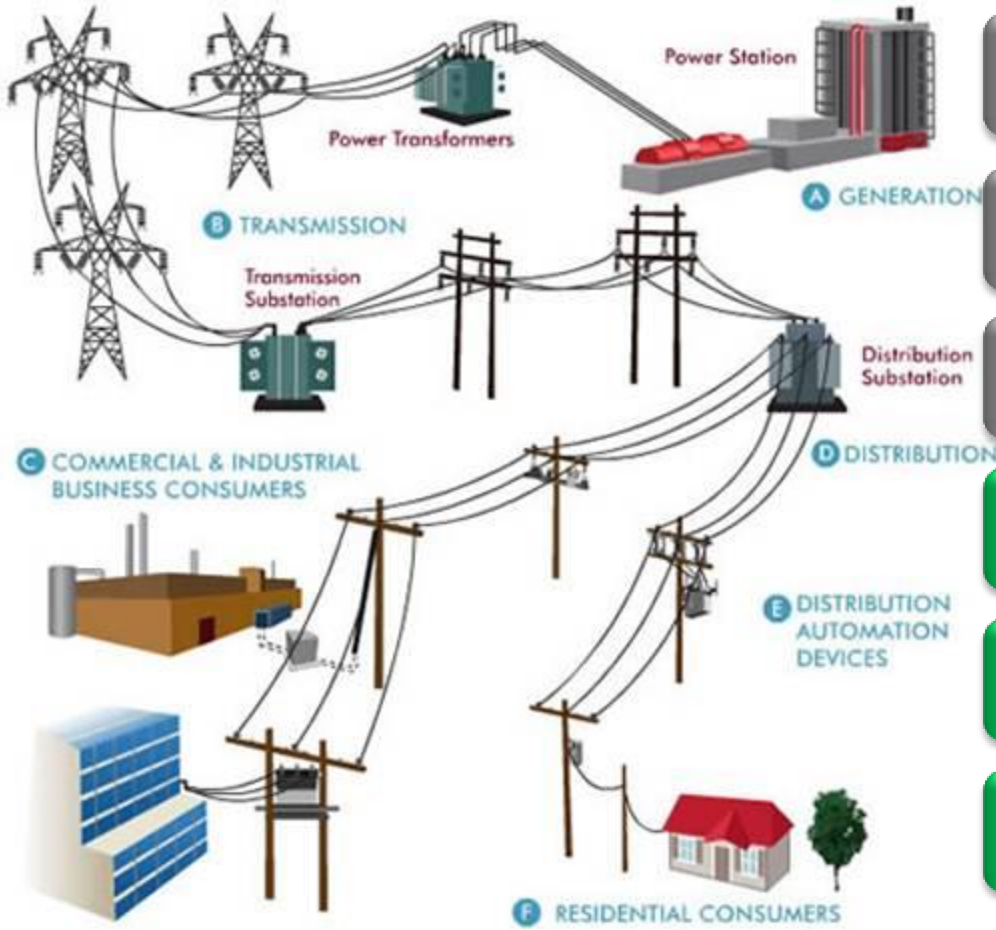
Information increase: how to deal with that? Standardization!



	# devices
Generation	**10^2**
Transmission	**10^2**
Primary Substation	**10^2**
Secondary Substation	**10^4**
Metering	**10^6**
Home Automation	**10^8**

