SmartGrids

A Vision For Intelligent Electrical Grids Serving the Energy User

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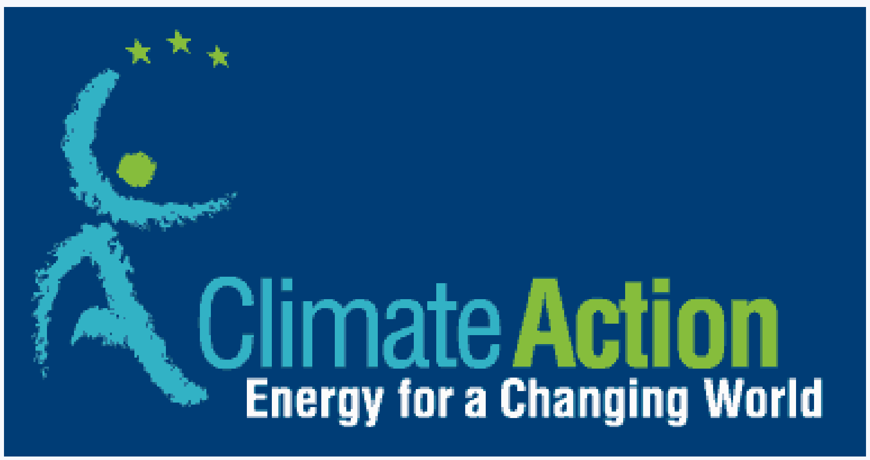
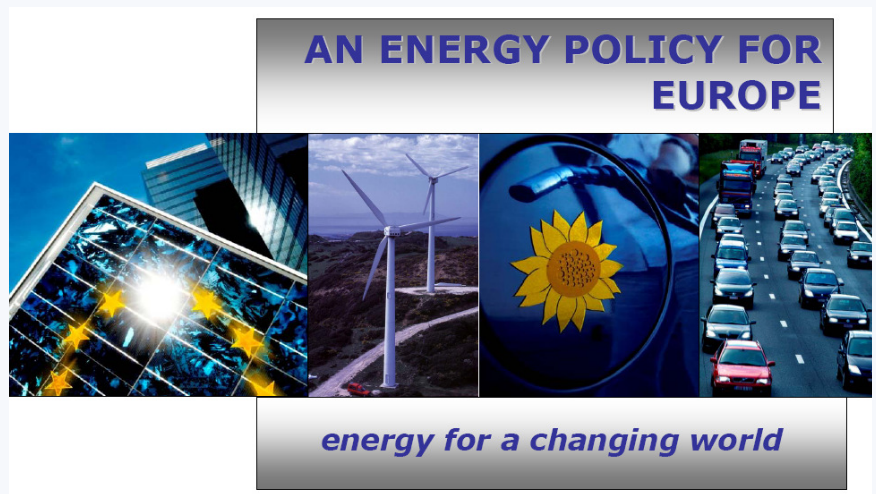
Agenda

- SmartGrids Vision & Deployment Document
- The grid in transition
  - New generation paradigm
  - Ageing assets
- Enabling technologies
  - From passive towards active grids
  - Ancillary services of small generation units
  - ICT requirements and reliability
- Need for RD&D
- SmartGrids Platform

European Policy

- Overall EU energy policy
- National implementation of each member state (tailored program/policy)

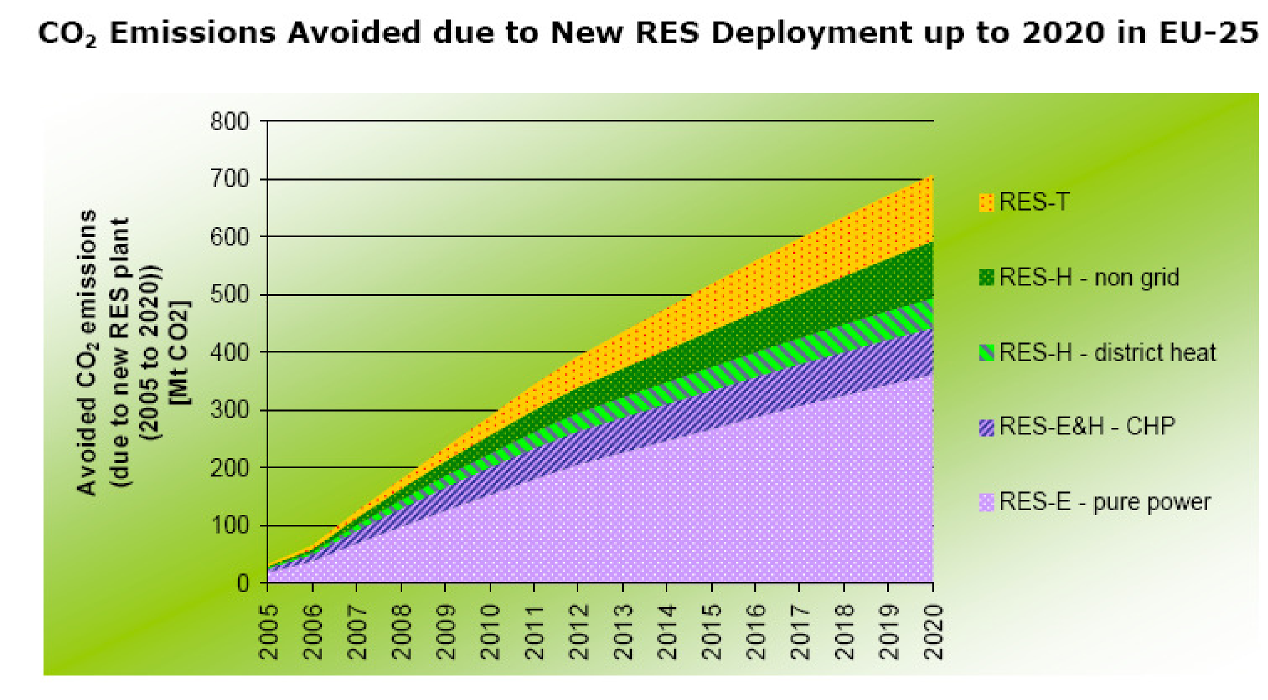




European Policy

EU targets 2020

- ✓ 20% reduction CO_2 emission
- ✓ 20% renewable sources
- ✓ 20% energy saving



European Policy

Ten point action plan

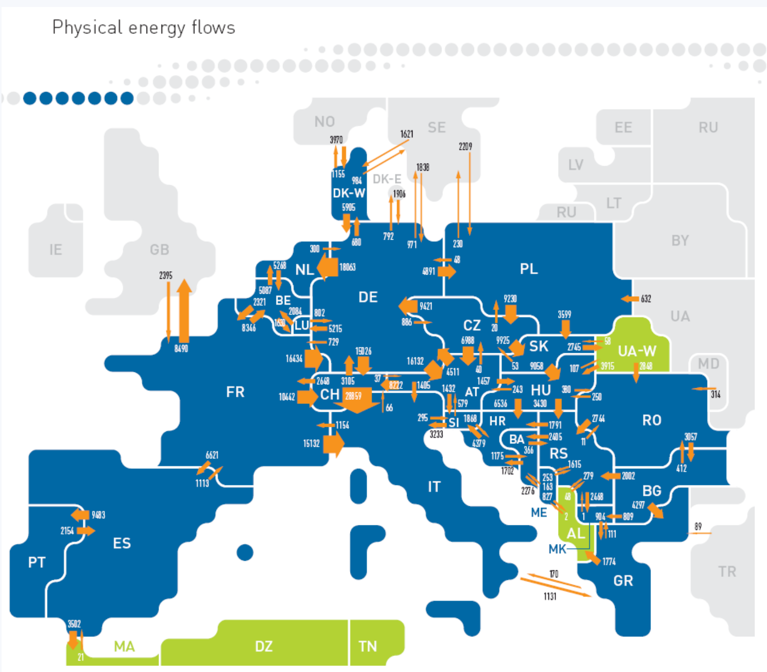
1. Use the new internal energy market better
2. Make it easier for Member States to help one another in case an energy crisis arises
3. Improve the EU Emissions Trading Scheme
4. Energy efficiency
5. Increase the use of renewable energy
6. Technology
7. Low carbon technology for fossil fuels
8. Safety and security of nuclear power
9. Agree to an international energy policy
10. Improve understanding

➲ **http://ec.europa.eu/energy/energy_policy/index_en.htm**

Challenges for 2020 and beyond

European power system

- 430 million people served
- 2500 TWh used
- 560 GW installed capacity @ 500€/kW = 280G€
- 230.000 km HV network @ 0.4M€/km = 90G€
- Approx. 5.000.000 km MV+LV network
- 1500€ investment per EU citizen
- Largest man-made system

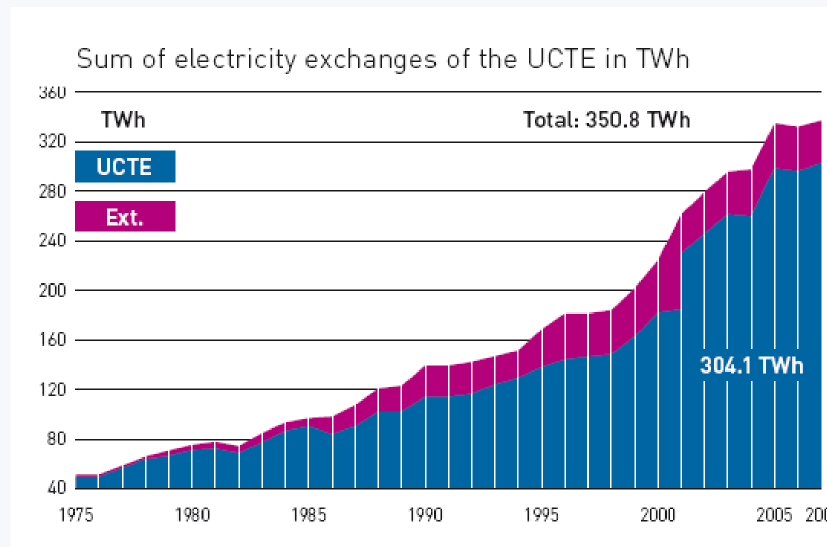


	Import	Export
AT	23 979	17 067
BA	3 743	4 344
BE	15 698	9 038
BG	3 057	7 520
CH	33 756	34 649
CZ	10 209	26 354
DE	44 270	63 385
DK_W	6 271	8 044
ES	8 796	14 098
FR	10 360	65 465
GR	6 421	2 055
HR	11 897	5 554
HU	14 680	10 696
IT	48 799	2 646
LU	6 845	2 886
ME	3 893	1 243
MK	3 388	905
NL	23 150	5 568
PL	7 752	13 107
PT	9 483	2 154
RO	3 965	6 051
RS	8 844	8 569
SI	6 106	5 680
SK	13 582	11 856
UCTE[1]	326 215	325 257
UA_W	2 852	6 821

