UNIVERSITEIT GENT

FACULTEIT INGENIEURSWETENSCHAPPEN

Smart Grids & The role of ICT

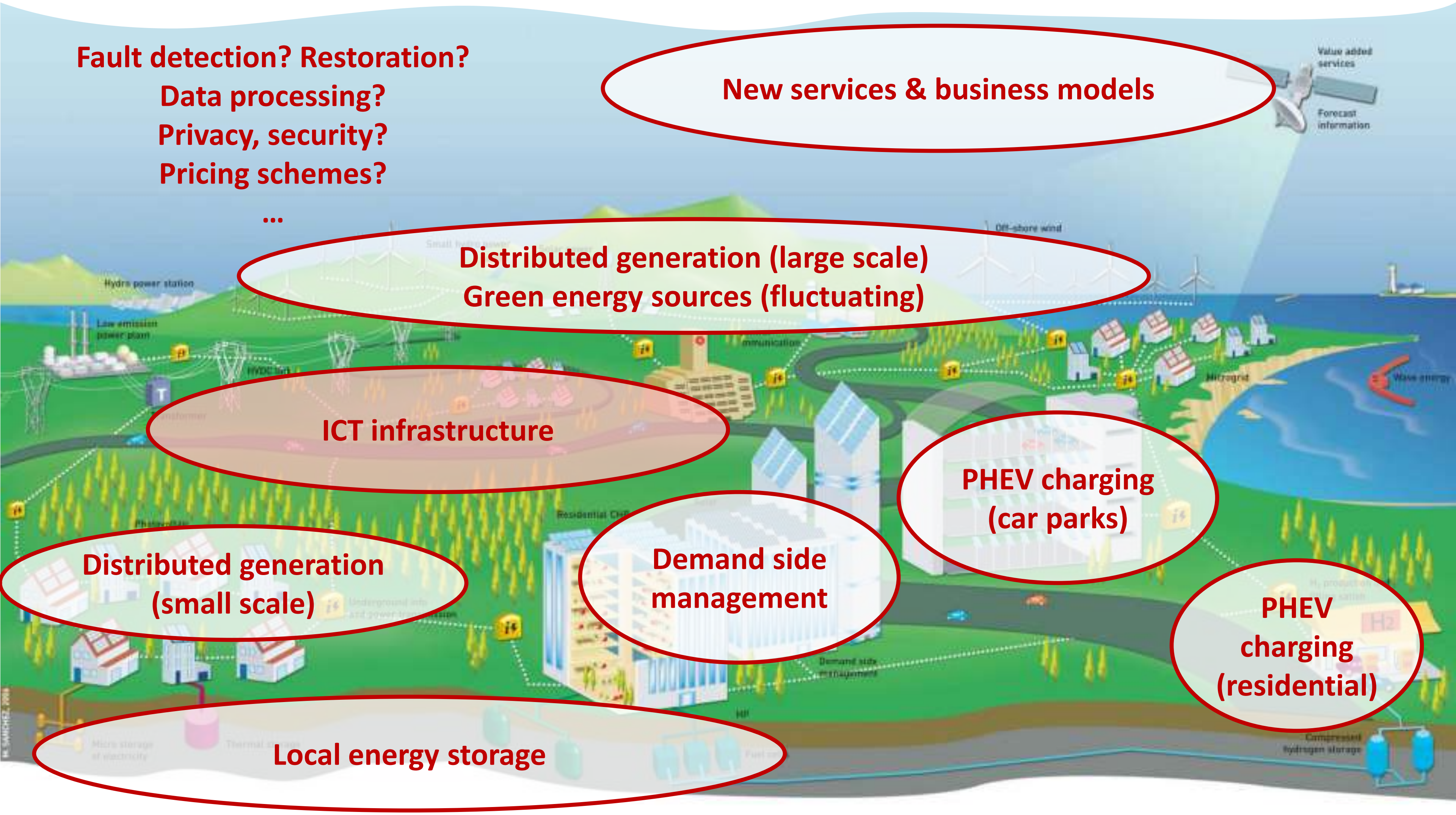
Chris Develder, W. Haerick, K. Mets, F. De Turck

Ghent University – IBBT, Belgium

ibbt

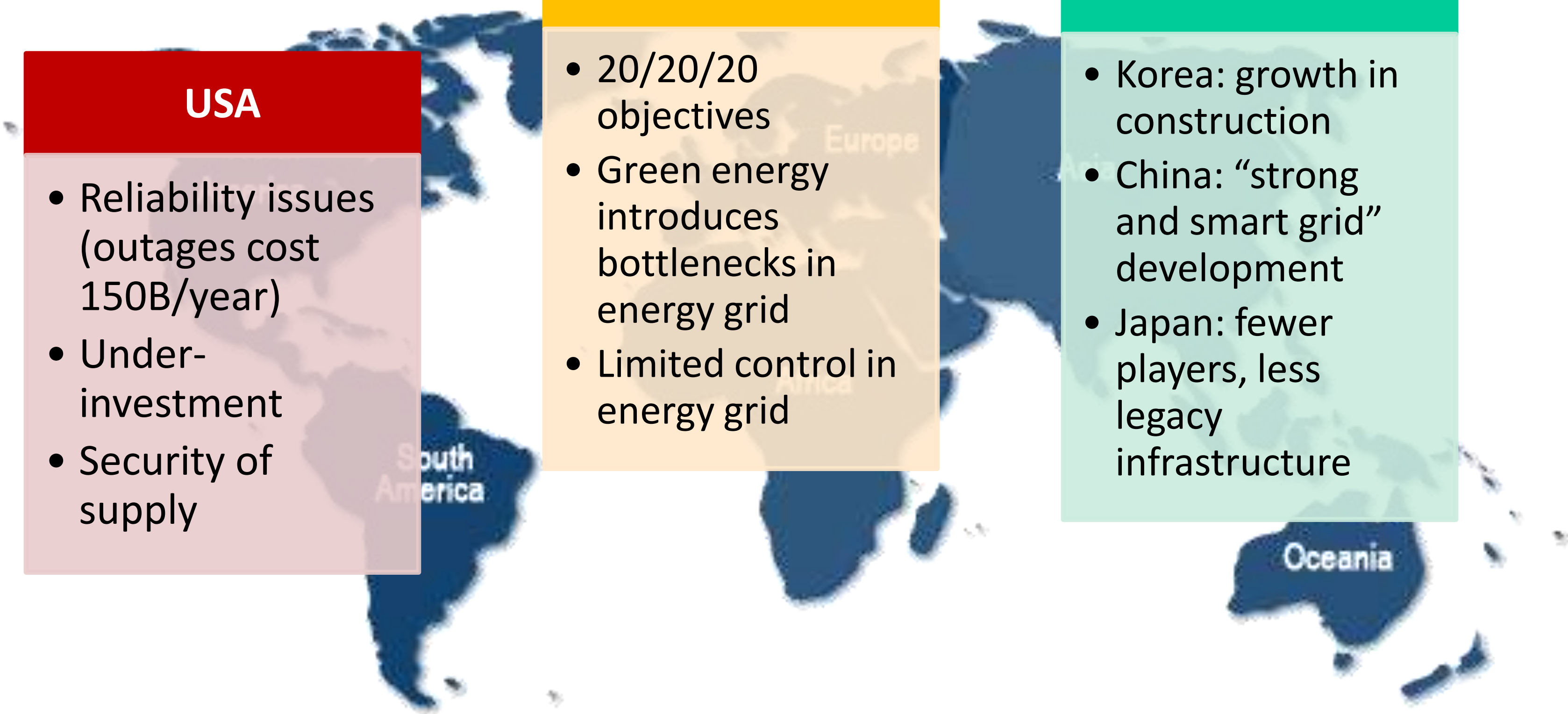
INTEC

Smart Grids



Fault detection? Restoration?
Data processing?
Privacy, security?
Pricing schemes?
…
New services & business models
Distributed generation (large scale)
Green energy sources (fluctuating)
ICT infrastructure
PHEV charging
(car parks)
Distributed generation
(small scale)
Demand side
management
PHEV
charging
(residential)
Local energy storage

Smart Grids: Driving factors[IEC]



USA

- Reliability issues (outages cost 150B/year)
- Under-investment
- Security of supply

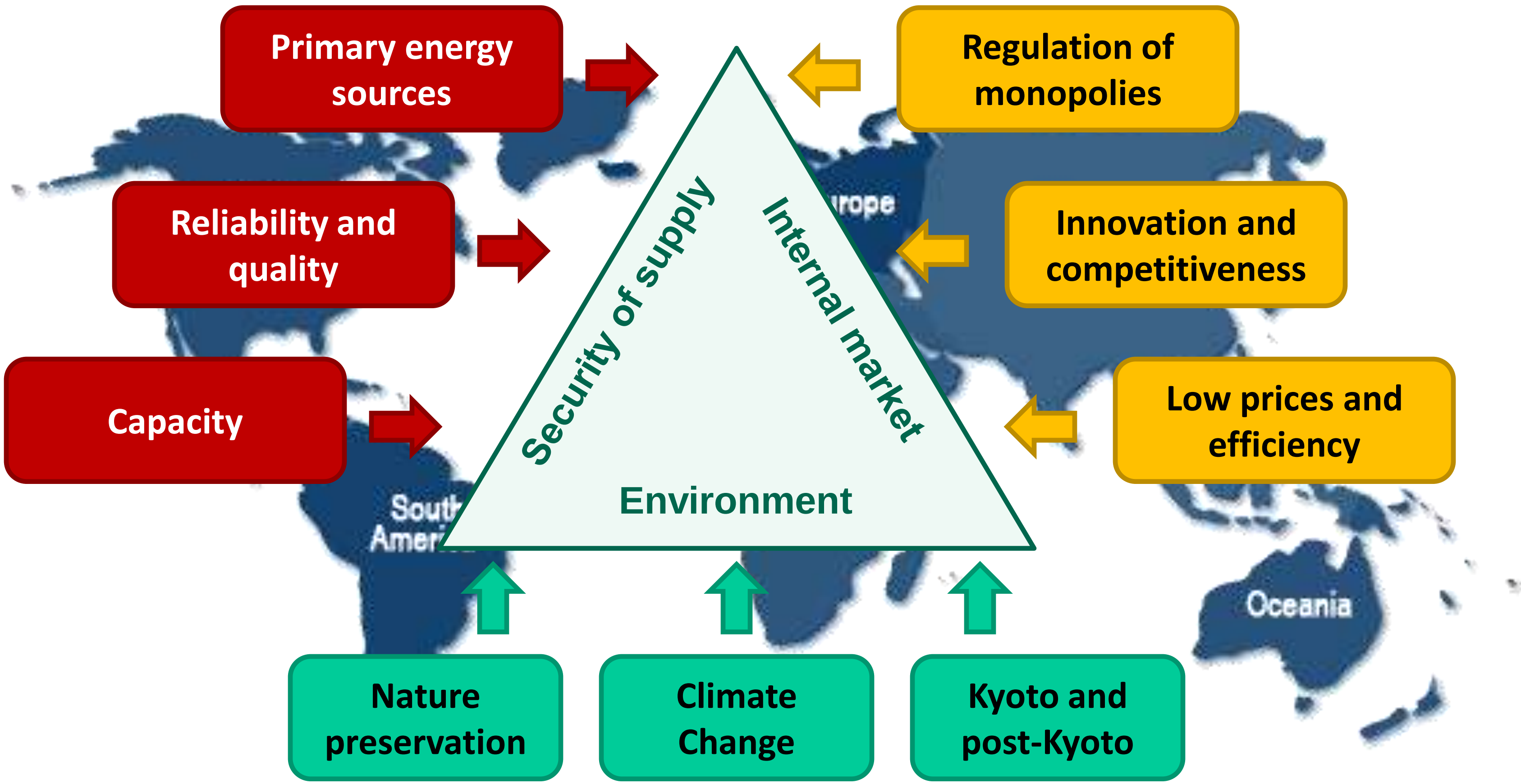
EU

- 20/20/20 objectives
- Green energy introduces bottlenecks in energy grid
- Limited control in energy grid

Asia

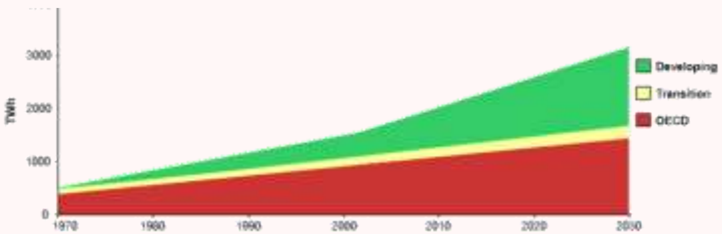
- Korea: growth in construction
- China: “strong and smart grid” development
- Japan: fewer players, less legacy infrastructure

Smart Grids: Driving factors[Bot10]



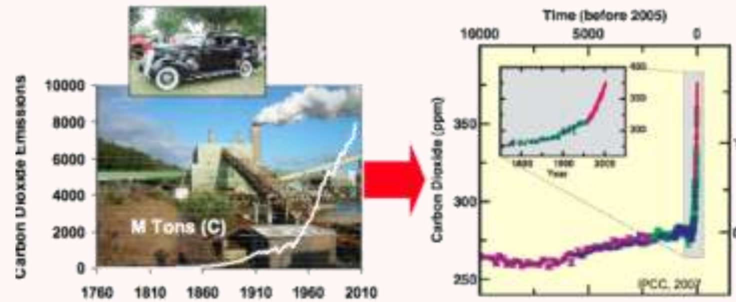
Long-term goal: Sustainability

Manage increasing energy demand



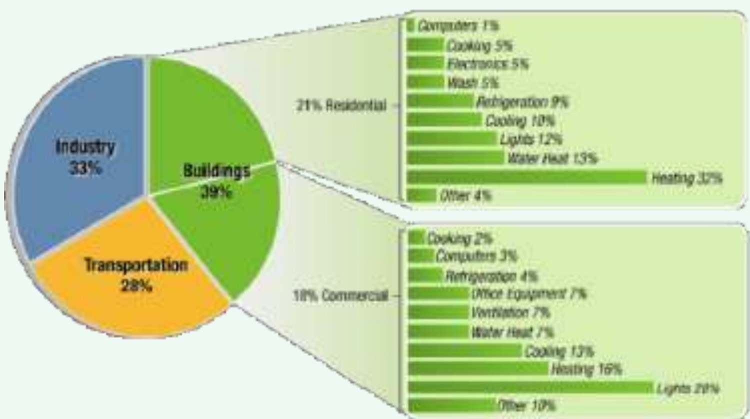
Source: IAEA

Manage CO_2 footprint



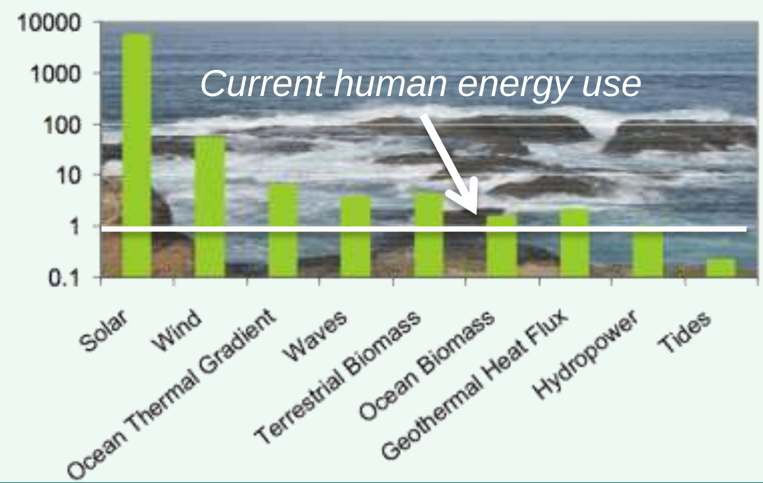
Source: Stanford Univ.