Smart Grid, key roles and information sharing

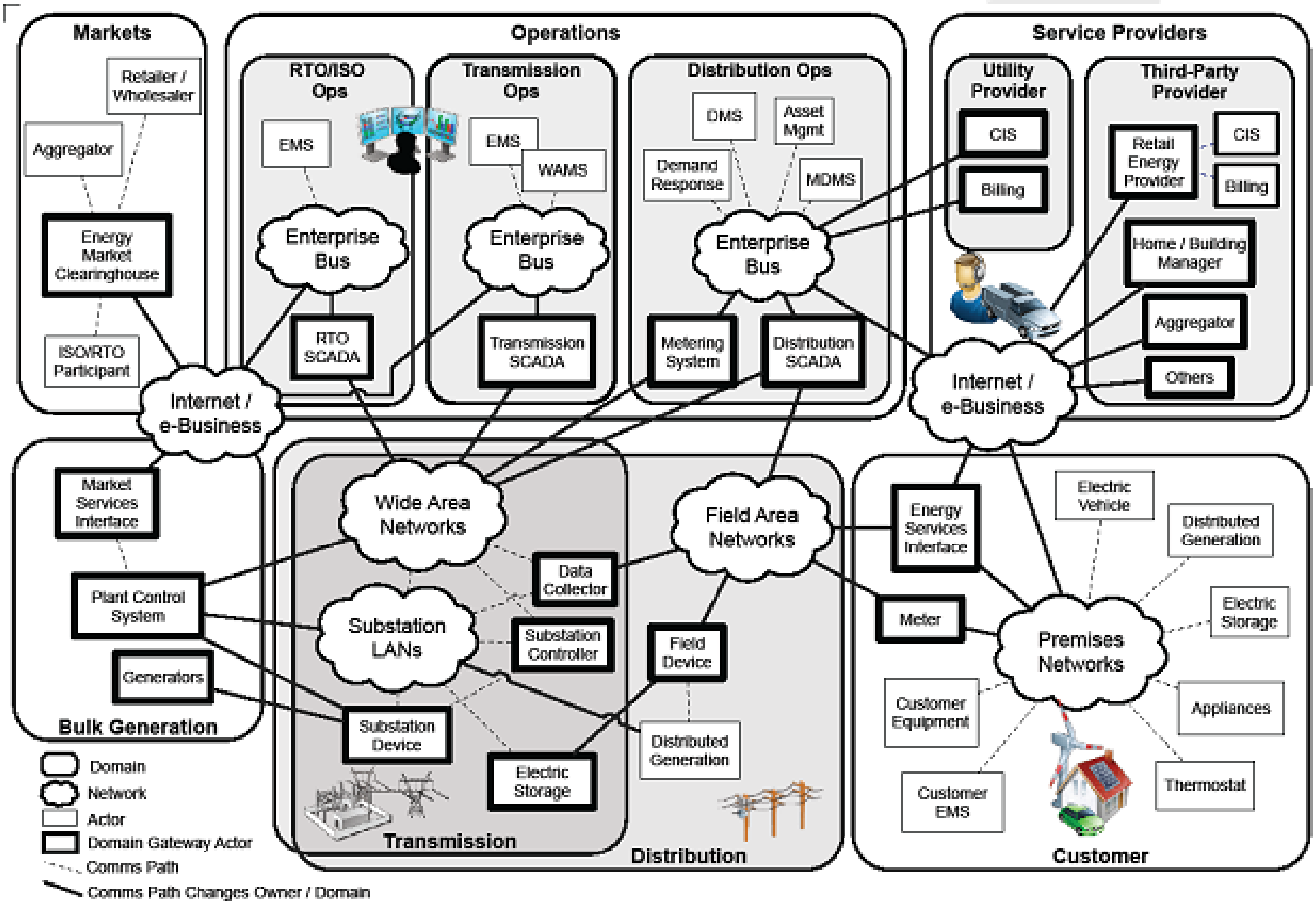
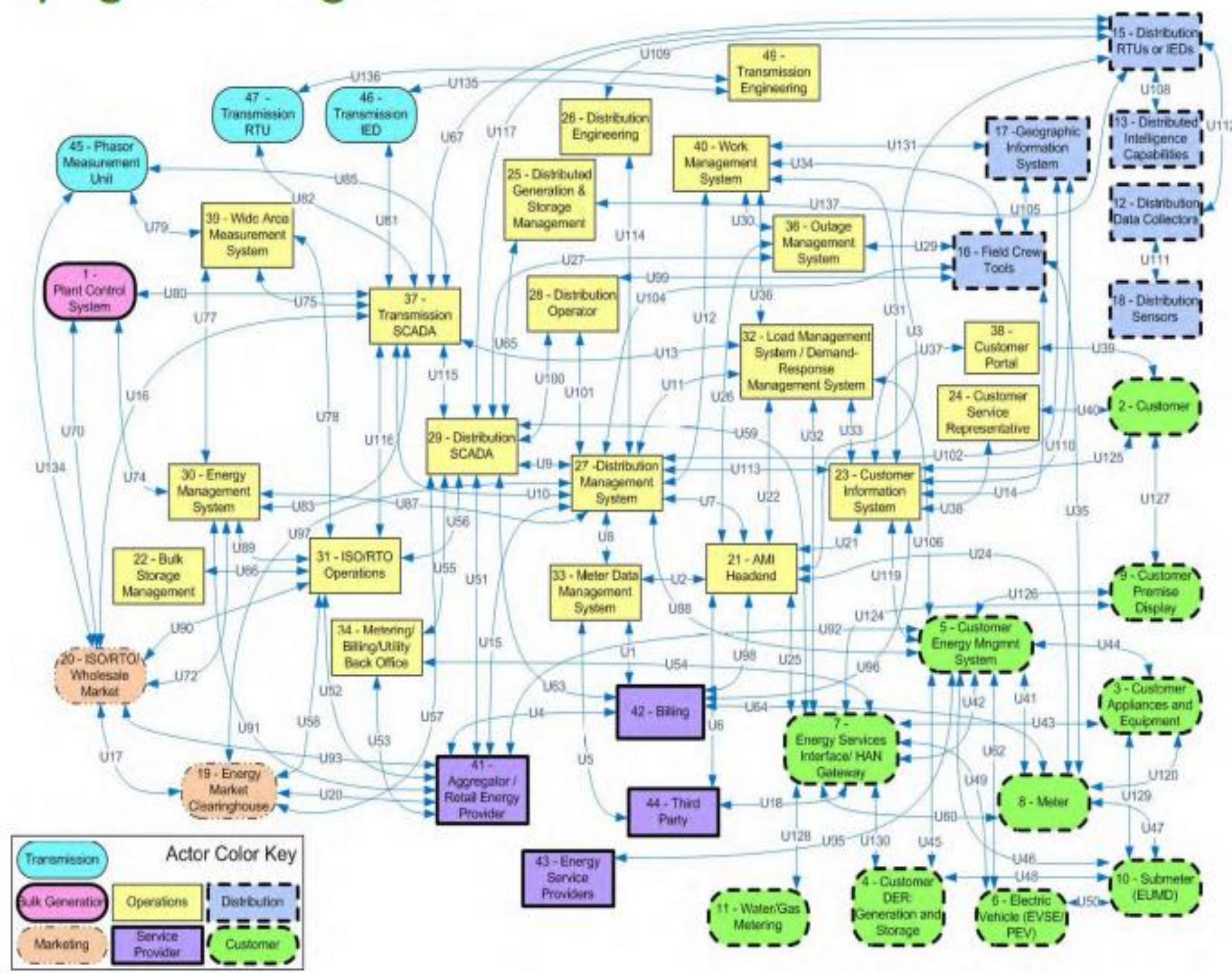


Figure 2.1 Information sharing components of the Smart Grid[7]

Information modelling and standards?

"NIST Spaghetti Diagram"



EC Mandate M/490

Under standardization mandate M/490 on smart grids deployment (published in March 2011 and accepted in June 2011), the ESOs have been tasked by the European Commission to deliver the following:

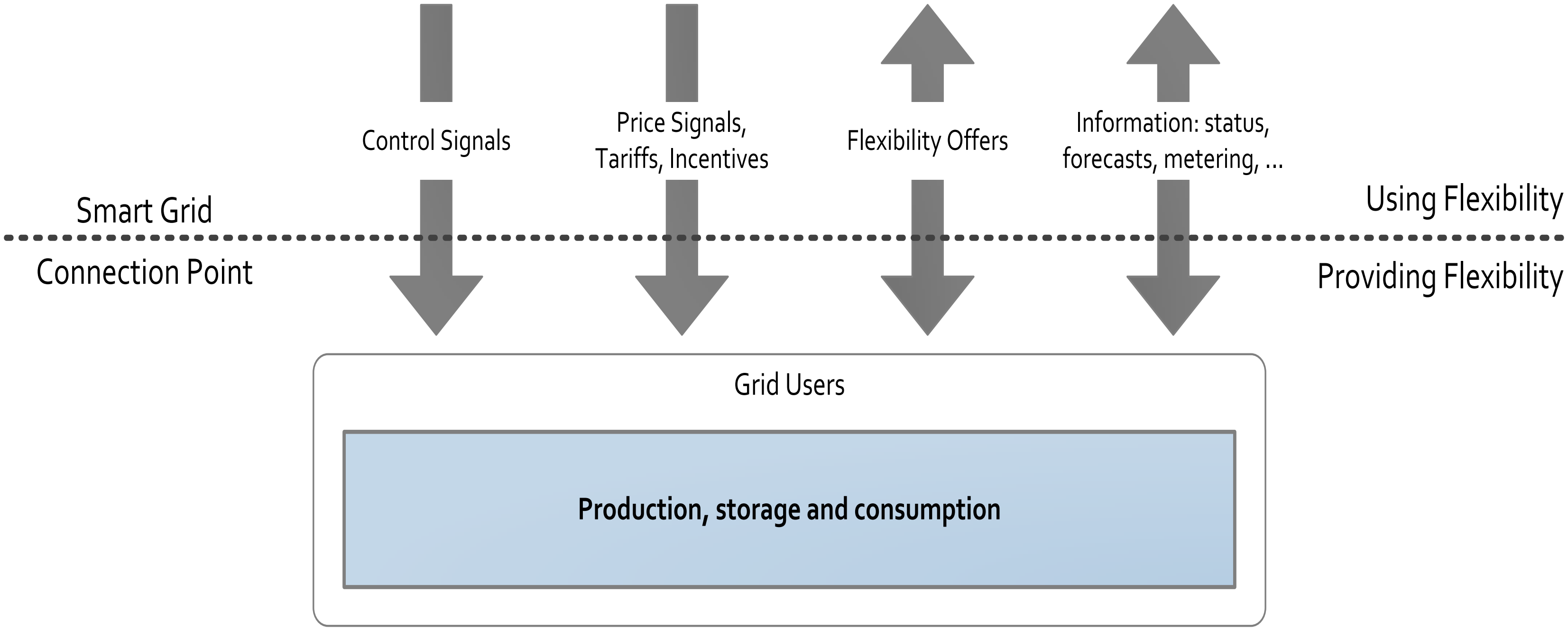
1. A **technical reference architecture** to represent the functional information data flows between the main domains and integrate many system and subsystem architectures.
2. A **set of consistent standards** to support the information exchange (communication protocols and data models) and the integration of all operators within the system.
3. Sustainable **standardization processes and collaborative tools** to enable stakeholder interaction, while also ensuring interoperability, security and privacy, etc.

A Smart Grid – Coordination Group (SG-CG) is set-up:

- Working Group on Methodology
- Working Group on Set of Standards
- Working Group on Interoperability
- Working Group on Security

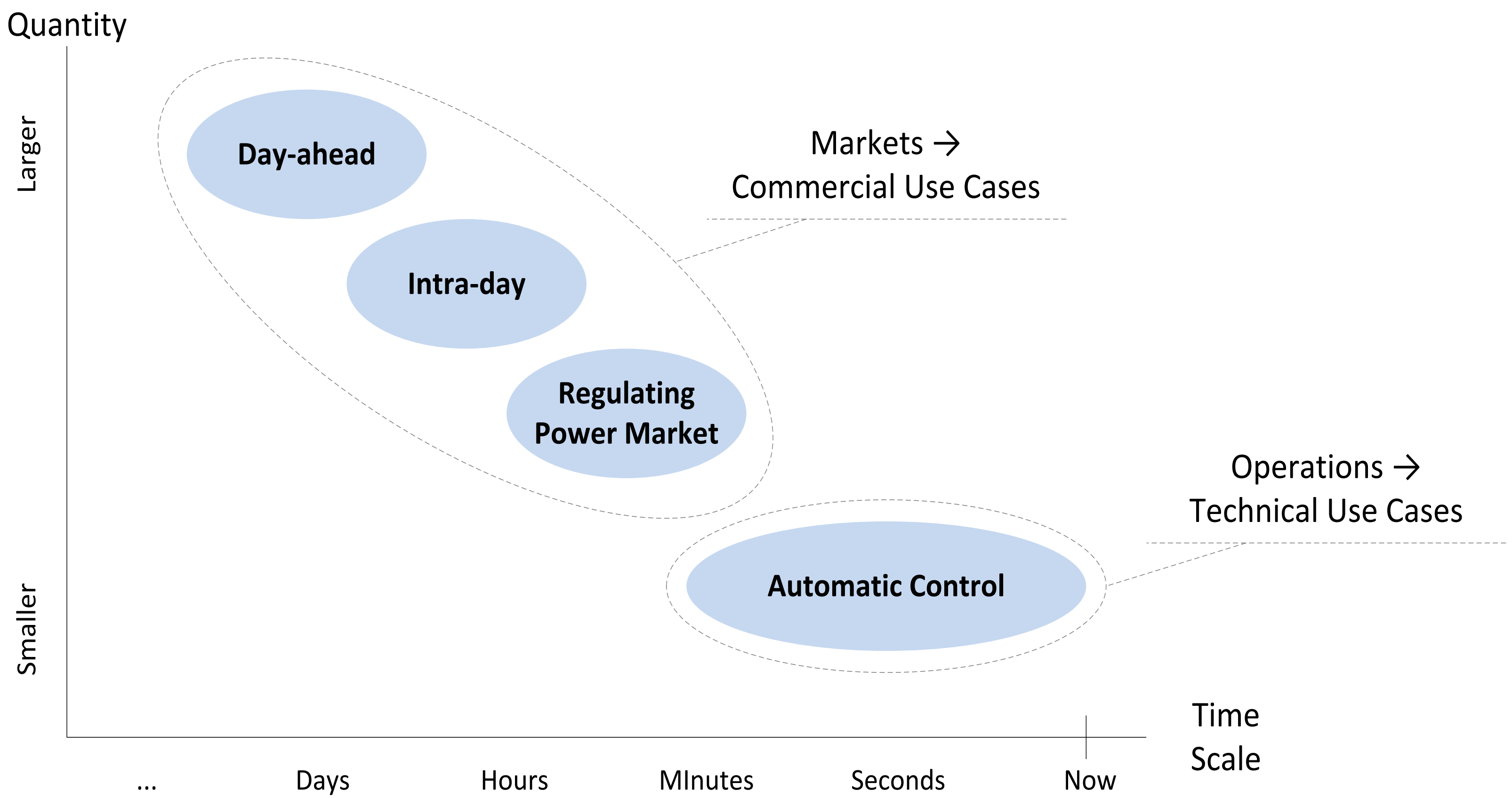
More info on:
www.cencenelec.eu/standards/Sectors/SustainableEnergy/Management/SmartGrids/Pages/default.aspx

