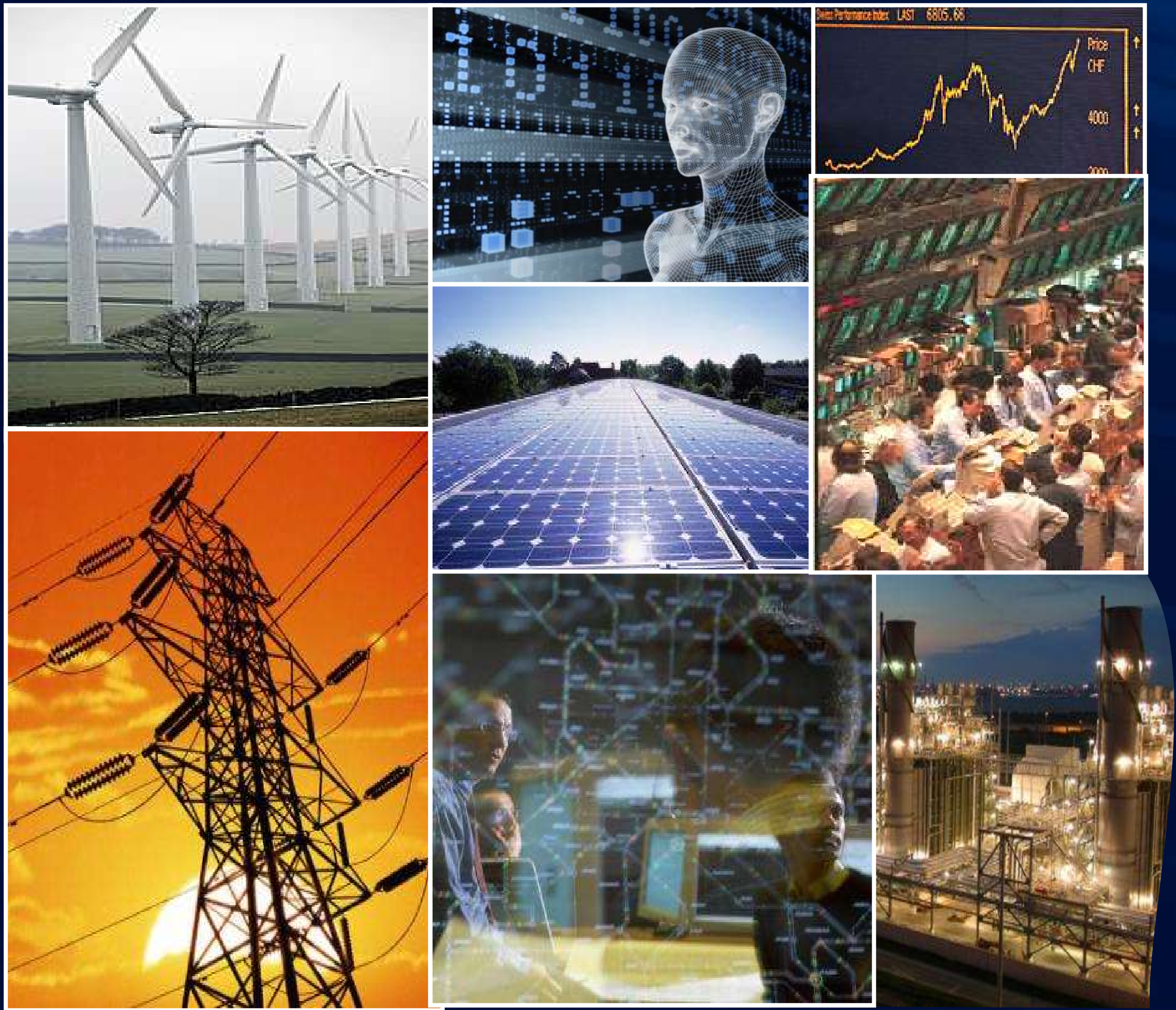
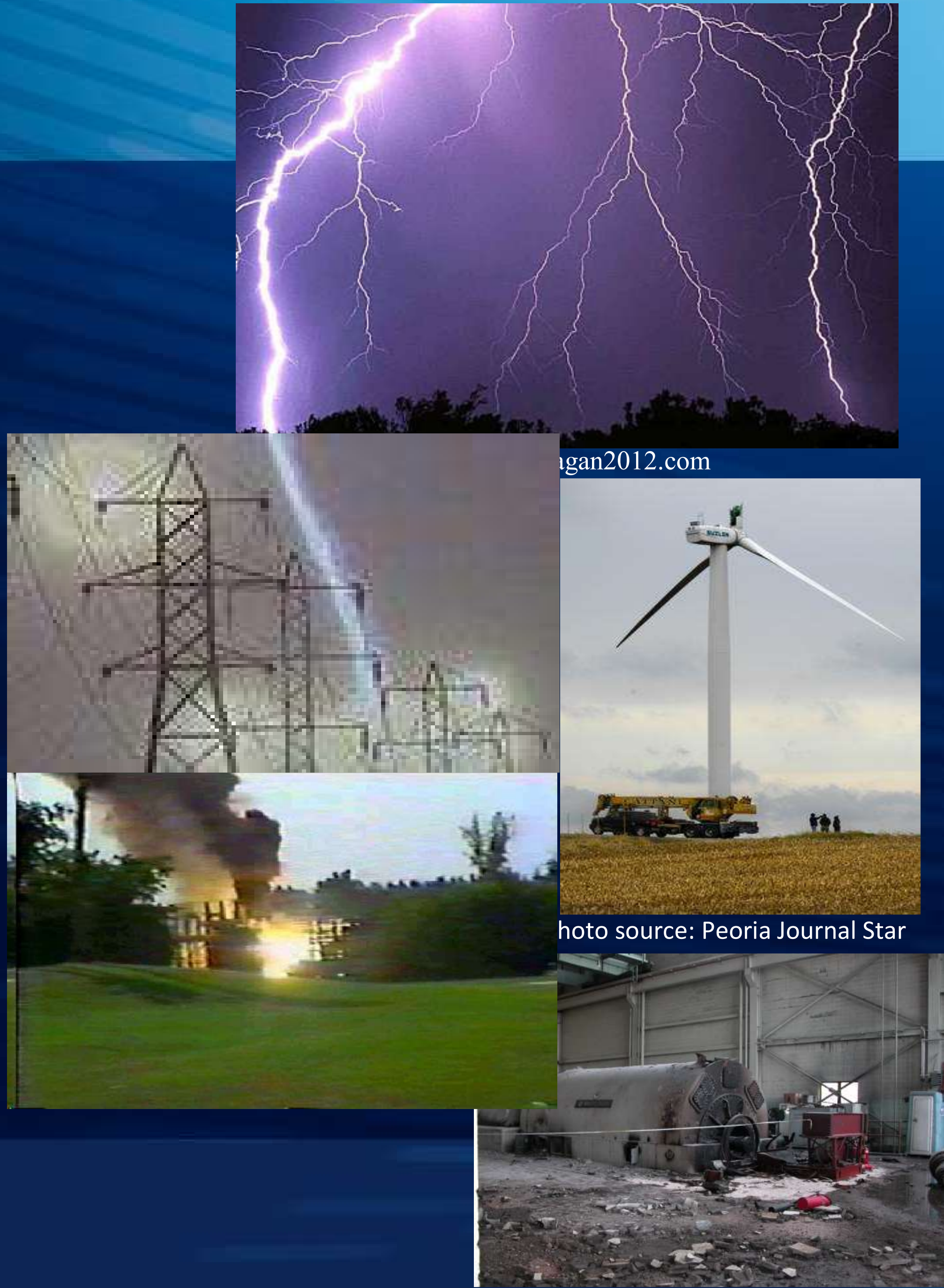
SmartGrids for Energy Transition



N. HADJSAID
Professor Grenoble INP/G2ELAB
President Scientific Council
ThinkSmartGrids - France

The power Grid:
A complex system

- Particularities of power grids:
  - **Strong Coupling** with other infrastructures
    - Open IC
    - Primary Energies
    - …
  - **Complex** System
    - Large scale – multi-layer system– interdependent
    - Chaotic behavior, difficult to master
  - Subject to various **disturbances**
- System vulnerability and & failures
  - High Economical **Consequences**
  - Less and **less accepted**
  - Ensure the **integrity** of the whole system whatever is the disturbance



ıgan2012.com

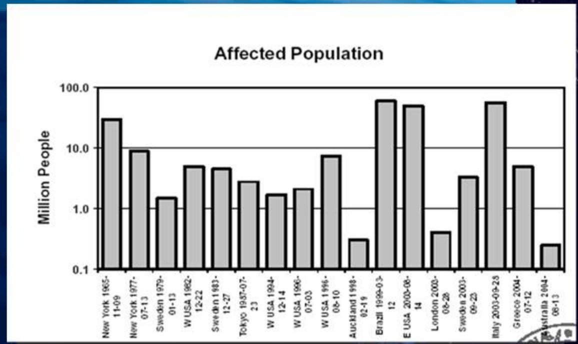
hoto source: Peoria Journal Star

System blackouts: a permanent threat…

- **Some recent large scale *Blackouts***

Country	Affected population	date
India	**670 Millions**	**30-07-2012**
Brazil & Paraguay	**87 Millions**	**10-11-2009**
Indonesia	**100 Millions**	**18-08-2005**
USA	**55 Millions**	**14-08-2003**
Italy	**50 Millions**	**29-09-2003**

- But also
  - Guadeloupe (2012), Malaysia (2005), Jordan (2004), Greece (2004), Finland (2003), Sweden & Danmark (2003), London (2003), ….
- Variable cost **but can approach 1% GDP**



Toronto, blackout August 2003 (wiki)

2014 Energy Transition Law

Key pillars & scenarios for medium/long term targets

6 PILLARS, 7 PROGRAMS

40% less greenhouse gas emissions in 2030 compared to 1990

30% less fossil fuel consumption in 2030 compared to 2012

Increase the share of renewable energy sources to **32%** of the final energy consumption in 2030 and **40%** of the electricity production

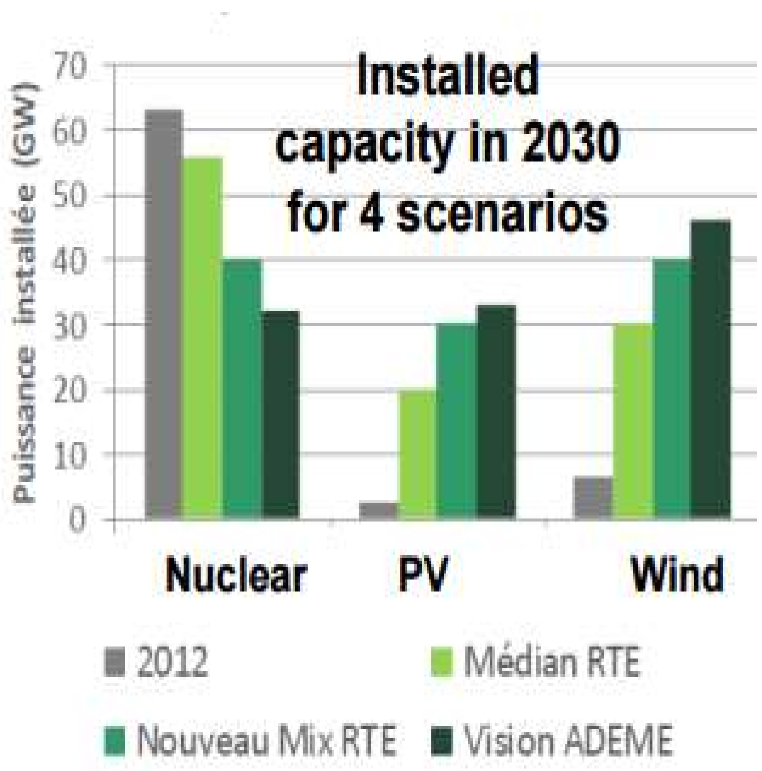
Reduce final energy consumption by **50% in 2050** compared to 2012

-50% less waste in landfill by 2025

Diversify electricity production and reduce the share of nuclear power to **50%** by 2025

1. Renovating buildings & homes
2. Clean, green transport
3. Circular economy, recycling
4. Renewable energy
5. Nuclear energy safety
6. Simplification for efficiency
7. Empowering citizens

GENERATION CAPACITY MIX IN 2030: SCENARIOS



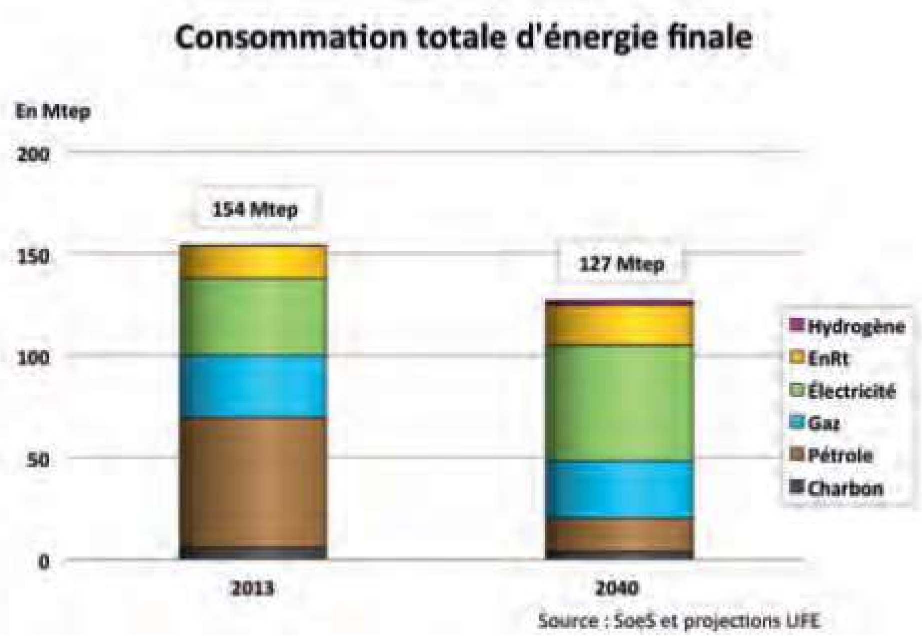
THE ENERGY TRANSITION for the GREEN GROWTH

Some highlights vs. prospectives

- **2015-2017**
  - **The warmest years** ever recorded (the coldest: 1909)
  - **Paris agreement** COP 21: legal agreement
  - **US$ 348 Billions** investment in RES (worldwide)*
    - PV: 303 GW, + 33 %
    - Wind: (487 GW, + 12,5 %
    - 2016: US$287,5 Billions investment
  - **Electric Vehicles:** 50% increase
  - **More than 300 millions** customers gained access to energy (worldwide)

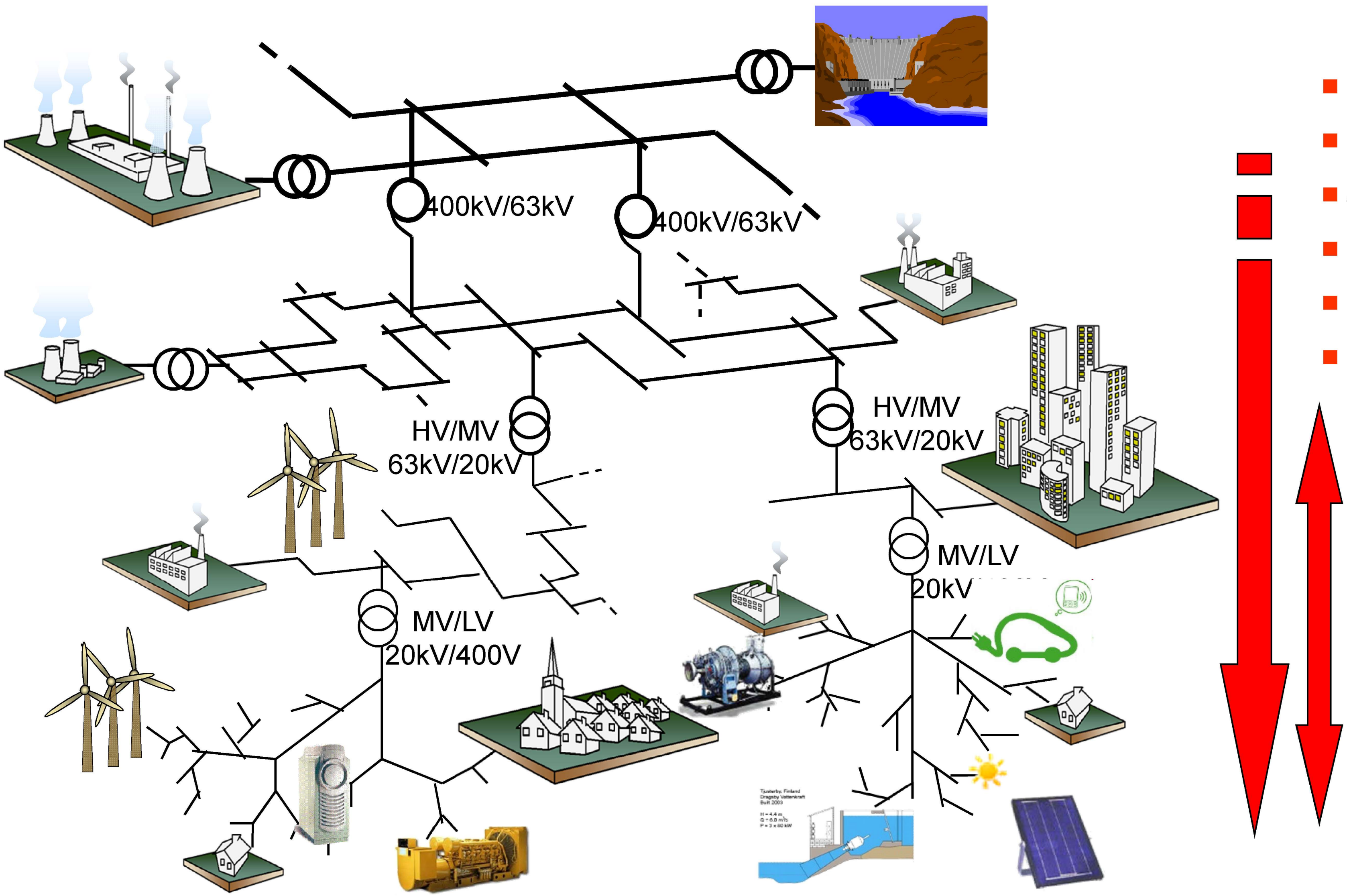
.