Efficiency



Source: Lawrence Berkeley National Laboratory

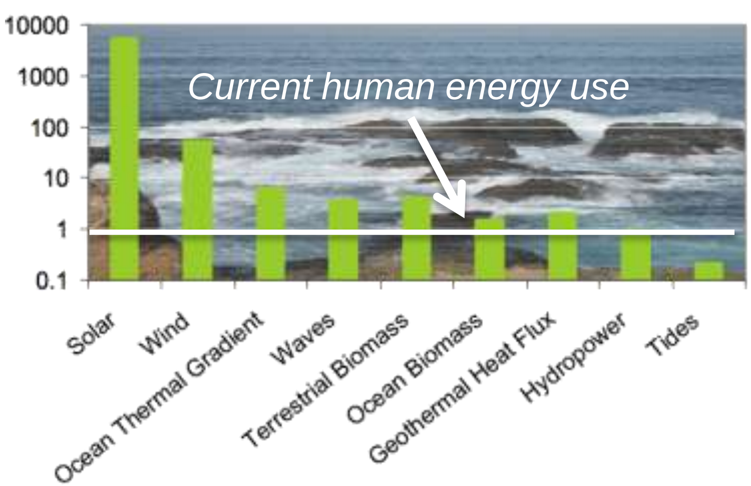
Affordable green

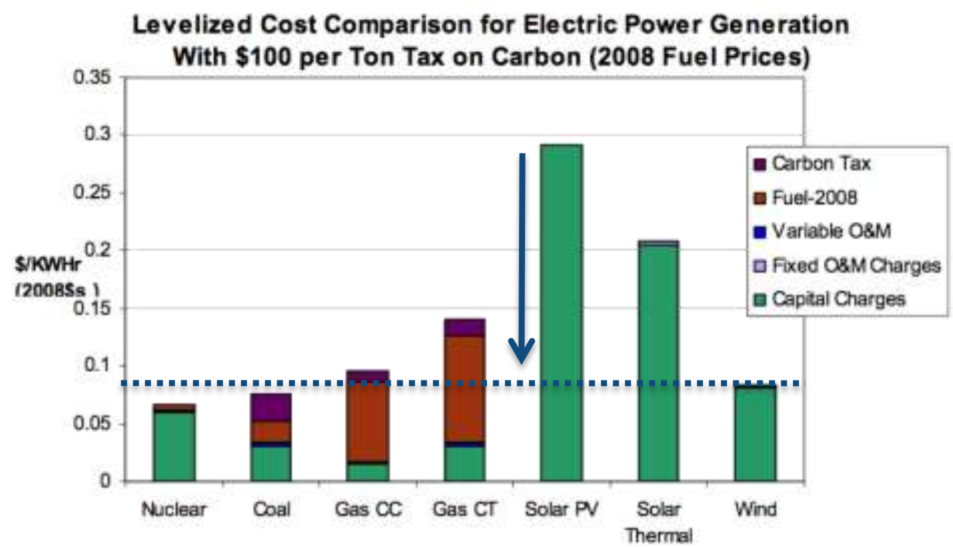


Long-term goal: Sustainability

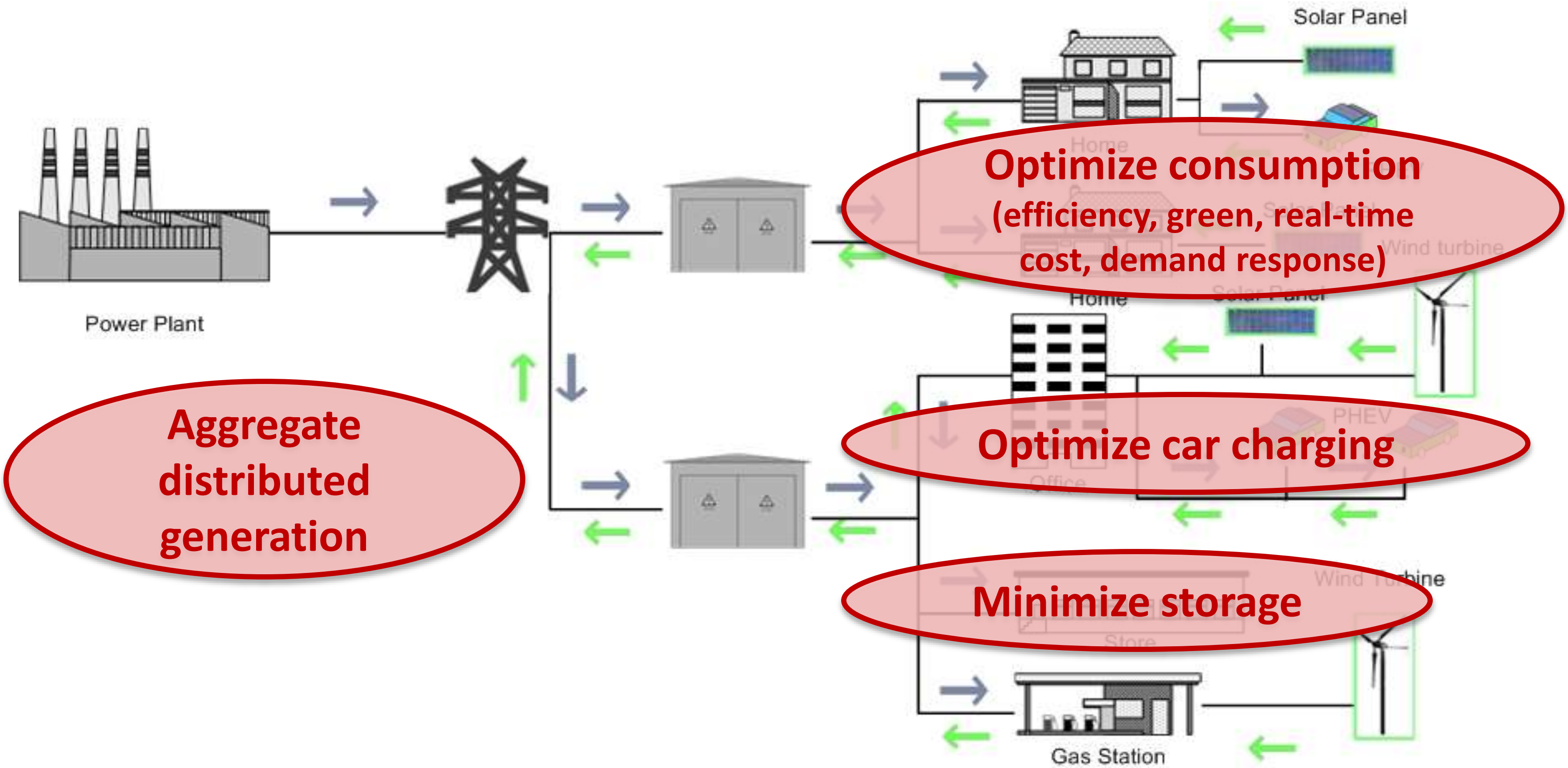
- Solar and wind are largest source for renewable energy
- However,
  - These sources suffer from fluctuations and geographical distribution
  - Energy storage is needed, and a more capable energy grid
  - Cost per kWh needs to decrease

⇒*ICT as enabler for cost reduction*





ICT as enabler: Minimize costs, optimize profit…



ICT as enabler: Demand-response

- What?
  - Voluntary, temporary adjustment of power demand by end-user or counter-party in response to market signal (e.g. price, emergency, etc.)
- Two main forms:
  - Direct Load Control
  - Price Response
- Enabling technology:
  - Automation (rule-based)
- Still subject to human behavior
  - user overrides possible

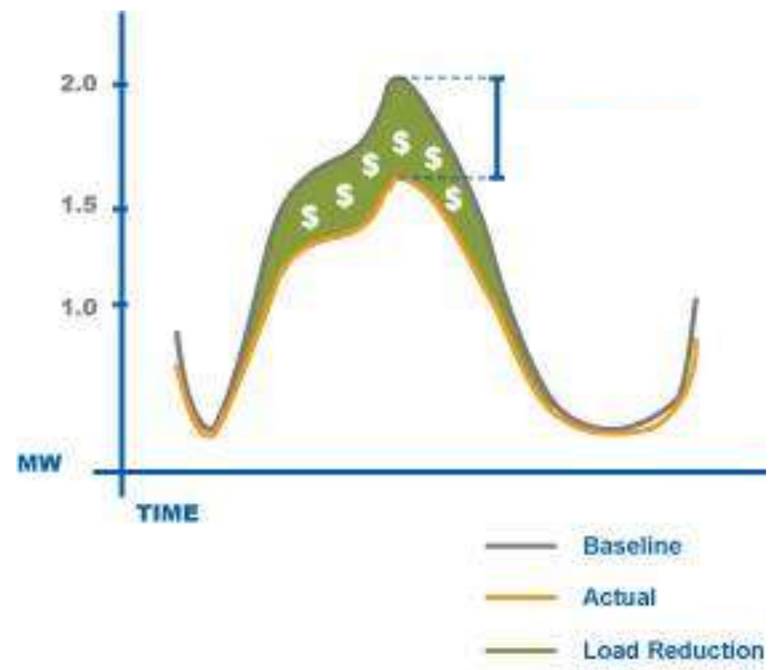


Image source: GDF Suez

Outline

- Introduction
  - Why smart Grids (now)?
  - Sustainability challenges…
- Current solutions
  - Architectures, standards, products…
- Research challenges
  - European projects
  - Vision
- Simulation tool
- Wrap-up

Current solutions
ICT architectures

Smart Grid ICT architectures

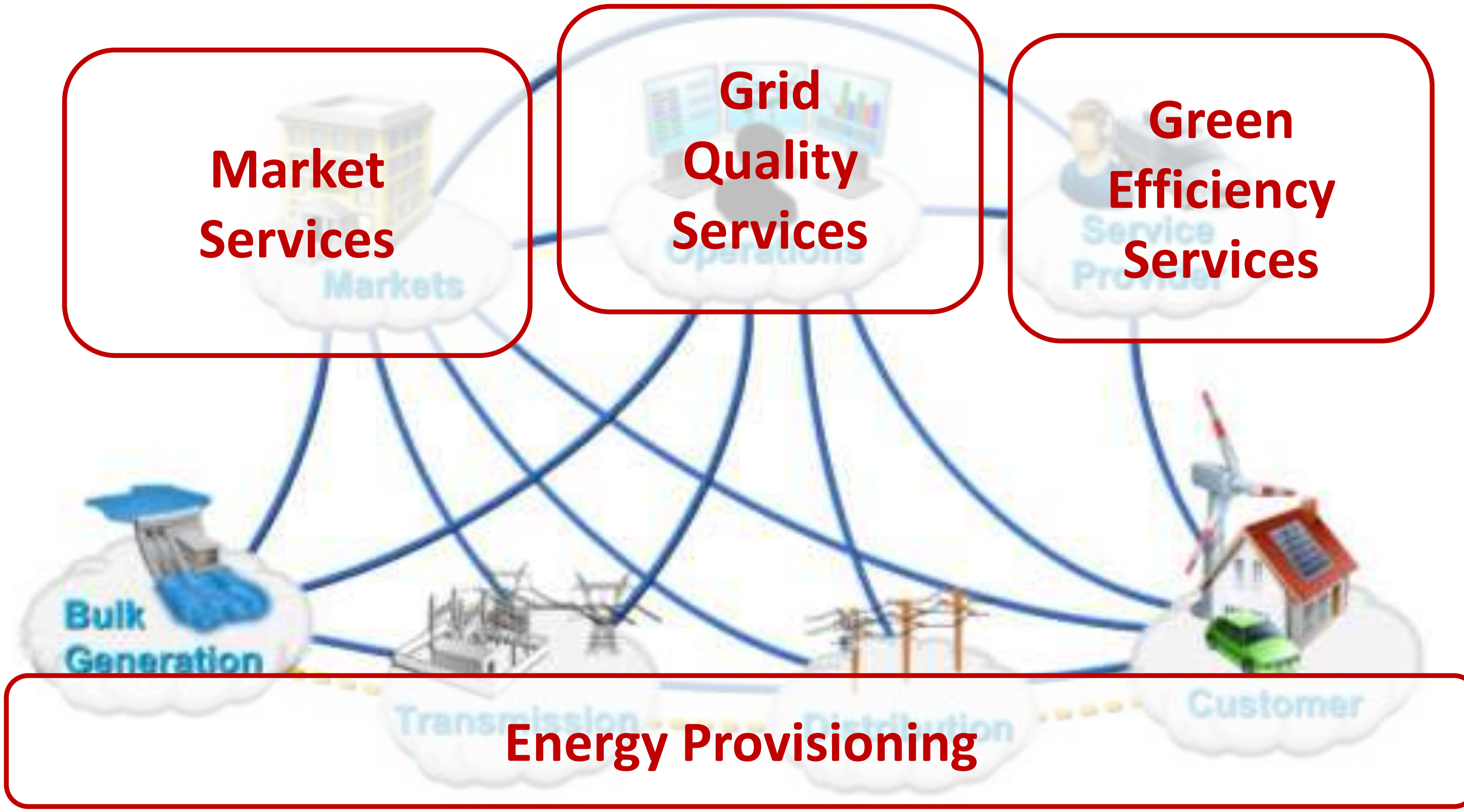
- Currently, closed solutions to control parts of energy grid:
  - SCADA (Supervisory Control and Data Acquisition)
  - EMS (Energy management systems)

⇒ not based on standards (multiple protocols)

⇒ Limited visibility: e.g. only energy transmission network, or substations

> There is a need for an OPEN architecture:
> - OPEN in terms of standard interfaces
> - OPEN in terms of players/actors

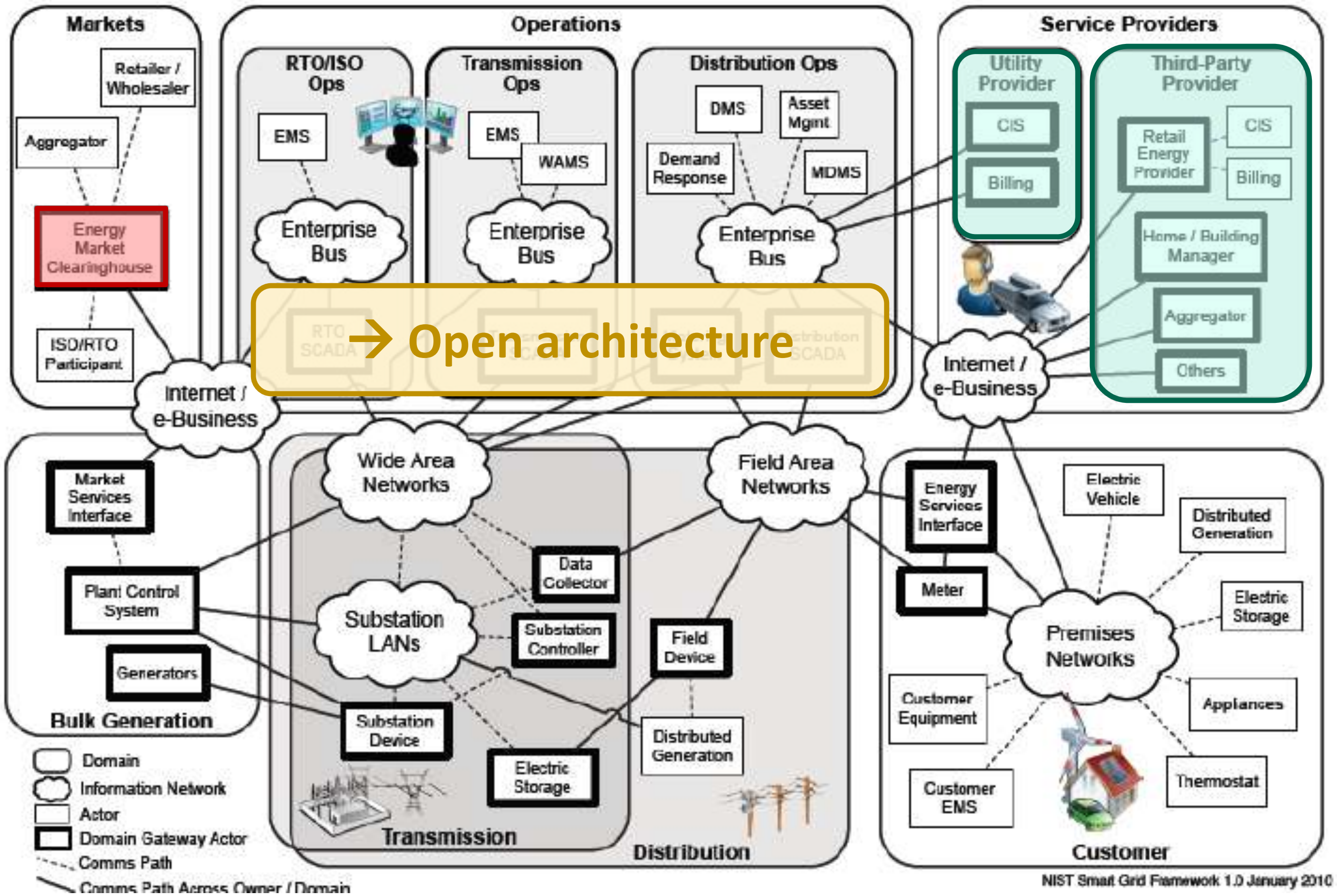
Smart Grid ICT architectures: Domains



Source: IEC (http://www.iec.ch/zone/smartgrid/grid_about.htm)