SG-CG WG on Methodology



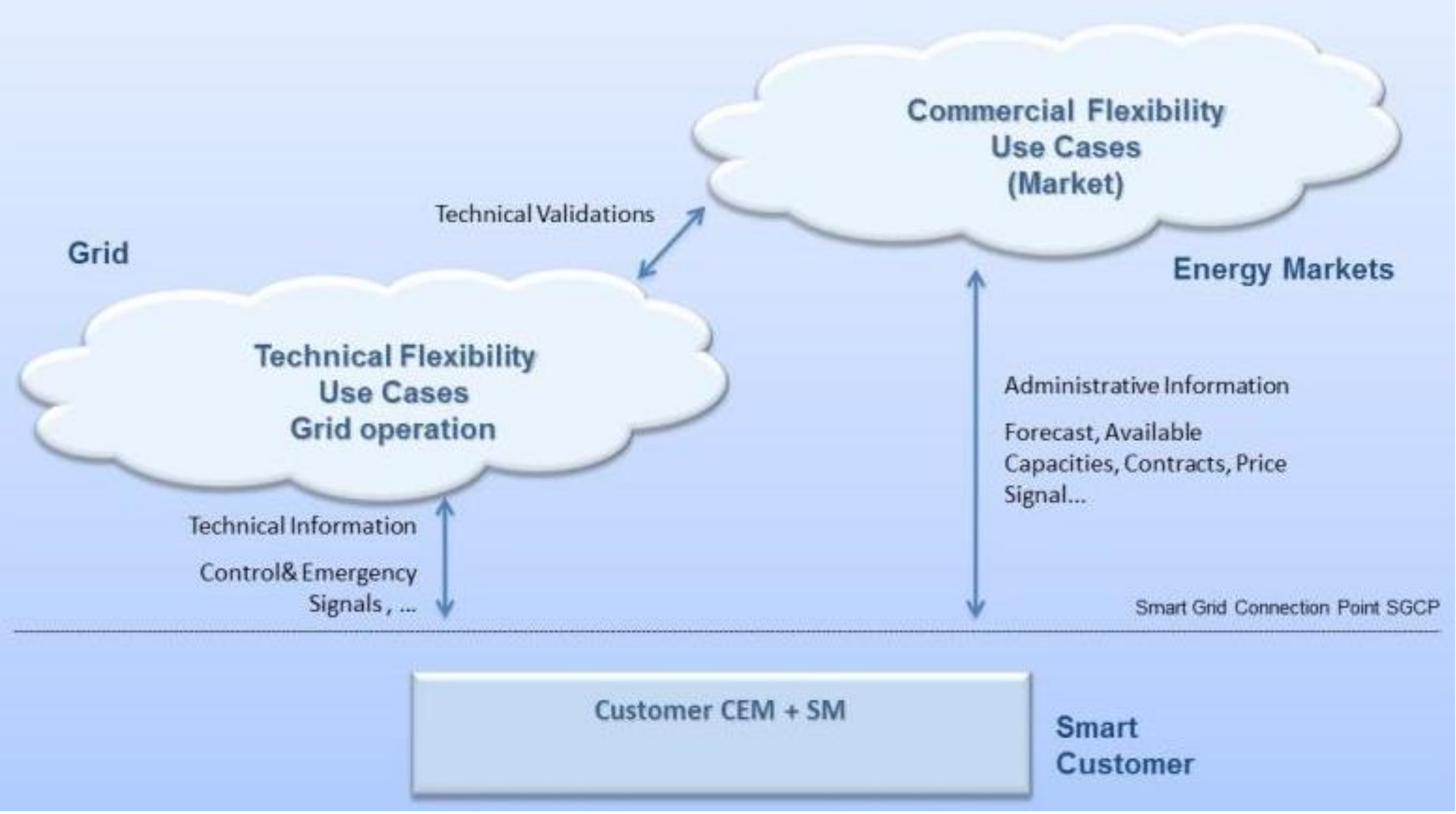
Interactions to provide/address flexibility of grid users