- **2025 - 2050**
  - Electricity for **digital**
    - +50 TWh à h 2040



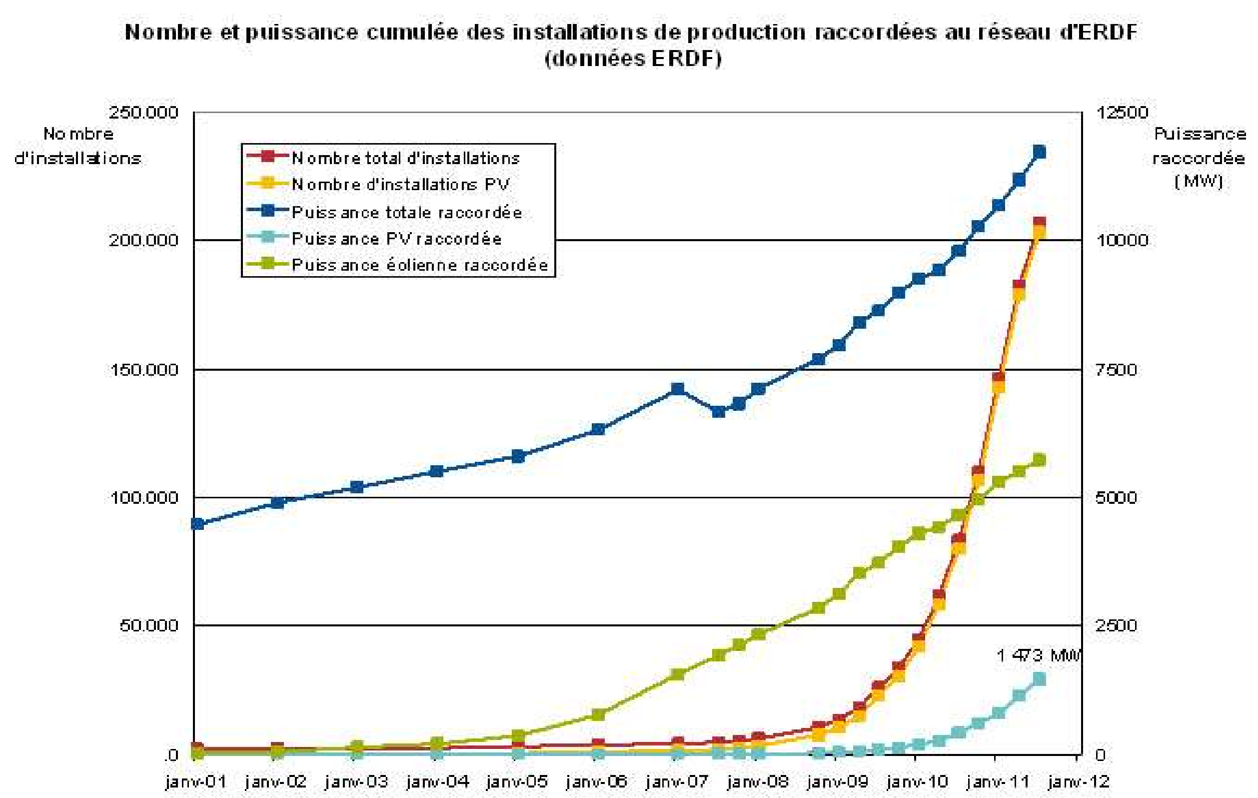
* Bloomberg

Heritage and paradigm change

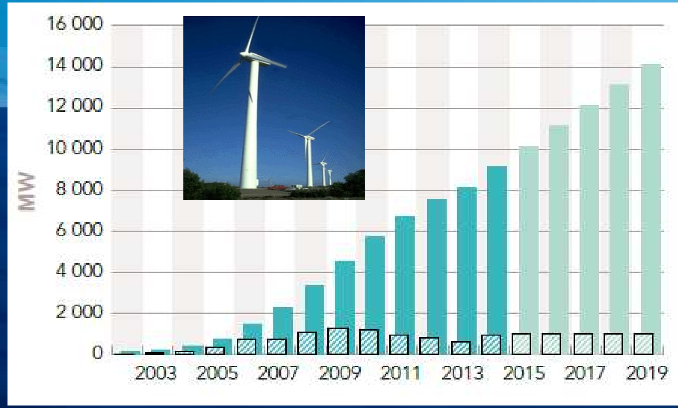


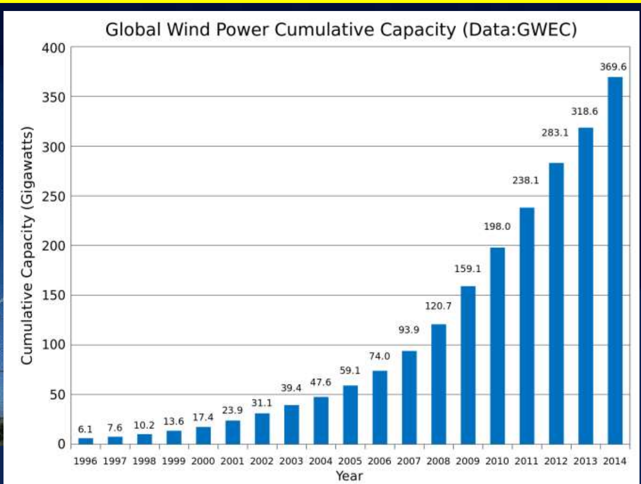
- Impacts: positive /negative
- Most RES
- Asset management
- Failure risks
- Cost and acceptability
- Grid evolution

French and wordwide evolution…

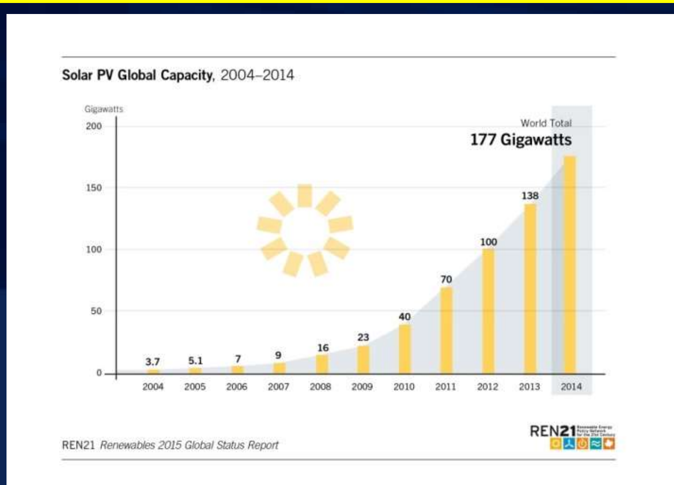


Source: ERDF



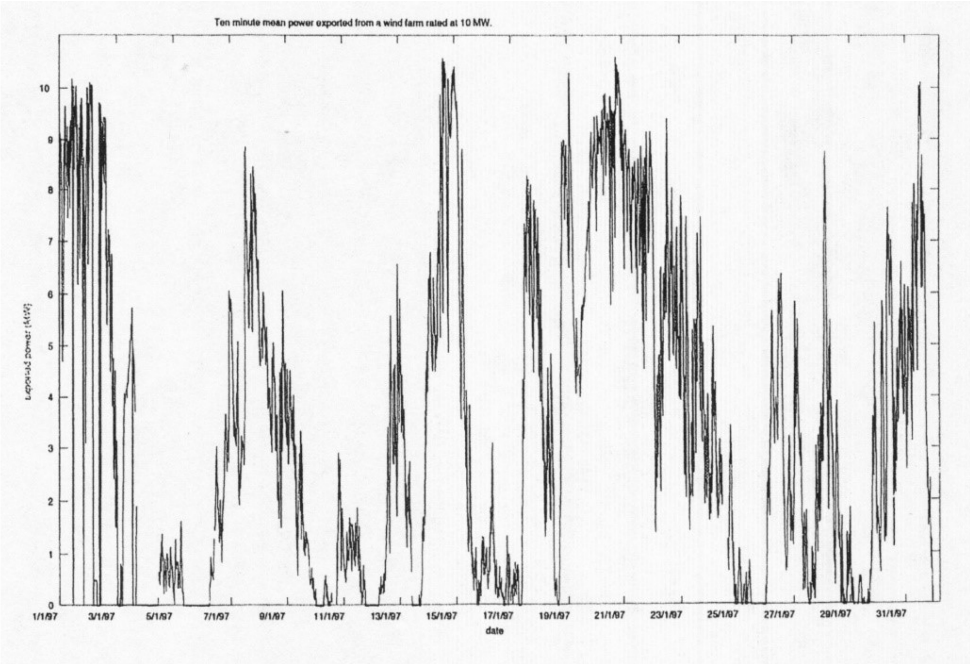


Worldwide

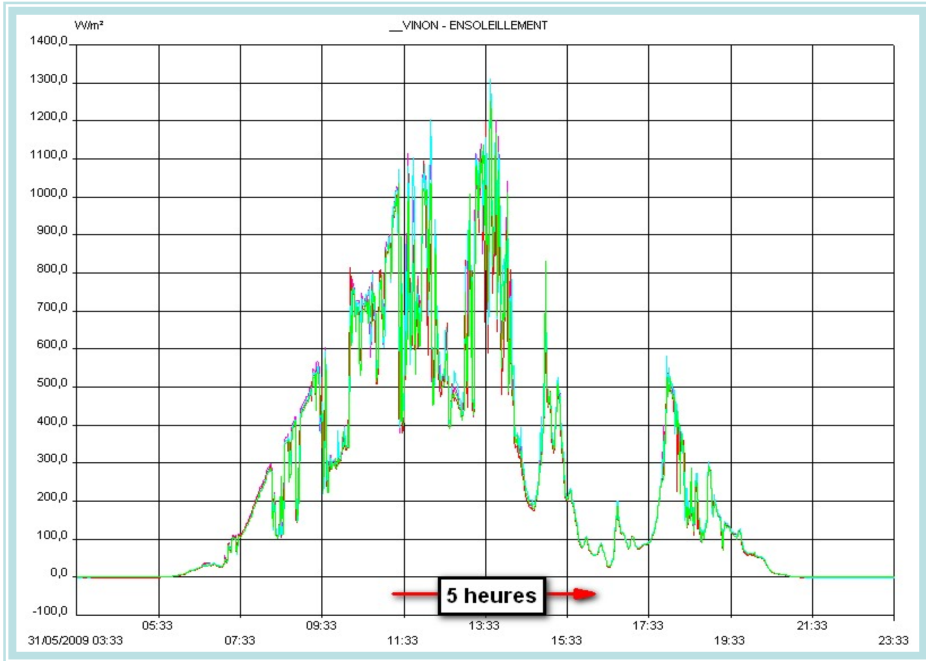


Integration intermittent energy and EV

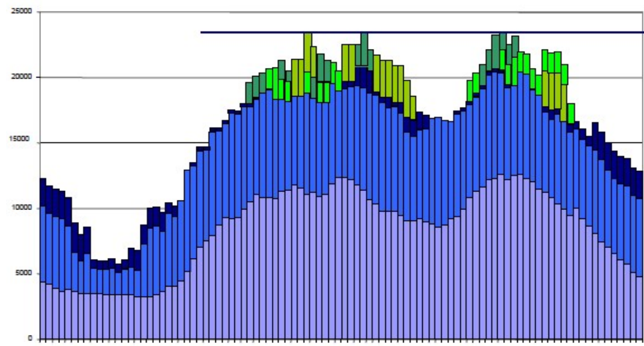
Wind: Poweroutput of a wind farm over 1 month, UK



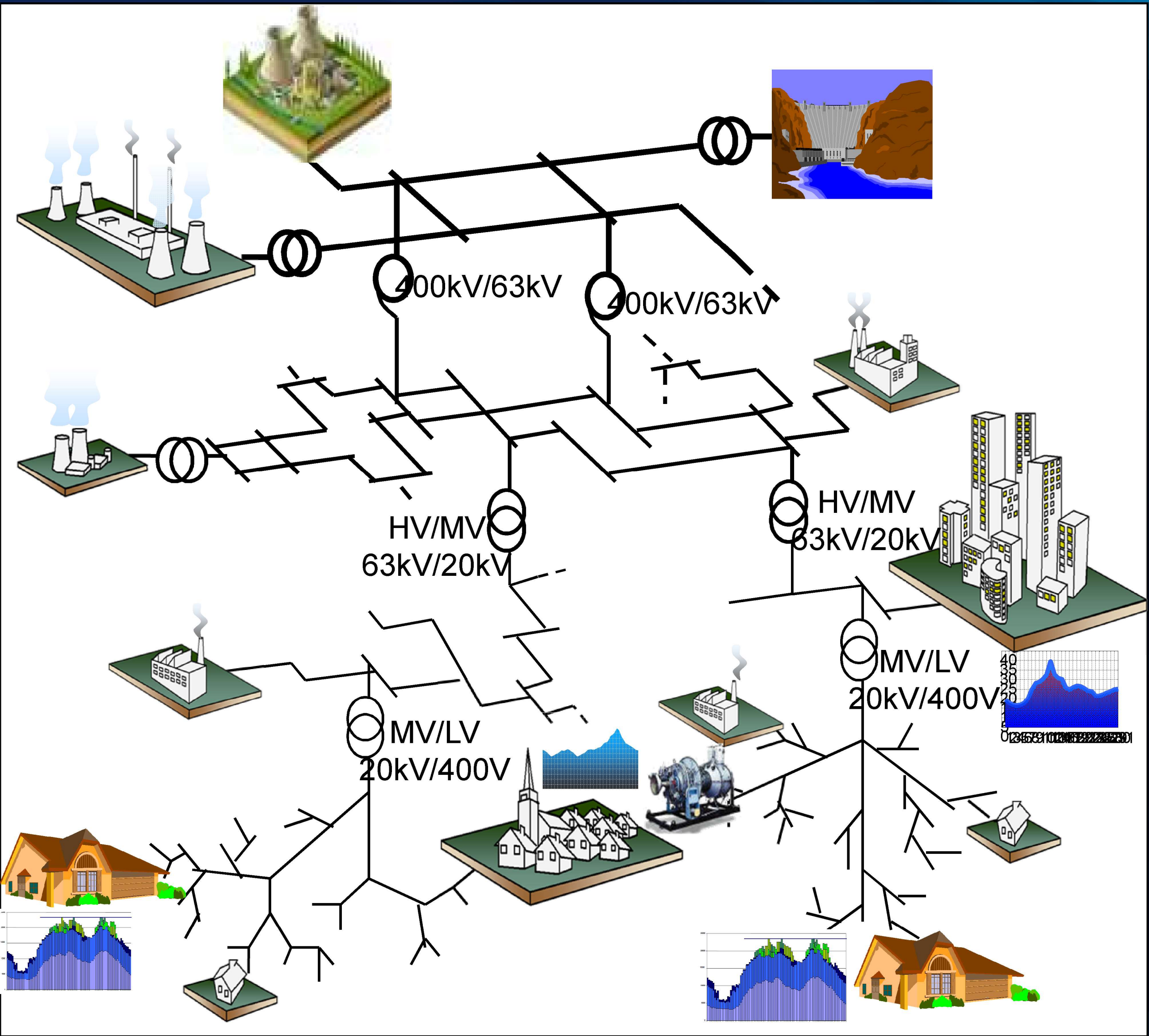
PV: ex of Vinon sur Verdon (May 31st 2009)



- **PHEV**
  - 1 Mo fast charging stations – 43 GW
  - Stochastic effects – geographical and temporal



The physical reality of Generation-consumption balance



Electrical grid: A common good, and economy factor

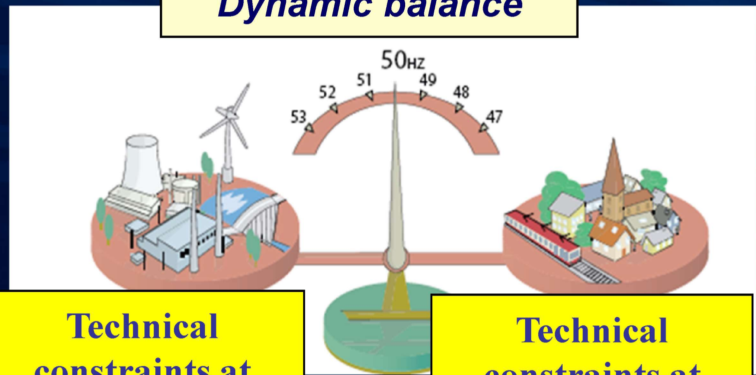
Pooling generation sources and load :