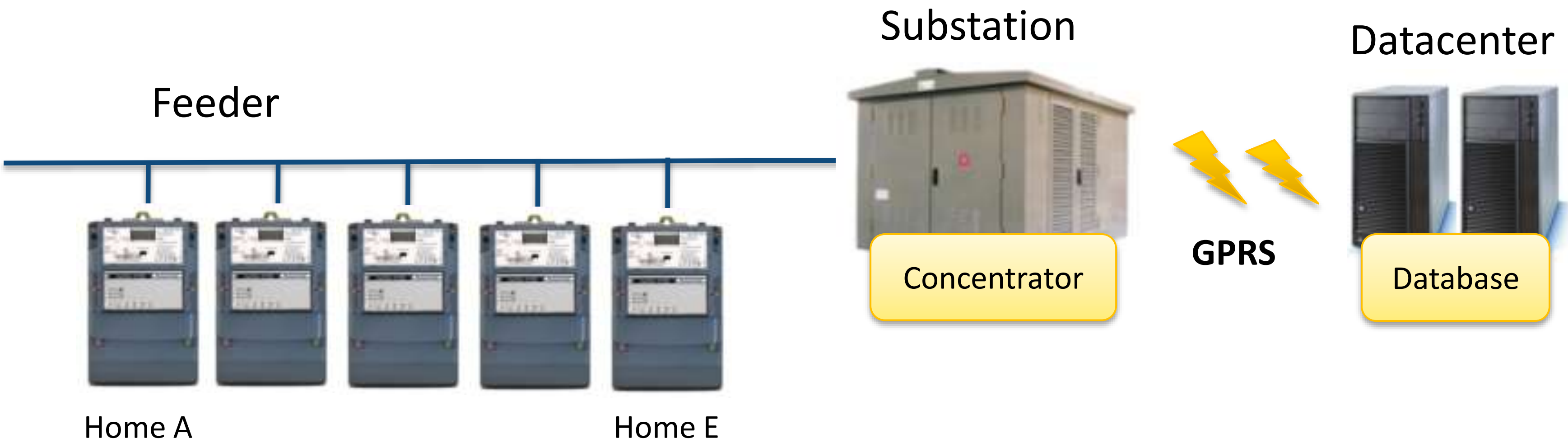
Smart Grid ICT architectures

Market services



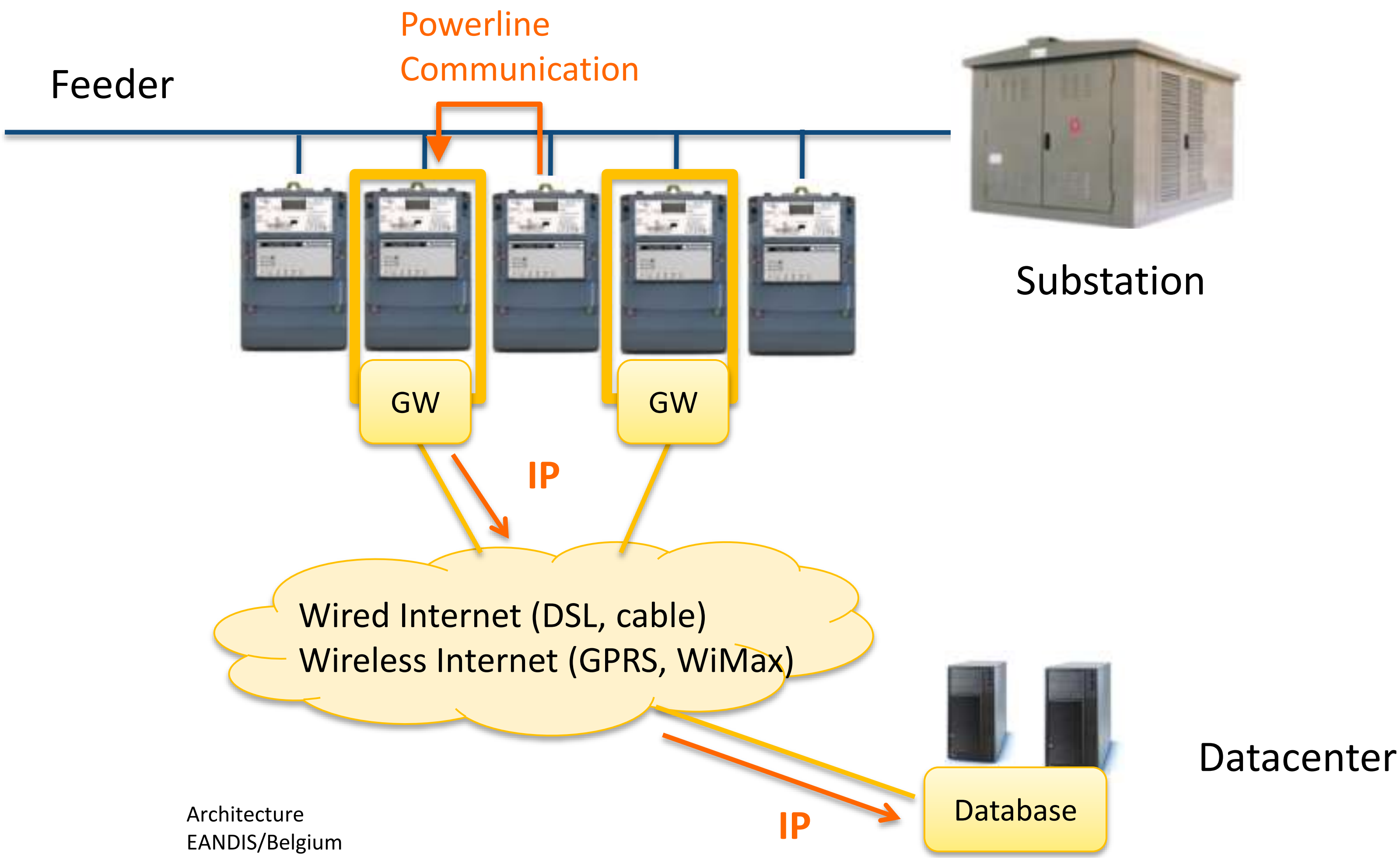
Utility & 3rd party services

Smart Grid ICT architectures: Last mile



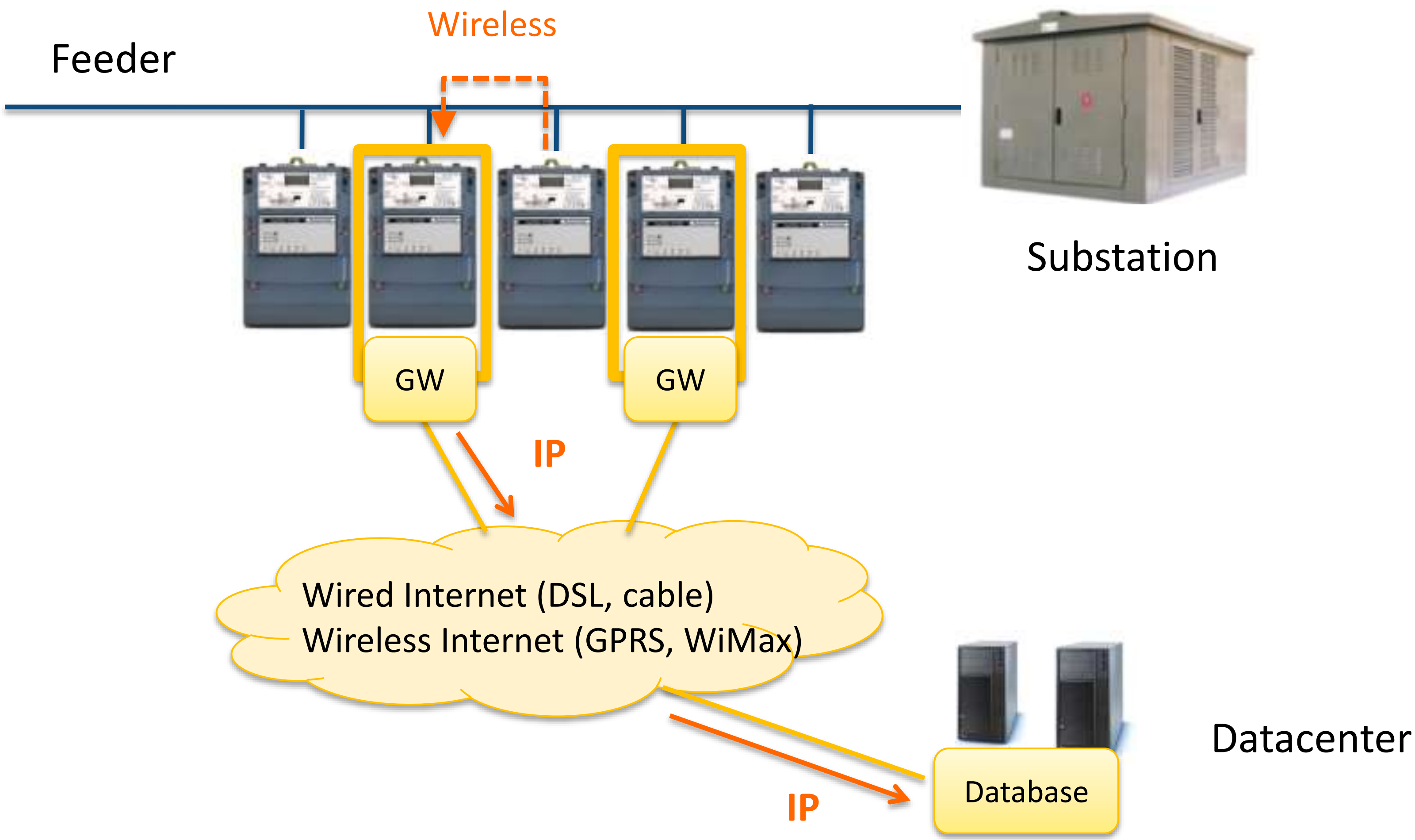
- Single point of failure
- Concentrator in LV-substation (longer distances)
- Lifetime of GPRS (heat, electro-magnetic field)

Smart Grid ICT architectures: Last mile

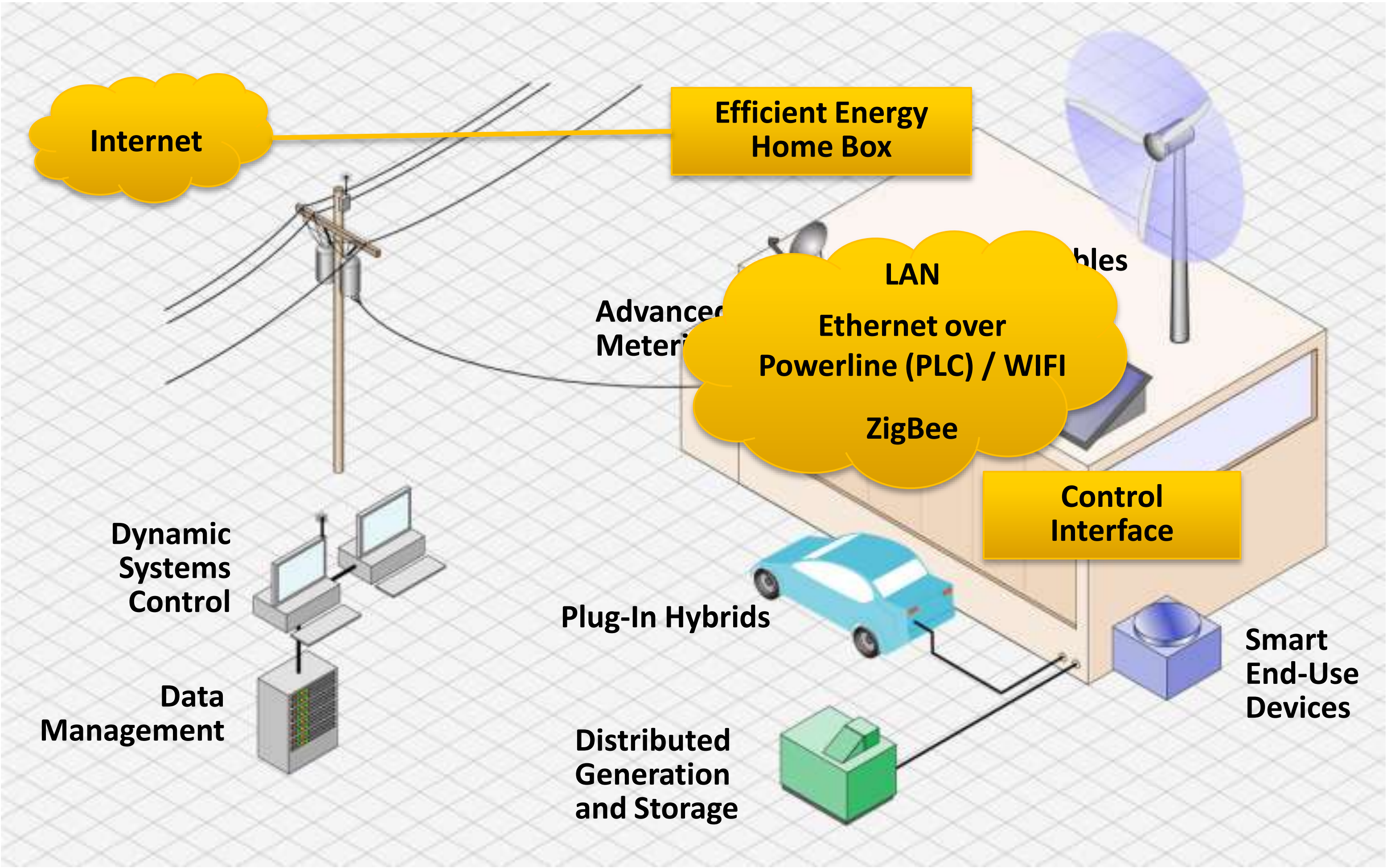


Architecture
EANDIS/Belgium

Smart Grid ICT architectures: Last mile



Smart Grid ICT architectures: Home



Based on figure from Electric Power Research Institute (EPRI)