Values in GWh

UCTE region

Synchronous operation with UCTE region



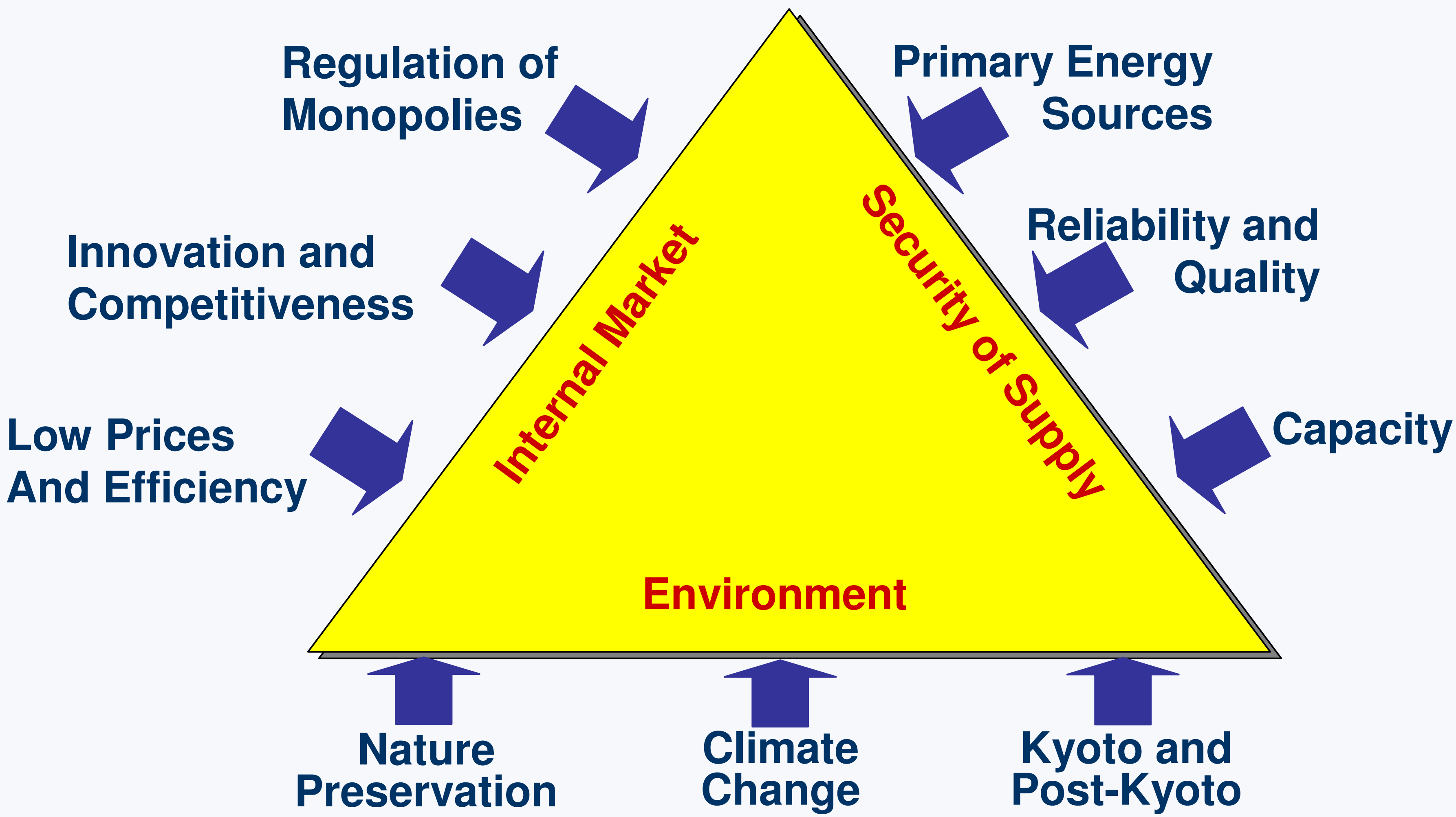
UCTE

Challenges for 2020 and beyond

- Demand
  - ⇨ **Growth 2%/year = +1250 TWh until 2030**
- Generation
  - ⇨ **Replacement & expansion 900 GW needed until 2030**
  - ⇨ **RES 500 GWpeak needed until 2030**
- Transmission & Distribution
  - ⇨ **Ageing assets, expansion and RES+DG integration 500G€ until 2030 needed**
- Markets & Regulation
  - ⇨ **Data + information need > 20G€ investment (based on 100€ per connection)**

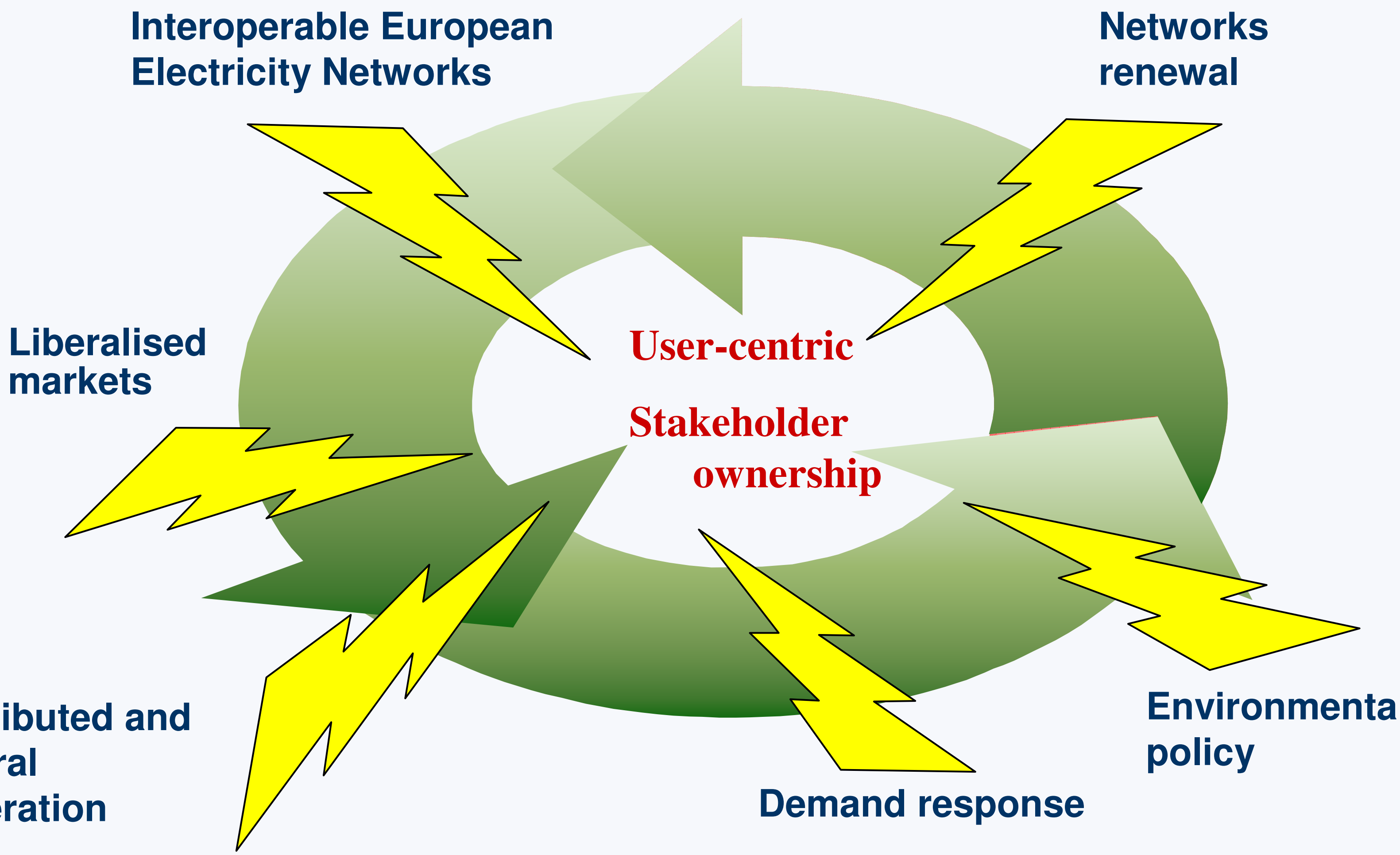
SmartGrids Vision

Drivers towards SmartGrids



SmartGrids Vision

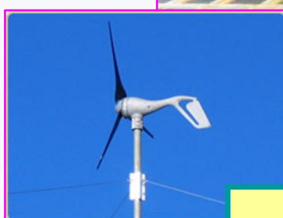
Why SmartGrids?

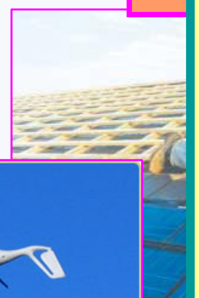


Challenges for 2020 and beyond

50GW of wind power in the North ?

Ackgt TechFreep





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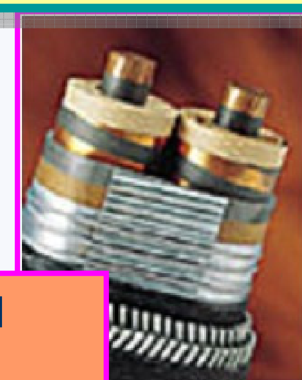
Smart Grids will be needed to ensure supply security, connect and operate clean and sustainable energy, and give value for money

plus wind variation / cloud cover / customer choice…

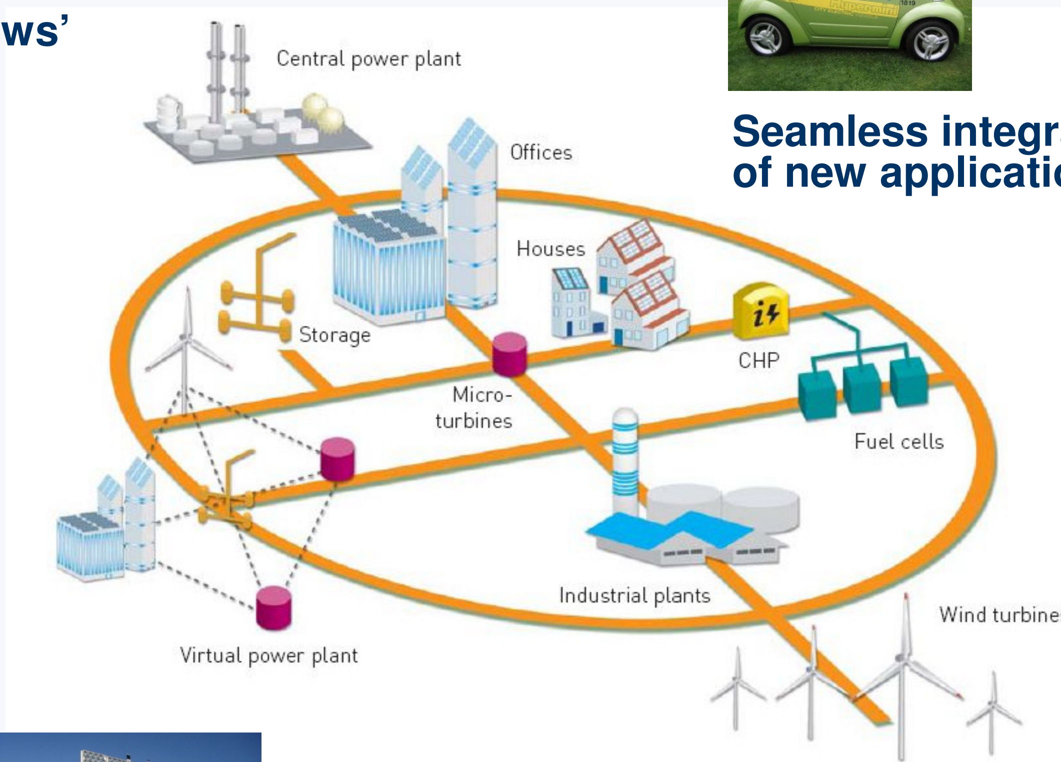
30GW of solar power in the South ?