$$\sum_{i\ generators} P_{installed} \geq \sum_{i\ loads} P_{consumed}$$

Very limited storage

↓

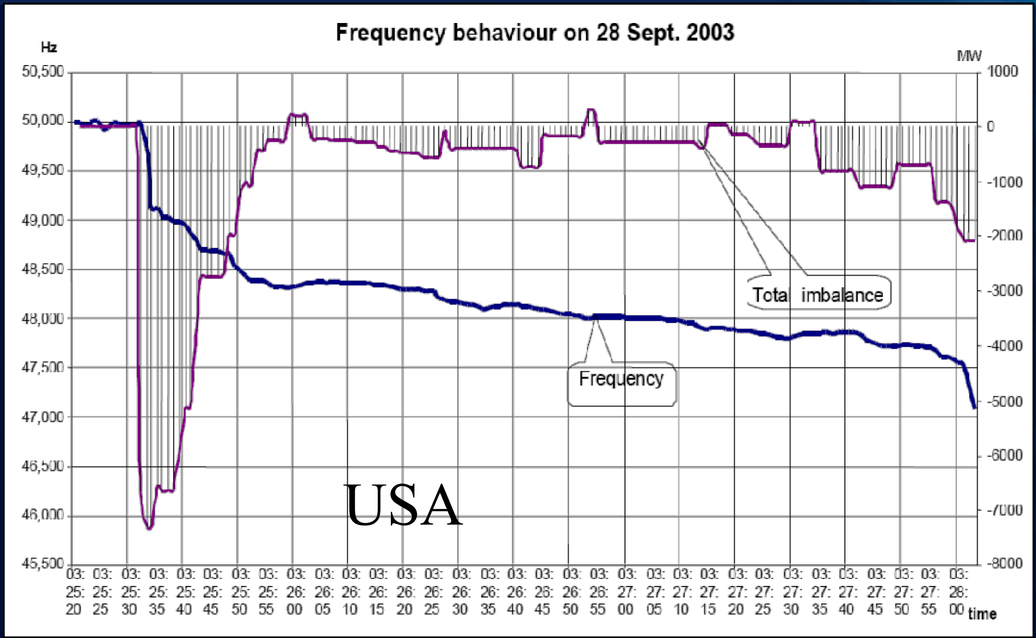
Dynamic balance

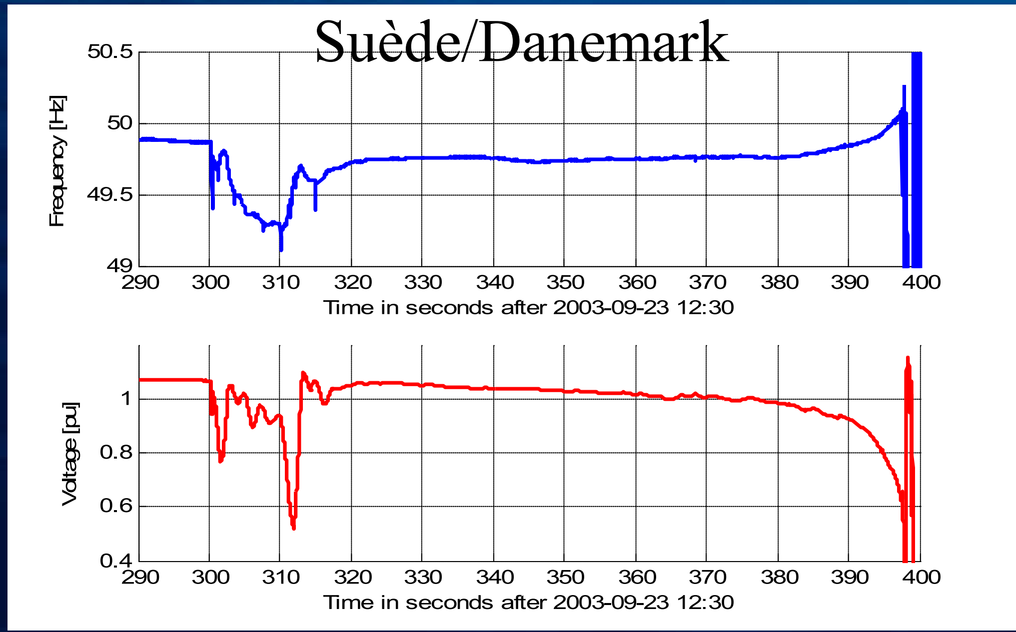


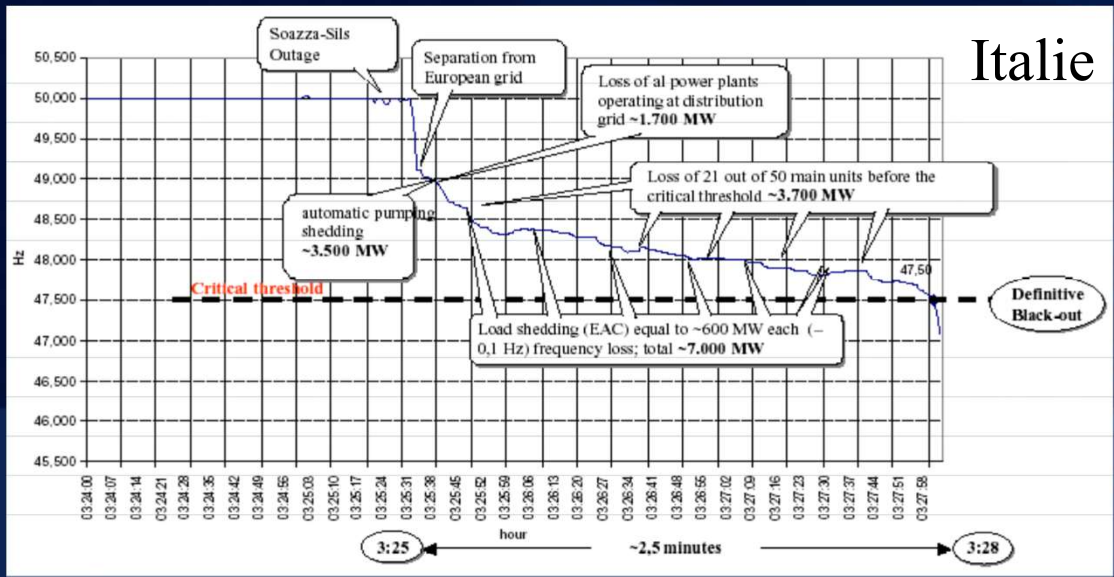
Technical constraints at injection points

Technical constraints at cons. points

Large blackouts and impact on frequency/voltage





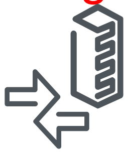


Frequency stability concerns

Reduction of the power system inertia

Power system inertia

Bulk assets phasing-out

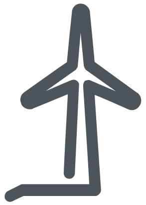


Power electronics penetration

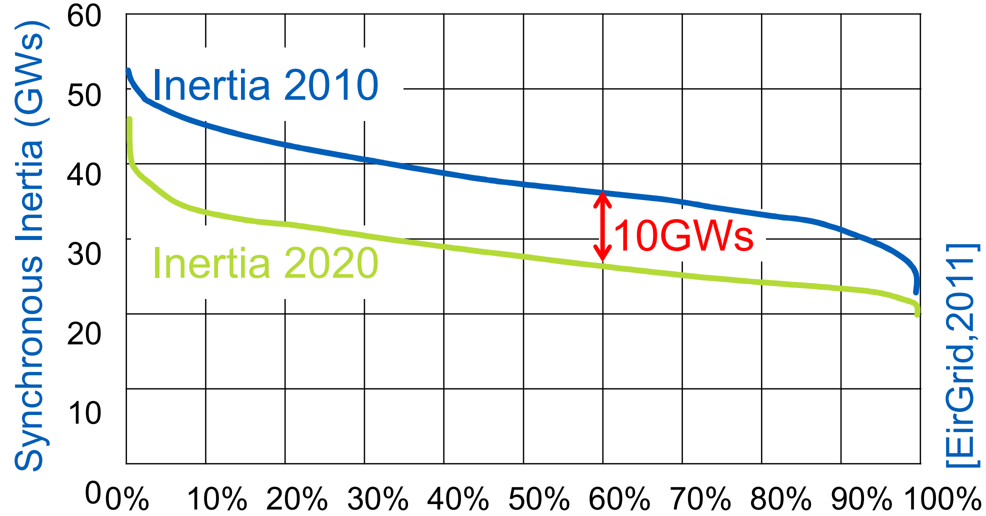
Ex. Ireland energy mix evolution from 2010 to 2020

-700MW

+ 4200MW



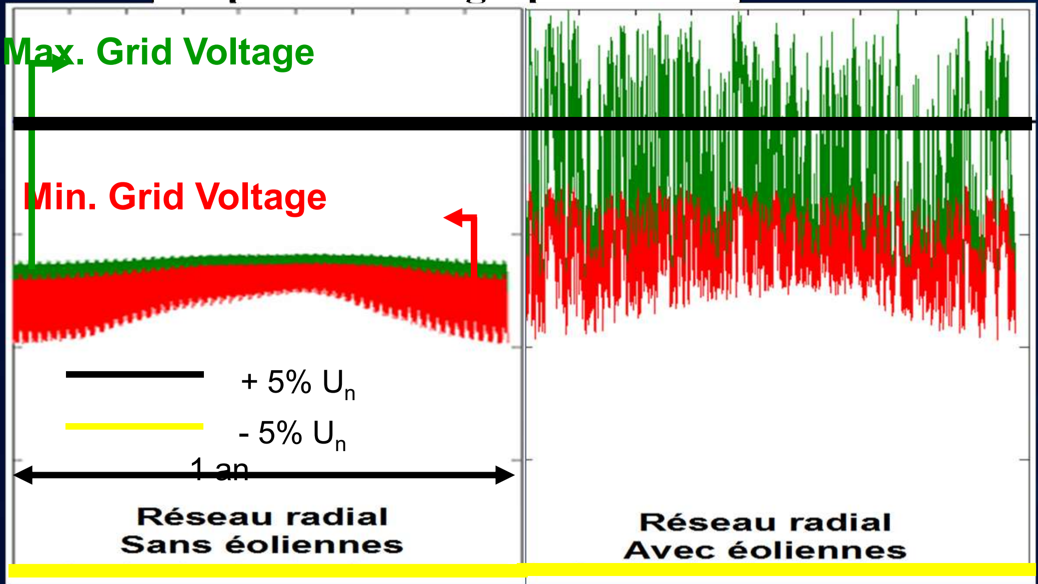
Impact on system inertia duration curve



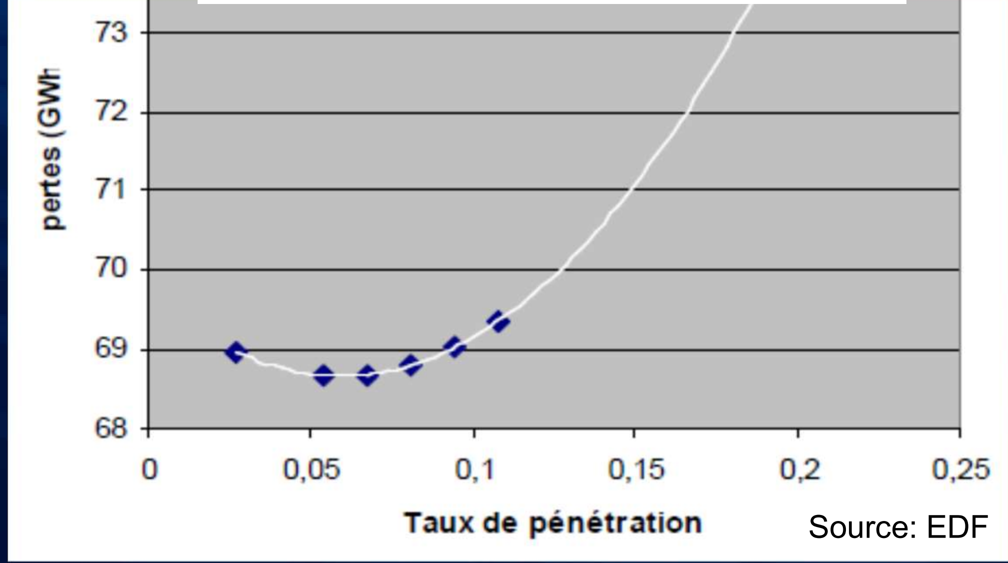
PhD: G. Lebel

Examples of technical impacts

Impact on voltage profile



Impact on technical losses



Source: EDF

Impact on harmonics

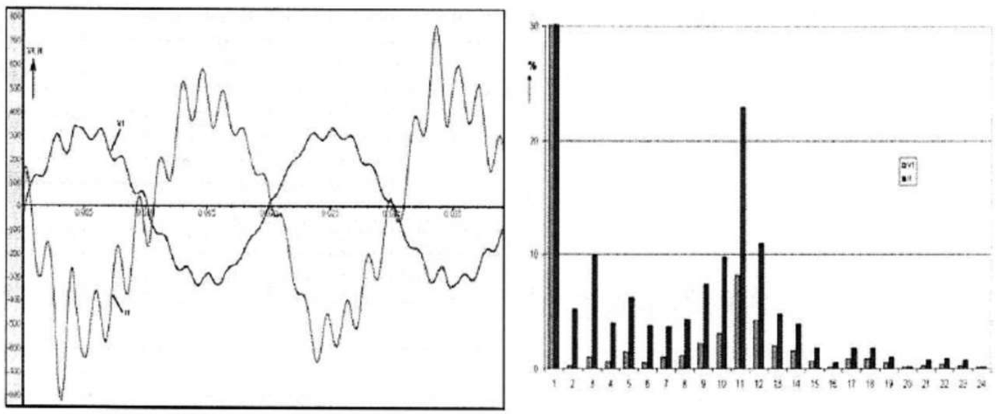


Figure 2. Voltage and current waveforms at the low voltage side of a MV/LV transformer, and spectral distribution of harmonics with the 11th harmonic salient due to grid resonance (Bosman 2006)

Source: PV Upscale

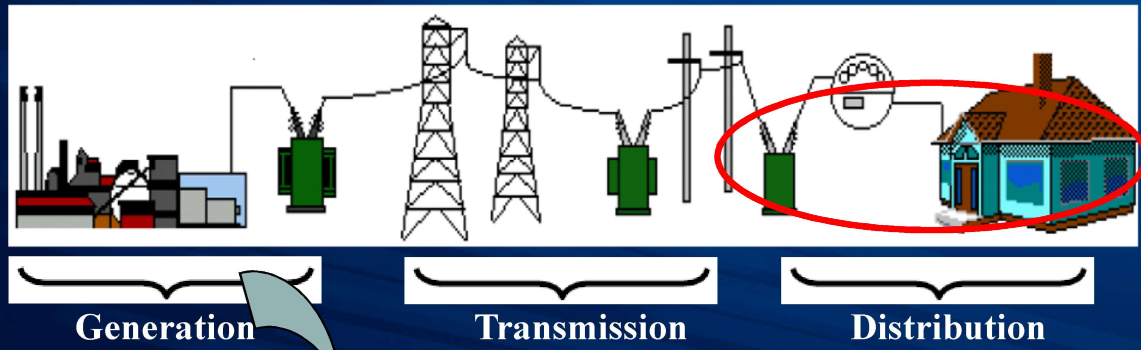
Need for more intelligence…

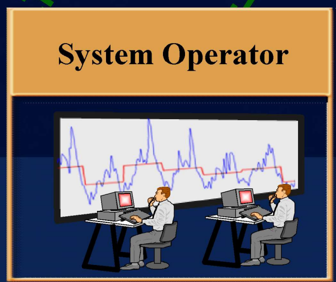
- **Increasing complexity: how to cope?**
  - Fulfill changing needs
    - New usages, consum'actor, ….
    - RES/DG integration
    - Increased uncertainties
- **Constraints:**
  - **Technological:**
    - Build on existing assets
    - Maturity of technologies
    - Centralized vs Decentralized approaches
  - **Economical**
    - Economical models and viability
  - **Regulation**
    - Incentive vs "a posteriori » regulation

SmartGrids evolution and value chain

SmartGrids deployment: Same fundamentals, different priorities

SmartGrids value chain

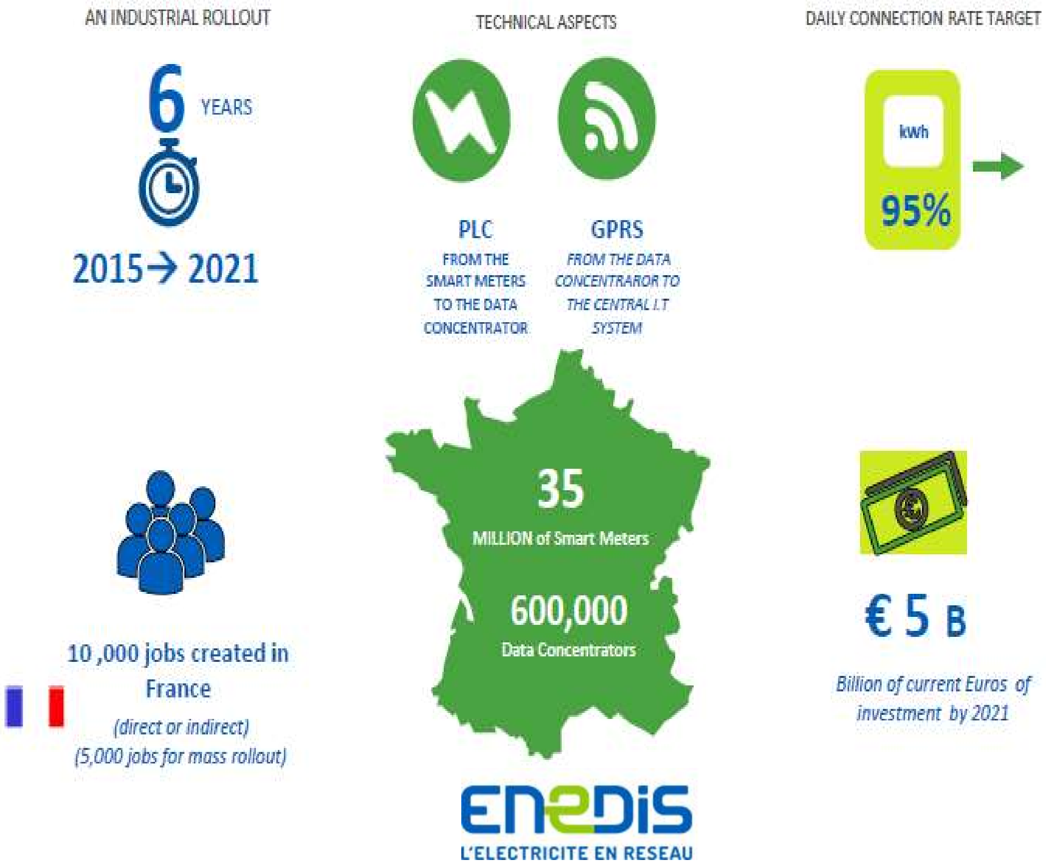


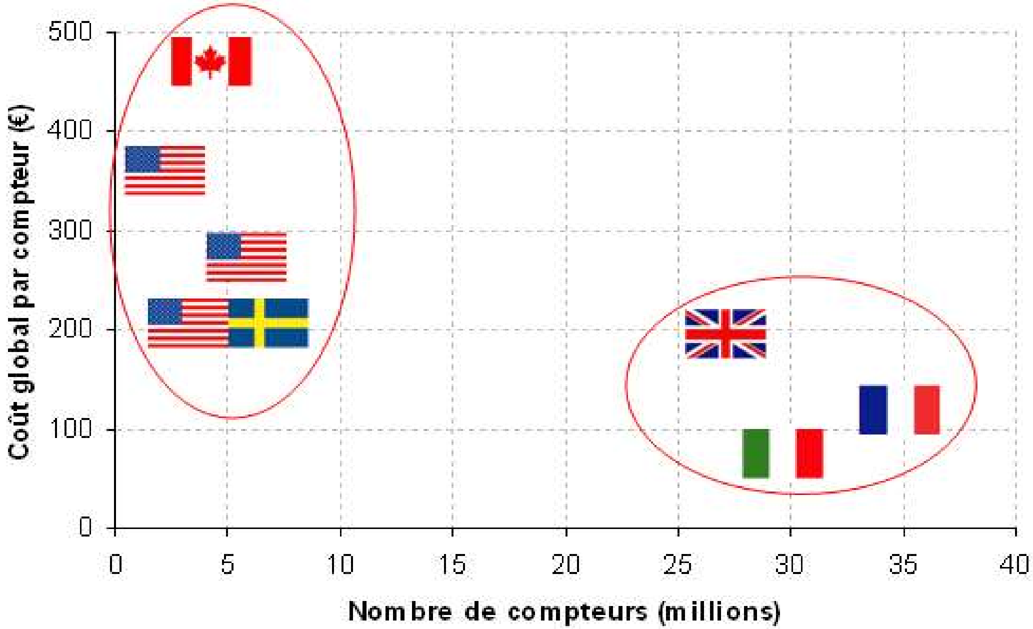


- **AMM** is a key element of SmartGrids but not the only one

The meters: communicating or smart?