Smart Grids[Bot10]

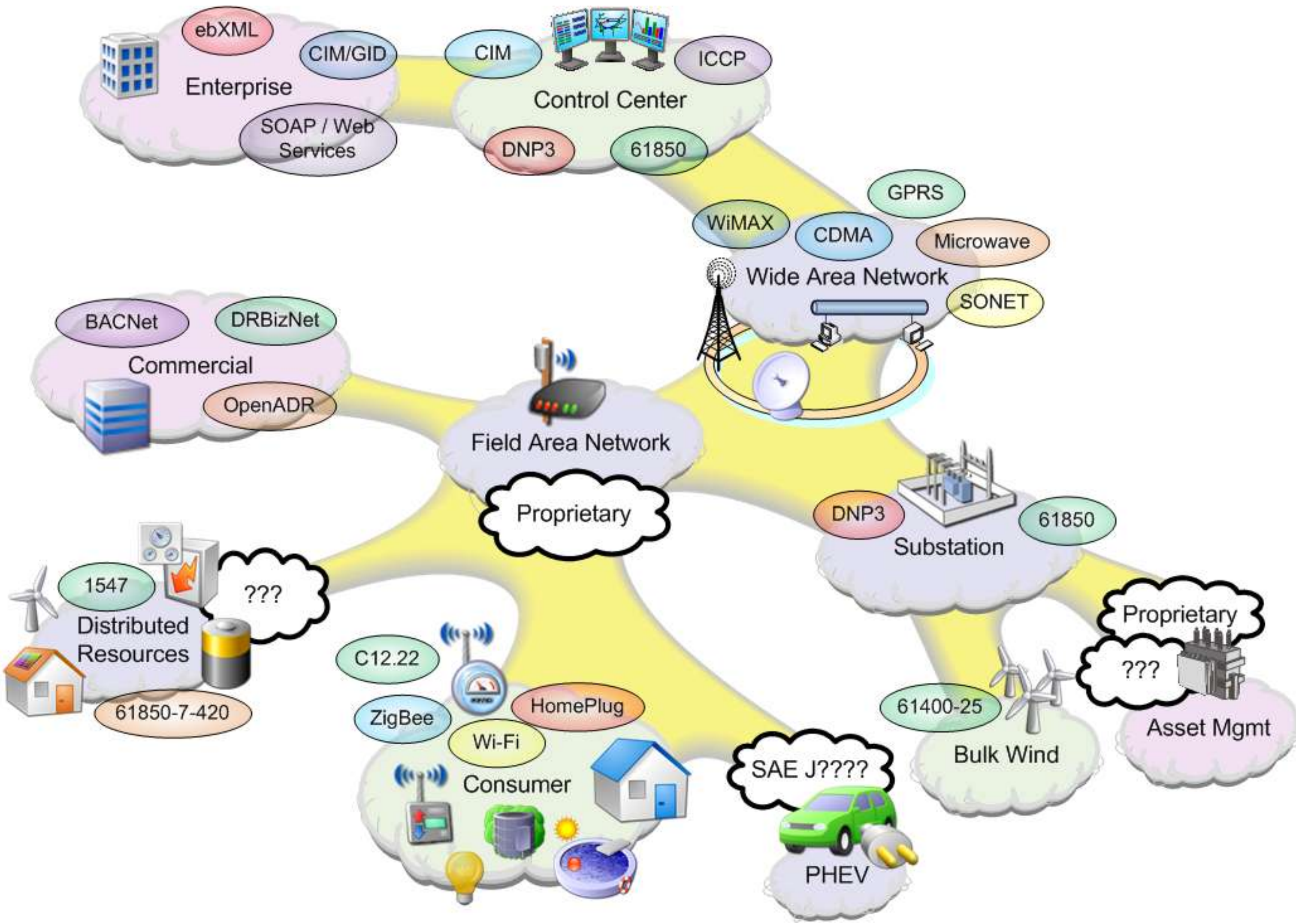
Traditional thinking: Smart metering	**Systemic thinking: Intelligent gateway**
• Delivers **information** for the consumer • Allows utility to **read** meter • Limited control function • Requires end user to make **manual decisions** on behavior • **Centralised** databases	• Acts as **automated broker** between intelligent building and active distribution grid • Can be programmed and tailored by end user via simple interaction • Provides **automated efficiency** • Enables **distributed** architecture and information usage

Smart Grids[Bot10]

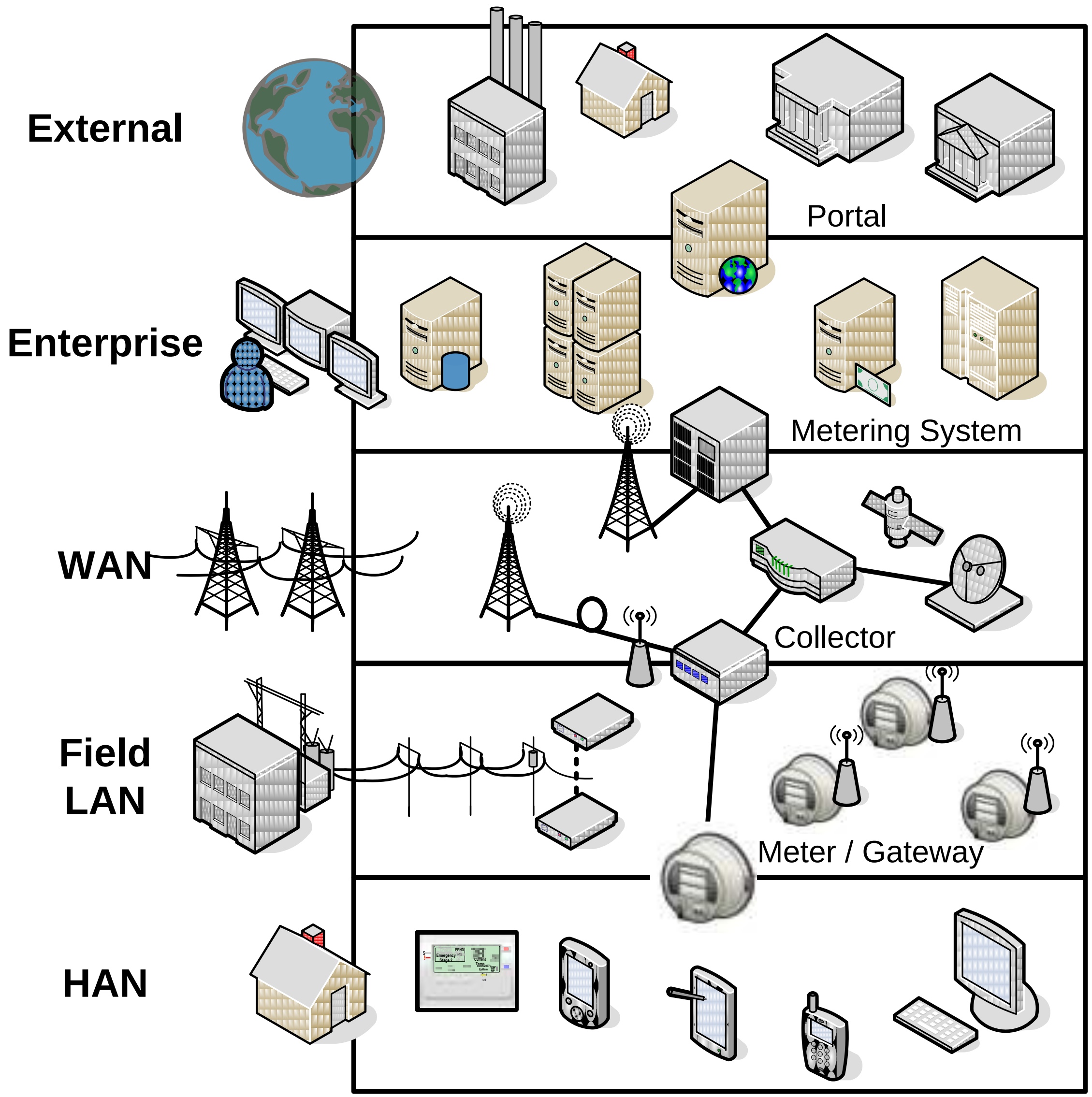
Traditional thinking	Systemic thinking
• **Silo-based** • Generation • Transmission – already reasonably smart • Distribution – just needs ICT to make it smart • Incremental results • **Low risk** strategy • **Demand** = load that can be interrupted	• **End-to-end integration** • Generation + Transmission + Distribution + Consumer (producer & service provider) • Different mindset: delivers step change results • **Market re-design** required! • Higher risk • Demand = integrated source & load, controllable by end user

Current solutions

Smart Grid ICT standards

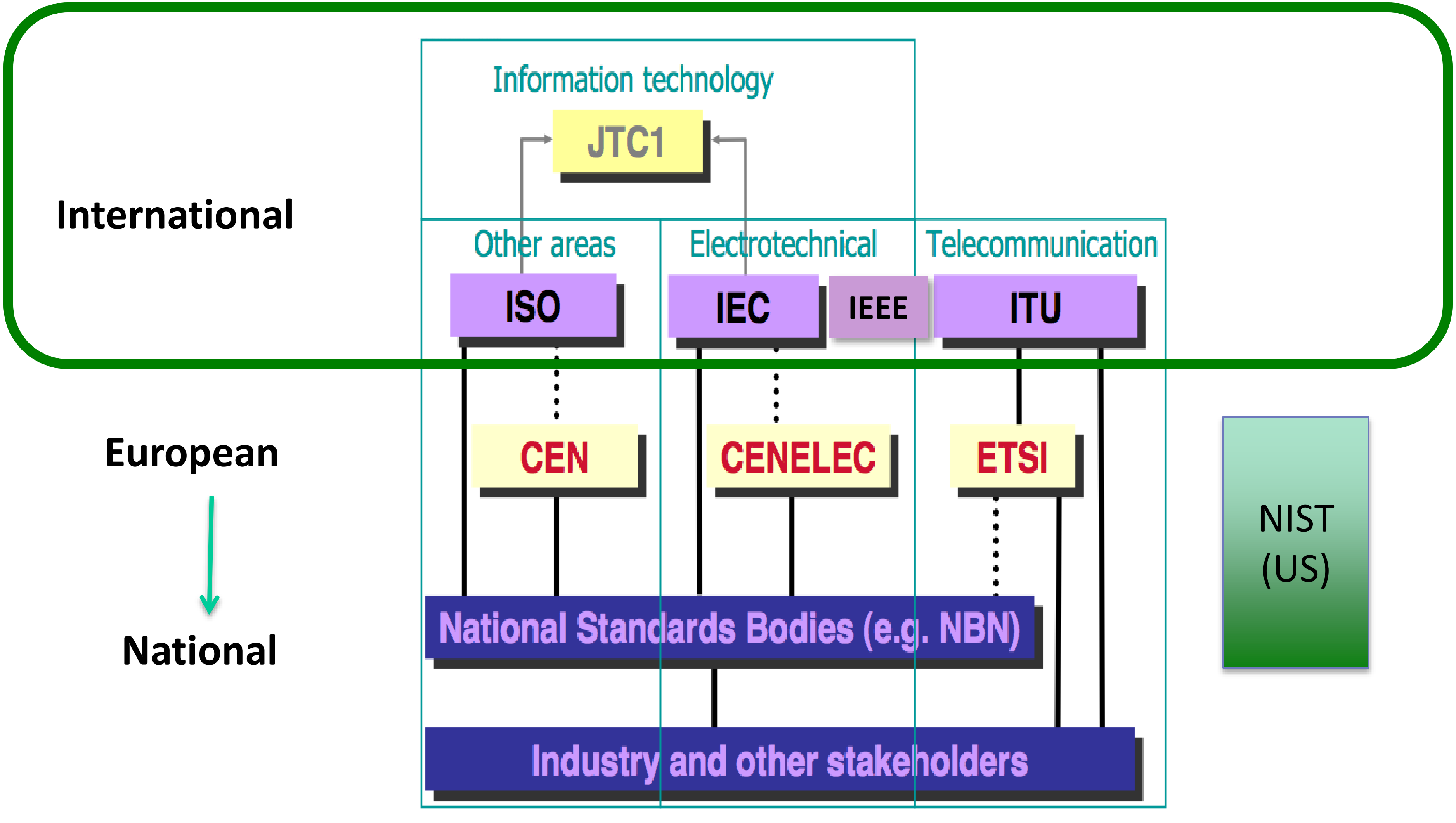


Smart Grid ICT standards



Example Members	Example Technologies
Retailers Aggregators Regulators Customers Providers	Internet Protocols World-Wide Web ebXML IEC 60870-6 ICCP
MDMS CIS/Billing OMS WMS EMS/DMS	IEC 61970 IEC 61968 Web Services Multispeak Message Buses
Routers Towers Ground Stations Repeaters Rings	SONET, WDM, ATM MPLS Frame Relay Satellite Microwave IEC 61850 DNP3
Relays Modems Bridges Access Points Insertion Points	WiMAX BPL / PLC Wireless Mesh ADSL Cellular Cable (DOCSIS)
Thermostats In-Home Displays Smart Appliances Field Tools PCs Building Automation	ZigBee WiFi LonWorks BACnet HomePlug OpenHAN

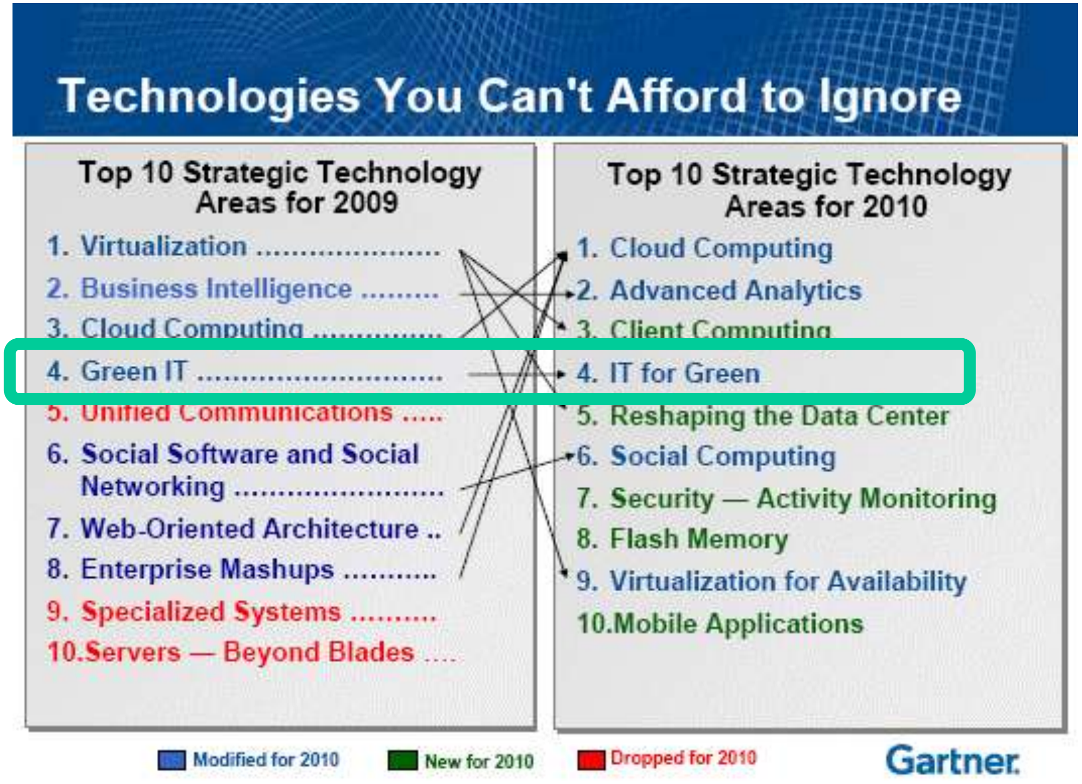
Smart Grid ICT standards
The landscape of standardization bodies