SG-CG WG on Methodology



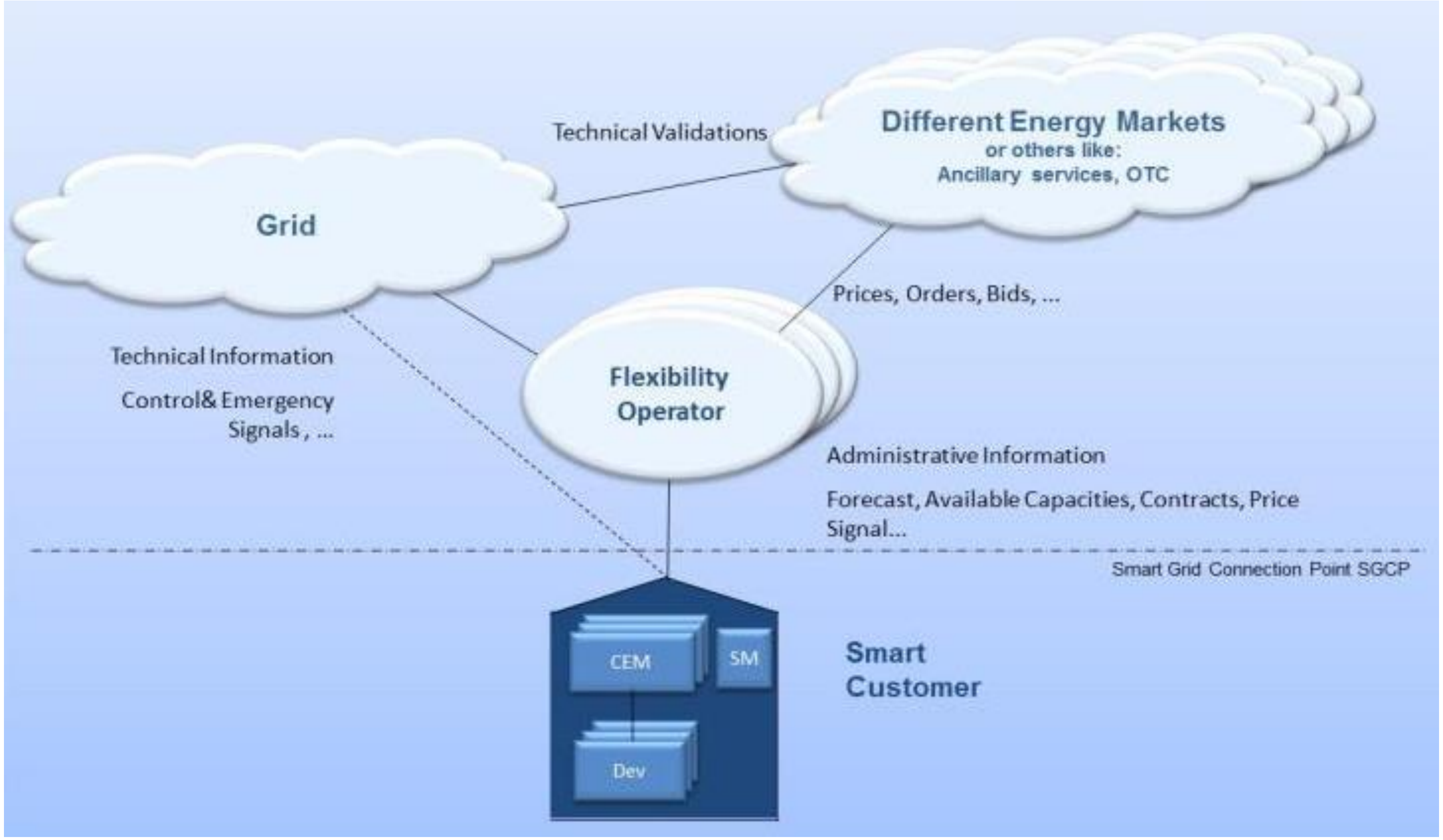
Use of flexibility on different time scales

SG-CG WG on Methodology



Commercial and technical flexibility use cases in the grid and market area

SG-CG WG on Methodology



Flexibility operator gathering flexibilities from different customers and sells them to end-users of flexibility (grid/system operators, commercial entities, etc.)

SG-CG WG on Set of Standards

› Information modelling

8	Gen-1 Dis-2	Harmonized glossary, semantic & modelling between back-office applications (CIM)) and field applications (IEC 61850))

› Distributed energy resources

10	Gen-3 Ind-2 HB-2	Extended field data modelling standard (part of IEC 61850) to support demand response, DER, VPP and home/building/industry automation Extended CIM to model more accurately Generation Fleet Management Applications in the case of Bulk Generation, and to integrate DER and VPPs Unified language for tariff information (for demand-response)

SG-CG WG on Set of Standards

	ID (from 1st iteration)	Gap summary (details available in Annex A) All gaps may not be 100% in the exclusive scope of M/490
1	PPC-1	Electronic Data models (glossaries alignment)
2	Com-1	Further develop power/distribution line communication
4	Dep-1	Check relevance of existing methodologies on smart grids (dependability - functional safety)
13	T1	HV-DC grid architecture
14	T2 Dis-6	Smart assets
15	T3	(transmission equipment fitting) offshore
19	Dis-5	Auxiliary power system standardisation
21	SM-2	Smart metering for Electrical Vehicles
24	Ind-4	Energy management harmonised data model for industry and power grid
40		Power Quality implementation guide in IEC 61850 (profile)
41		Data communication between Electrical Vehicle supply equipment and Electrical Vehicle operators and E-mobility Service Providers for E-mobility Smart Charging
42		Enabling to leverage on harmonized infrastructure security and administration standards across smart grid sectors and layers
43		Interoperable identification and billing capabilities in the Smart Grid
44		Applicability of Requirement Standards for Operation and Implementation of Security and Privacy Measures
45		Applicability of Solution Standards Implementation of IT Security Measures
46		Handling DER integration
47		Unified product data structure to support asset management
48		Data modelling for Micro Grid Management
49		Handling storage as a DER
50		System management

SG-CG WG on Set of Standards

Table 5: List of selected Gaps - To be included in future Work Programme

	ID	Gap summary (more details available in Annex A)	Gap Impact	Standardisation chance	Consensus level	TCs directly involved - CLC as default	Concerned standards	WG affected within the selected TCs	already engaged work
49		Handling storage as a DER	3.9	3.3	8.0	IEC TC 57, TC 8, TC 120, details in annex A	IEC 61850 series and IEC 61968 series	TC 57: WG 14, 17, 10 and 21	IEC TC 57 with IEC 61850-90-15 and IEC 62746
46		Handling DER integration	4.5	3.2	10.0	CLC TC 8X, TC 13 IEC TC 8, TC 57	IEC 61850 series and IEC 61968 series and IEC 62325	TC 57: WG 14, 17, 10 and 21	IEC TC 57 with IEC 61850-90-15 and IEC 62746 and IEC 61968 series
44		Applicability of Requirement Standards for Operation and Implementation of Security and Privacy Measures	4.1	3.0	8.0	IEC TC65 ISO/IEC JTC 1 SGCG WGIS	IEC 62443 series	WG 10 SC27	To be identified
45		Applicability of Solution Standards Implementation of IT Security Measures	4.3	2.9	11.0	IEC TC22 TC57 TC13 SGCG WGIS	IEC 62351 series IEC 62056-5-3	SC3 WG15 WG14	Details in annex A