New DC Links and Interconnections

SmartGrids Vision

Multi-directional 'flows'



Seamless integration of new applications

End user real time Information & participation

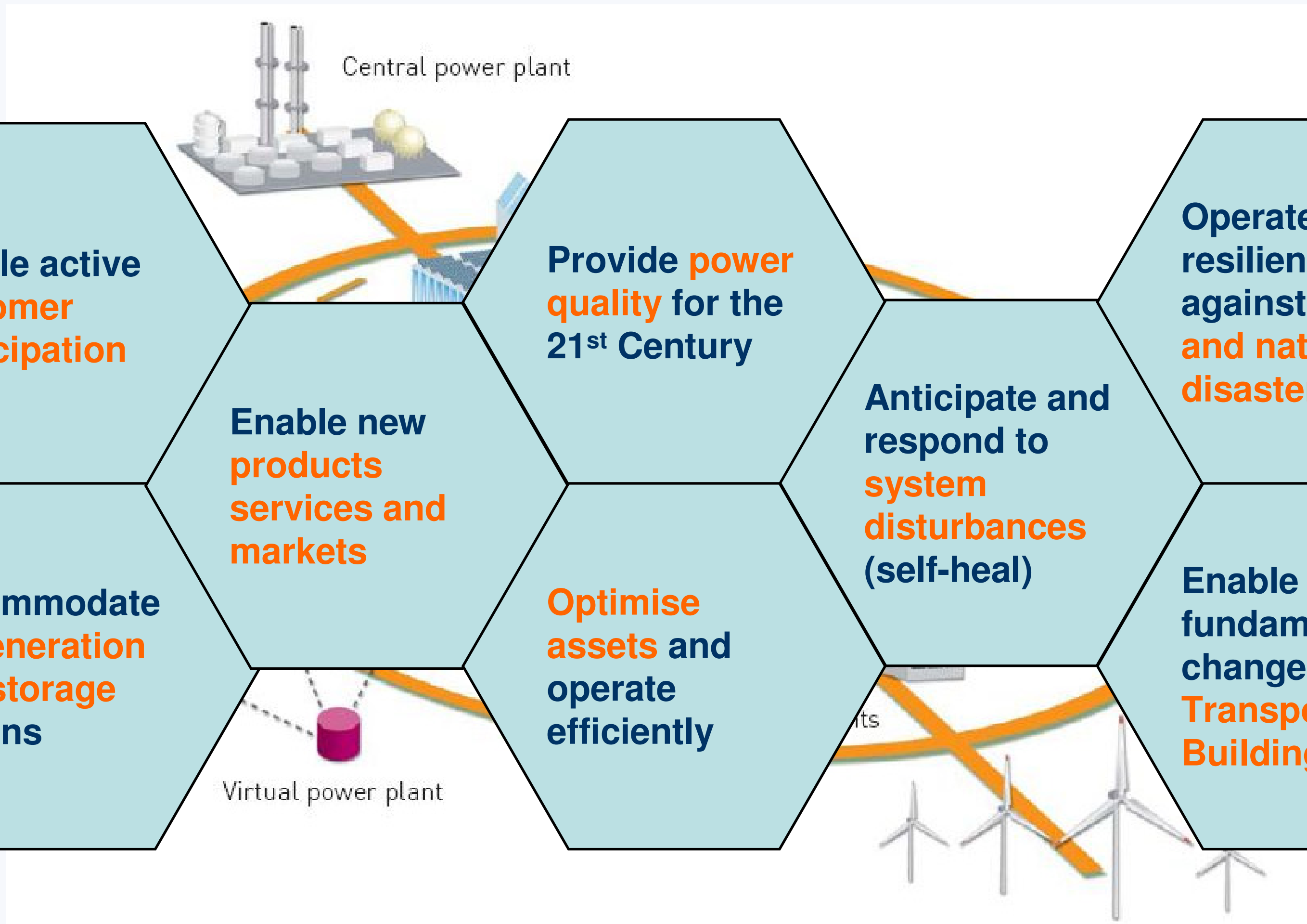
Central & dispersed intelligence

SMARTGRIDS

Smart materials and power electronics

Central & dispersed sources

SmartGrids Vision



- Enable active customer participation
- Enable new products services and markets
- Accommodate all generation and storage options
- Provide power quality for the 21st Century
- Optimise assets and operate efficiently
- Anticipate and respond to system disturbances (self-heal)
- Operate resiliently against attack and natural disaster
- Enable fundamental changes in Transport and Buildings

(Source: SmartGridNews.com)

SmartGrids Vision

20th Century Grid	21st Century Smart Grid
Electromechanical	Digital
Very limited or one-way communications	Two-way communications every where
Few, if any, sensors – “Blind” Operation	Monitors and sensors throughout – usage, system status, equipment condition
Limited control over power flows	Pervasive control systems - substation, distribution & feeder automation
Reliability concerns – Manual restoration	Adaptive protection, Semi-automated restoration and, eventually, selfhealing
Sub-optimal asset utilization	Asset life and system capacity extensions through condition monitoring and dynamic limits
Stand-alone information systems and applications	Enterprise Level Information Integration, inter-operability and coordinated automation
Very limited, if any, distributed resources	Large penetrations of distributed, Intermittent and demand-side resources
Carbon based generation	Carbon Limits and Green Power Credits
Emergency decisions by committee and phone	Decision support systems, predictive reliability
Limited price information, static tariff	Full price information, dynamic tariff, demand response
Few customer choices	Many customer choices, value adder services, integrated demand-side automation

a smart metering revolution?

a networks perspective

losses management & rewards

“an RTU at every service head”

intelligent demand control in emergencies

the portal to demand & micro-gen services

local network also the comms channel ?

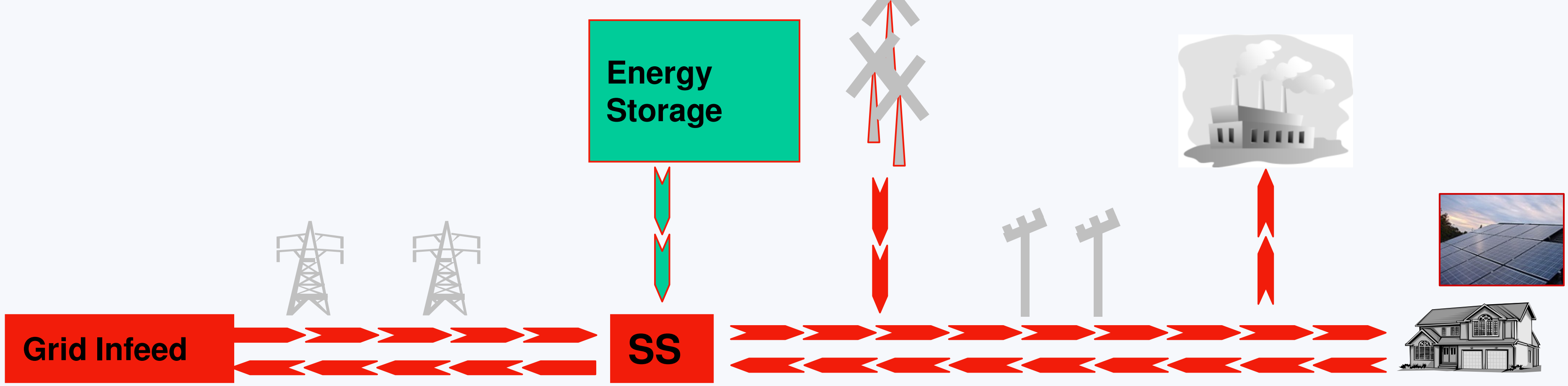
operational visibility of local networks

Load-limiting & remote disconnection

new services to delight customers….

SmartGrids Vision

New roles for Network Co's



Integrator

- Energy efficiency
- Customer overall participation
- Customer micro-gen types
- Heat networks
- Carrier communications

Optimiser

- Manage constraints and minimise losses
- Utilise smart meter data
- Manage asset condition / predict failure events
- Intelligent demand management in emergencies

Aggregator

- Aggregator and manager of dispersed power sources
- Aggregator and manager of ancillary services for local network and the grid

(Source: EON Central Networks)

SmartGrids Vision

What is a SmartGrid?

A SmartGrid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

A SmartGrid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- better facilitate the connection and operation of generators of all sizes and technologies;
- allow consumers to play a part in optimizing the operation of the system;
- provide consumers with greater information and choice of supply;
- significantly reduce the environmental impact of the whole electricity supply system;
- deliver enhanced levels of reliability and security of supply.

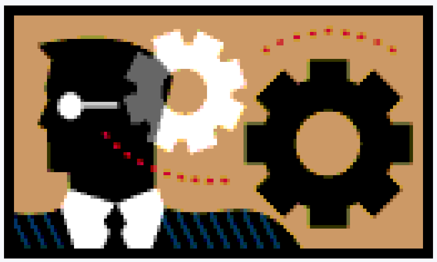
SmartGrids deployment must include not only technology, market and commercial considerations, environmental impact, regulatory framework, standardization usage, ICT (Information & Communication Technology) and migration strategy but also societal requirements and governmental edicts.

SmartGrids Vision

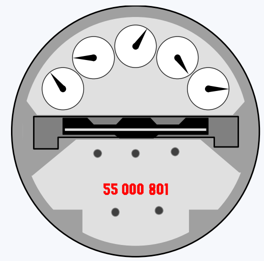
The Key Challenges for SmartGrids

- Strengthening the grid – ensuring that there is sufficient transmission capacity to interconnect energy resources, especially renewable resources, across Europe;
- Moving offshore – developing the most efficient connections for offshore wind farms and for other marine technologies;
- Developing decentralized architectures – enabling smaller scale electricity supply systems to operate harmoniously with the total system;
- Communications – delivering the communications infrastructure to allow potentially millions of parties to operate and trade in the single market;
- Active demand side – enabling all consumers, with or without their own generation, to play an active role in the operation of the system;
- Integrating variable generation – finding the best ways of integrating intermittent generation including residential microgeneration;
- Enhanced intelligence of generation, demand and most notably in the grid;
- Capturing the benefits of DG and storage;
- Preparing for electric vehicles – whereas SmartGrids must accommodate the needs of all consumers, electric vehicles are particularly emphasized due to their mobile and highly dispersed character and possible massive deployment in the next years, what would yield a major challenge for the future electricity networks.