Smart Grid ICT standards
EU Mandate M/441 Standardisation Area

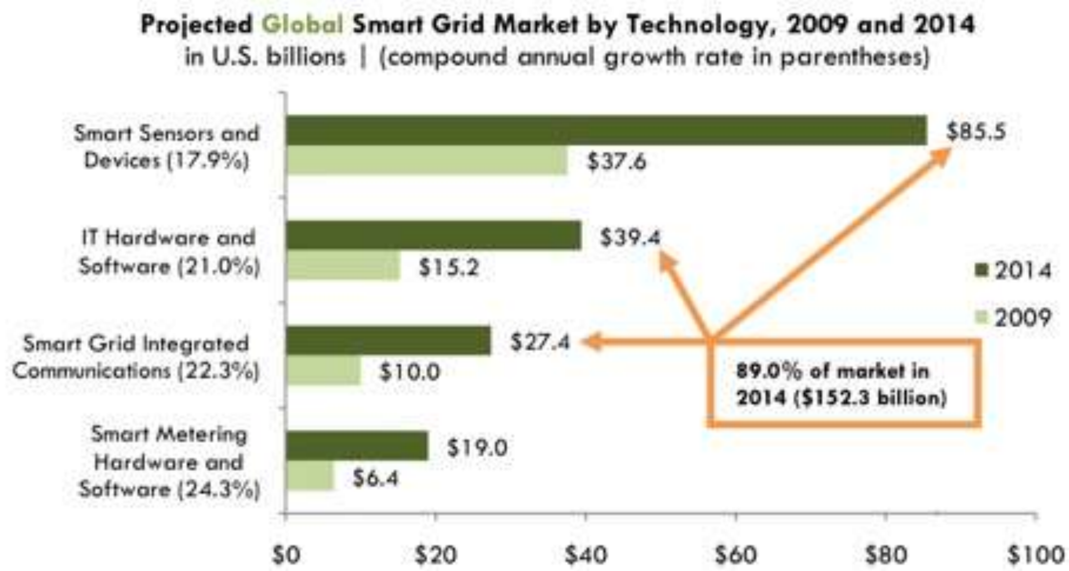
- Issued in March 2009 by DG-TREN
  - sent to the 3 ESO's : CEN, CENELEC and ETSI
- Main objectives:
  - build standards for European smart meters (electricity, gas, water, heat)
  - harmonized solutions within an interoperable framework,
  - based on communications protocols within an open architecture
  - allow consumer actual consumption awareness
- Time schedule :
  - T0 + 9 months : State-of-the-art of existing standards, gap analysis, and first Work program
  - T0 + 30 months : Develop new smart metering standards

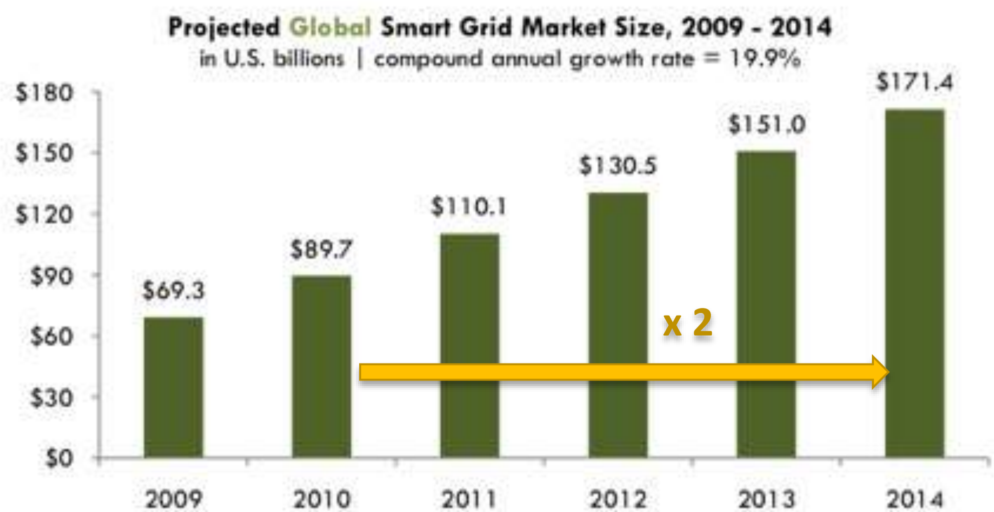
Smart Grid ICT products/solutions



GridPoint, SilverSpring

Smart Grid ICT products/solutions





Source: Market Research ZPRYME.com

Smart Grid ICT products/solutions

Advanced Metering Infrastructure

GE

Itron

Landis+Gyr

SilverSpring Networks

Cisco Systems

EnerNOC

3000 MW
=30 peak-power plants

Utility Data Management Systems

eMeter

IBM

ORACLE

...

Home Area Network

iControl

Control4

EnergyHub

TENDRIL

Cisco Systems

Microsoft

Google

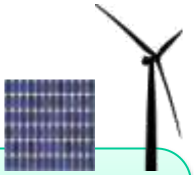
GRIDPOINT

PHEV

better place

Research challenges

Smart Grids: Research challenges

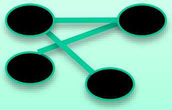


- Integration of large-scale stochastic (uncertain) **renewable generation**
- Impact of massive number of **distributed** PV panels on LV-segment (voltage increase, synchronisation, increased losses)

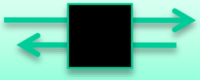
- Integration of (electric) energy **storage: cost, capacity, level**

- Integration of plug-in hybrid electric **vehicles** (high load)

- Energy-saving and cost-saving potential of **demand response and load/generation aggregation: selling stable profiles, flexibility**

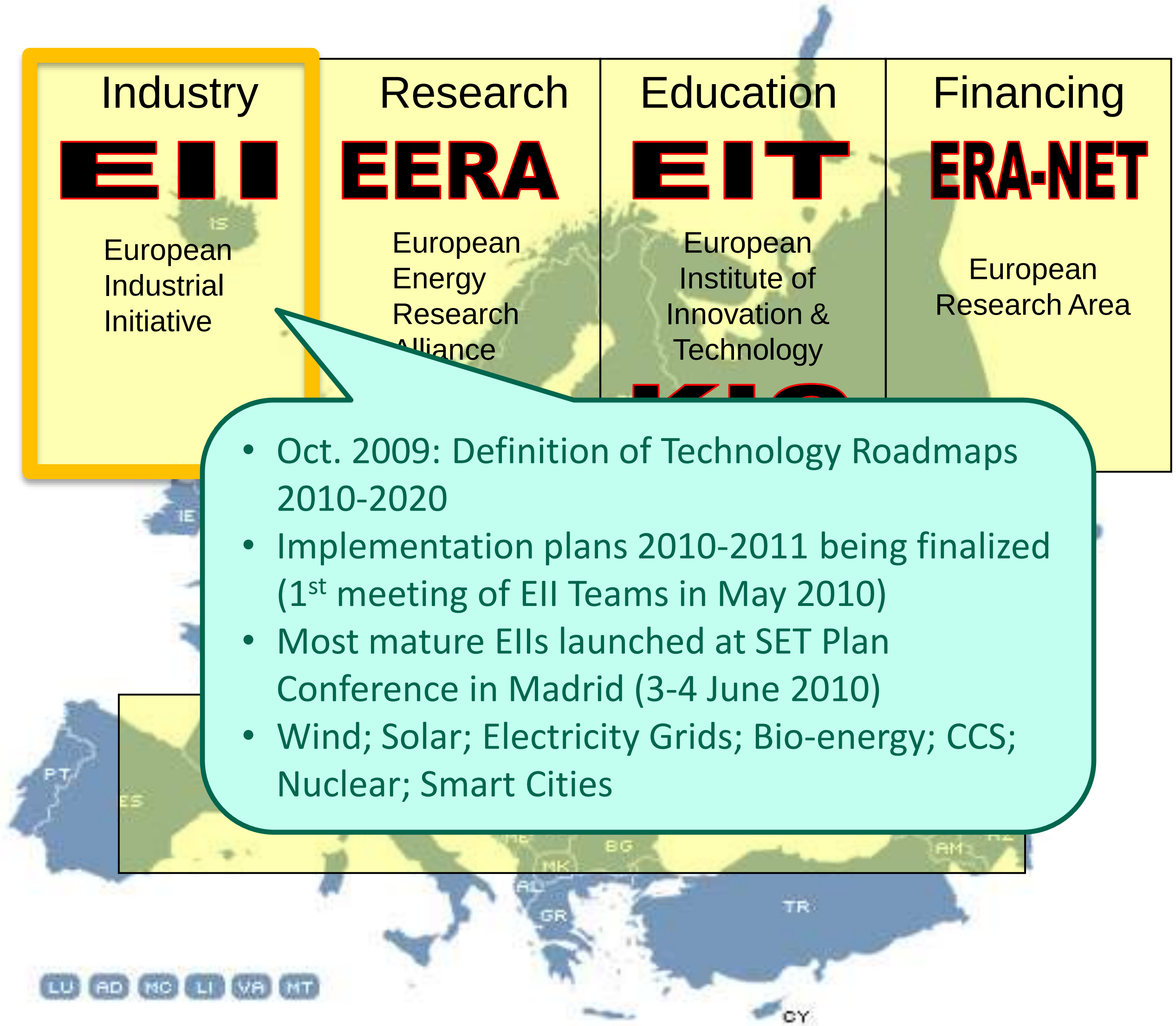


- **Autonomous** services deployed as a cloud service (privacy)
- **Reliability** of the smart power grid (what in case of failures)
- **Interoperability and openness** of the smart grid



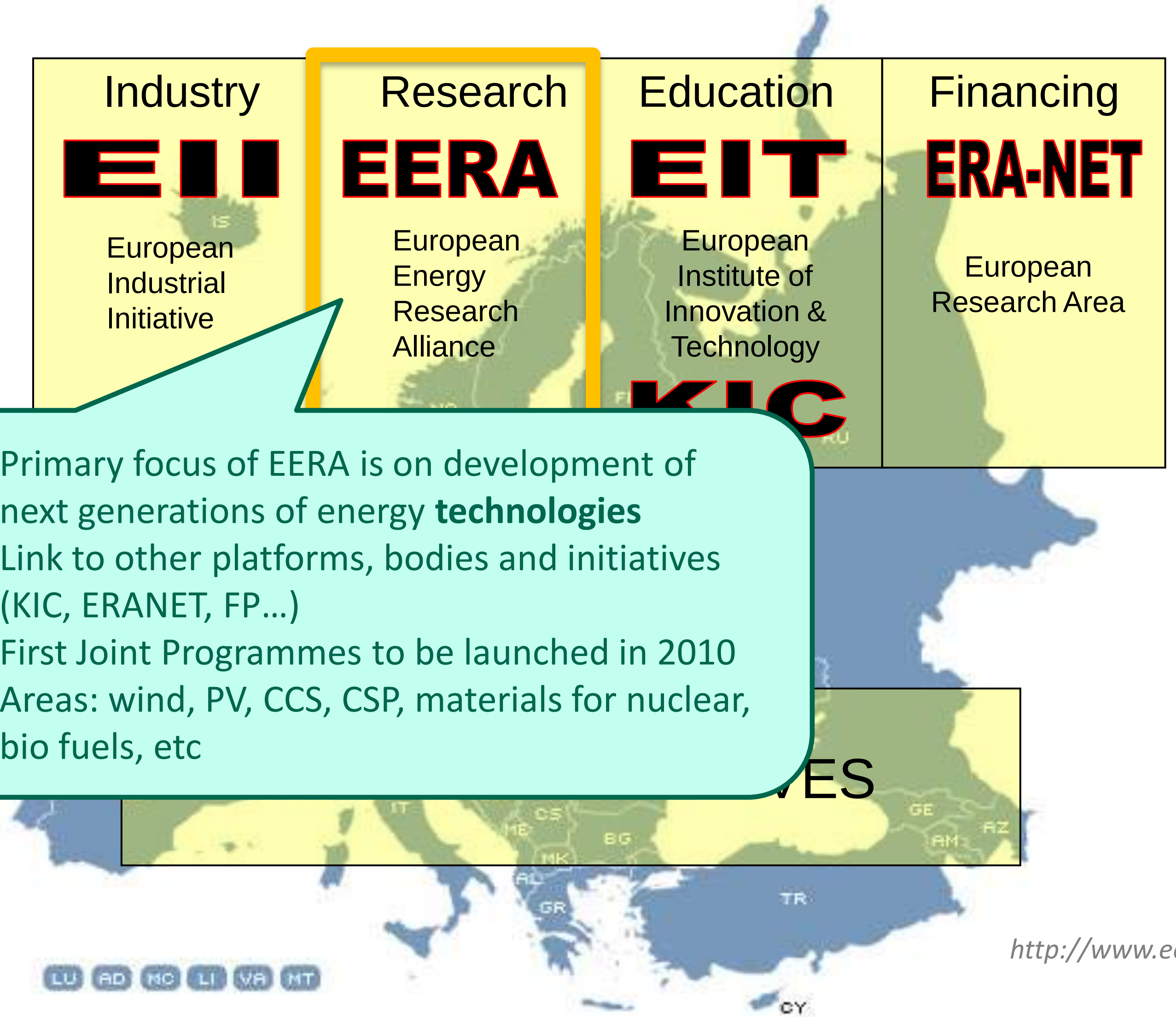
- Microgrids, safety and **power routing**

European projects/initiatives



- Oct. 2009: Definition of Technology Roadmaps 2010-2020
- Implementation plans 2010-2011 being finalized (1st meeting of EII Teams in May 2010)
- Most mature EIIs launched at SET Plan Conference in Madrid (3-4 June 2010)
- Wind; Solar; Electricity Grids; Bio-energy; CCS; Nuclear; Smart Cities