Linky project main data and International benchmark

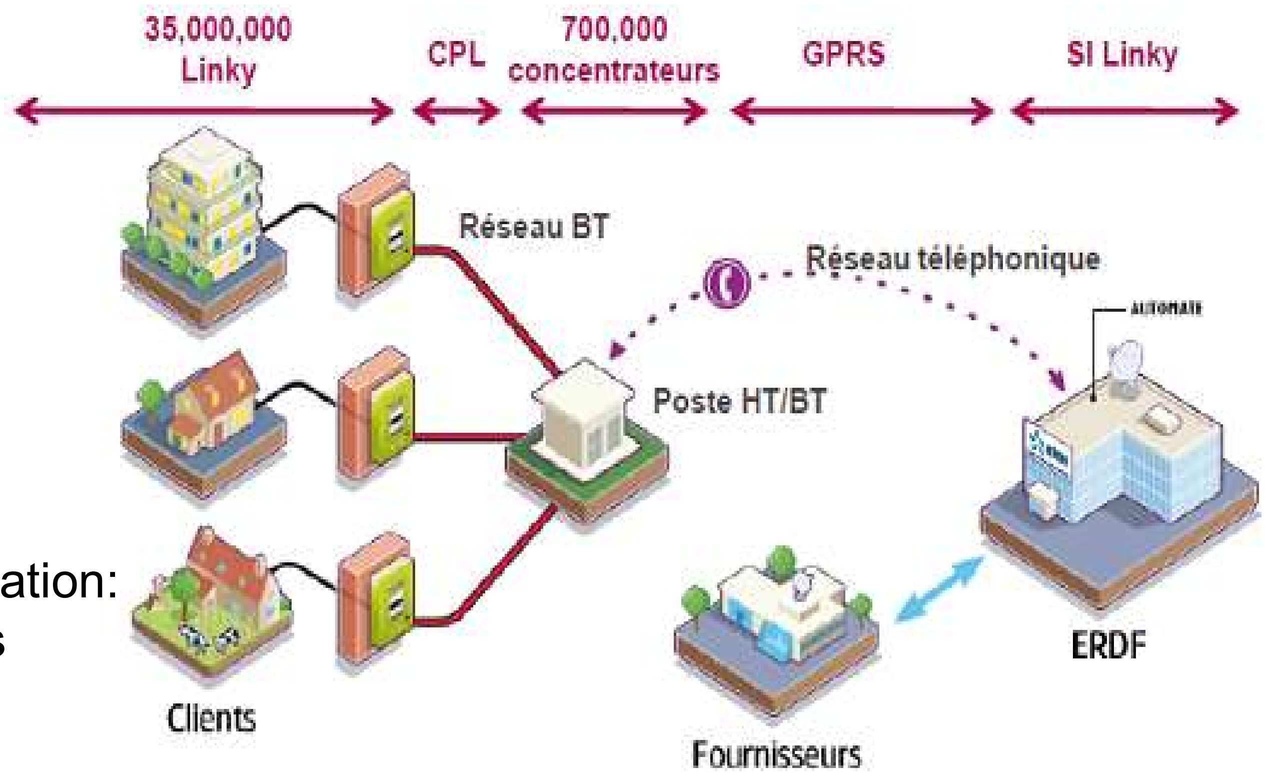




	Global cost of the project	Nb. of meters	Global cost per meter
Italie (Enel)	€ 2,1 Billions	30 millions	€ 70
UK (Ofgem)	€ 5,2 Billions	27 millions	€ 193
Suède (E.ON)	€ 0,2 Billions	1 million	€ 220

French Advanced Metering Technology LINKY smartmeter

- **March 2011 → End of large scale experimentation**
  - 300 000 ERDF's LINKY (in both urban and rural area)
  - € 5 Billions

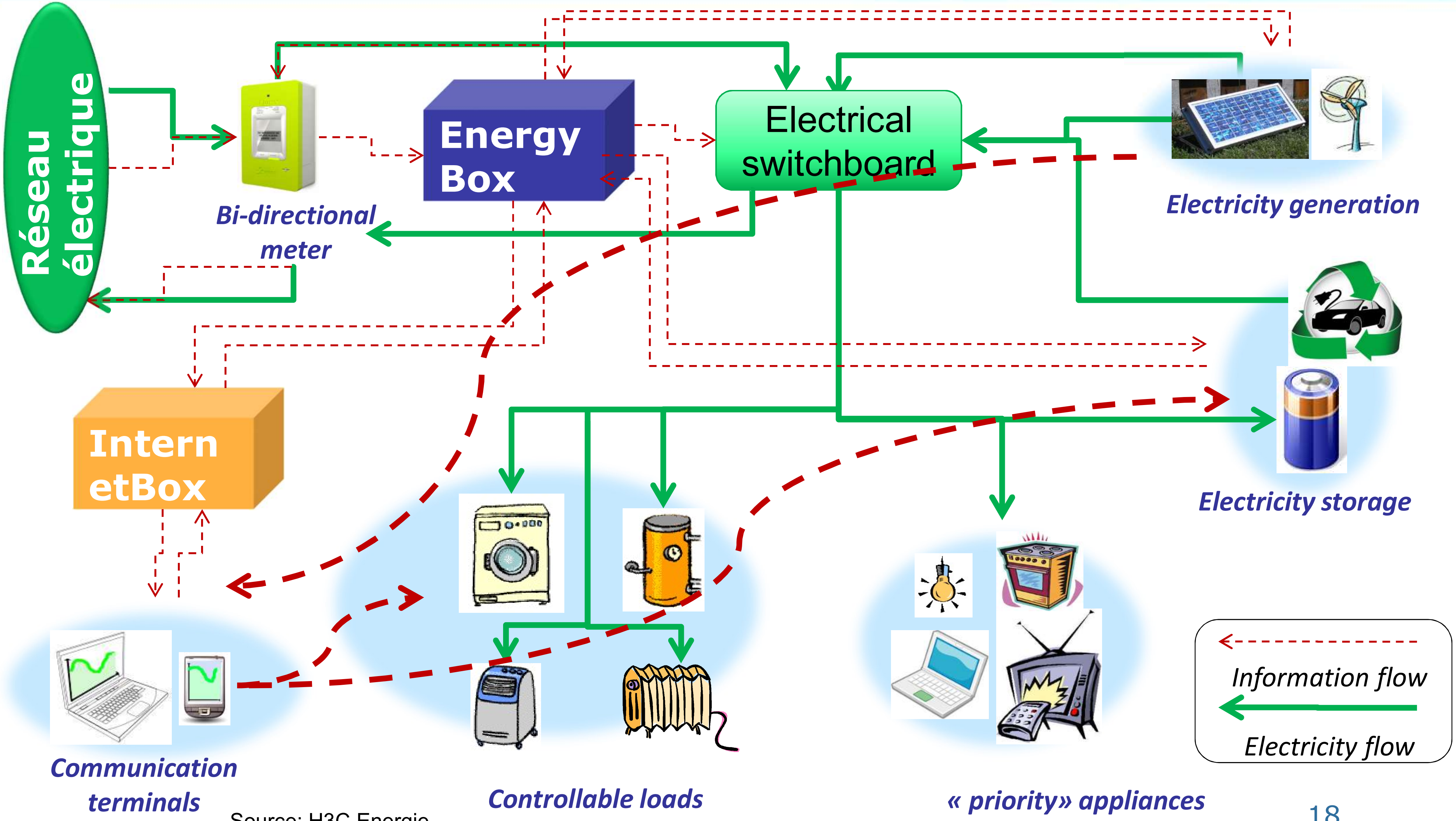


- **Load control functionalities**
  - Bidirectional transfer of information:
    - Price options to end users
    - Load curves to providers
    - …

- **Mass deployment started end 2015**

Smartgrid at the end user

Energy box as « Energy Manager »

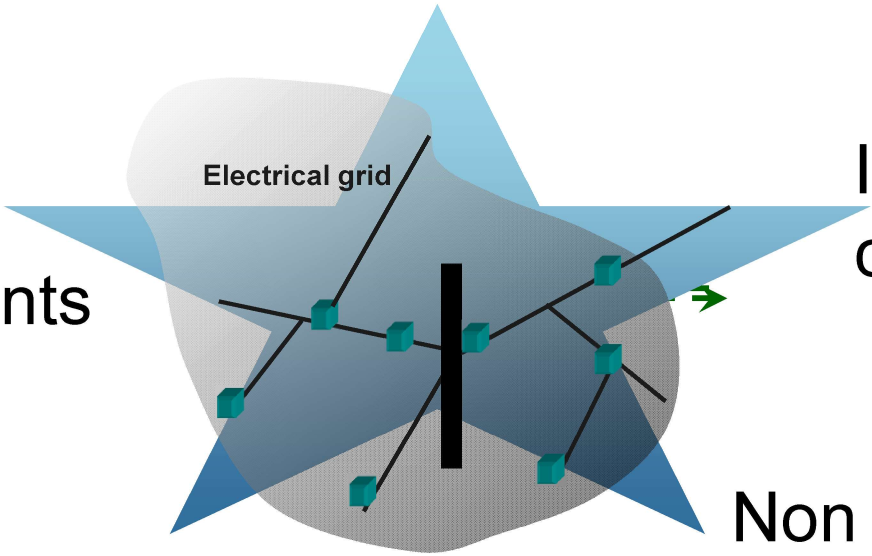


Source: H3C Energie

SmartGrid Technology challenges: Main categories

Advanced supervision & control

Advanced sensors & measurements



Interfaces, communications

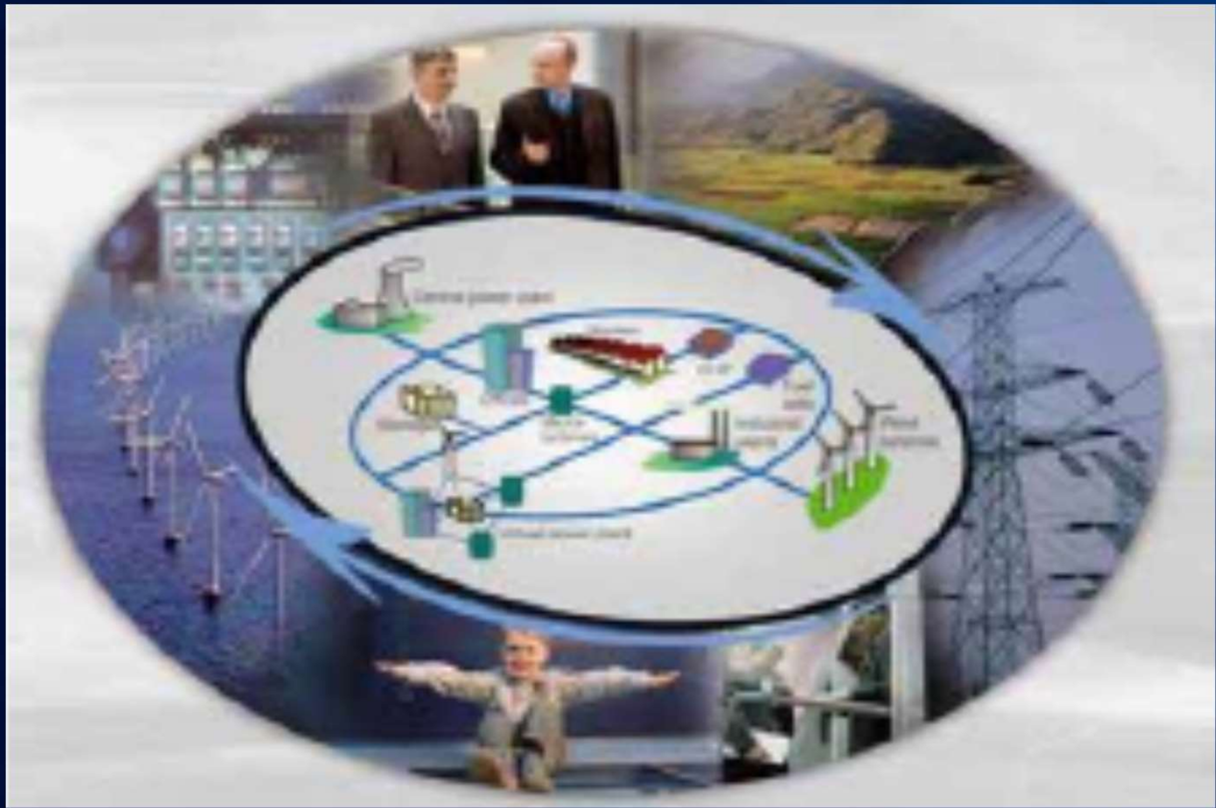
Advanced grid components

- Storage
- T&D (intelligent substation, new gen cables, …)
- Actuators (compensators, smart protections…)
- Robust switching and fault management

Non utility components

- Generation (PV, WT, …)
- Electric Vehicle
- ESP & End user interface (box, appliances, …)

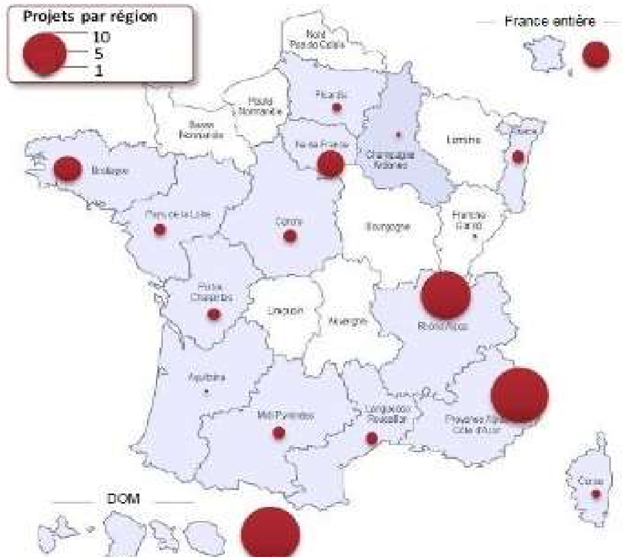
SmartGrids demo projects in France



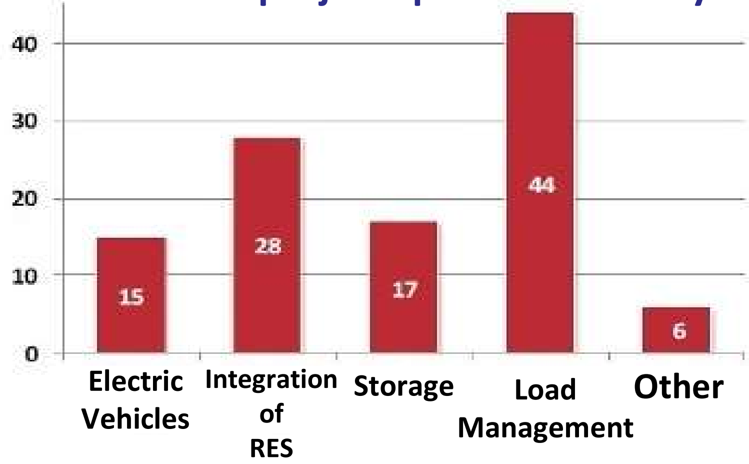
French Smart Grids initiatives: From extensive R&D effort to real life pilot projects

Currently, over 120 projects on the French territory

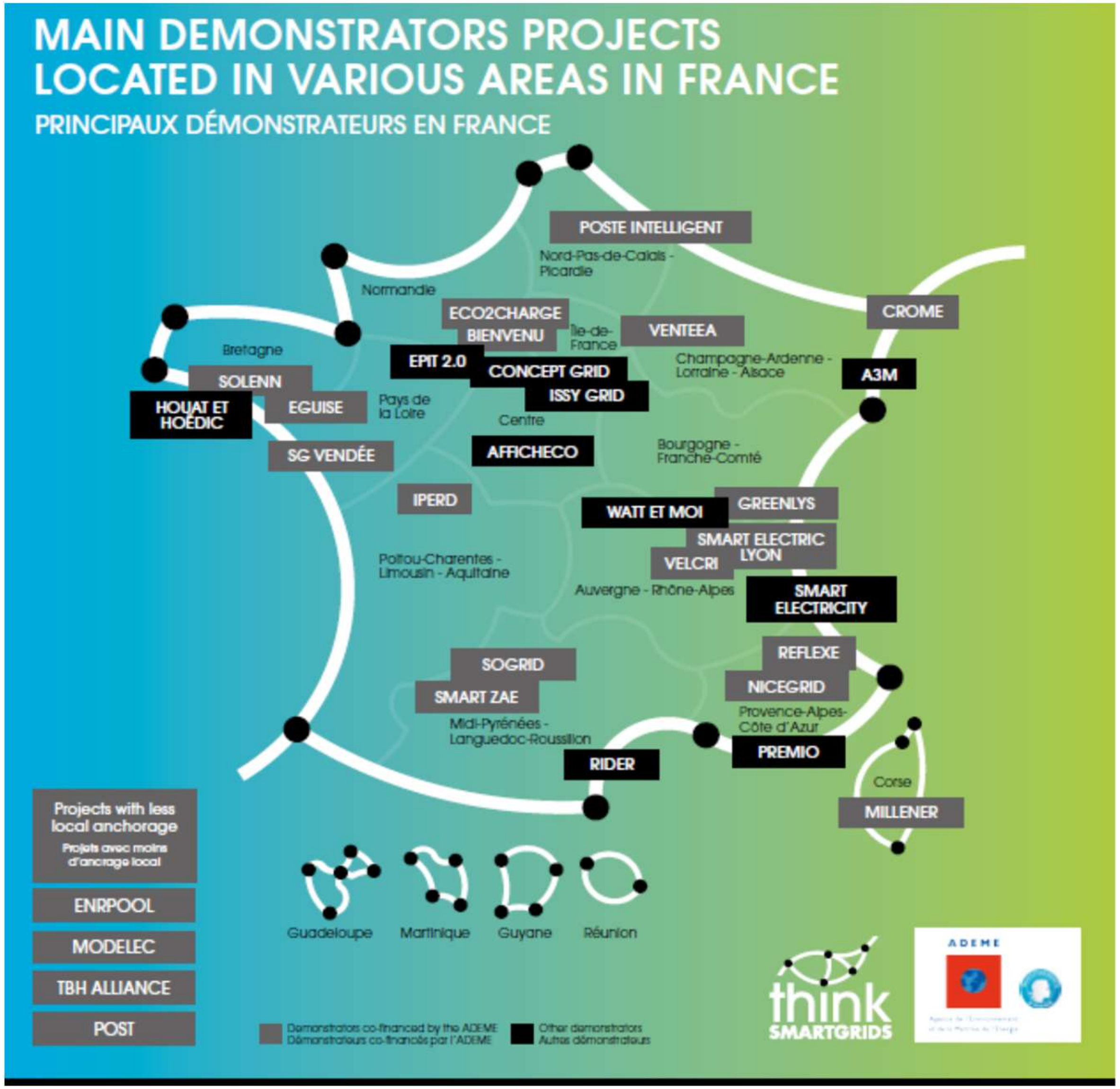
- Research **Roadmap** on Smartgrids
  - ADEME, ANCRE, EU SRA-2035
- **Funding** large number of R&D and demo pilot projects
  - France:
    - Public agencies: ADEME with Future Investment Council, ANR,…
    - Industry research funds
  - EU: under various research programs
- French **pilot** R&D project specificities
  - **Whole** energy chain coverage
    - Generation-T&D-customer involvement
    - Planning and Operation
    - Extended stakeholder landscape and consortia:
      - academia, research centers, industry, local communities, regulators,
  - **Innovation** and **validation** of technology options, opening up future R&D directions