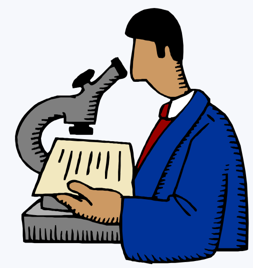
Stakeholders

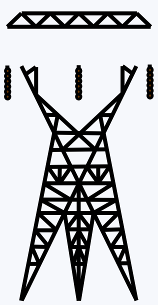

Technology providers


Users

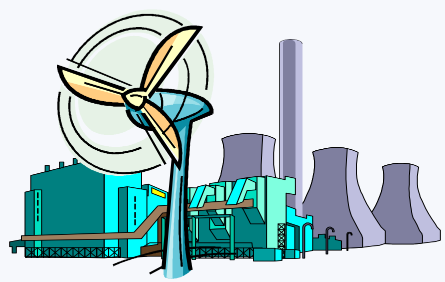


Energy service providers

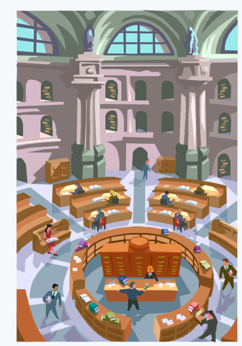

Researchers


Network companies


Traders


Generators


Regulators


Governmental agencies

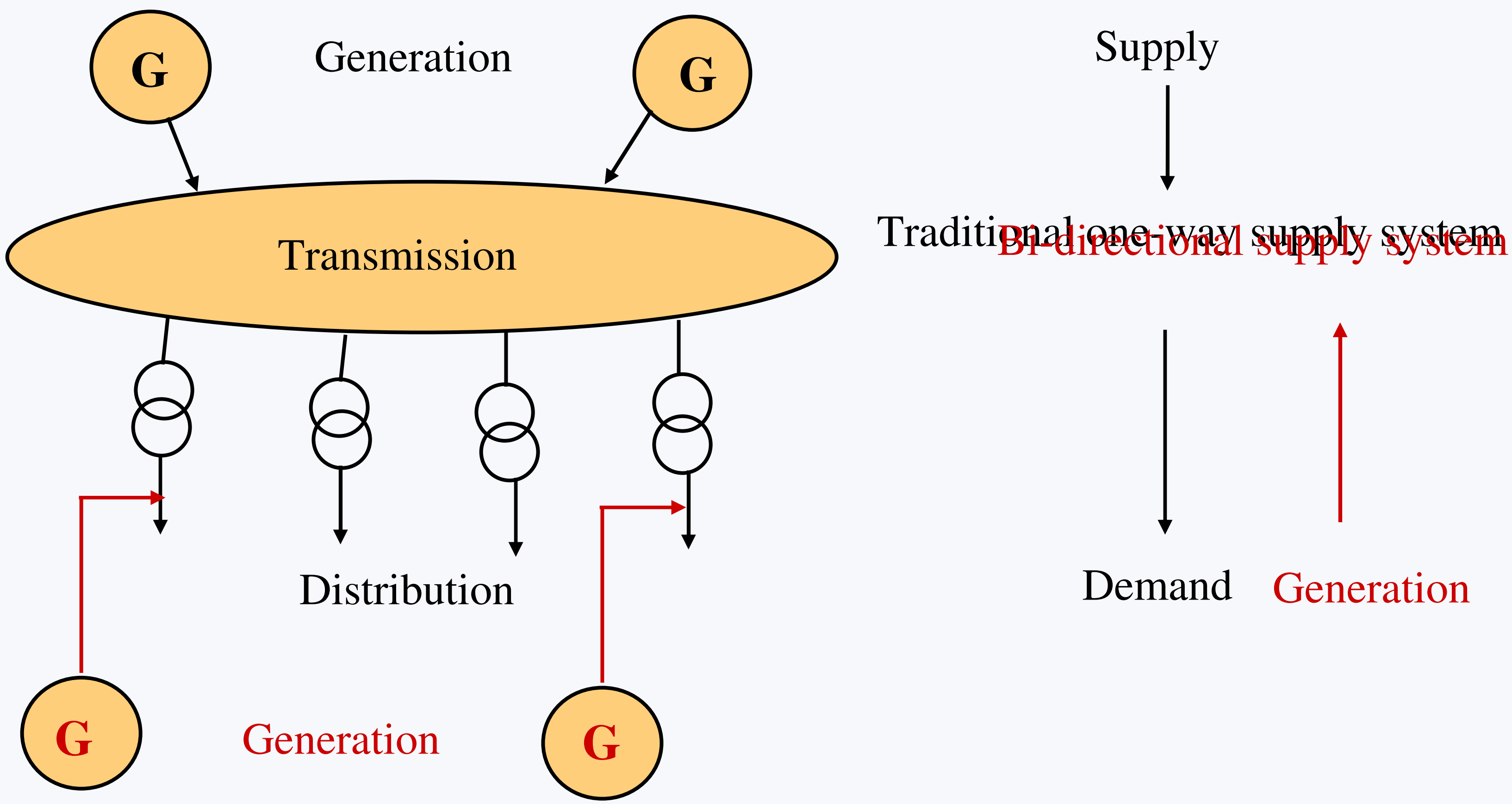
Technical miracles of the 20th century

1. **Electrification**
2. Automobile
3. Airplane
4. Safe and Abundant Water
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Interstate Highways
12. Space Exploration
13. Internet
14. Imaging Technologies
15. Household Appliances
16. Health Technologies
17. Petroleum and Gas Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High Performance Materials

(Source: National Academy of Engineering)

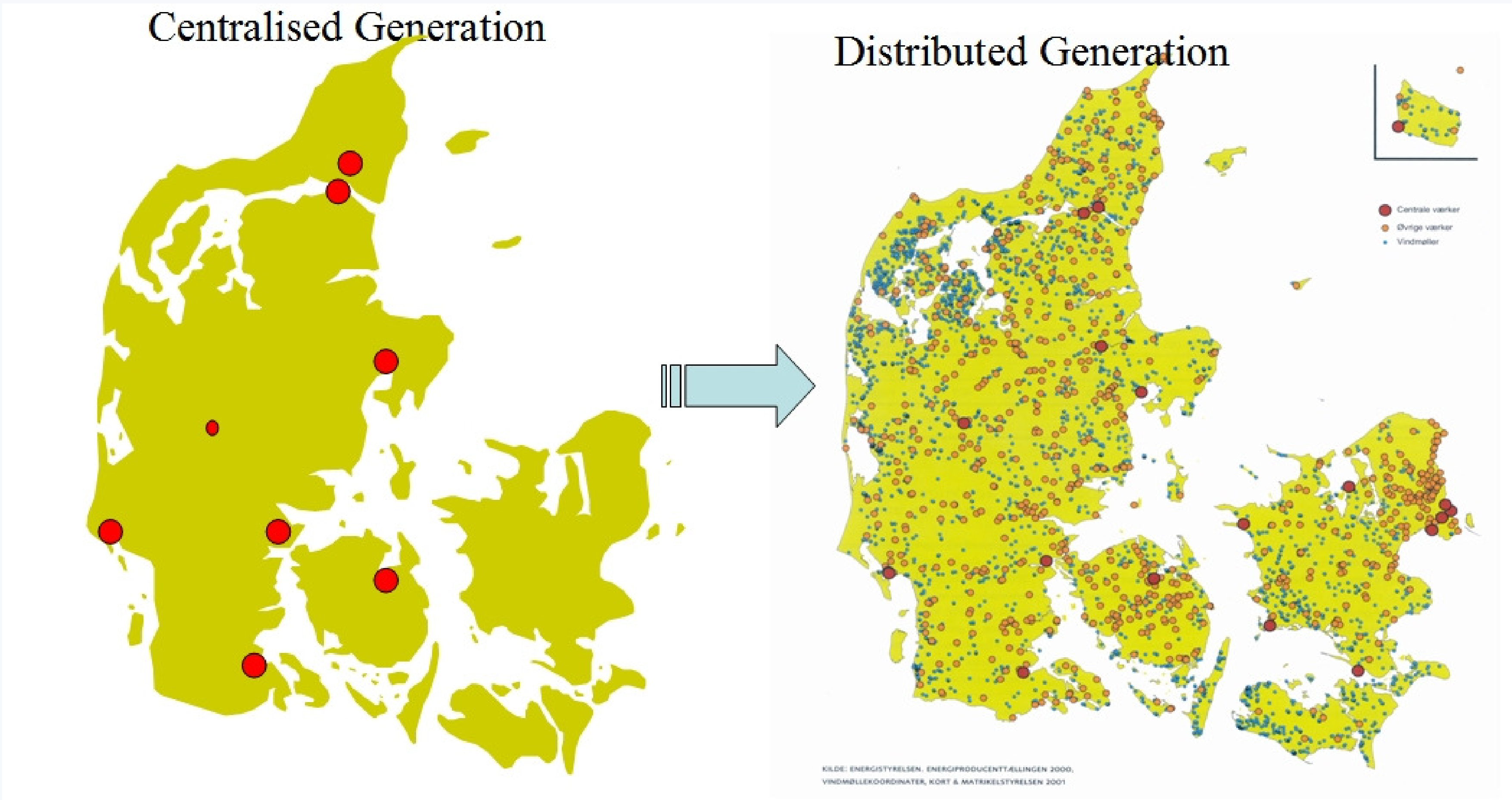
Still…
new generation paradigms
& ageing assets pose a serious challenge…

New generation paradigm



New generation paradigm

E.g. increasing wind generation & CHP units in Denmark

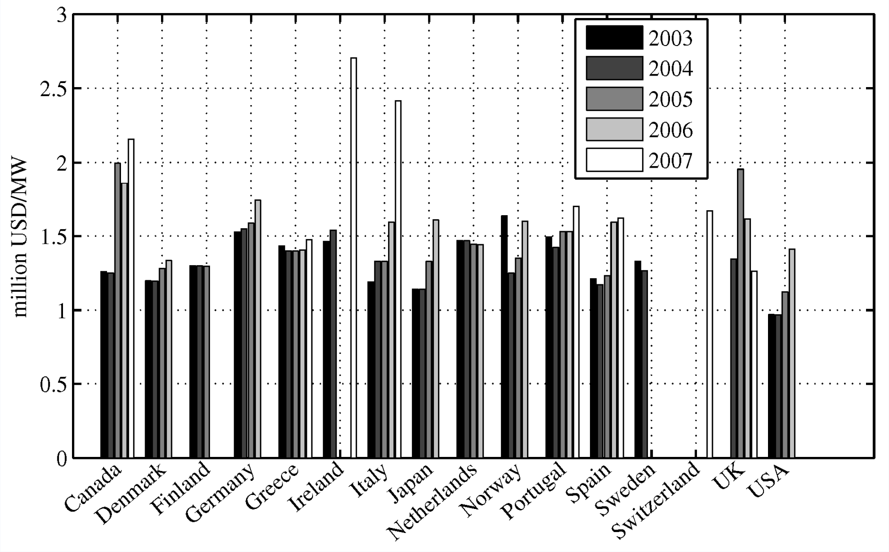


Source: Risö

New generation paradigm

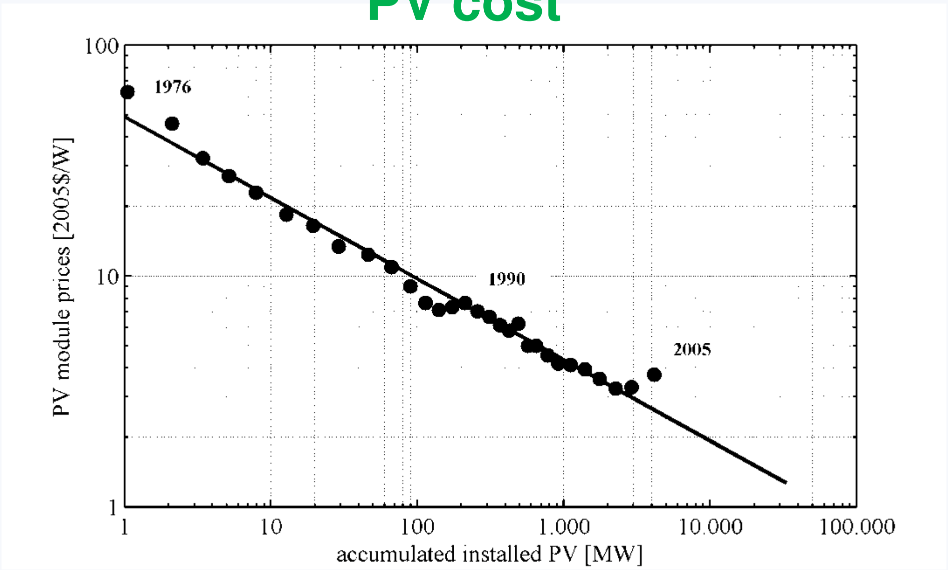
Demand-pull
- Environmental concerns
- Dependency on primary energy sources
- Rising/fluctuating (?) fuel prices
- Liberalized market opportunities
- Energy efficiency: CHPs
- Subsidies, e.g. ROC