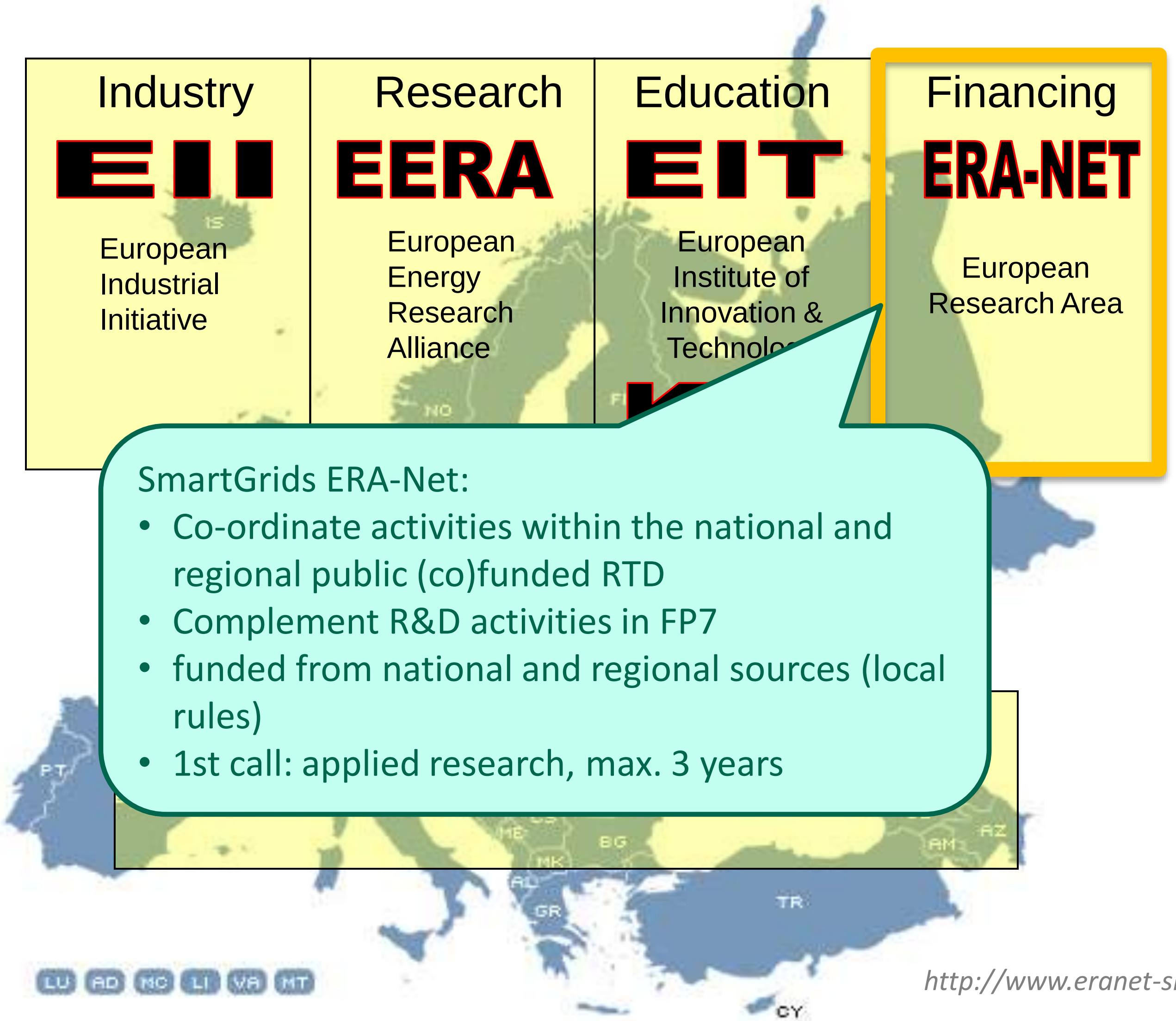
European projects/initiatives



- Primary focus of EERA is on development of next generations of energy **technologies**
- Link to other platforms, bodies and initiatives (KIC, ERANET, FP…)
- First Joint Programmes to be launched in 2010
- Areas: wind, PV, CCS, CSP, materials for nuclear, bio fuels, etc

http://www.eera-set.eu

European projects/initiatives

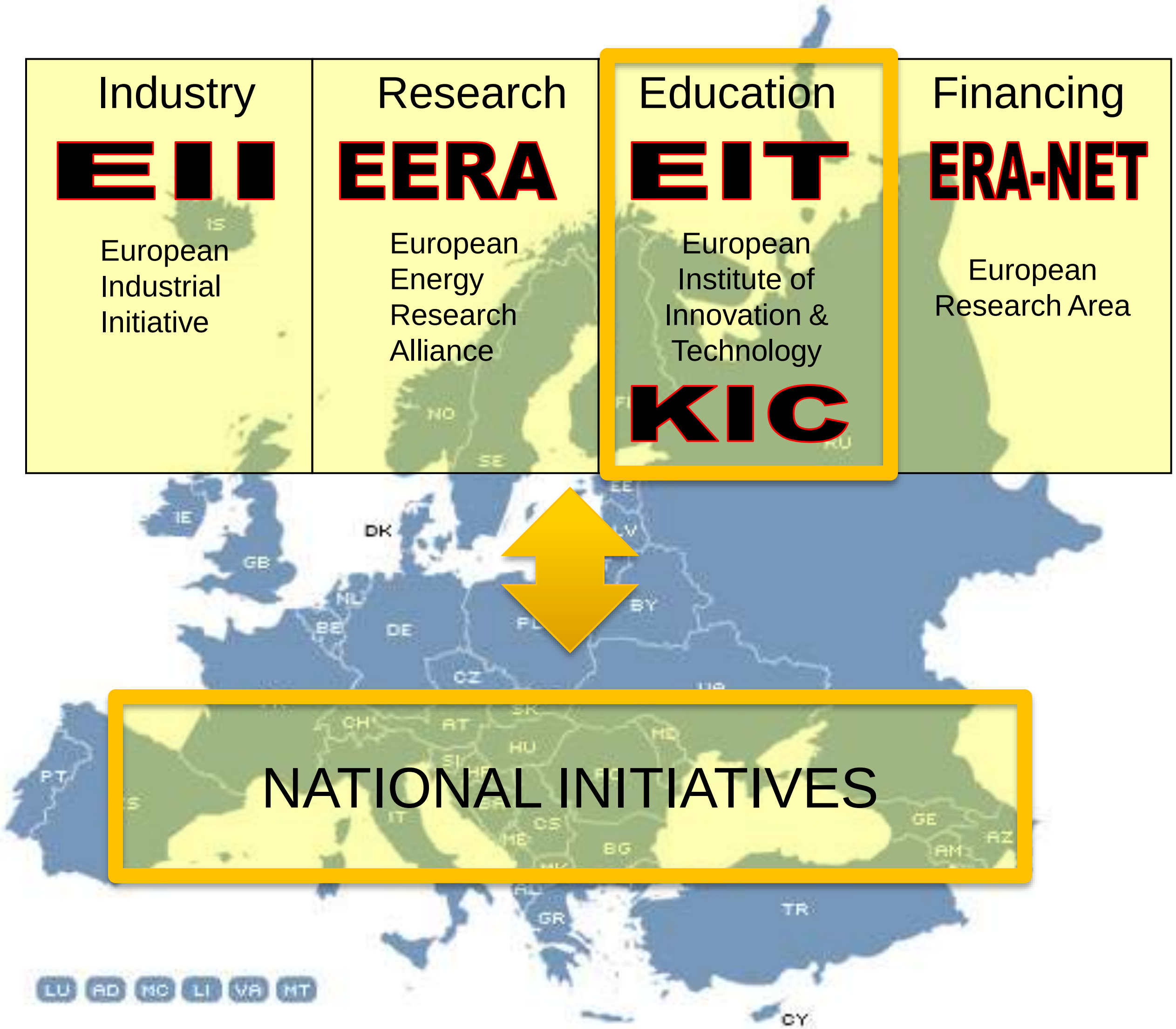


SmartGrids ERA-Net:

- Co-ordinate activities within the national and regional public (co)funded RTD
- Complement R&D activities in FP7
- funded from national and regional sources (local rules)
- 1st call: applied research, max. 3 years

http://www.eranet-smartgrids.eu/

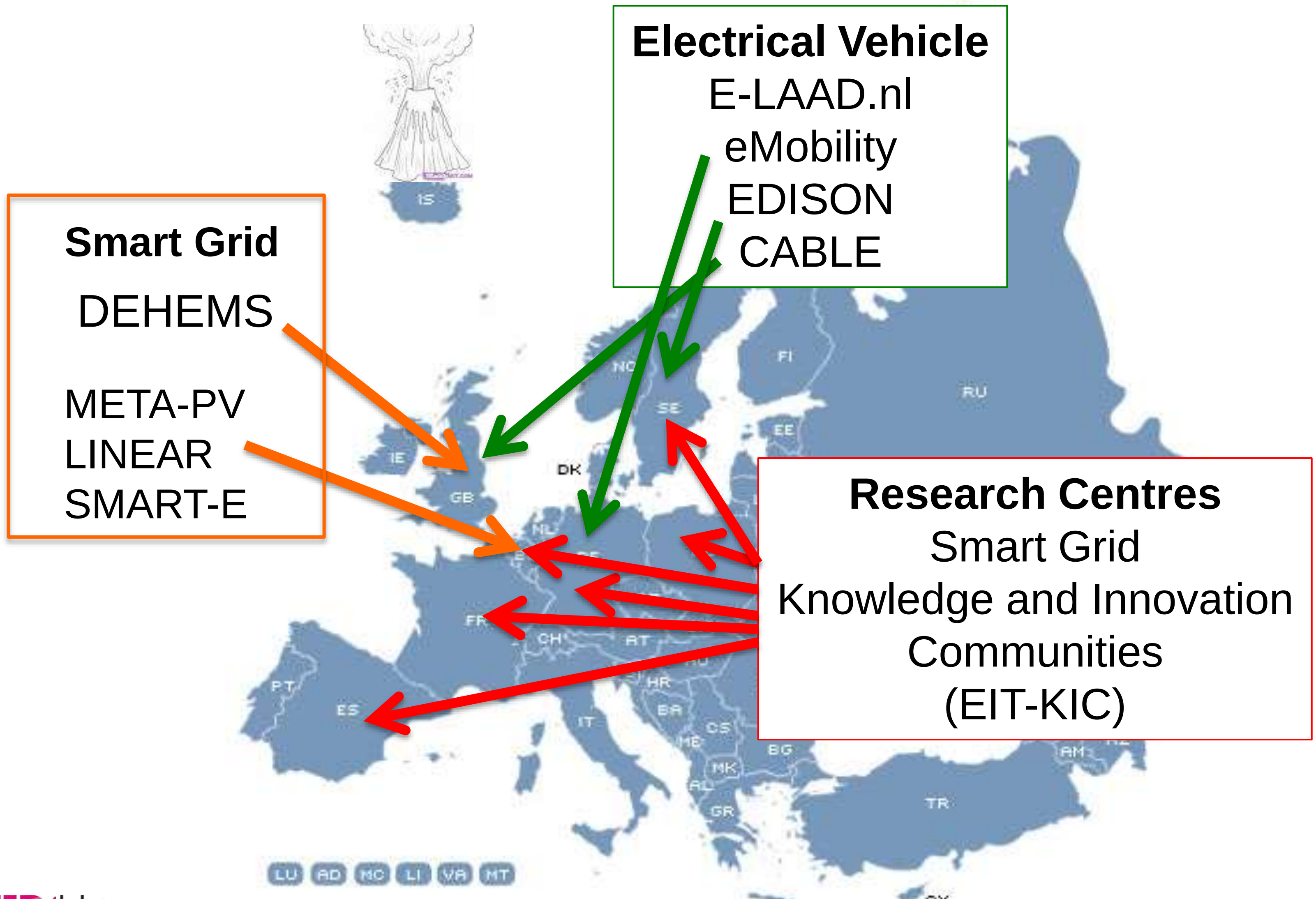
European projects/initiatives



Industry	Research	Education	Financing
EII	**EERA**	**EIT**	**ERA-NET**
European Industrial Initiative	European Energy Research Alliance	European Institute of Innovation & Technology	European Research Area
		KIC	

NATIONAL INITIATIVES

European projects/initiatives



Smart Grid Simulator[2]

[iSUP] K. Mets, W. Haerick, C. Develder, "A simulator for the control network of smart grid architectures", in *Proc. 2nd Int. Conf. on Innovation for Sustainable Production (i-SUP 2010)*, Brugge, Belgium, 18-21 Apr. 2010

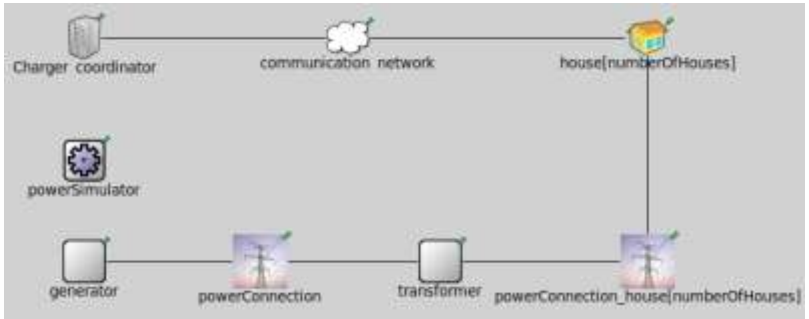
Why do we need a smart grid SIMULATOR?

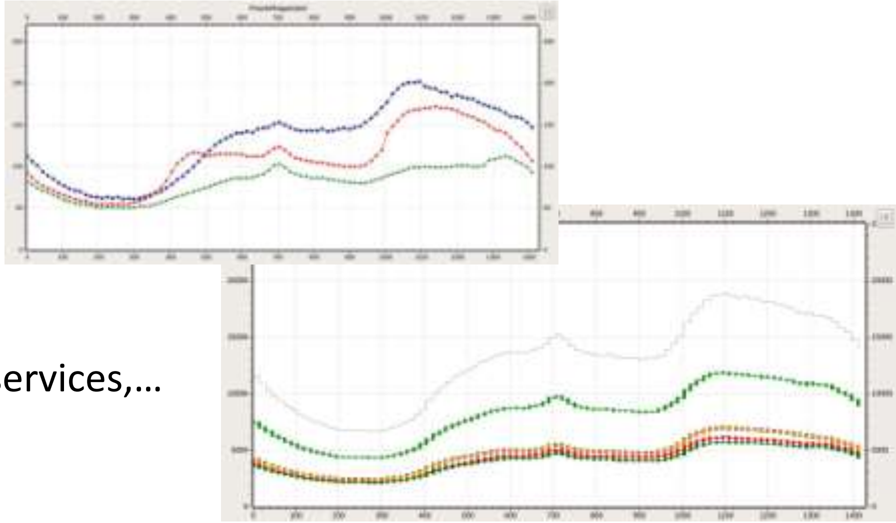
- Provide a tool to develop and analyze …
  - Control strategies
  - Software architecture (client-server, multi-agent…)
  - Communication network requirements (Influence of delays, network failures, …)
  - The resulting effects on the power grid

- Main focus is on the ICT aspects
- Detailed power simulation can be handled by external tools
  - Extensible, flexible, scalable, …

Simulator design

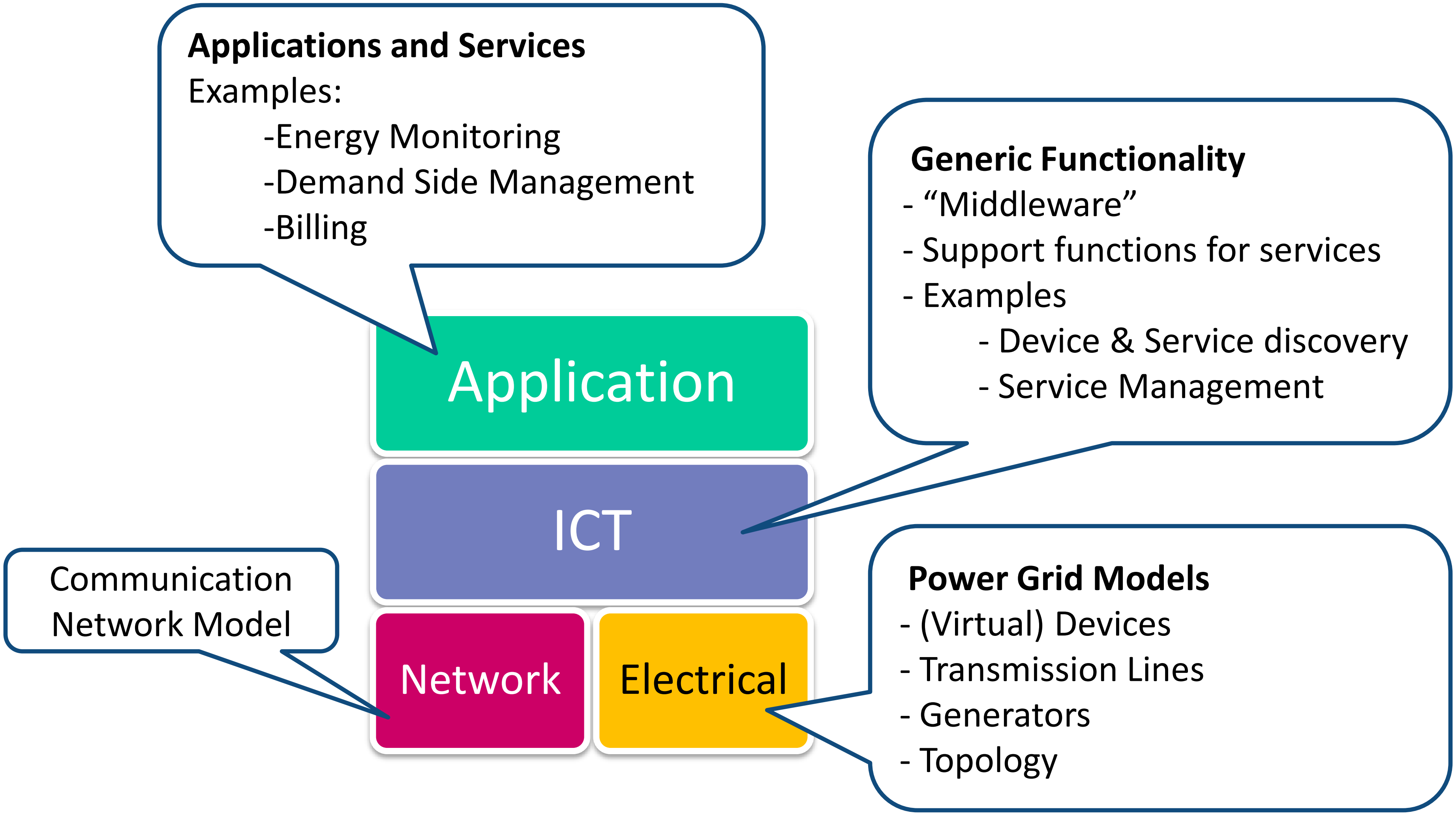
- Discrete Event Simulator: OMNeT++ [3,4]
  - Modular, Scalable, Cluster support
  - Models for communication networks
  - Random Data Generation
  - Graphical representations
  - Data logging, presentation, processing,..
  - Open source
  - Integrated in Eclipse
  - ....