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Handling DER as a storage

- Provide data model and any other communication standards to enable to **remote monitoring and controlling** of a storage installation (or an installation with storage capabilities) and especially to **manage its status** related to its connection to the grid (loading, storing, producing, forecasted capabilities, etc)
- **TCs/WGs to be involved:** CLC TC8X, IEC TC8, IEC TC120 IEC TC57 WG10/14/17/21, IEC PC118, IEC TC64, IEC TC22, TC69, CLC TC13
- **Affected standards/work items:** (IEC and other SDOs) IEC 61850 series, IEC 61968 series

Handling DER integration

- Provide harmonised data model and any other communication standards to **manage DER**, in aggregated mode or not, and to **integrate them to the operation and enterprise levels of Utilities**, etc, different groups of DER are involved. The idea is that we will not specify the gap for each individual group of DER.
- **TCs/WGs to be involved:** CLC TC8X, IEC TC8, PC 118, IEC TC57 WG10/14/17/21,CLC TC13 for checking metering requirements
- **Affected standards/work items:** (IEC and other SDOs) IEC 61850 series, IEC 61968 series, IEC 62325 series (regarding the communication with market)

IEC TC 57 WG 21

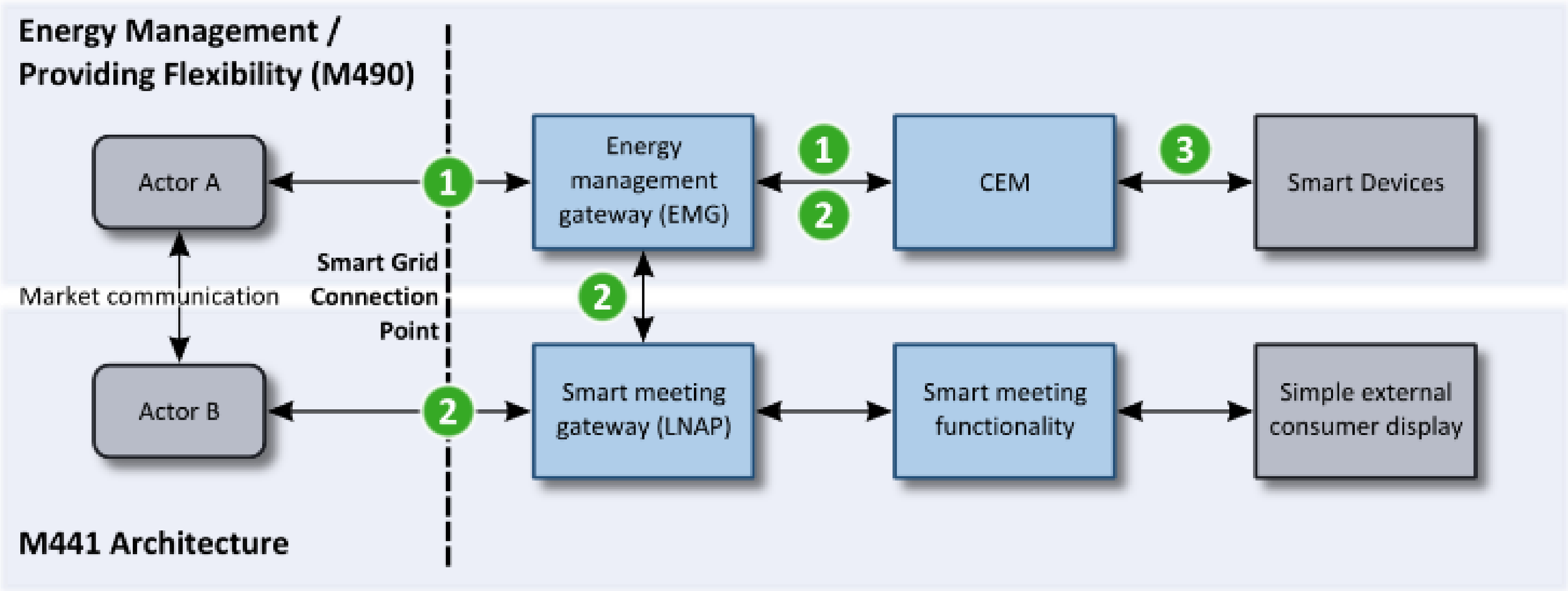
- Development of 62746 series of standards:

Systems interface between
customer energy management system
and the power management system

Ed. 1.0:	approved new work
Part 2: Use cases and requirements	1st draft
Part 3: Architecture	1st draft

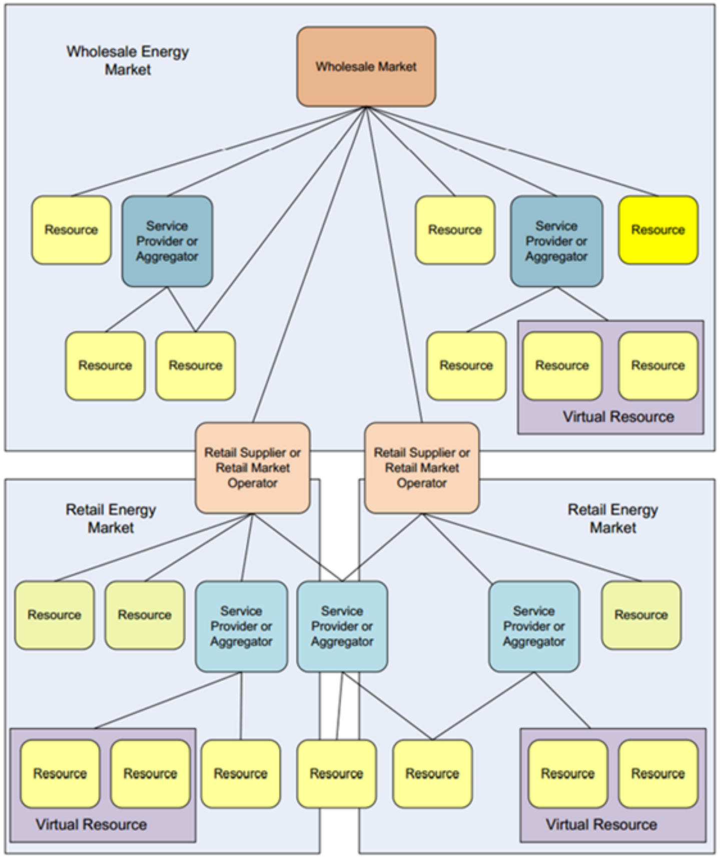
Part 2: Use cases and requirements

- Defines use cases / user stories and analyze requirements for the information exchange on the Smart Grid Connection Point
- 27 use cases identified covering various topics from laundry, to EV charging and grid stability issues to selling flexibility.