Wind generation cost



Source: IEA

PV cost

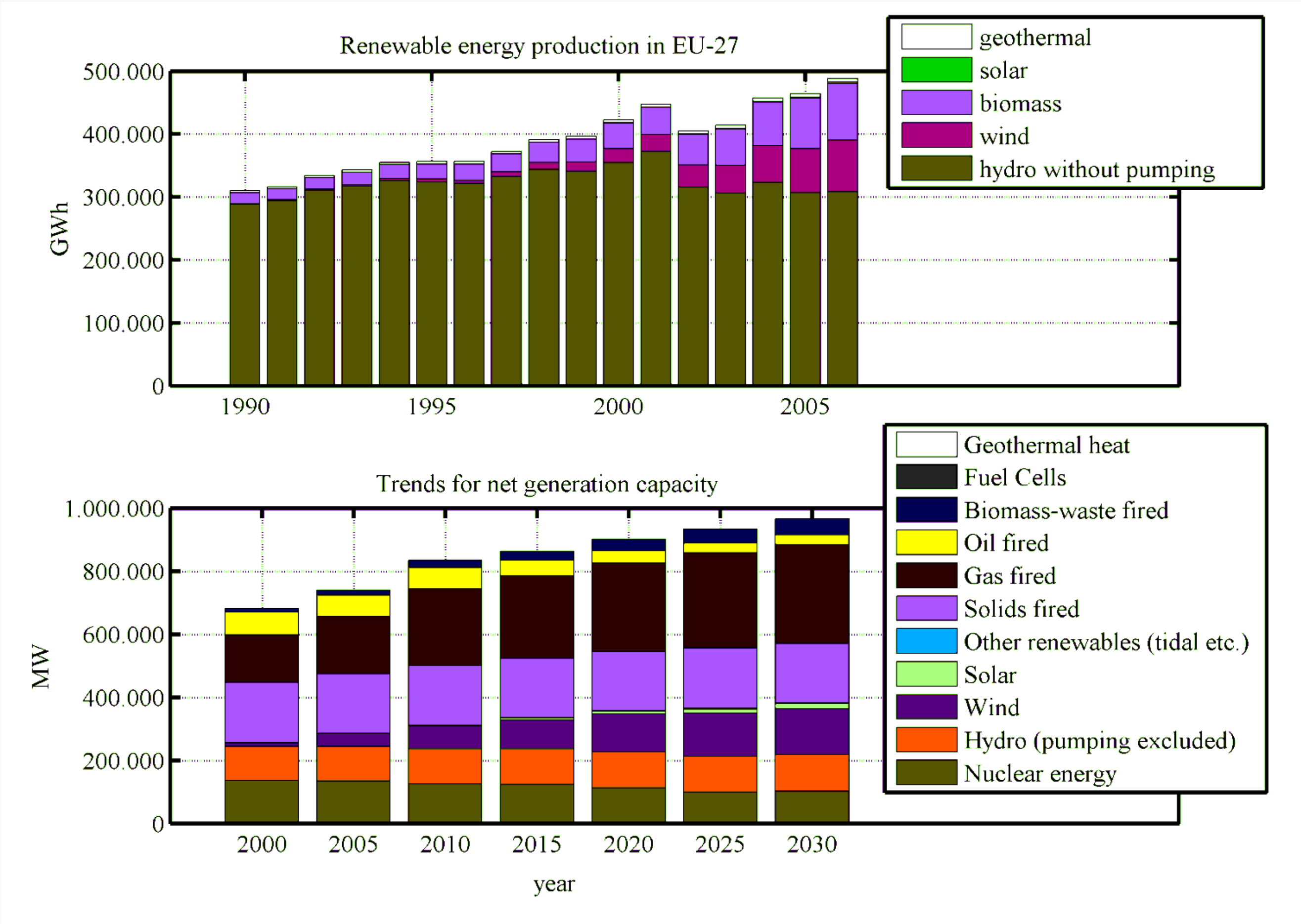


Source: PhD G. Nemet

Technology-push
- Experience curves of PV and wind
- Break-even point?
- Although not entirely true for wind due to bottlenecks in supply chain…
- Electrical energy storage?

New generation paradigm

Evolution in renewable energy production
& Trend in PRIMES base scenario



http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/2007_en.htm

From passive towards active grids

Integration of decentralized generation?

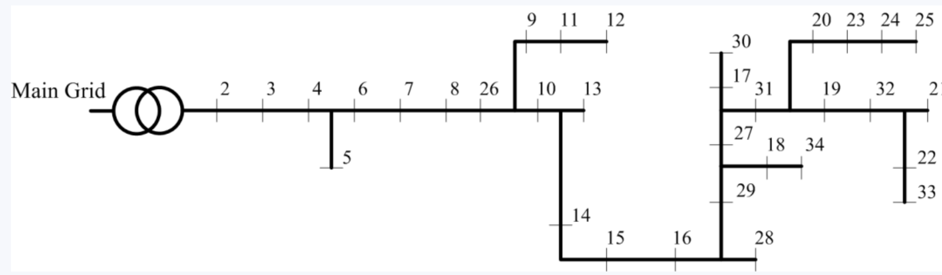
- Passive grids = Fit and Forget
  - Fault detection: bidirectional flows
  - Power Quality: responsibility?
  - Voltage control: responsibility?
  - Grid Planning: deterministic peak planning, cfr ER P2/5 in UK
  - ⇨ Significant grid problems at low levels of decentralized generation

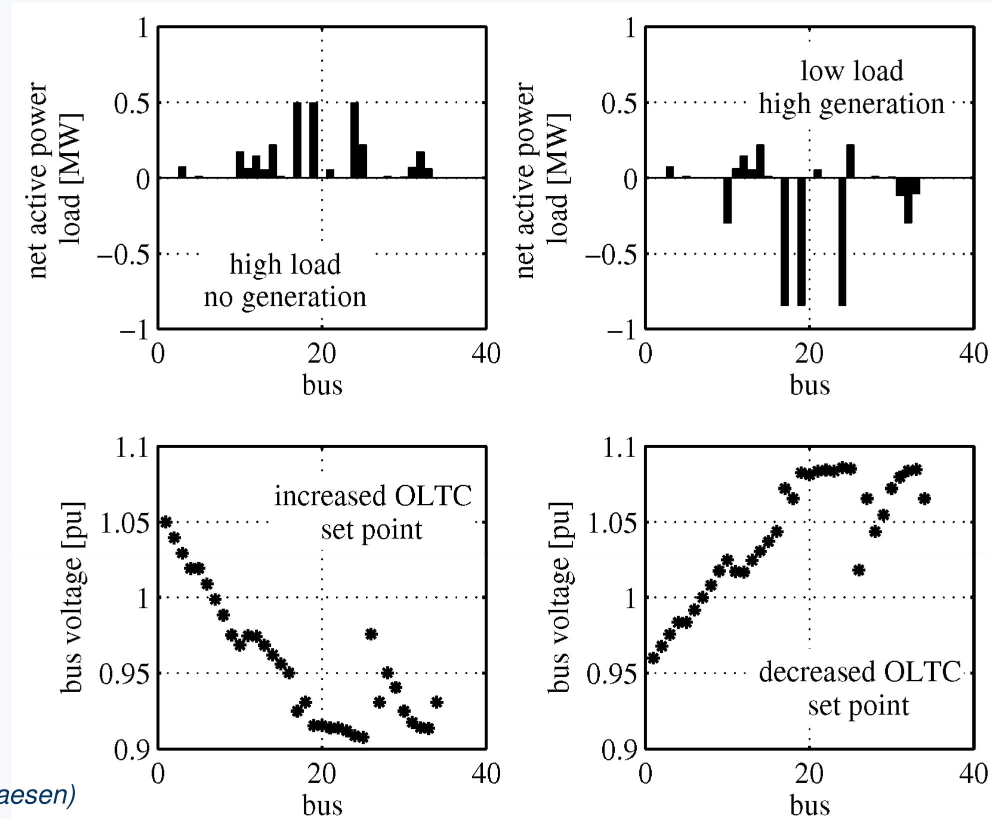
- Active grids
  - Normal operation
    - **Curtailment of generation**
    - **Reactive power control**
    - **Coordinated voltage control by On-Load Tap Changing transformers**
    - **Voltage regulators in-line**
  - Fault situations

From passive towards active grids

Illustration

- 34-bus system with On-Load Tap Changing transformer
- Adjustment of secondary voltage allows tolerable voltages with
  - High load / low generation
  - Low load / high generation



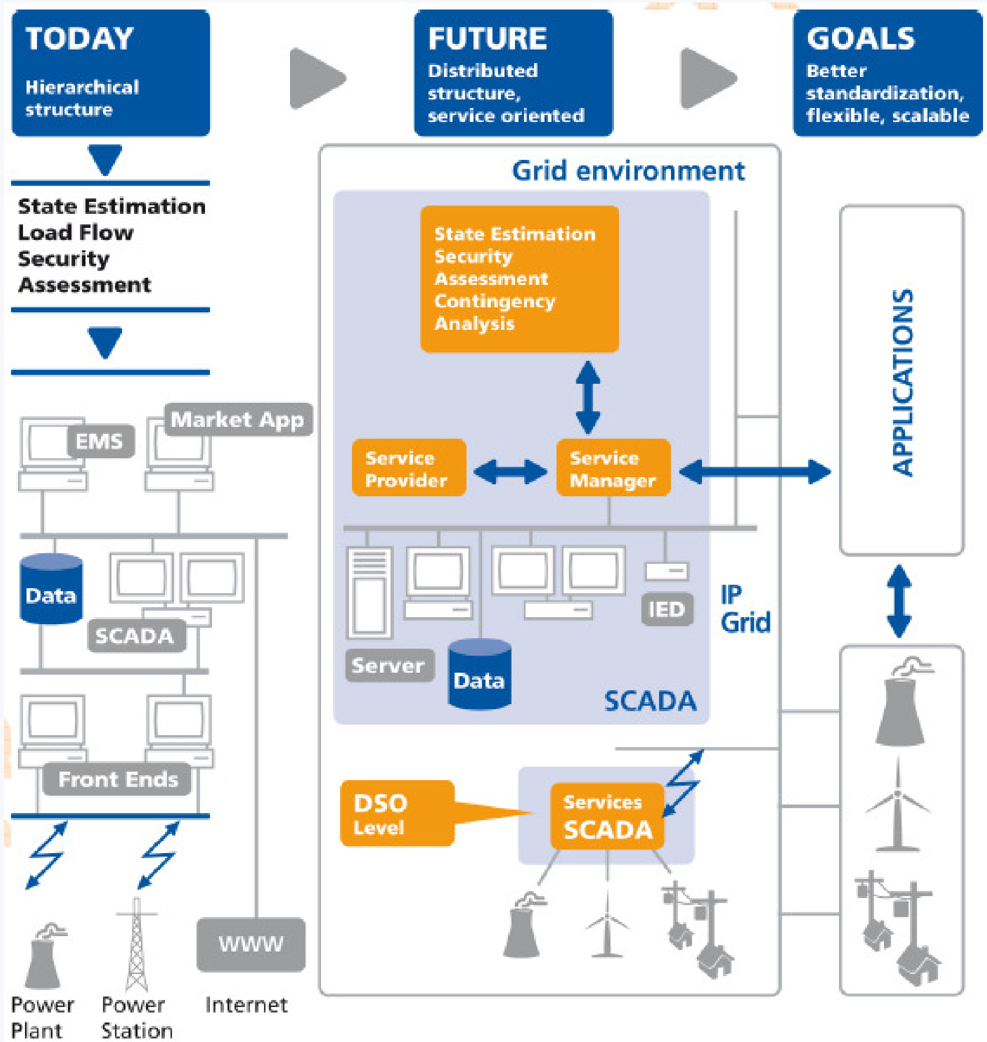


(Source: PhD E. Haesen)