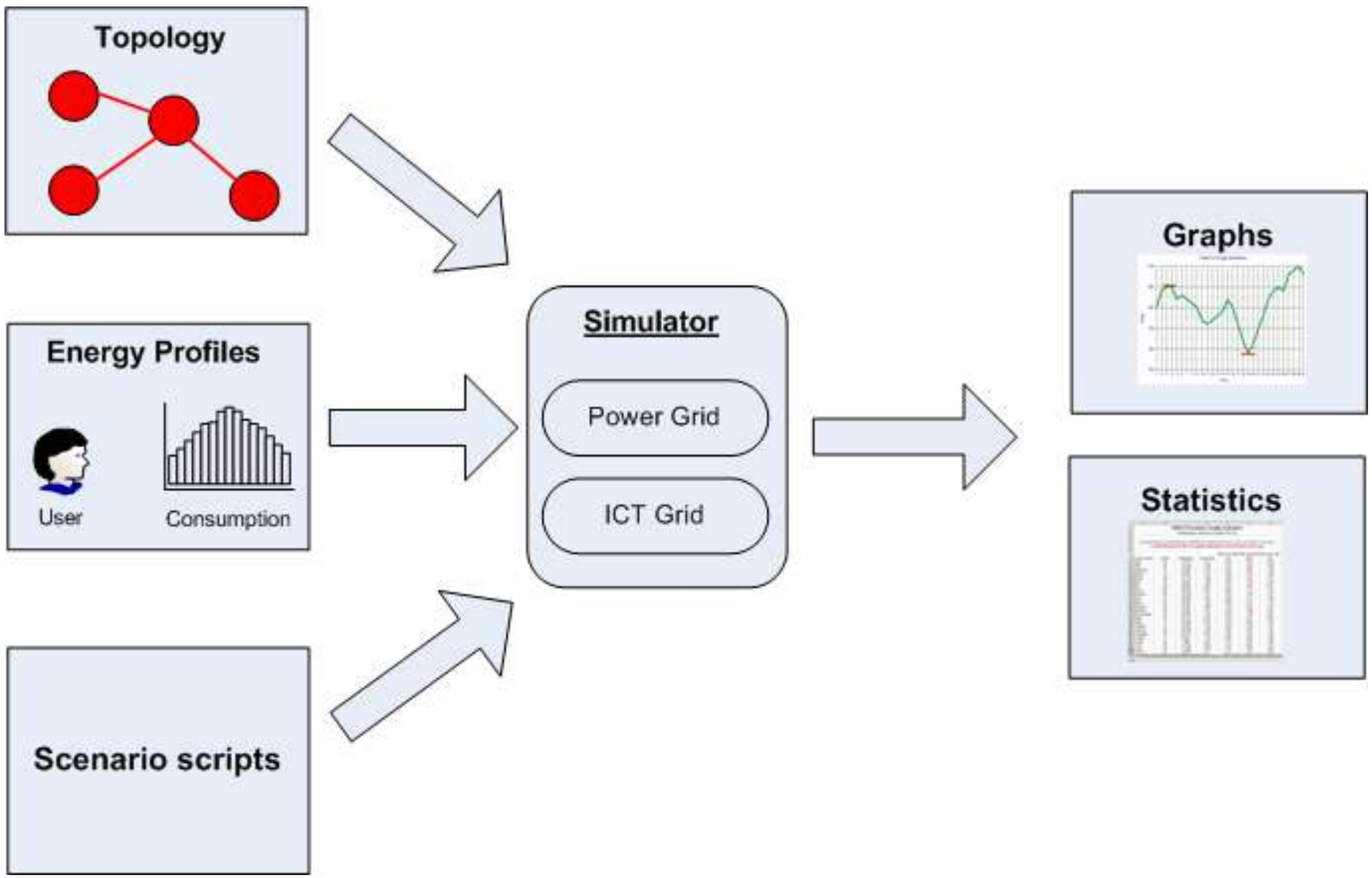


- Custom Components:
  - Electric components: loads, generators, etc.
  - ICT components: smart devices, coordination services,…

Simulator design: Layered approach



Smart grid simulator



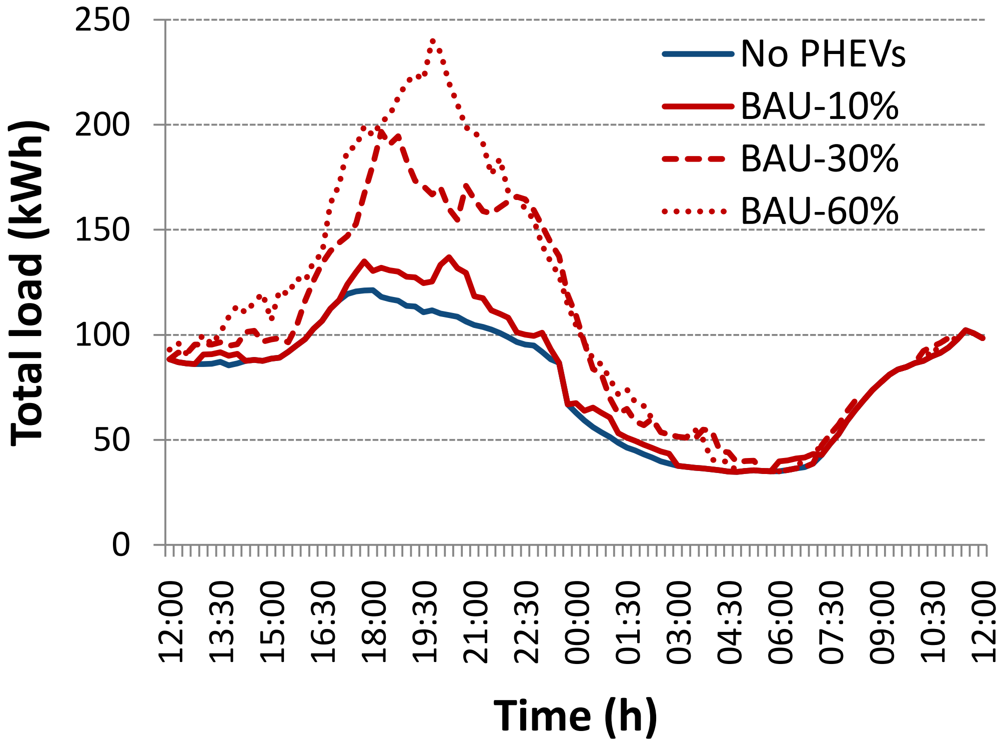
Smart Grid Simulator

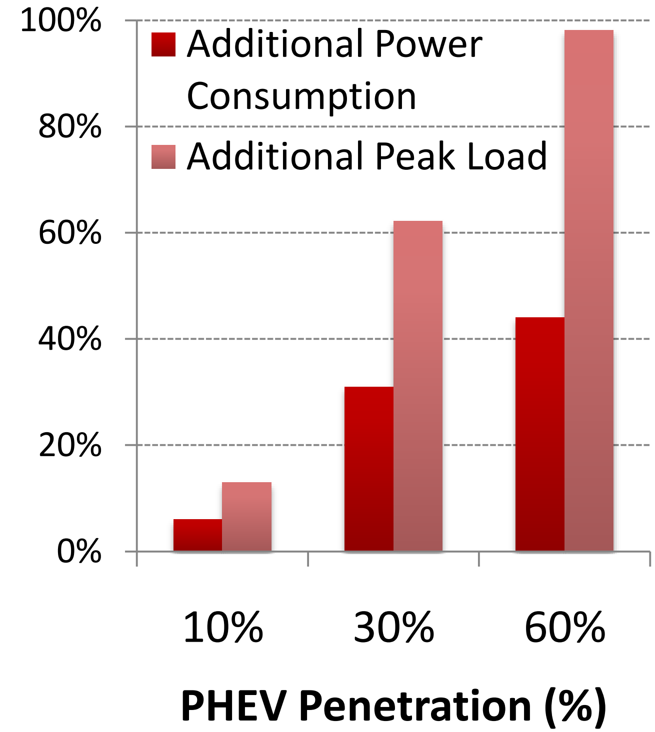
Sample use case[5]

[NOMS] K. Mets, T. Verschueren, W. Haerick, C. Develder, and F. De Turck, "Optimizing smart energy control strategies for plug-in hybrid electric vehicle charging," in *Proc. 1st IFIP/IEEE Int. Workshop on Management of Smart Grids, at 2010 IEEE/IFIP Netw. Operations and Management Symp. (NOMS 2010)*, Osaka, Japan, 19–23 Apr. 2010

Impact of PHEV charging

- Sample analysis for 150 homes, x% of them own a PHEV
- BAU = maximally charge upon arrival at home





Impact of PHEV charging

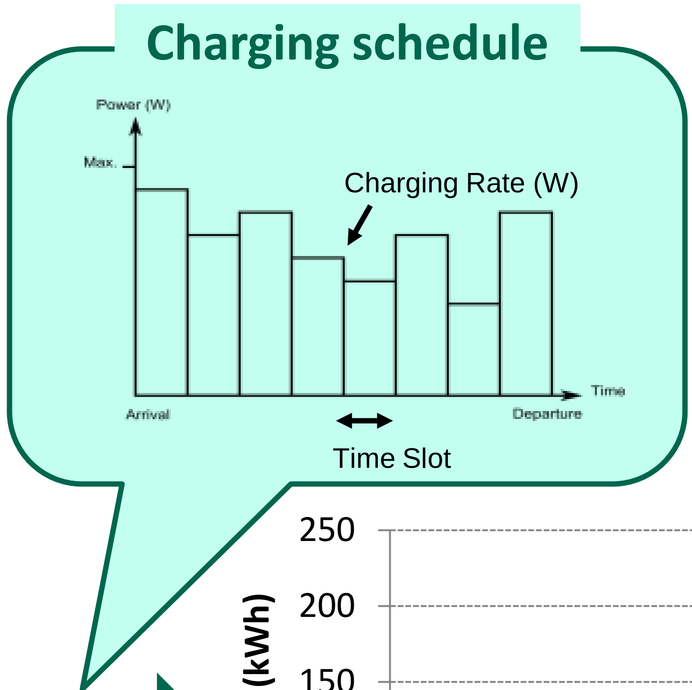
- Potential problems:
  - Overloads
  - Additional generating capacity required
  - Compromised grid stability and reliability

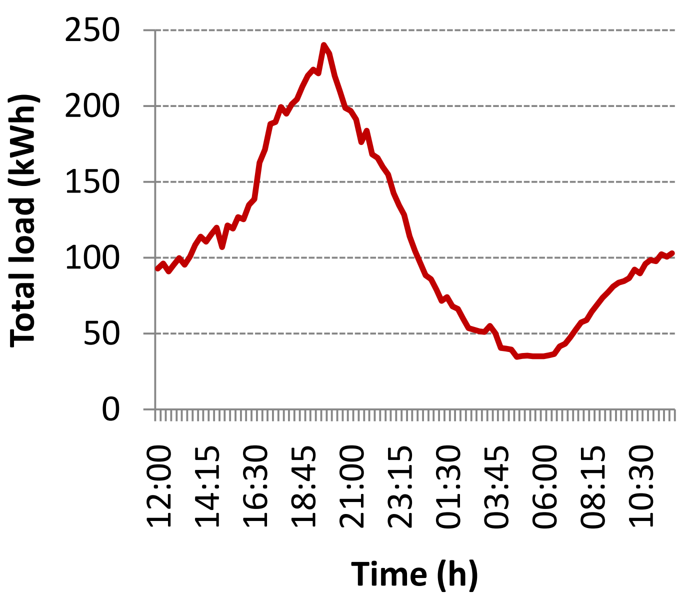
➡ ***Demand side management is needed!***

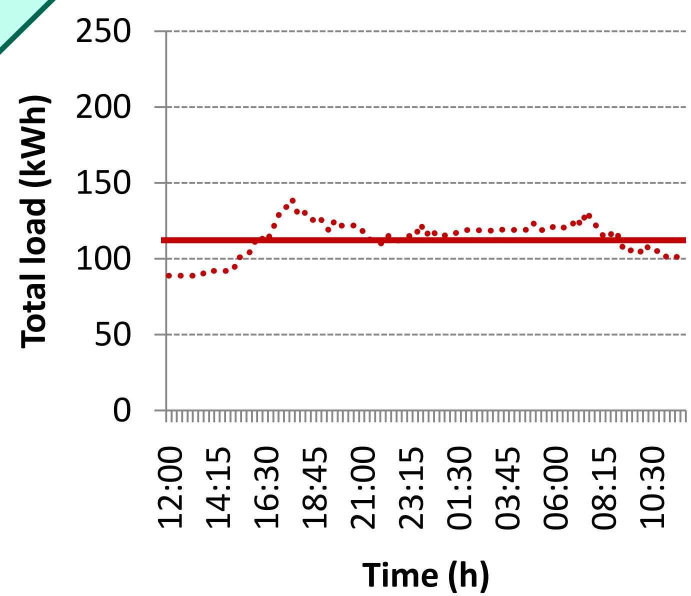
- Support for a larger number of electric vehicles
- Optimal usage of renewable energy
- Reduce peak load
- Minimize costs

Controlling PHEV charging?