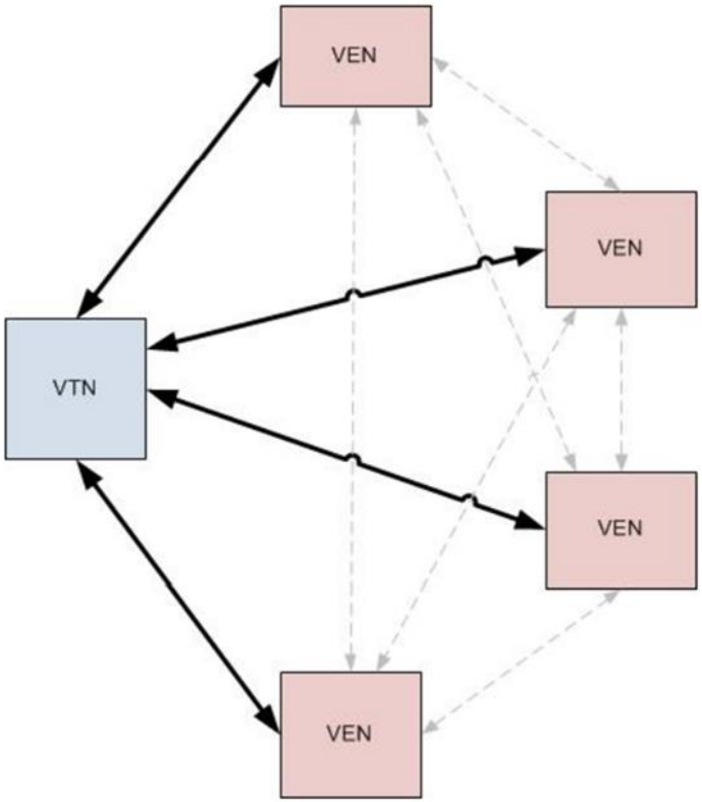
Part 3: Architecture

- Considers various actors and roles:
  - Energy Resources and Virtual Energy Resources
  - Service Providers / Aggregators
  - Wholesale market
  - Retail market
  - Retail suppliers



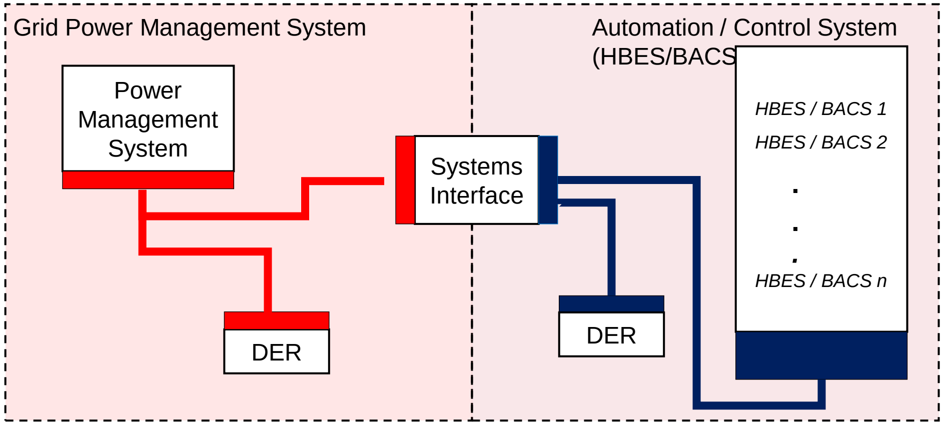
Part 3: Architecture

- Applies Virtual Top / End Node structure from OpenADR
- Establishes basic messaging patterns:
  - Request / reply
  - Queries
  - VTN originated broadcasts
  - Publish / subscribe