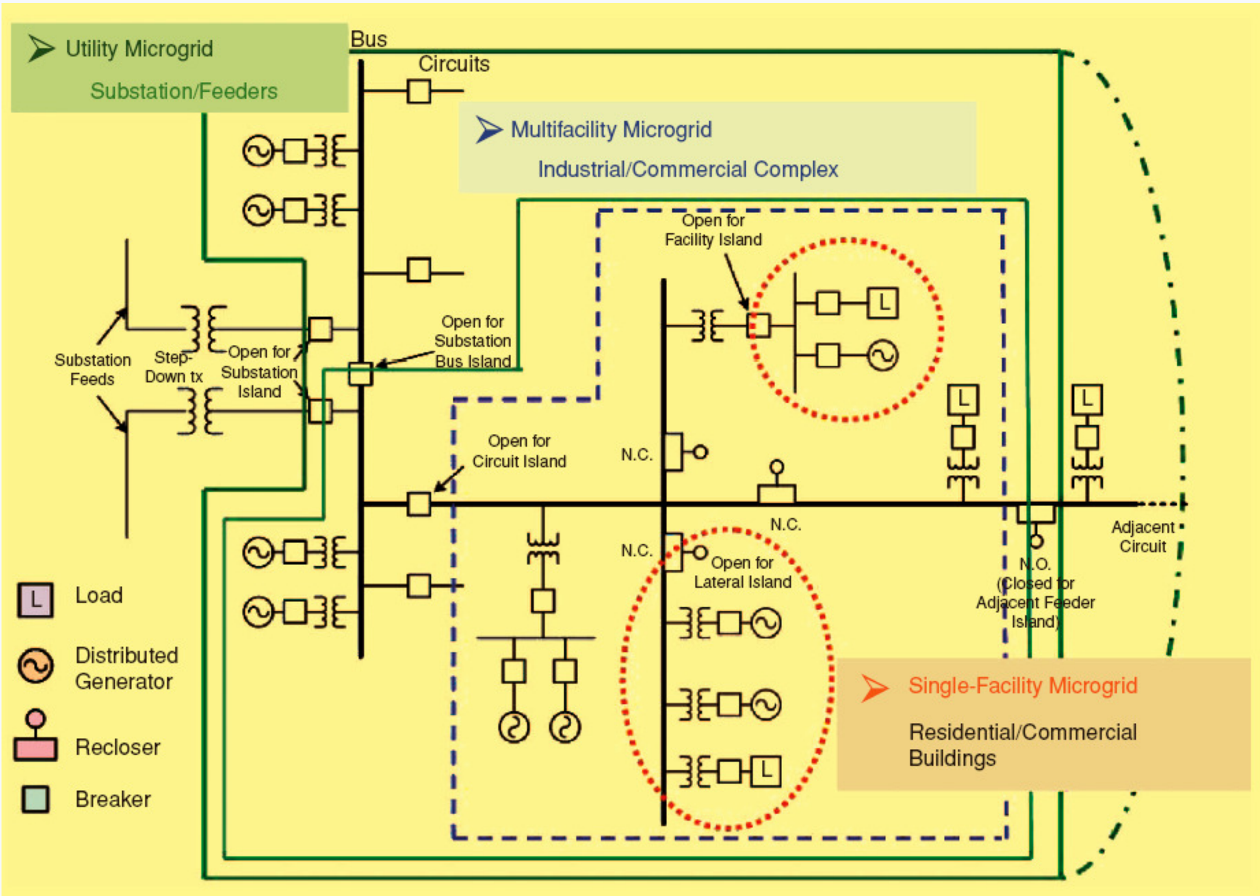
From passive towards active grids

Active distribution system has three layers

1. Copper based energy infrastructure (electricity)
   - Optimized topology
   - Power electronic devices
2. Communications layer
   - requirements of speed, quality, reliability, dependability with costs
   - different communication technologies at the same time
3. Software layer
   - multiple software functions for normal operation: doing locally and independently the maximum number of functions, reporting/requesting from the upper level the minimum possible information necessary
   - network reconfiguration
   - self-healing procedures
   - fault management
   - forecasting, modeling and planning.



Microgrids



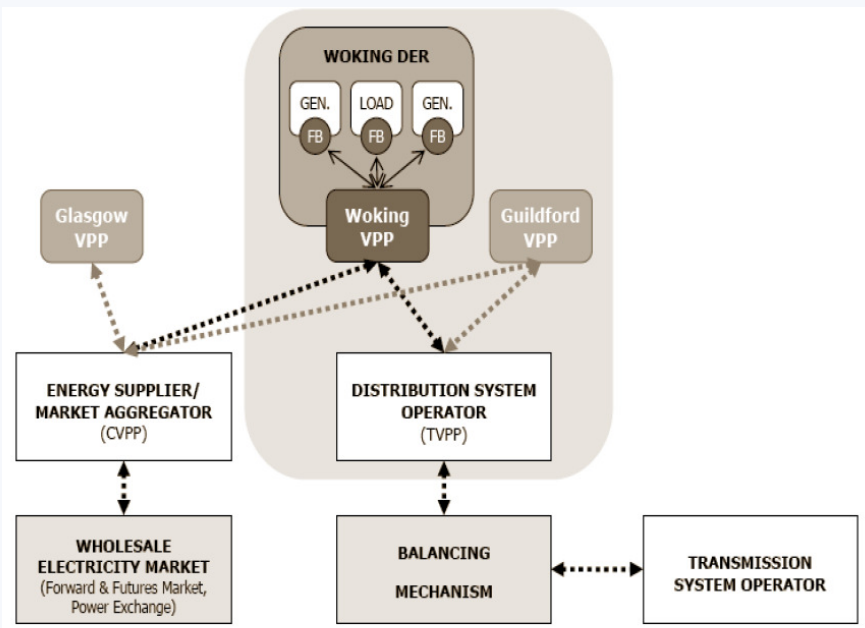
(Source: IEEE 1547)

Local balance between energy (heat/electricity) generation and load, at the level of

- A single customer
- An industrial/commercial complex
- A distribution grid subsystem

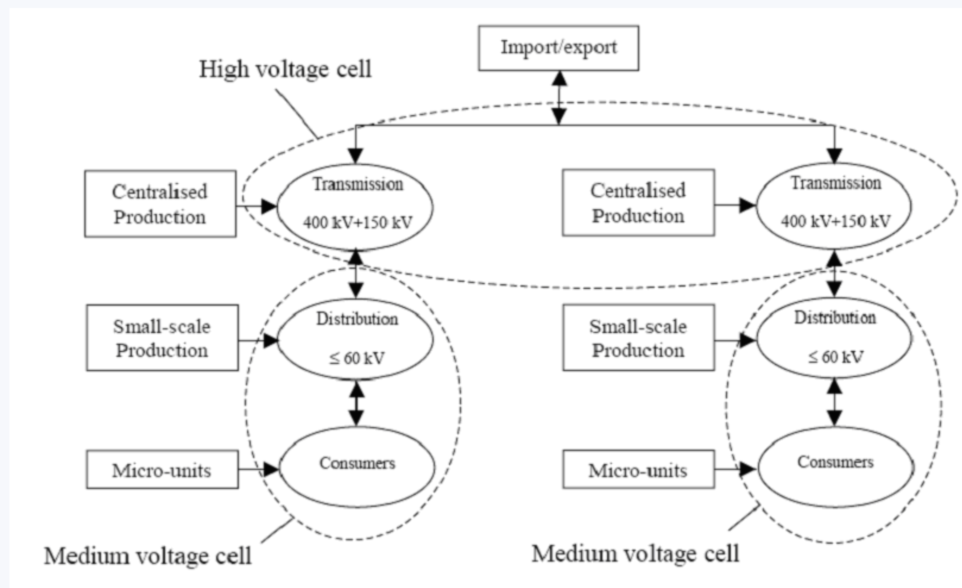
From passive towards active grids
New grid hierarchies

Virtual Power Plants (VPP)
Flexible representation of load & generation, acting as 1 entity towards DSO/TSO



(Source: www.fenix-project.org)

Cell concept (Denmark)
Hierarchical structure in the power system in which each cell coordinates local balance (market for DG), clears fault situations and communicates with other cells in energy trading



(Source: Risö)

Ancillary services of small generation units

Ancillary services

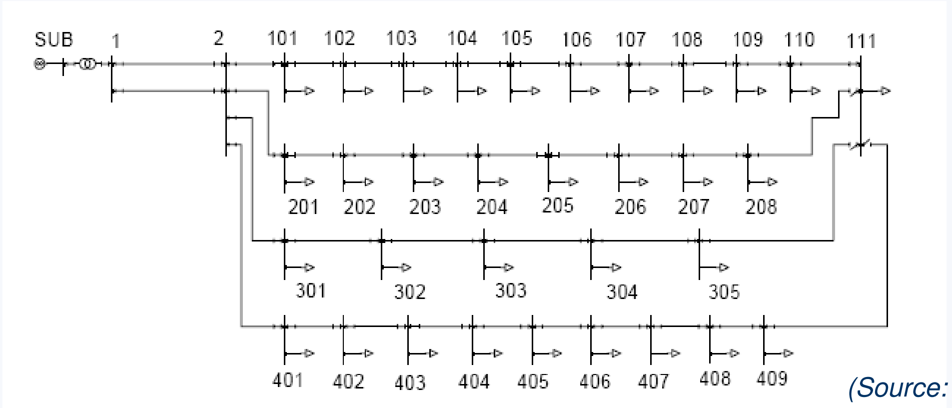
- Voltage support
- Feeder/transformer congestion
- Impact on T&D reinforcement deferral
- Black start capability of local grids?

By means of

- Generation curtailment,
- Generation dispatch, e.g. CHPs
- Reactive power control
- Demand control?
- Storage?