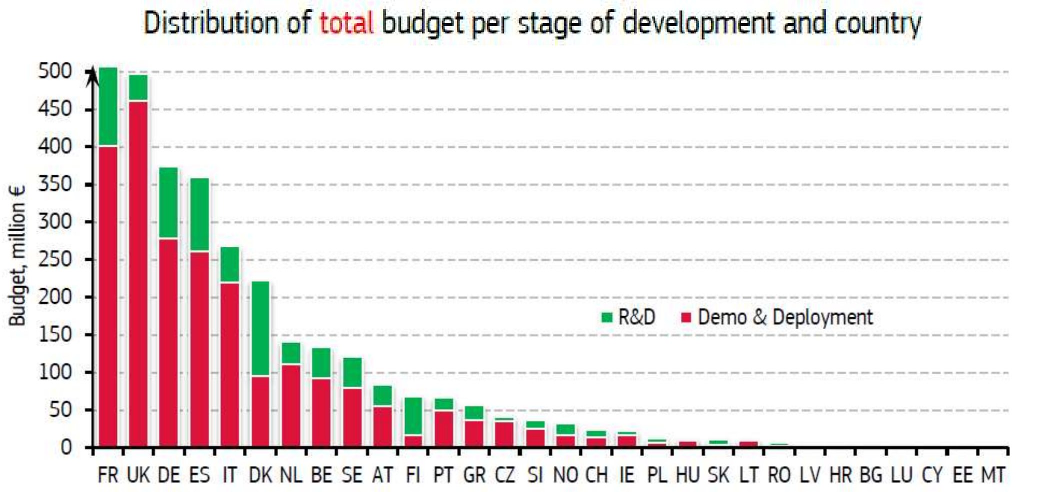


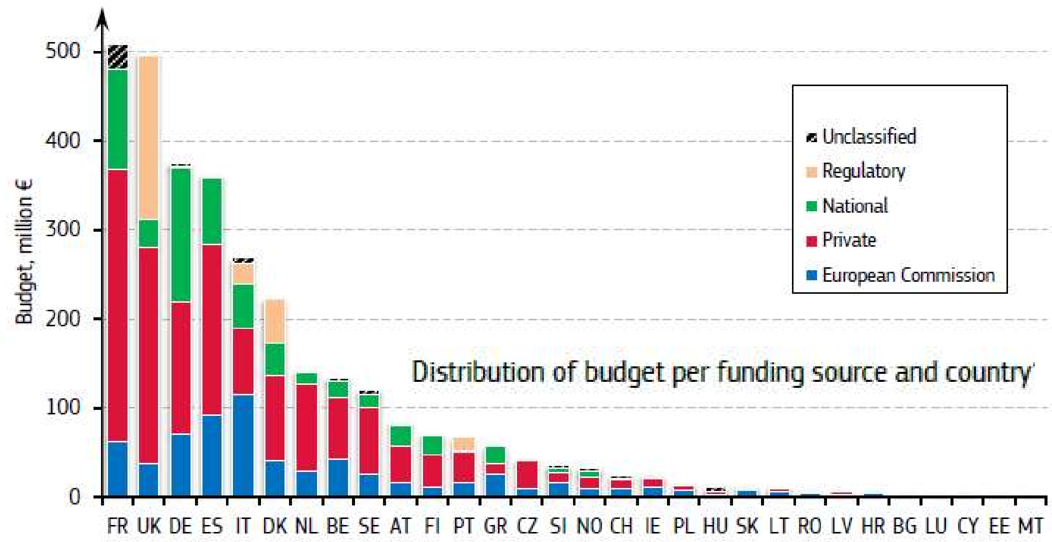
Number of projects per functionality



Some figures and EU comparaison

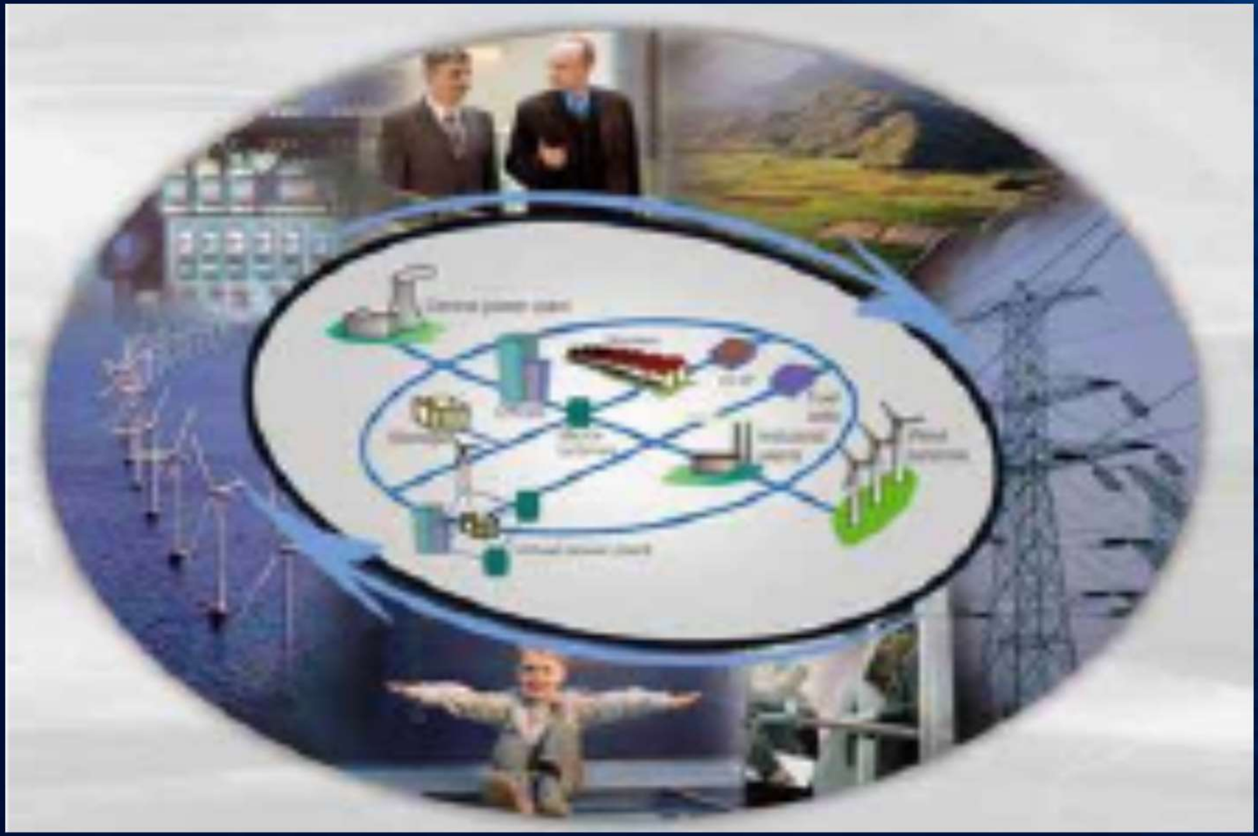






Source: JRC

Example of the GreenLys Demo Project



An Urban SG demo project,
Involving the various value chain stakeholders

- ✓ 1er urban full scale demonstrator in Grenoble et Lyon
- ✓ Awarded in the first « Investment of the future » program from ADEME
- ✓ 1000 real end users and 40 commercial sites involved
- ✓ 43 million euros investment (Smartmeters not included, already funded)
- ✓ 4 year experimentation 2012-2016

Complementary stakeholders representing the French energy chain

	TSO / DSO	Generation Supplier	Research & University	Manufacturer	ICT	Associations
Circle 1	ERDF Électricité Réseau Distribution France; GEG	GDF SUEZ Être utile aux hommes	Grenoble INP	Schneider Electric		
Circle 2	RTE Réseau de transport d'électricité		CEA	ALSTOM	Atos	Rhonalpénergie Environnement; HESPUL

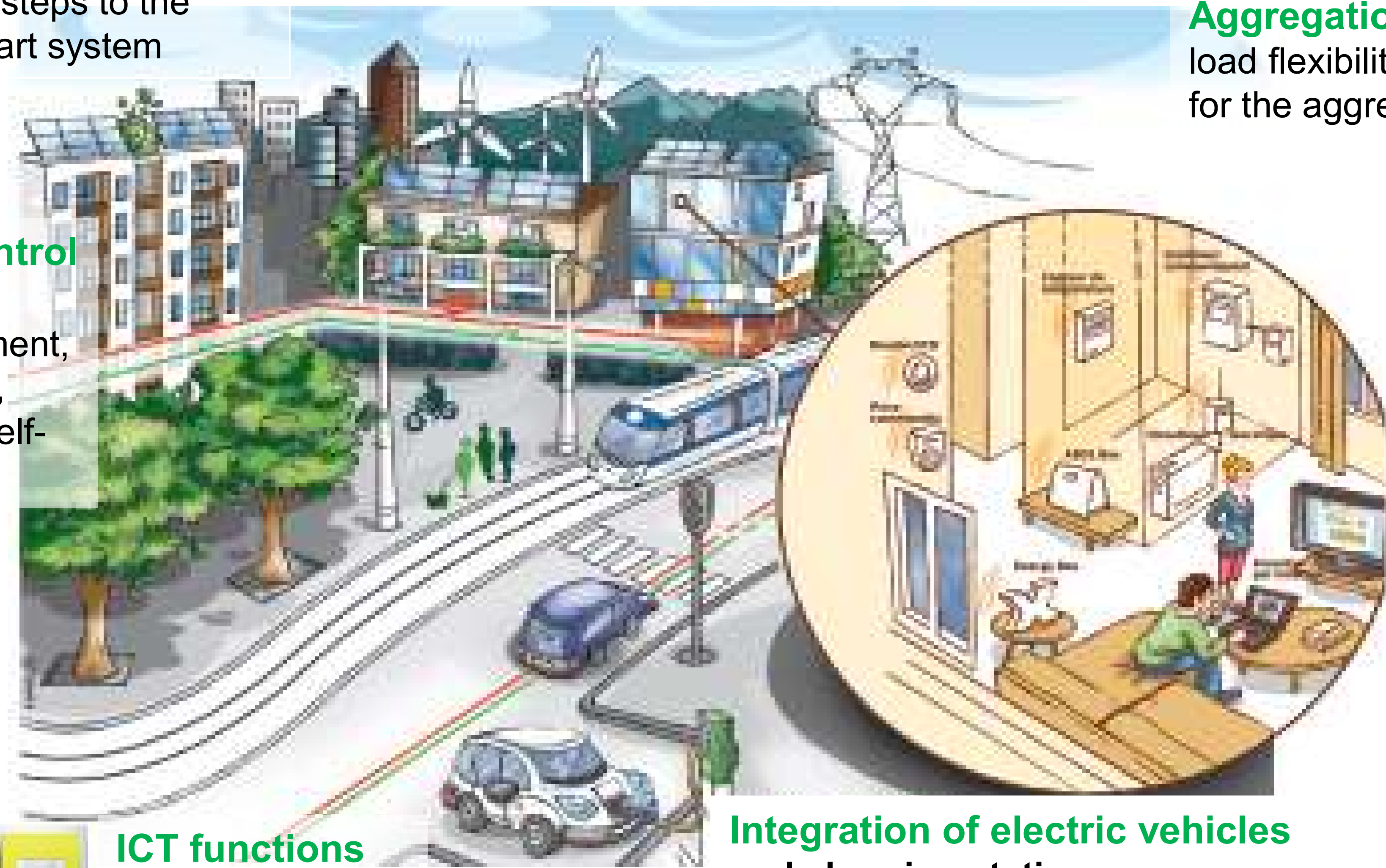
A project that covers the whole energy chain

Cost-Benefit Analysis
Specification of the transition steps to the future smart system

Connection and control of DG
(PV, cogeneration…)

Aggregation platform for load flexibility/business model for the aggregator

Smart control solutions
(measurement, monitoring, analysis, self-healing…)



Experimentation of **energy management tools (Linky & Energy box):**
Appliance curtailments + behavioral and sociological studies

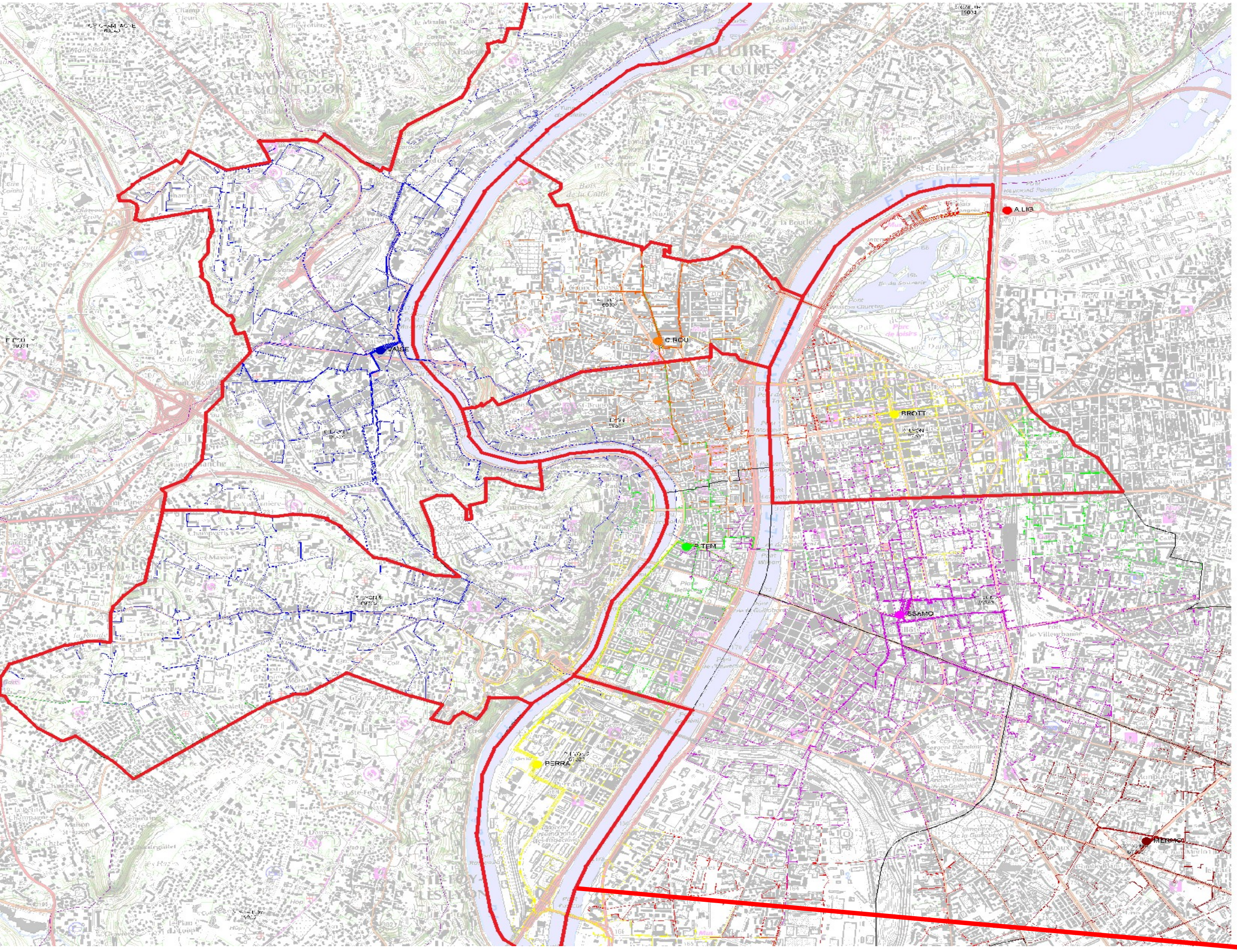
ICT functions
Through **Linky** smart meter and E-Box

Integration of electric vehicles and charging stations

GreenLys

Lyon : Confluence District

G2E Lab
Grenoble Génie Electrique
Grenoble Electrical Engineering

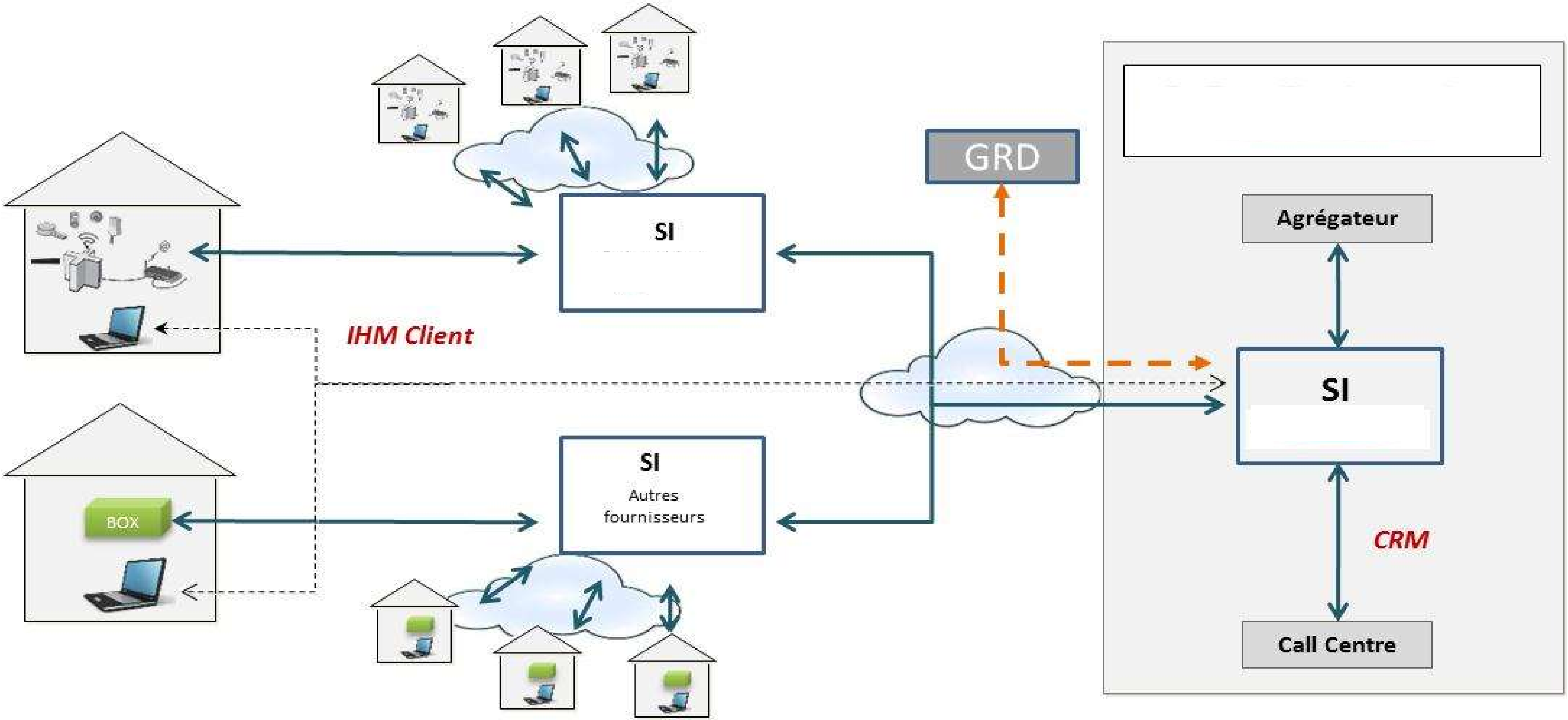


Confluence district

Grenoble : 2 districts

Caserne de Bonne and Bouchayer-Viallet

An operational LC system for the residential customer



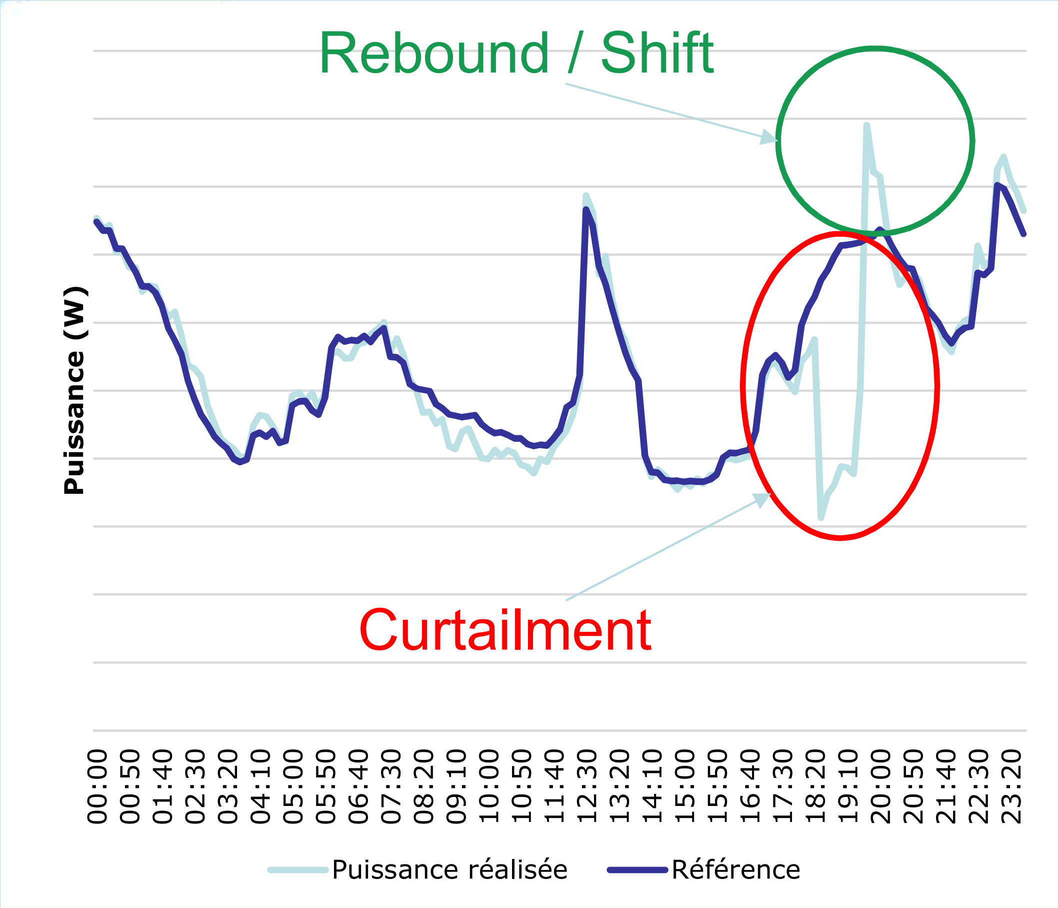
Data gathered from the energy boxes

- **Total consumption** of the site
- **Heating** consumption
- **SHW** consumption (Hot Water)
- **House** Temperature
- **Temperature** setting