- Objectives:
  - Reduce peak load
  - Flatten (total) load profile



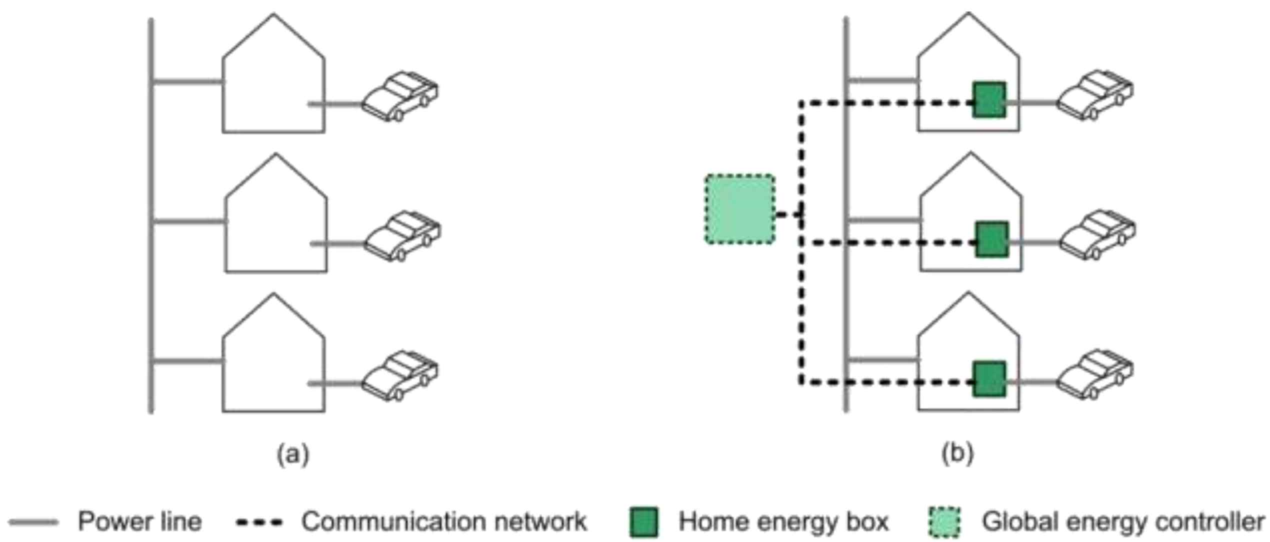




What is maximal peak load reduction possible?

- Assuming "all-knowing" controller, i.e. full information on
  - Base load (i.e. electricity consumption apart from PHEV)
  - PHEV battery status & departure time
  - Power grid constraints (= maximal total power to household)

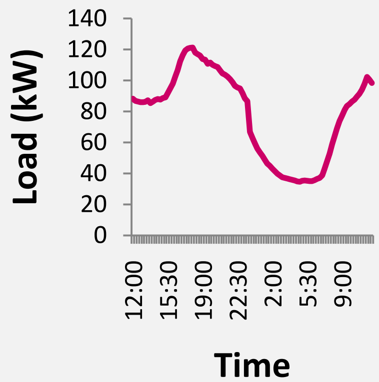
BAU = charge upon arrival vs Coordinated charging



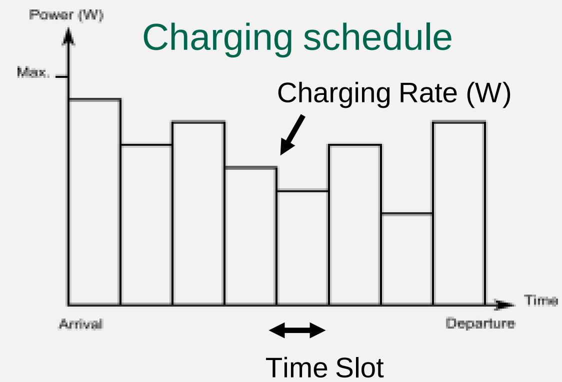
Simulation: Comparison of control strategies

Input

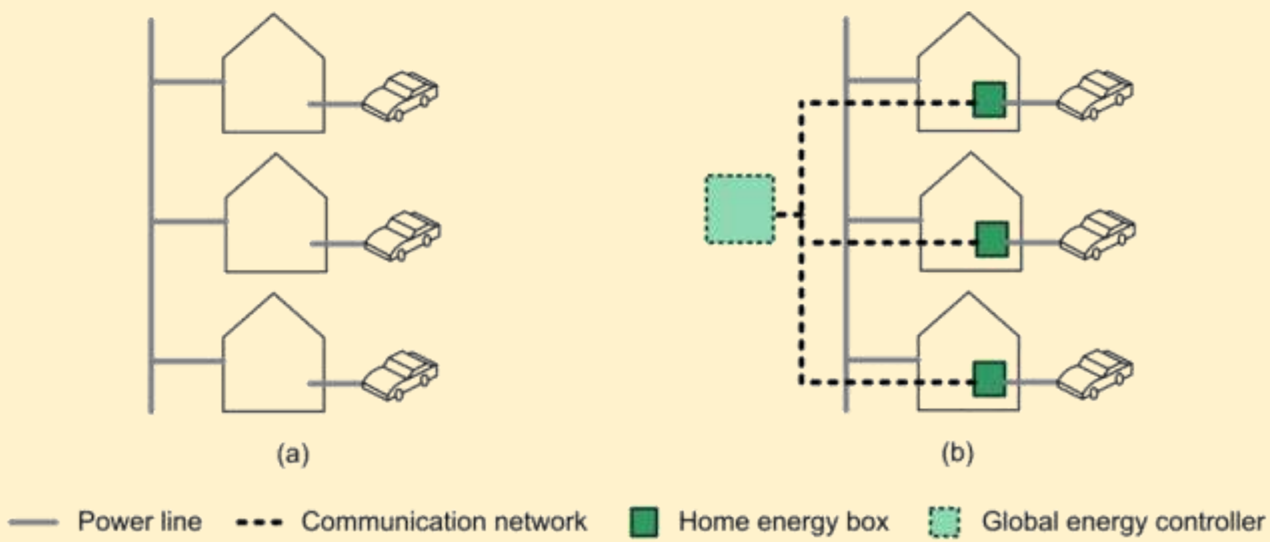
- Base load (excl. vehicle)
- Arrival & departure times
- Battery characteristics



Output

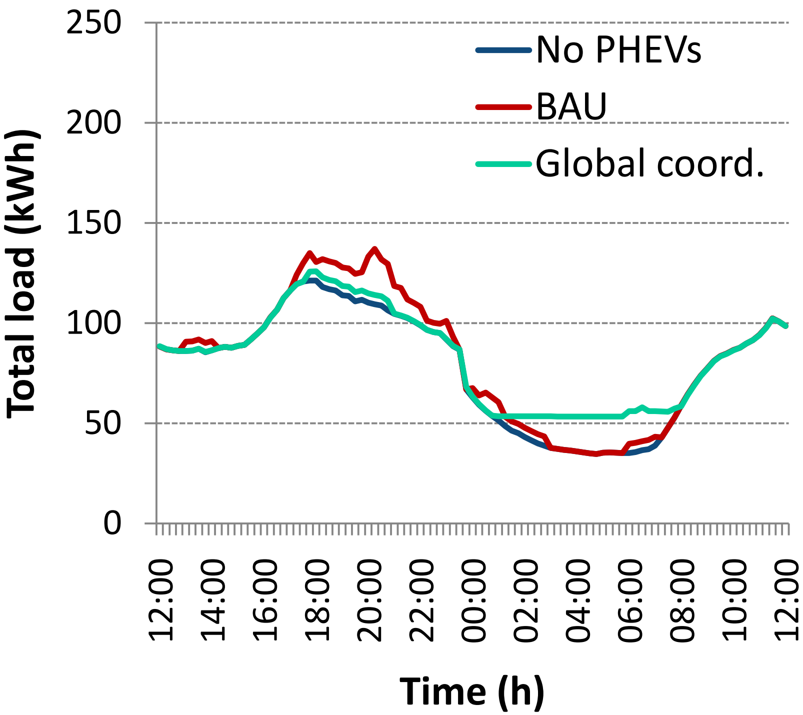


BAU = charge upon arrival vs Coordinated charging



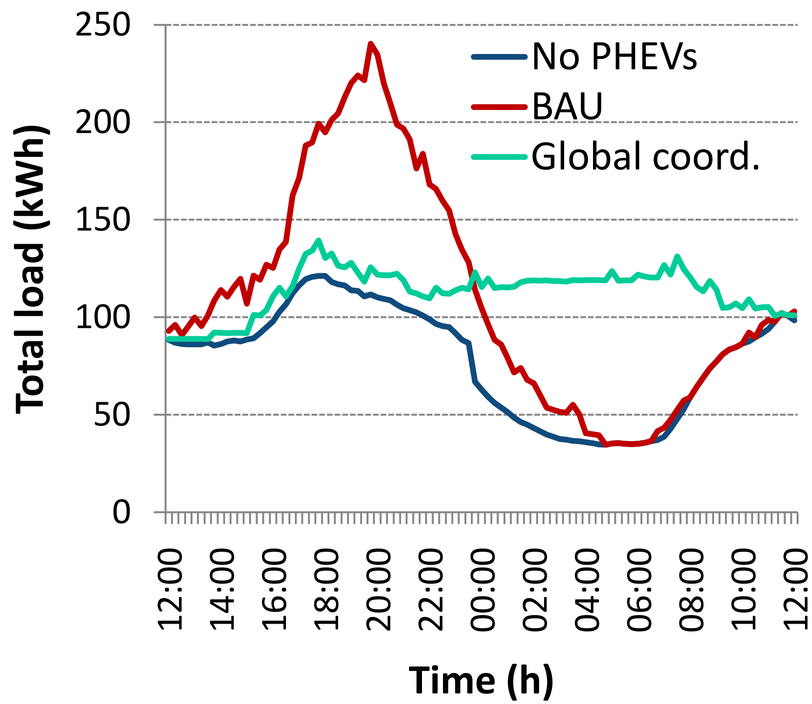
Results

10% Electrical Vehicles



Parameter	Reduction (vs BAU)
Peak load	8%
Variance	44%

60% Electrical Vehicles



Parameter	Reduction (vs BAU)
Peak load	42%
Variance	96%

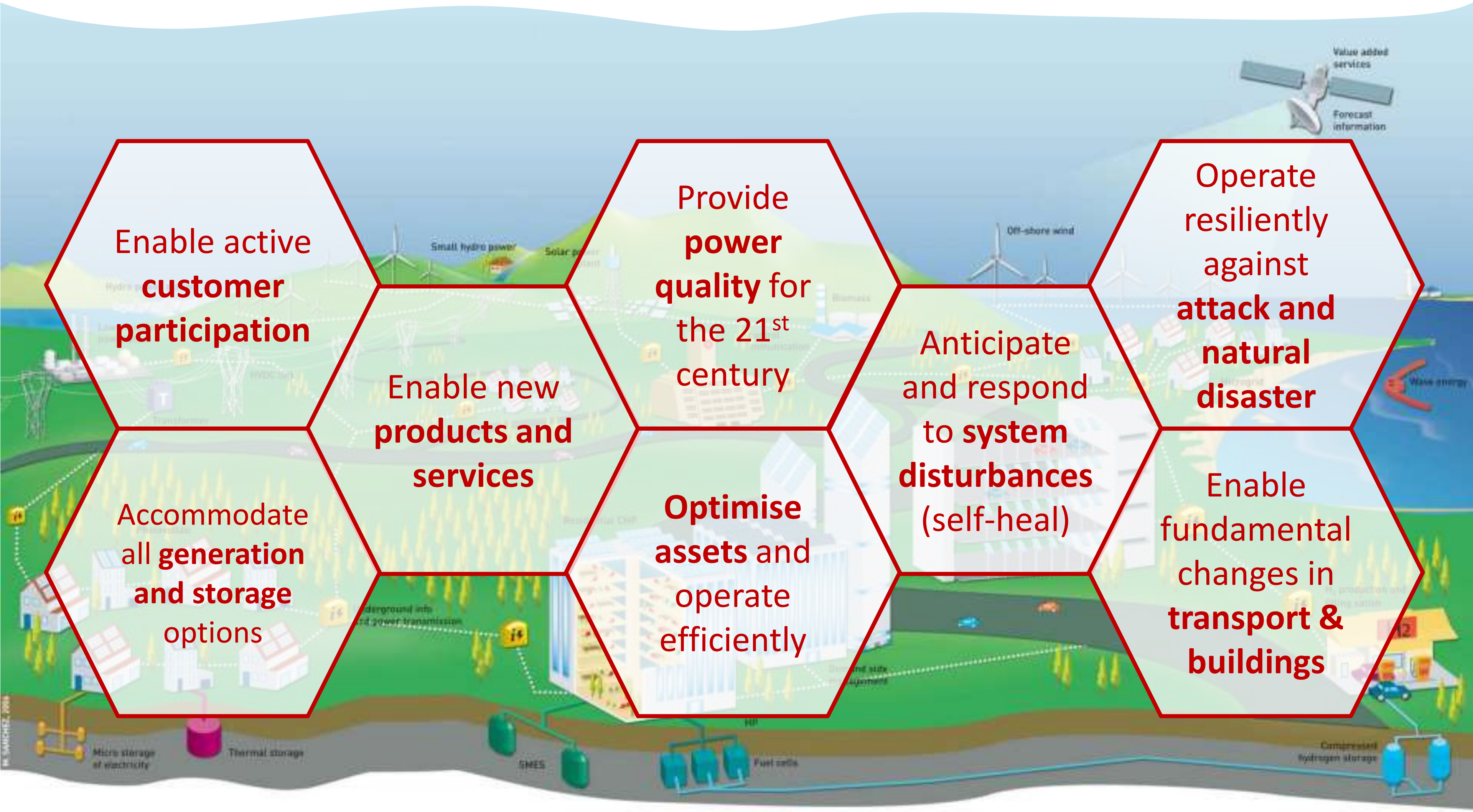
Wrap-up

Smart Grids: Main issues

- Modernization of the electrical network
  - Renewable energies: The power grid was not equipped to handle new power sources like wind or solar (focus on wholesale markets)
  - Outages due to e.g. inadequacy between demand and production
  - Little integration of operational data with asset management

- New application opportunities
  - Demand response: control electricity usage on the demand side
  - Home automation: control electrical appliances
  - Electrical vehicles: allow flexible charging mechanisms

Smart Grids: Vision



Source: SmartGridNews.com [Bot10]

Key elements to drive the DSM challenge[Ban10]

Distributed demand?

- "We cannot change what we do not know"
- Dissemination of energy efficiency best practices

Energy saving objective?

- Implementation of DSM measures (Home automation, Smart Grid, network driven DSM,…)

Effectiveness of prices?

- Time of use prices to
- make the final consumer sensitive to the real cost of energy and when this energy is consumed

Support from regulation?

- Clear objectives
- Minimum regulatory framework that allows the development of energy efficiency-oriented markets

End users: Who will pay? Adoption? Incentives? …

Thank you... Any questions?

prof. Chris Develder
Ghent University – IBBT
chris.develder@intec.ugent.be

Acknowledgements

Linear – Intelligent networks
Research project funded by the Flemish Government

SmartE: Smart Energy – ICT for Energy Efficiency
IBBT ICON project
www.ibbt.be

IWT – Agency for innovation by Science & Technology
Ph.D. grant K. Mets
www.iwt.be

Research Foundation – Flanders (FWO)
Post-doctoral fellowship C.Develder
www.fwo.be

References

- [IEC] http://www.iec.ch/smartgrid
- [Ban10] S. Bañarez, “What can future internet mean for smart energy?”, Future Internet Assembly, Valencia, Spain, 15 Apr. 2010
- [Bot10] D. Botting, “SmartGrids: Future Internet a component, not a solution”, Future Internet Assembly, Valencia, Spain, 15 Apr. 2010
- [iSUP] K. Mets, W. Haerick, C. Develder, “A simulator for the control network of smart grid architectures”, in Proc. 2nd Int. Conf. on Innovation for Sustainable Production (i-SUP 2010), Brugge, Belgium, 18–21 Apr. 2010
- [NOMS] K. Mets, T. Verschueren, W. Haerick, C. Develder, and F. De Turck, “Optimizing smart energy control strategies for plug-in hybrid electric vehicle charging,” in Proc. 1st IFIP/IEEE Int. Workshop on Management of Smart Grids, at 2010 IEEE/IFIP Netw. Operations and Management Symp. (NOMS 2010), Osaka, Japan, 19–23 Apr. 2010