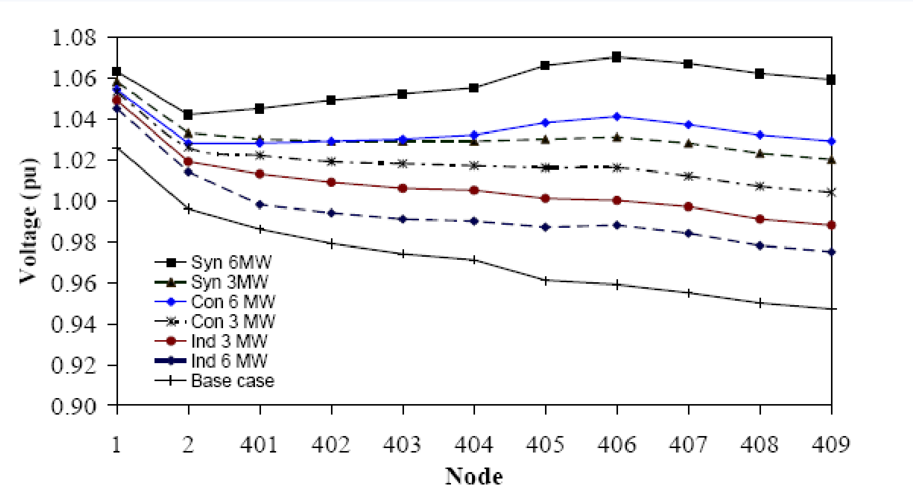
Ancillary services of small generation units

Grid impact local generation

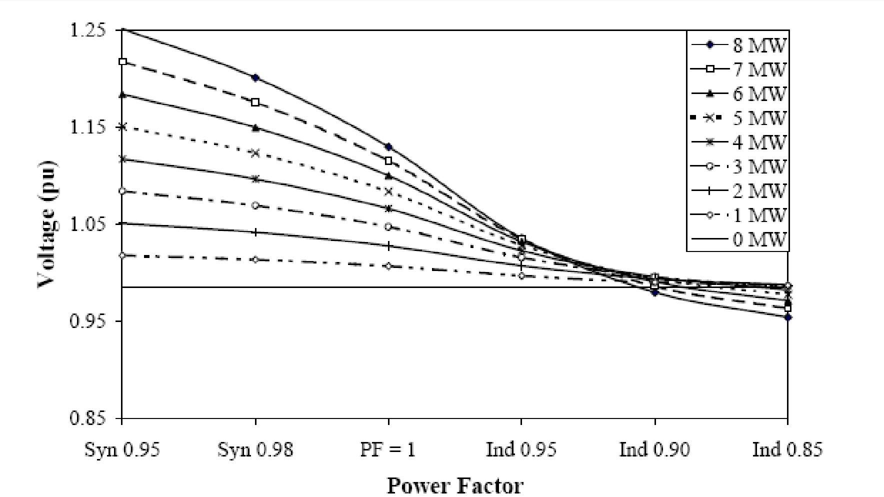


(Source: PhD T. Vu Van)

Voltage profile of feeder 4 with DG connected at node 406 with different DG technologies and power factors



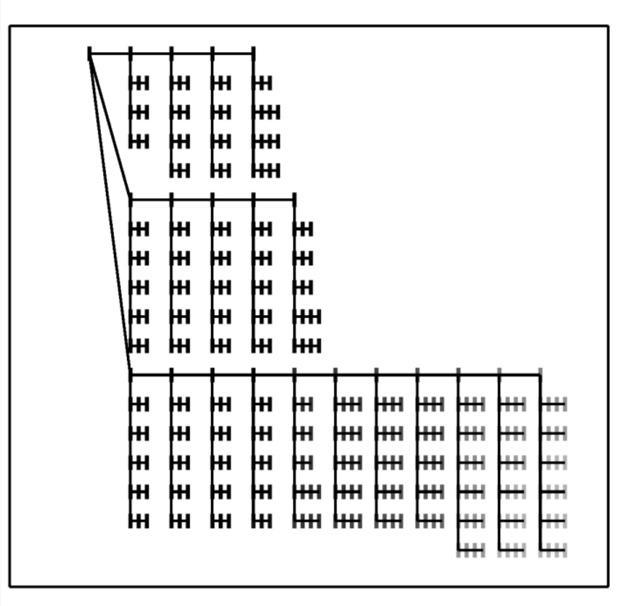
Voltage at node 406 with different power generation levels

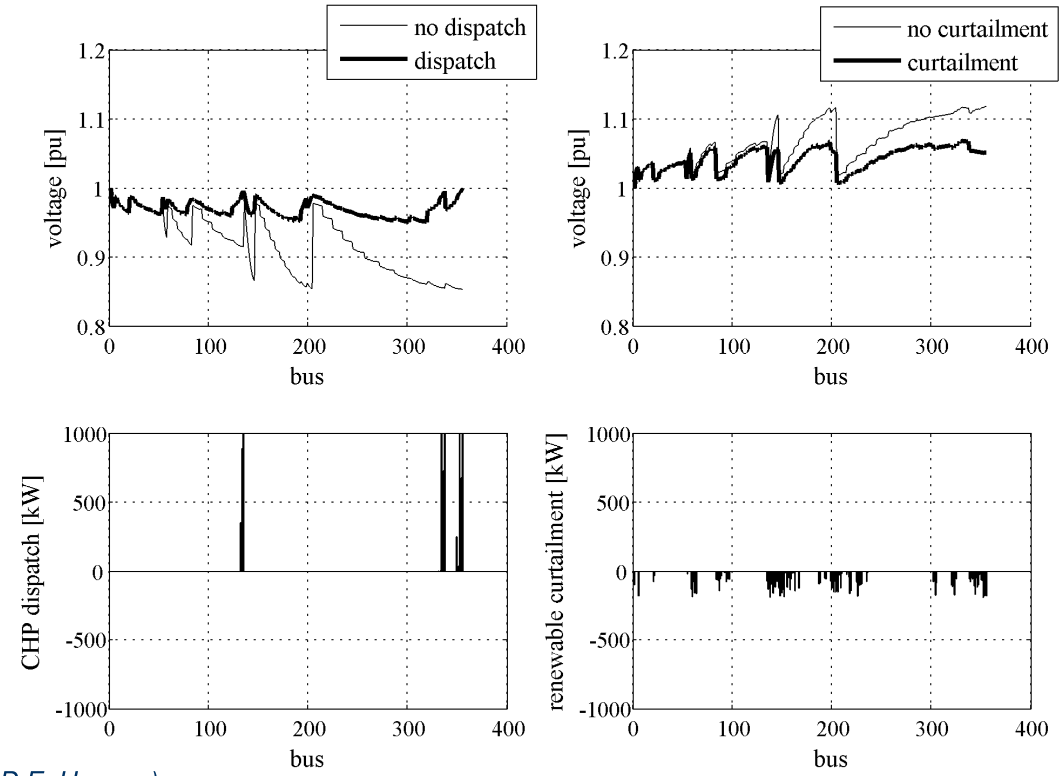


Ancillary services of small generation units

Illustration

- Radial 355-bus system
- Central Optimal Power Flow for CHP dispatch and DG curtailment
- Allows higher integration of DG
- Possible trade-off for T&D grid reinforcements





(Source: PhD E. Haesen)

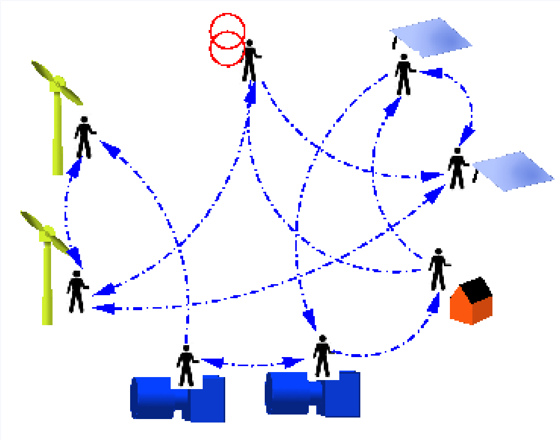
ICT requirements and reliability

- IEDs (intelligent electrical devices)
  - connected to grid via power electronics (inverter front-ends)
  - interconnected via communication network
- distributed control of DER
  - optimize voltage level (*secondary* control)
  - optimize production costs (*tertiary* control)
  - data aggregation, system monitoring etc.
- layout of communication architecture
  - point to point infrastructure vs. overlay network
  - distributed agents vs. centralised control

    + small capital investment

    + no single point of failure

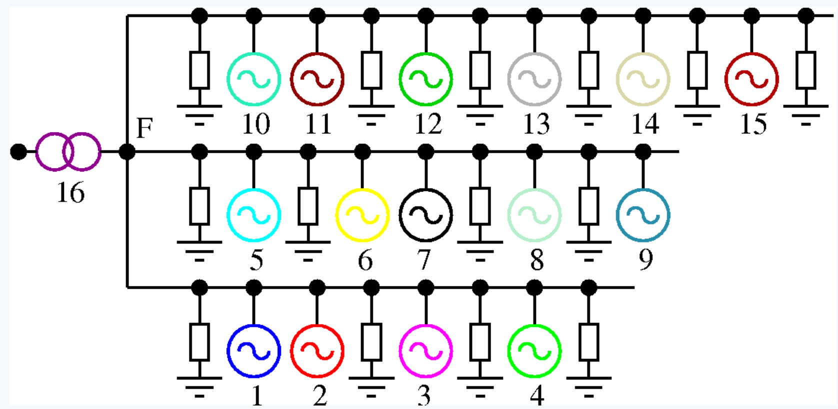
    - security more difficult



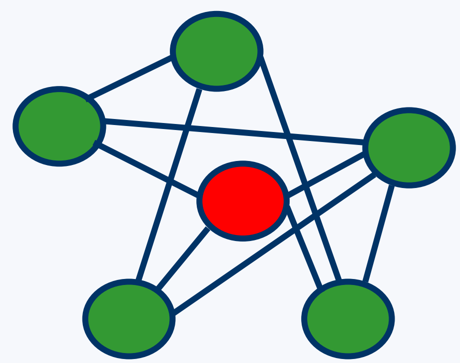
ICT requirements and reliability

Microgrid simulation model

- low voltage power distribution segment
  - grid connected
  - high DG penetration
  - variable loads
- agents
  - form overlay network
  - control power output
- primary, secondary, tertiary control
- overlay networks dynamically constructed
  - here: neighbour choice based on node description
- malicious node send wrong descriptions
  - other nodes choose it as a direct neighbour



Source: Crutial (KU Leuven, CESI Ricerca)



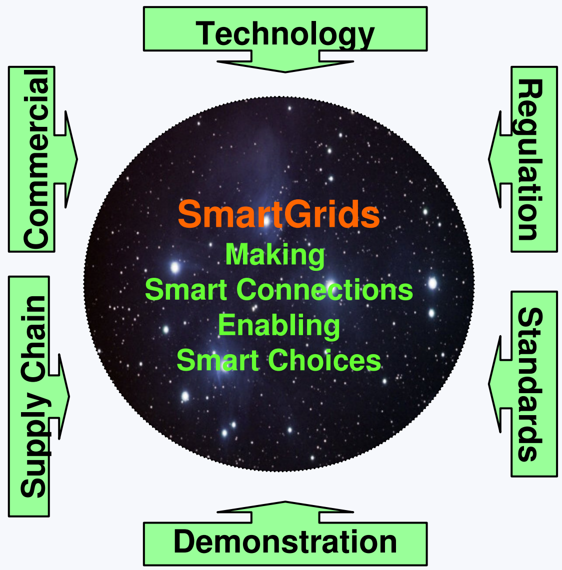
What are the Elements for Success?