2 Load control modes

- Decrease of -1° C of T° setting
- Heating system stop (On/Off)

Deformation of the load curve assessed



First results :

- Without control, the rebound in power can be significant and increases the peak at the substation
- The energy shift is observable an hour after the curtailment. Beyond that, it merges with the noise

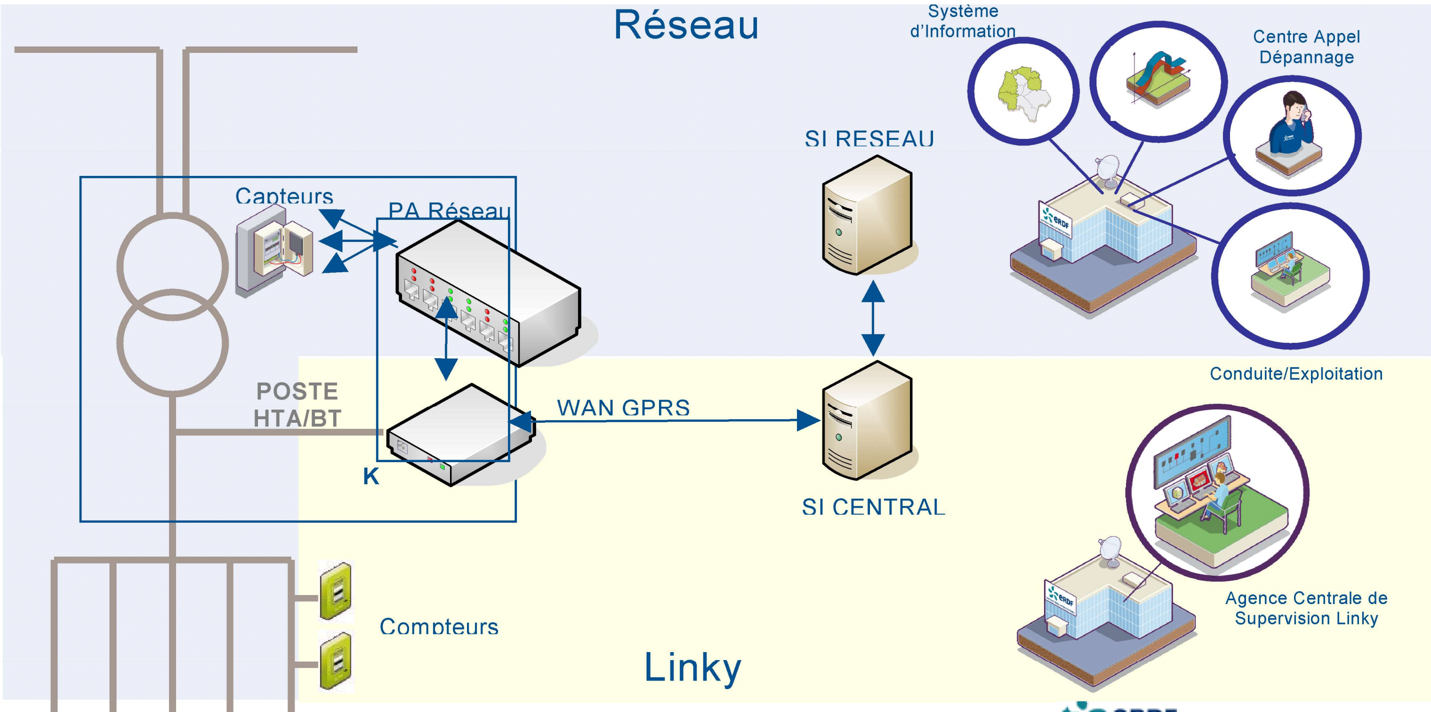
Multiple stakes :

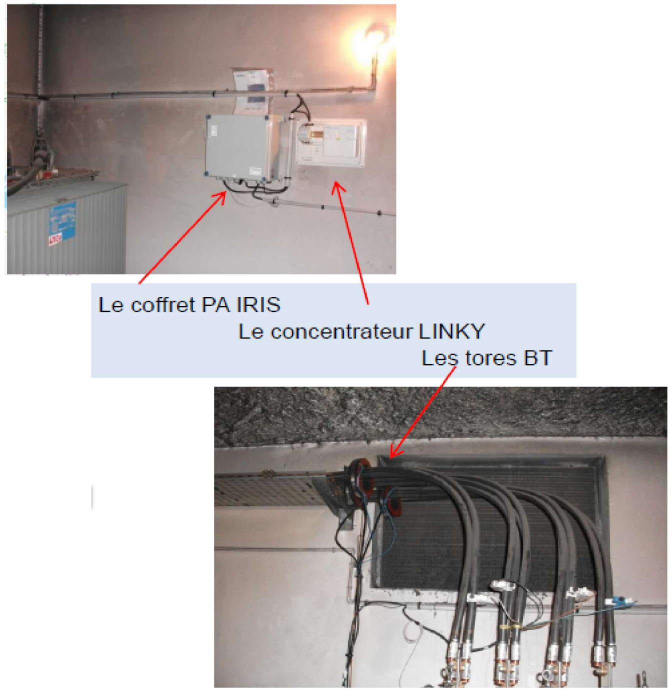
- The rebound in power must be mastered in order to limit T&D costs
- The energy shift can represent a cost to customers and suppliers, which should be minimized

Quantity	Values
Rebound	Between 25 % (local rebound control) and 45 % (without control)
Shift (1h later)	Between 20 % (local rebound control) and 60 % (without control)
Modelled shift	100% over 24h

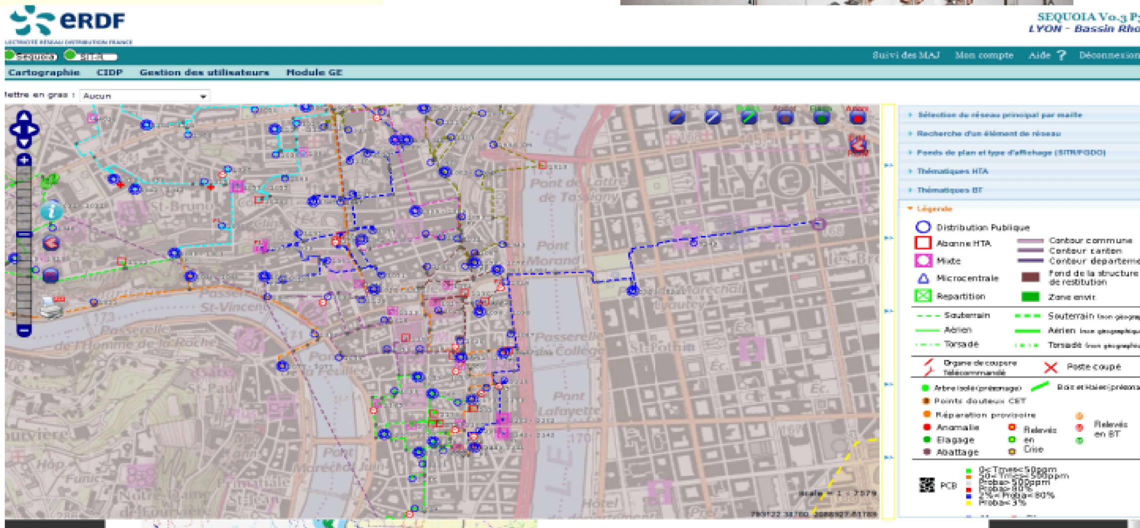
GreenLys: Observability for Flexibility
Testing new integrated technologies

Linky data for grid operation and upgrading





Implementing an IS for the supervision of MV/LV grid at « Séquoia » à Lyon

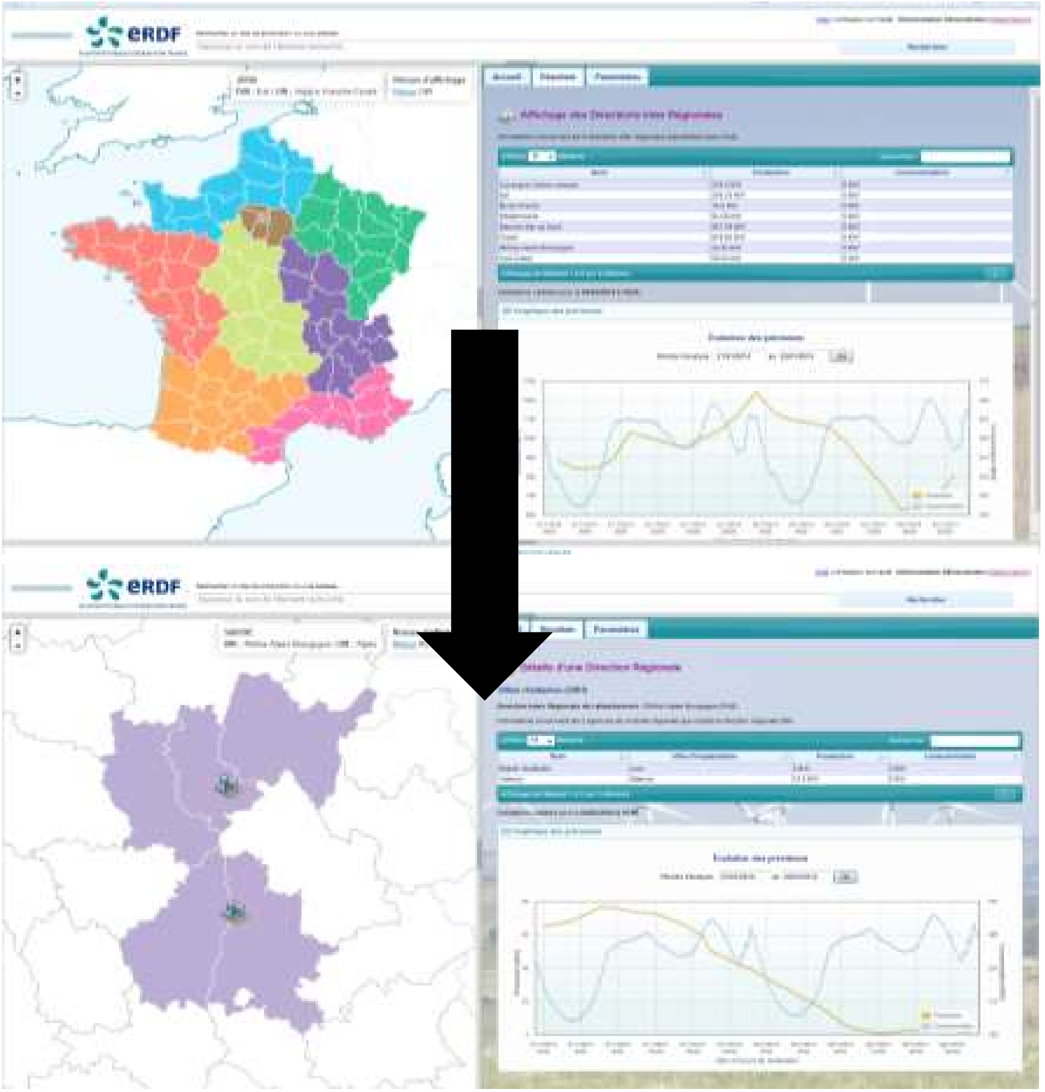


The distribution grid is totally observable, Linky is the basis of this observation

Innovative forecasting solutions tested

for better integration of RES/DG and grid management

RES/DG integration: a variability issue…



A solution tested in GreenLys : Prév'ENEDIS

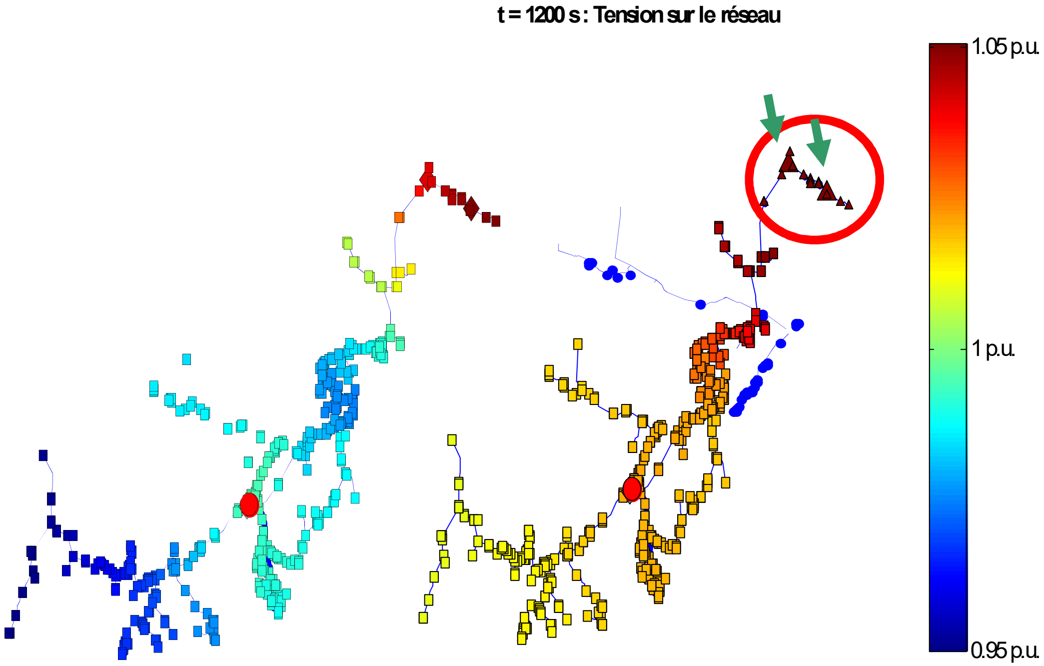
- PV with CEA INES & HESPUL
- Wind with RTE (Préol)
- Consumption within ENEDIS

Solution prototyped in 2014

- Local vision « from D-3 to H-15mn »
- A vision at a substation perimeter
- A vision at the generation site connected to MV
- At MV/LV substation for sites connected at LV grids

Innovative D-VVC for higher RES/DG integration rate

- **RES insertion limit**
  - **With P/Q classical control**
    Smax = 2 * 900 kW
  - **With D-VVC**
    Smax = 2 * 2600 kW



D-VVC

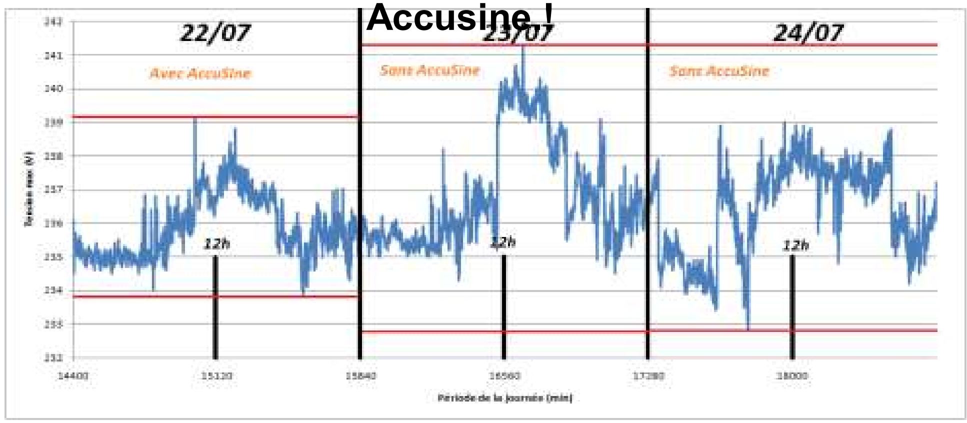
Classical P/Q Control

Overvoltages

GreenLys Accusine for VVC with RES Manufactured by Schneider Electric

PV panels located in Lyon Confluence on which the "Accusine" solution was tested.

The voltages varies : by +/-1% with the Accusine And by +/-8% without the Accusine !