CLC TC 205 WG 18

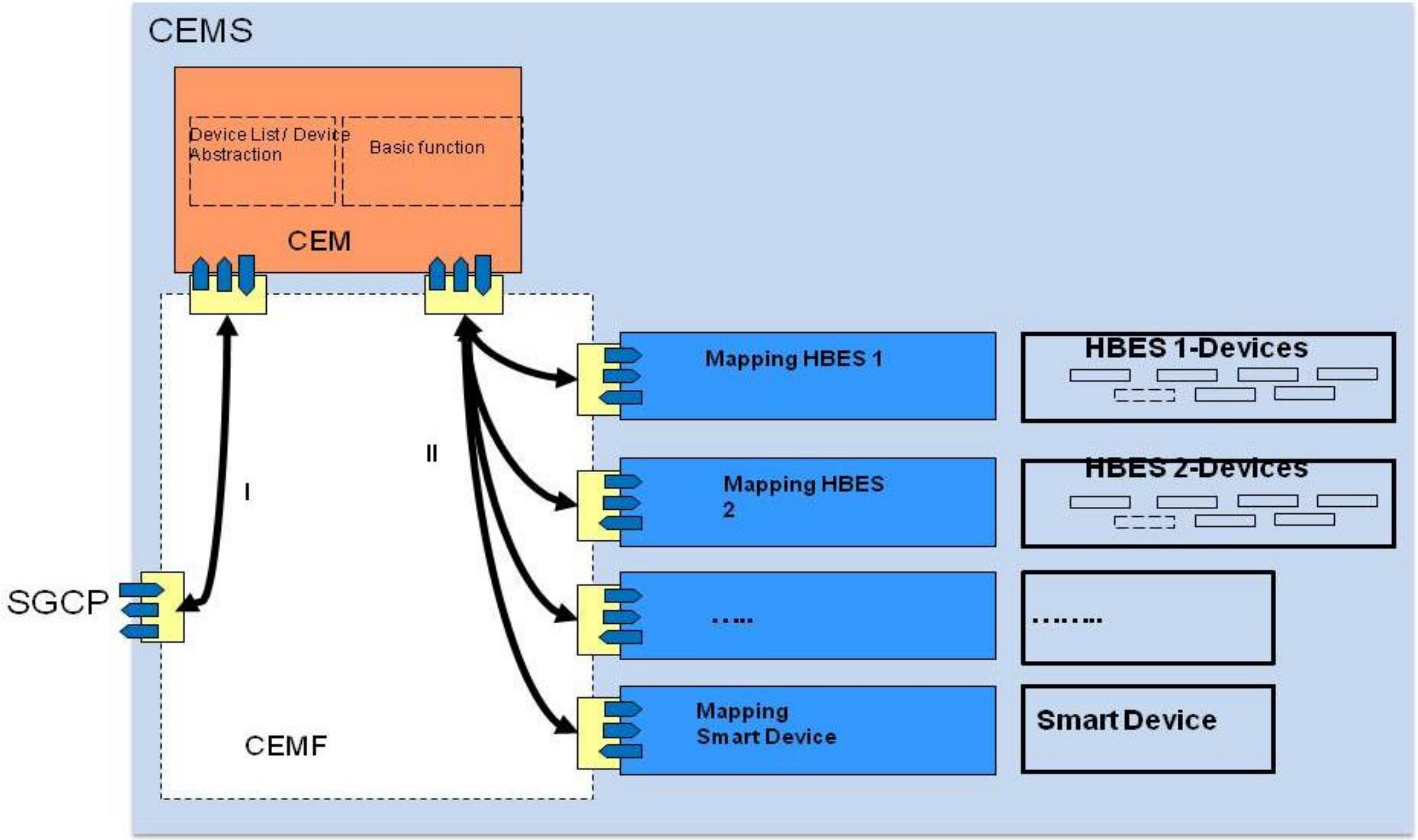
- Develops prEN 50491-12 Goal to map the SGCP to various HBES protocols via a CEMF as part of a CEMS



- CEMF = Customer Energy Management Framework
- CEMS = Customer Energy Management System
- prEN = Proposed European Norm
- SGCP = Smart Grid Connection Point
- HBES = Home Building Electronic System
- BACS = Building Automation Control System

Architecture overview

› Relationship between CEM, CEMF and HBESs



Interface mapping elements

- CEMF functions:
  - HBES recognition
  - Device recognition
  - Device capabilities / configuration
  - System runtime operation
- CEMF data structures related to time, energy, measurement units, etc.
- Function Profiles
  - actuatorSwitch
  - actuatorLevel
  - Tariffs / incentive values

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Flexiblepower Alliance Network

- The Flexiblepower Alliance Network (FAN) is an **open industry alliance** for the **development and promotion** of semantic (de facto) standards, with respect to communication of and communication with energy consuming and producing devices for end users. These standards will **facilitate** the emergence and use of **energy services**, on a **uniform, accessible and cost-effective** manner.
- FAN wants to **stimulate the implementation** of the FAN standards in energy devices and services, by offering the standards and a reference implementation as open source and enabling the industry with implementation support tools.
- FAN currently consists of Alliander, Accenture and TNO

Challenges with IT in the smart grid

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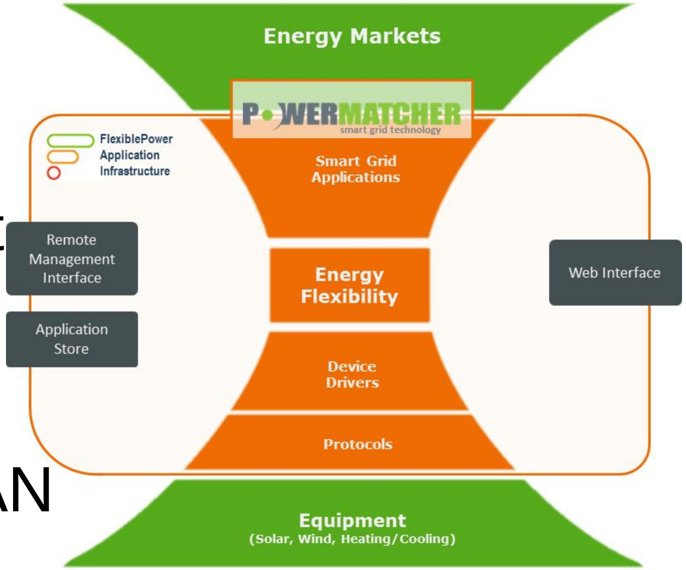
Standardization challenge!

- A lot of activity around local power generation and flexibility, also in different standardization arenas
- Danger of full-stack stove-pipe standards that are incompatible at the various layers!
- Decoupling of layers like in the FAN approach is necessary!



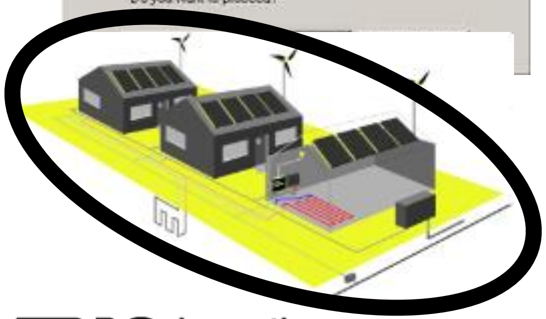
Security challenge!

DNO → Responsible for control

DNO → Network in danger = take action''

Certification Authority role for DNO?

- *All* SmartGrid equipment registered !!
- *All* SmartGrid equipment known
  (remote control) behavior standard
- *Some* SmartGrid equipment forms a local (control) syste and use security certificates to communicate



Thus….

- Dealing with flexibility is a solution to local balancing
- Local balancing requires control in local area and the home
- The DNO is responsible for grid stability and security of supply
- Local control requires standard control behavior and security
  - which is not obvious !!

The DNO is in the position to pick up the role of security authority

The DNO is responsible for the security of electricity network, but…

also for the data network?

Main challenge

Smart grid becomes “enriched” by ICT components

How can we get this critical infrastructure secure and standardized enough?

Questions

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