A Model for SmartGrids

- Market frameworks may not facilitate innovative solutions
- Attention to intellectual property
- Export opportunities

- There are real technical challenges
- They are solved or solvable by research
- But technology alone is not enough

- Regulatory frameworks may have unintended barriers to innovation
- New thinking takes time to implement



- Innovation needs wide deployment
- But supply chains have limited capacity
- Manufacturing, raw material, services and skills

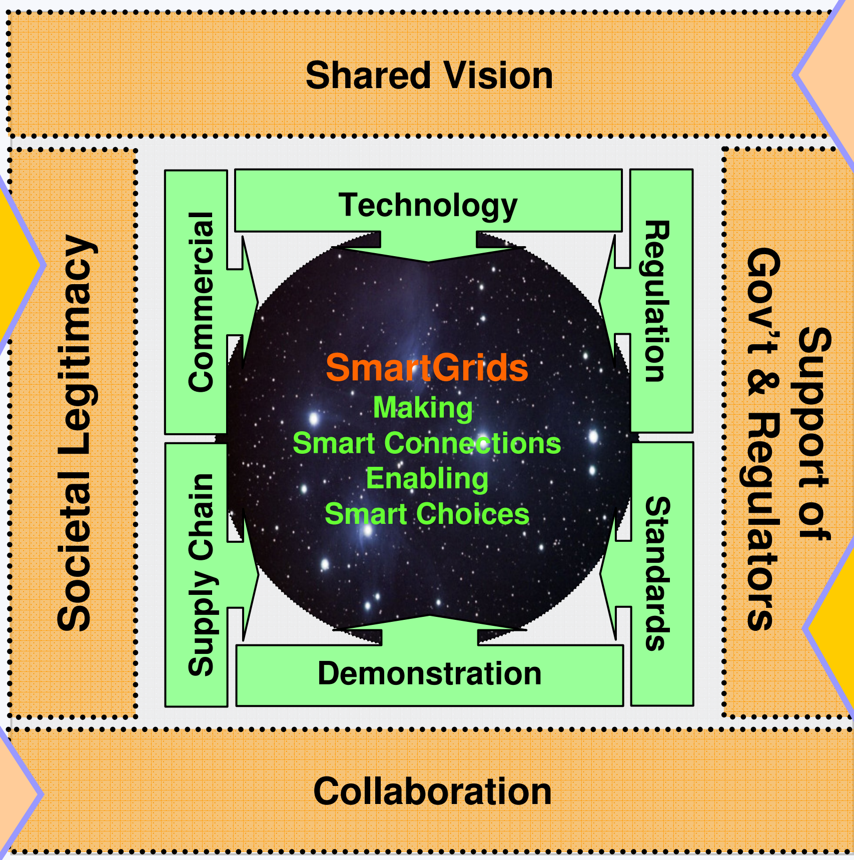
- Standards and protocols underpin open systems
- A Plug & Play approach is needed
- But there are no quick changes here

- Demonstration/pilot projects are key
- Operational proving is a critical step
- Beware the Valley of Death……

What are the Elements for Success?

- Consents for development will be needed; also
- *Permission to Operate* in the wisest sense
- Trust & social impact requires special attention

- Multiple parties must form a common view of success
- A shared and living Vision is a must for 'joined up thinking'



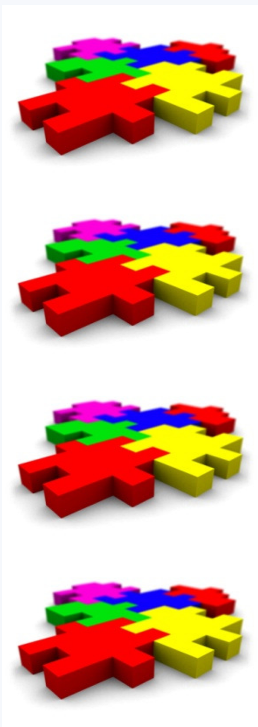
- Major change requires shared priorities and co-operation
- Especially for framework changes and between different sectors

- Collaborative working underpins integration & efficiency
- It is the way a market handles complexity

much more than technology…

Smart Grids extend beyond networks and will embrace transport, the built environment, the behaviours and engagement of customers, and will need societal acceptance.

Smart Grids will require



Customer Acceptance and Participation

....Intelligent Appliances & Demand

…Smart metering with 2-way communications

…Micro-generation providing grid services

The Technology Platform

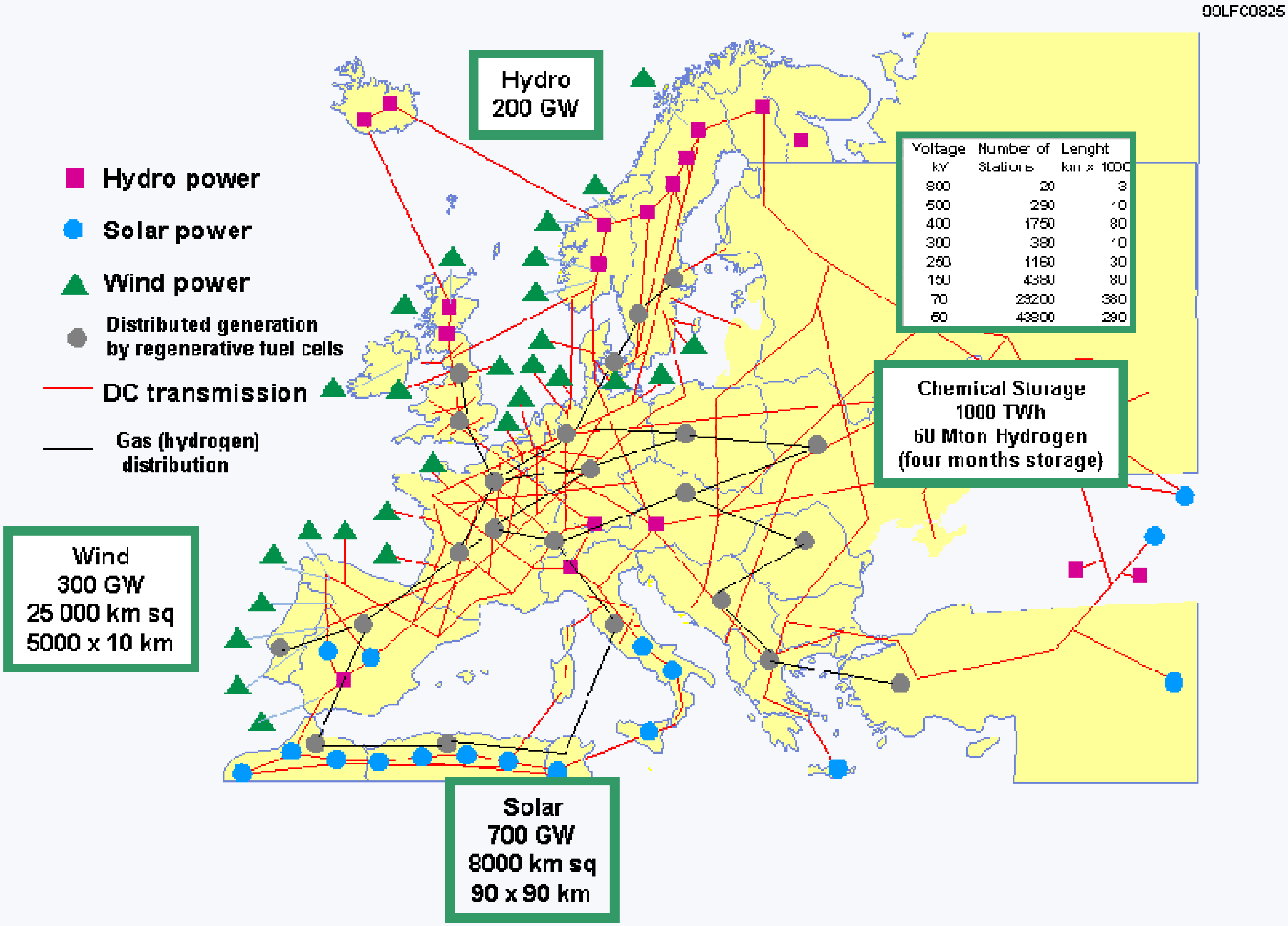
- **The Platform brings together key EU stakeholders**
- **Vision document published**
- **Strategic Research Agenda published**
- **Smart Grids short video is available on the website**
- **The Strategic Deployment Document is in final drafting**

A common agenda

- **Over 200 experts**
  - **Engineers**
  - **Investord**
  - **Academics**
  - **Politicians**
- **And acknowledged in**
  - **ERA-net**
  - **Reliance**
  - **FP7**

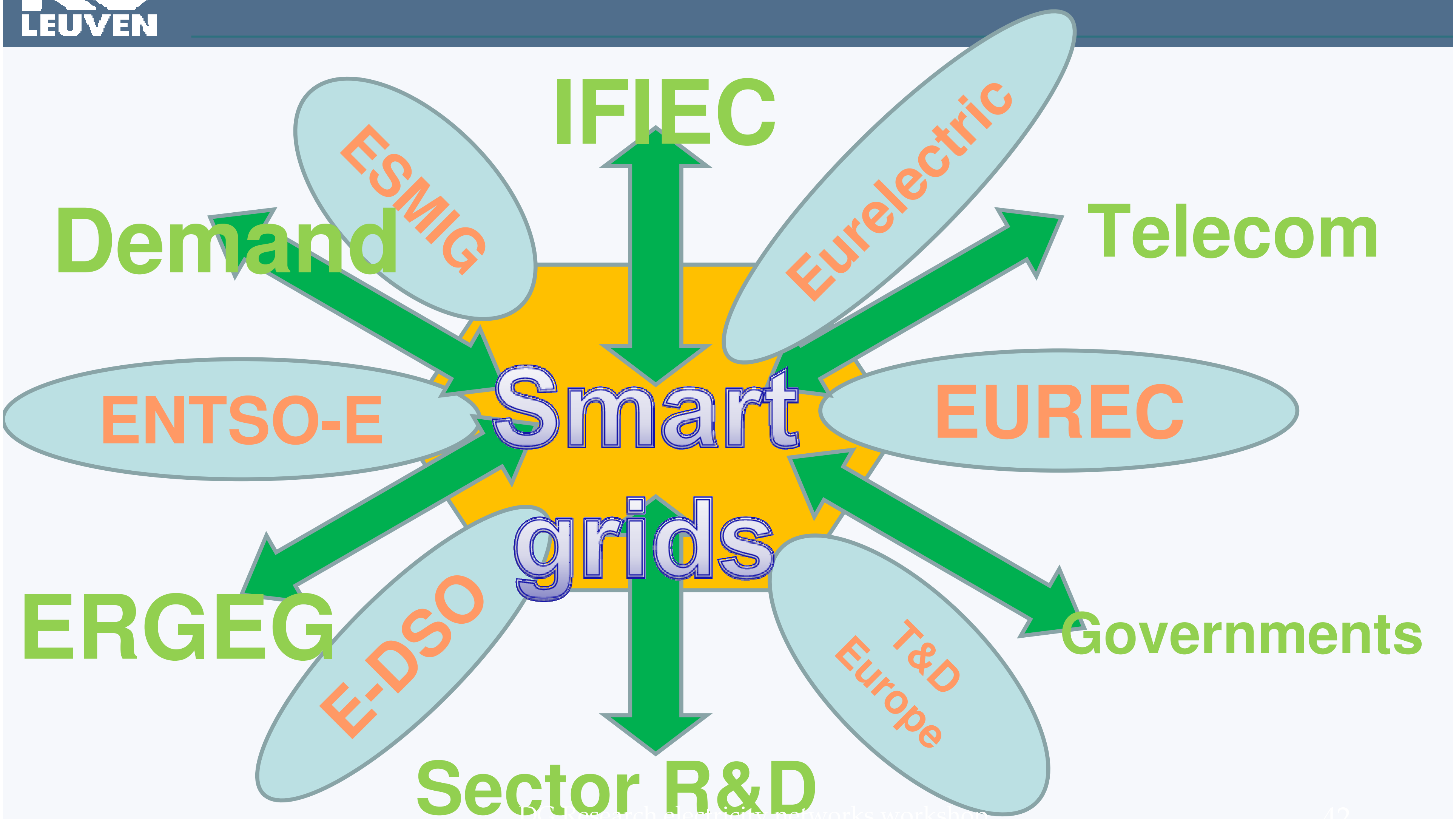
Future urban view

Future European view



Voltage kV	Number of Stations	Lenght km x 1000
800	20	3
500	290	10
400	1750	80
300	380	10
250	1160	30
150	4380	80
70	23200	380
60	43800	290

Smartgrids Forum



Thank you for your attention !

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SMARTGRIDS
EUROPEAN TECHNOLOGY PLATFORM FOR THE ELECTRICITY NETWORKS OF THE FUTURE