DG and Grid investment on Grenoble system

Étape 1:
Diagnostic – Inventaire du réseau existant

↓

Étape 2:
Connaissance et prédiction des charges

↓

Étape 3:
Construction de la cible long-terme

Étape 4:
Stratégie d'évolution et réseaux intermédiaires

Principes du test :

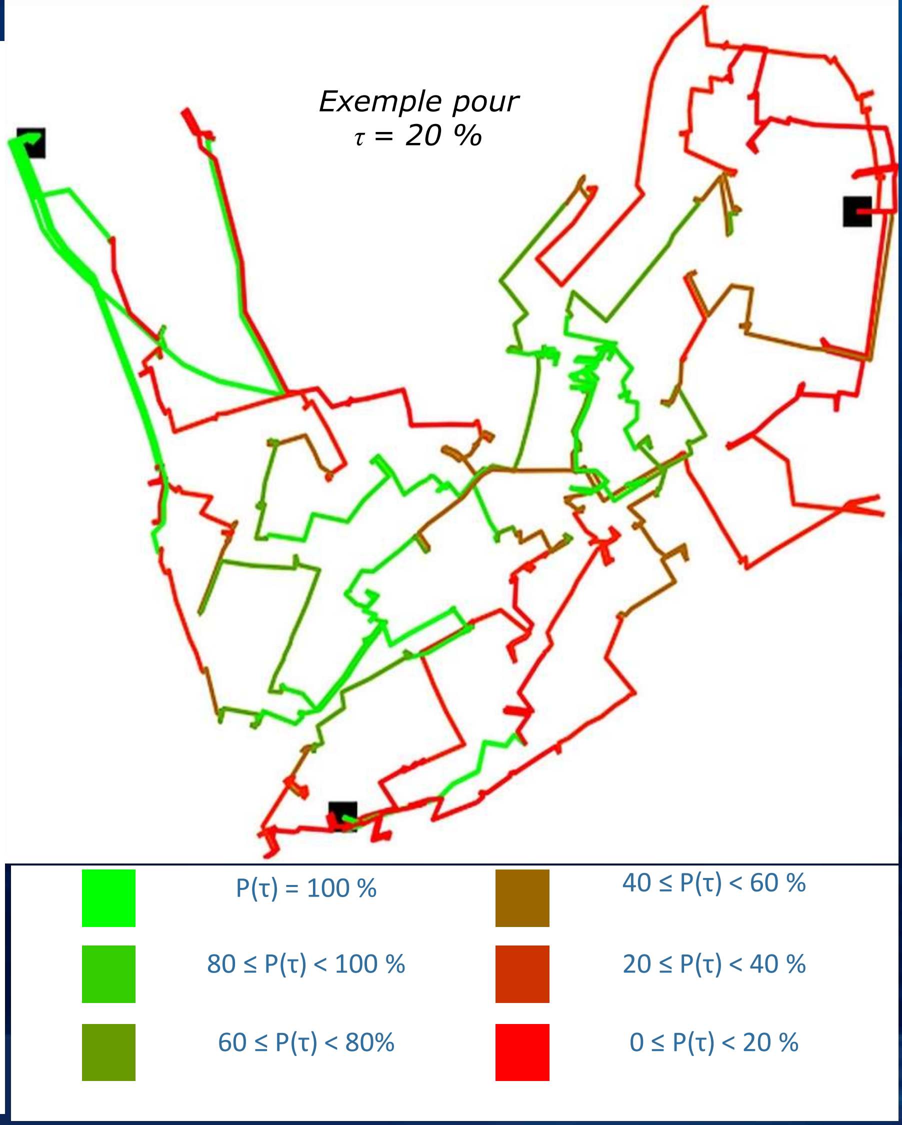
- Approche statistique (Monte Carlo)
- Pas d'hypothèse sur l'emplacement, le nombre et la puissance

Taux d'insertion :

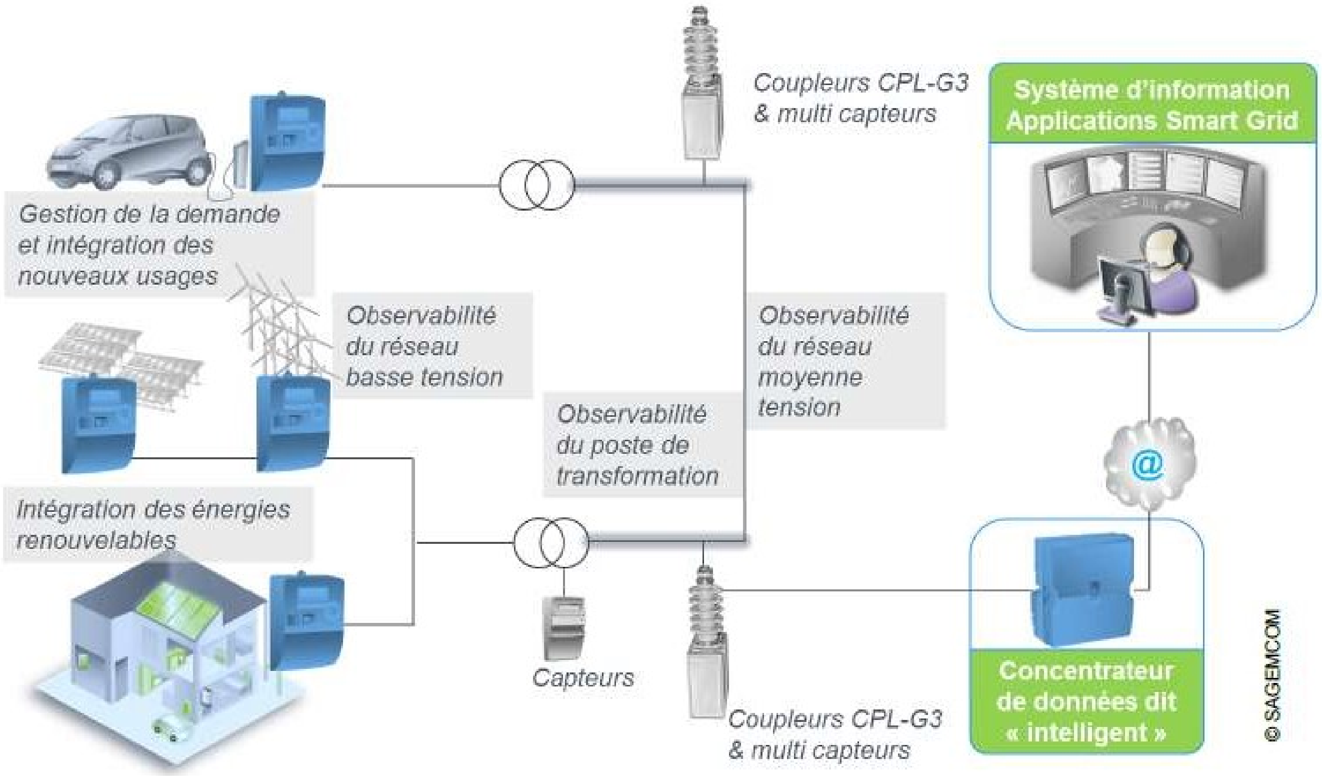
$$\tau = \frac{P_{GED}}{P_{réseau}} \ (en\ \%)$$

Probabilité de fonctionnement du réseau :

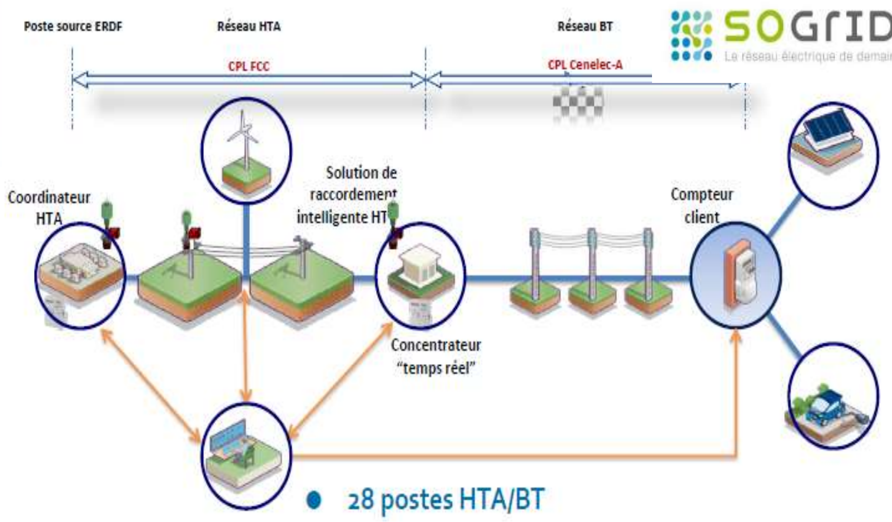
$$P(\tau) = \frac{N_{essais\ réussis}}{N_{essais}} \ (en\ \%)$$

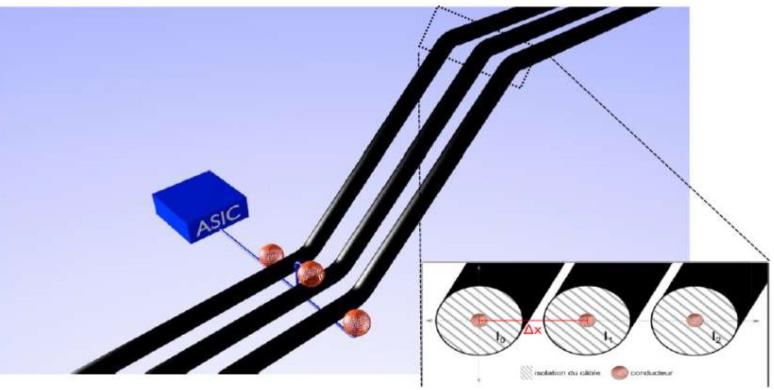


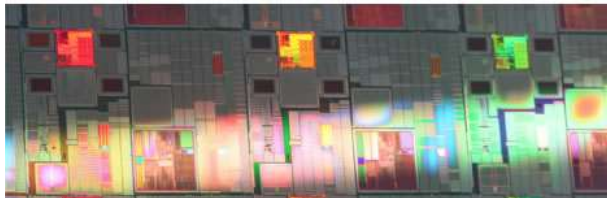
Projet SOGRIDProject : Connected power grid through PLC-G3 all over the whole energy chain chaîne



SOGrID
Le réseau électrique de demain

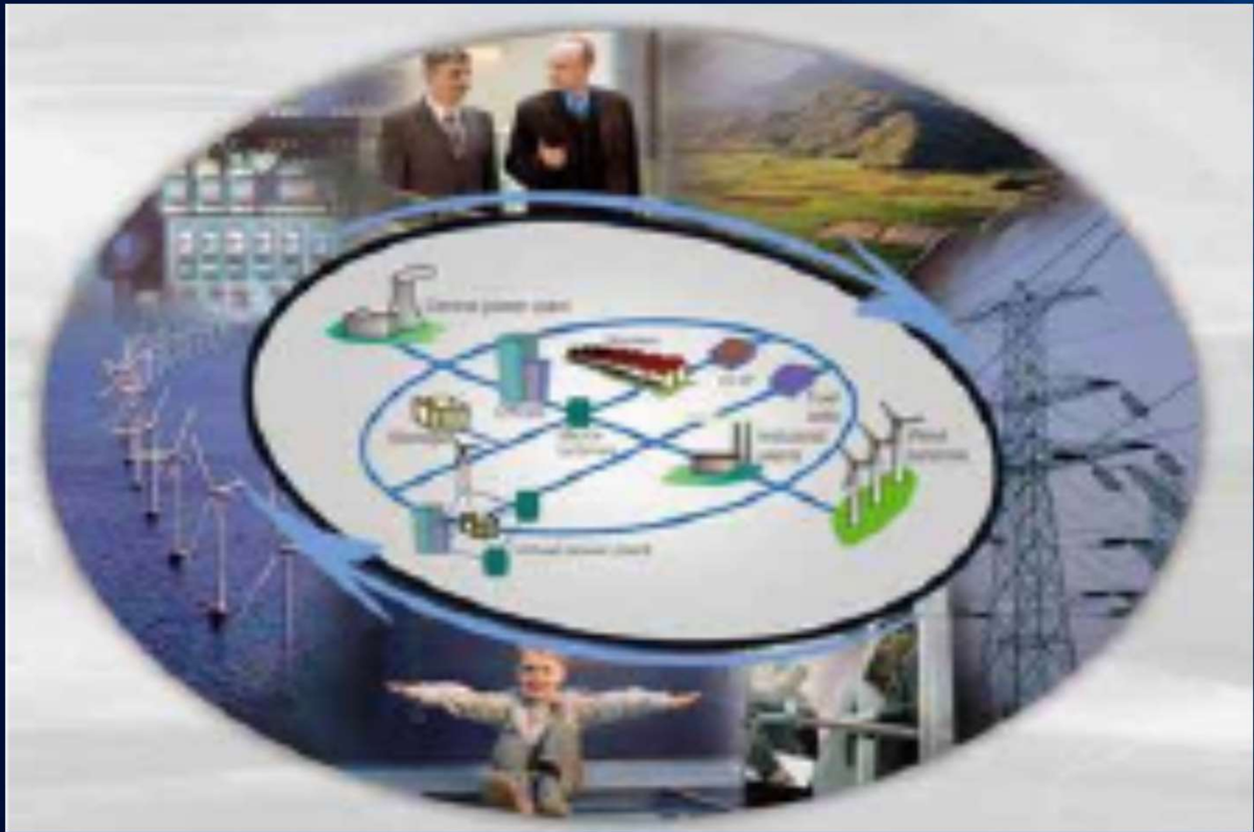






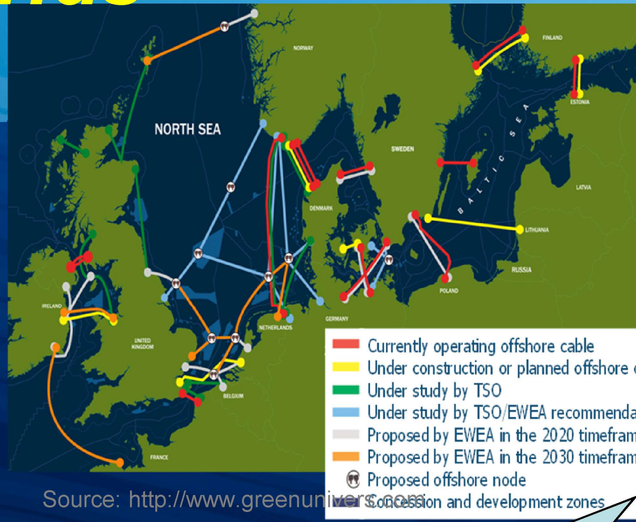
Full PLC-G3 IS based system operation from Linky to LV and MV grid.

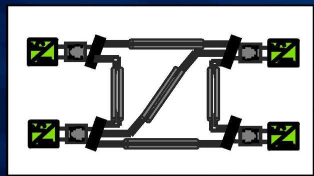
Multi-scale of Smartgrids

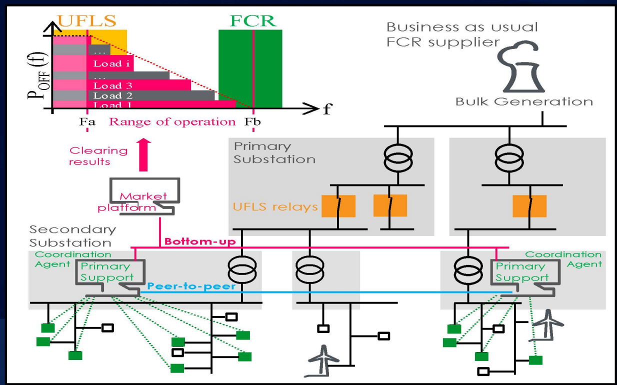


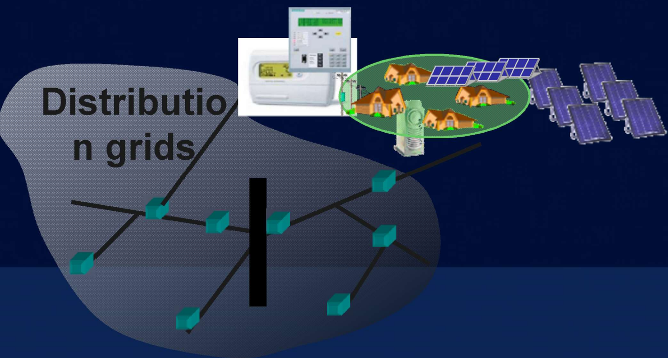
« Cooperative » systems vision : from Microgrids to Supergrids

- **Need for a « system » vision and a global security of supply**
- **Different scales but complementarities: geography and generation profiles**
- **Microgrid:**
  - Decentralized generation - RES
  - Local energy management -resilience
- **Supergrid:**
  - Combining vertical and horizontal visions
  - MTDC grids
- **Distributed intelligence:**
  - Facing complexity

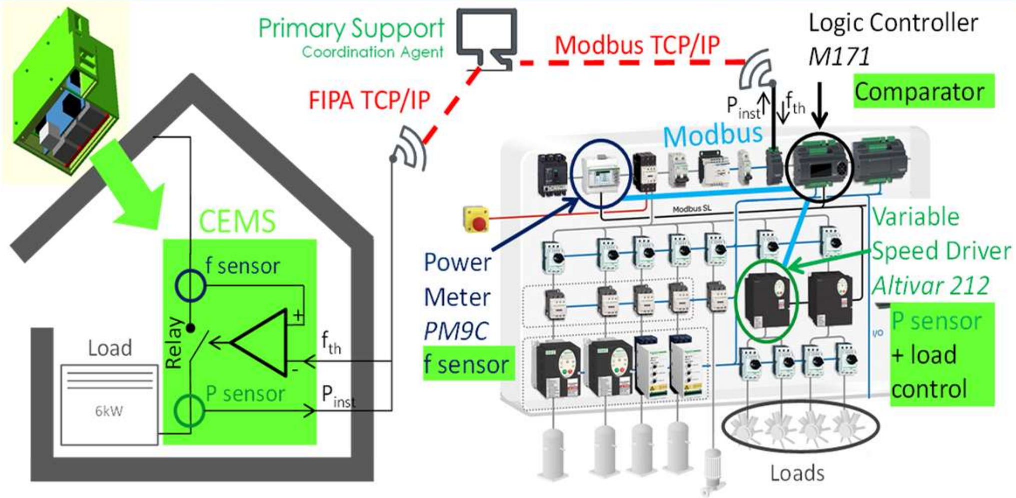






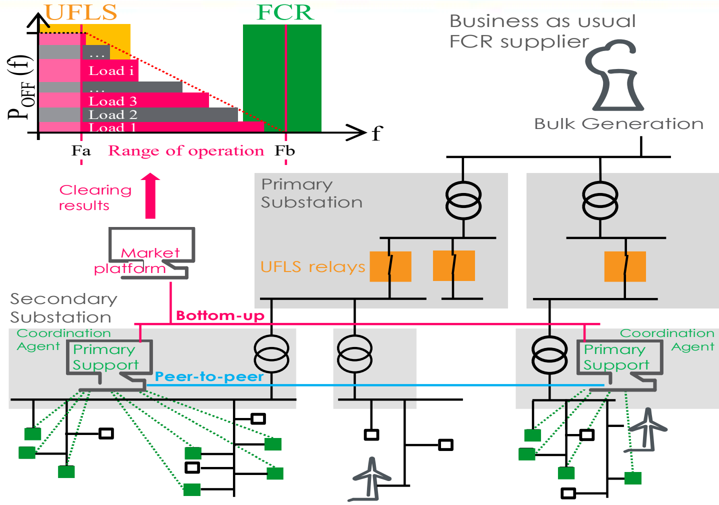


Innovative strategy for stability of microgrids

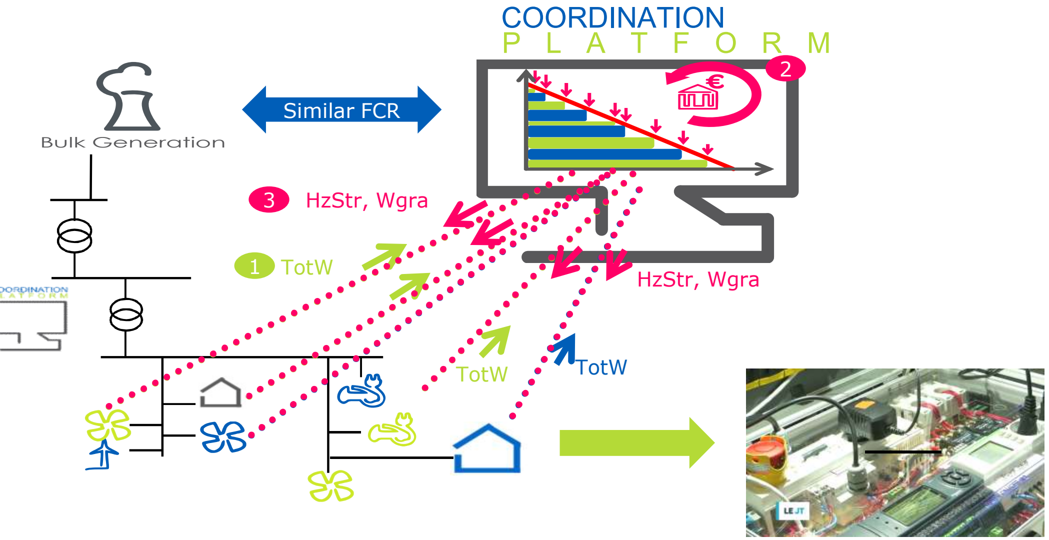


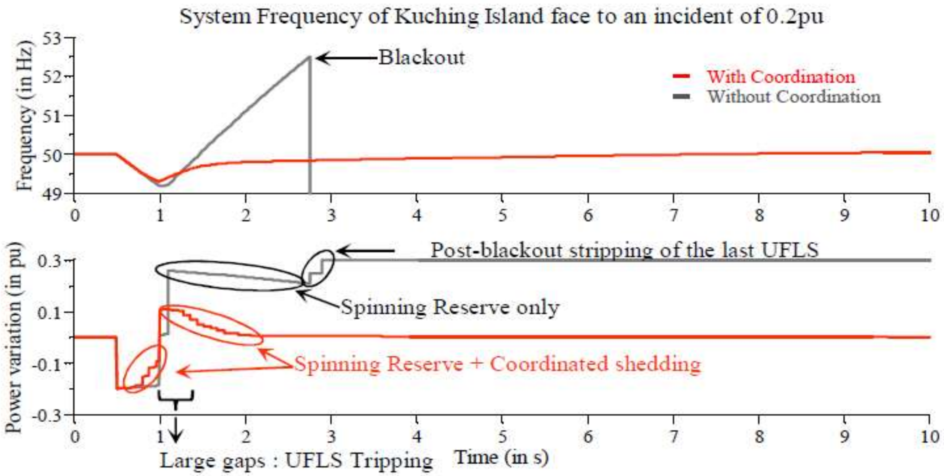
(a) Resistive loads (b) HVAC system

CEMS (customer energy management services architectures)



Large scale architecture





Targeted step-by-step droop curve

Source: PhD: G. Lebel

Some tendencies on energy systems

More ELECTRIC

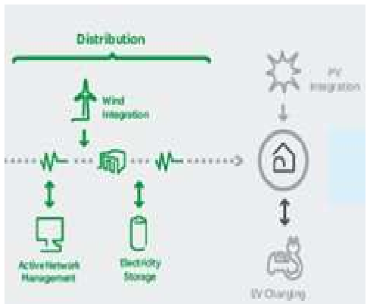
- **Electricity** demand driven by "decarbonization" and new usages, smart devices, …
- **2X** increase of demand Elec/energy by h 2040

More CONNECTED

- **IoT** will connect at least 50 billions objects during the next 5 years

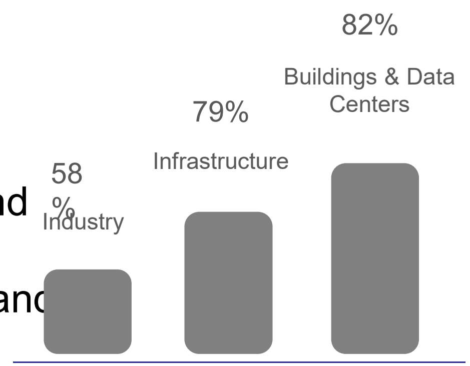
More DISTRIBUTED

- Integrating **decentralized energies** close to end users, dispersed, PEB/PET, microgrids, local management of energy, consum'actor, …
- **70%** of generation units will be RES by h 2040



More EFFICIENT

- **2/3** of **energy efficiency** potential not yet explored:
- Buildings, industry & infrastructures, end users and data centers seeking for performance improvement, and Carbon footprint



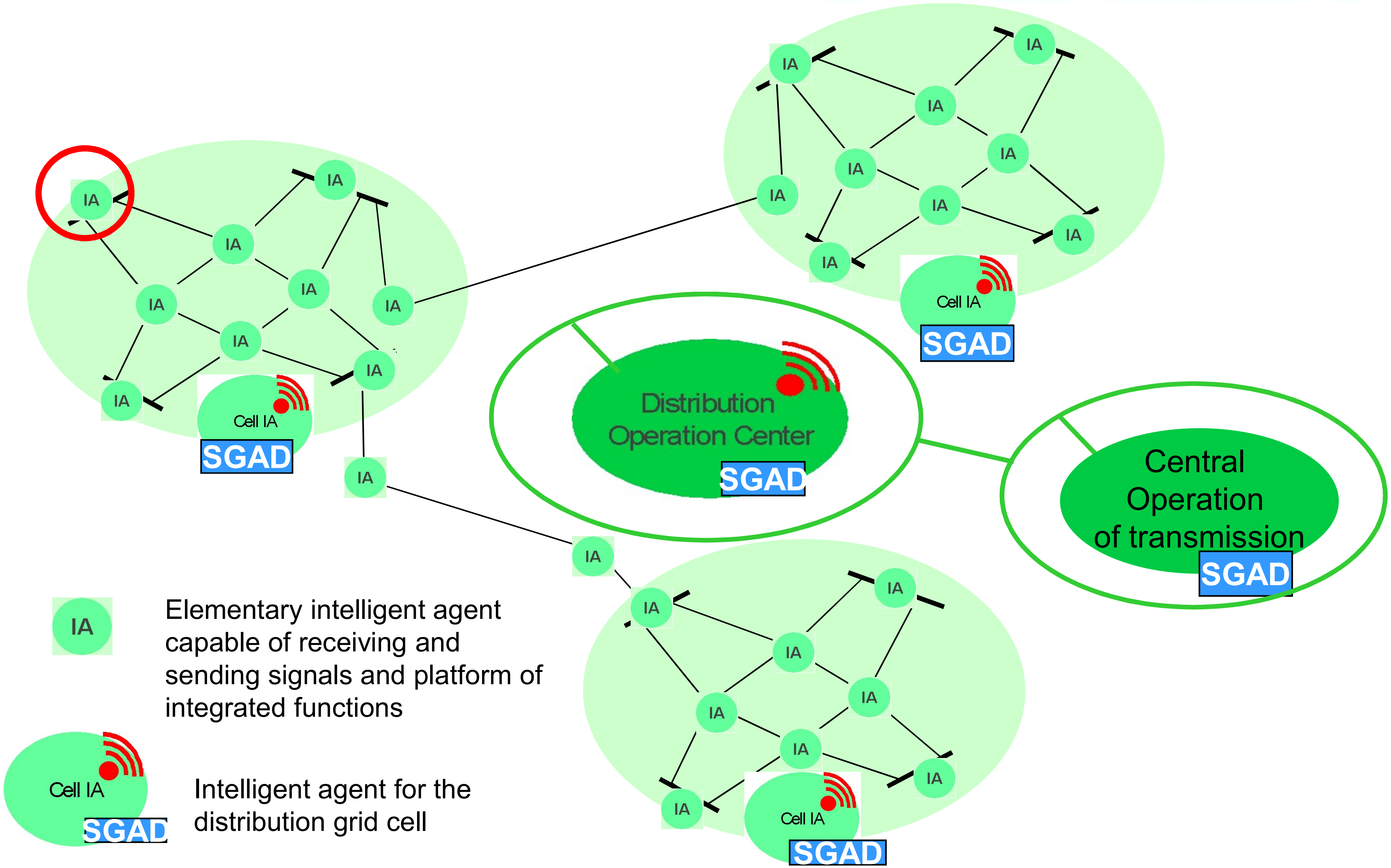
Untapped energy efficiency potential by segment[1]

1 World Energy Outlook 2012, OECD / IEA, Internal analysis/Schneider Elec.

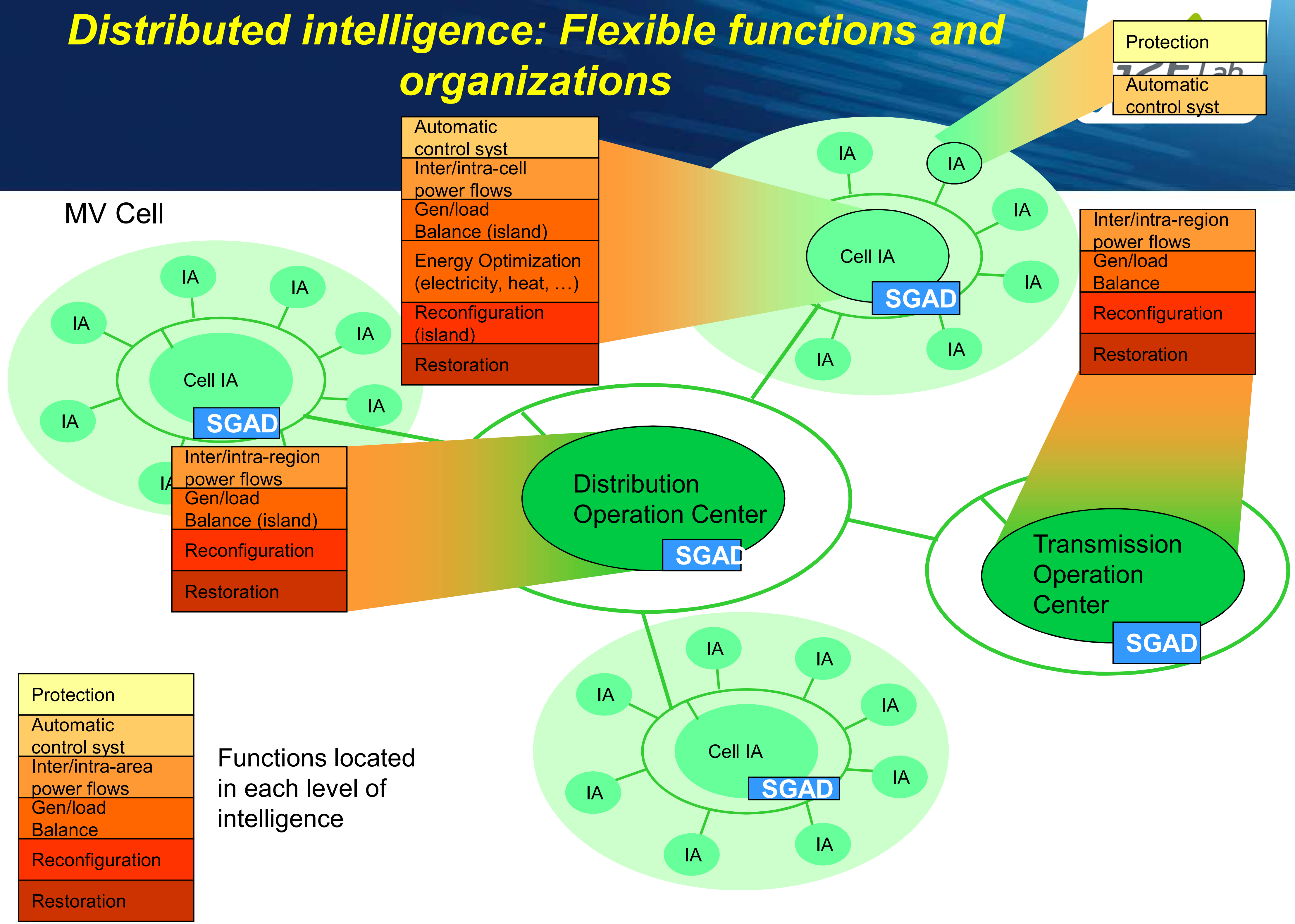
Emerging consequences…

- **Towards a revenge of Edison (back to DC) ?…RES and efficiency**
- **Emergence of local actors and « communities» on local power generation and new usages, …**
- **Paradigm change : economical and technical**
  - From ***marginal cost*** based energy systems to ***service offer*** paradigm
  - From ***passive*** consumption to ***synchronizing*** demand on energy ***availability*** (variability)
  - From ***microgrids*** to ***bloc chain concept*** at local scale
- **Managing local grid «cells »**
- **The challenges:**
  - *Grid* value?
  - *Market* model : local vs global vs liquidity
  - *Quality* of service needs?

Distributed intelligence for local energy management

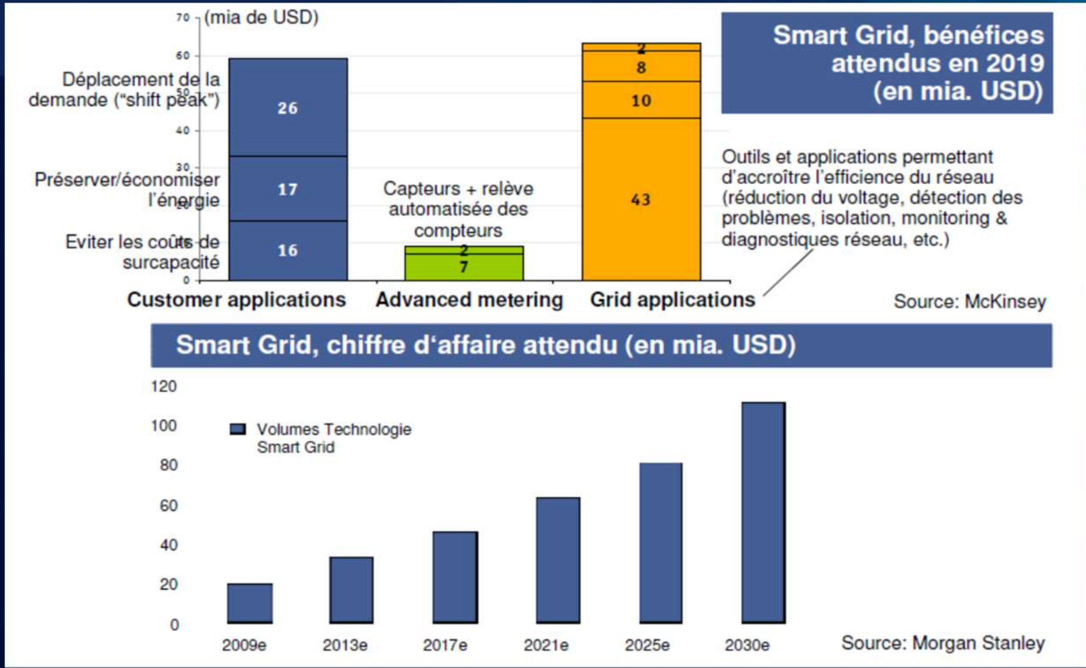


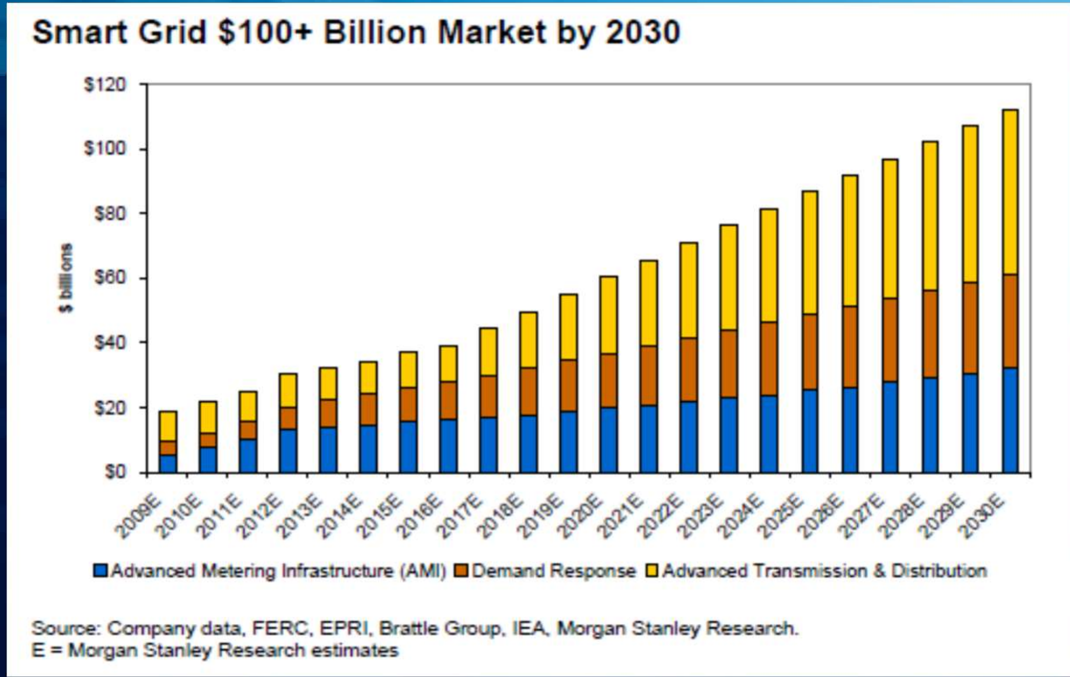
Distributed intelligence: Flexible functions and organizations



Functions located in each level of intelligence

Economic value of the integration of SmartGrids: Estimations





We expect the smart grid market to grow 100% in the next five years and 400% by 2030,

from $20 billion today to $100+ billion in 2030. Since 2001, investors have provided ~$3.6 billion of private funding to smart grid companies

Morgan Stanley

G2E lab
Grenoble Génie Electrique
Grenoble Electrical Engineering

Conclusion

- **Major societal stakes**
  - Climate – Energy – security of supply
  - Energy transition and paradigm change
- **Grid issues: Increasing Complexity**
  - RES on the rise and evolution of consumption patterns
  - Increasing uncertainty level
  - Technological, economical and regulatory challenges
- **From Heritage to innovation**
  - **Power grid**: evolution vs. revolution
  - Need for a **system view**: avoid analysis per « segment »
  - Complementarity of **local** and **global** actions
  - Remarkable field of **scientific and technological developments**
- **Managing transitions for a Smarter Grid …**