Smart Grid as a Complex System

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Smart grids

- IT and TC integration (1995-2010)

- Smart grid integration - power system and telecommunication integration (2005-2020?)

Complexity science approach to energy (smart) system

Complexity in energy systems is in general a vague concept. It is often used as a synonym of complicated systems.

I consider a strong complexity approach for smart grids

- **Study of nonlinear, emergent, self-organized, resilient dynamic properties in new types of energy systems**

Strategic breakthroughs for new type of (smart) grids

Generation

- new types of energy production (fusion, better PV efficiency, new type of renewables, energy storage devices etc)

Grids

- (high temperature) superconductivity, digital energy transmission, FACTS, HVDC

Telecommunication

- broadband over power network, improved wireless telecom, etc

Smart home and smart factory

- advanced metering , internet of things (home appliances)

Complexity science approach to energy (smart) system

Two approaches are known:

European –**smart grids** as the extension/modification of **distribution grids**

USA –**smart grids** are new way the grids are considered including **generation/transportation and distribution networks including bulk systems**

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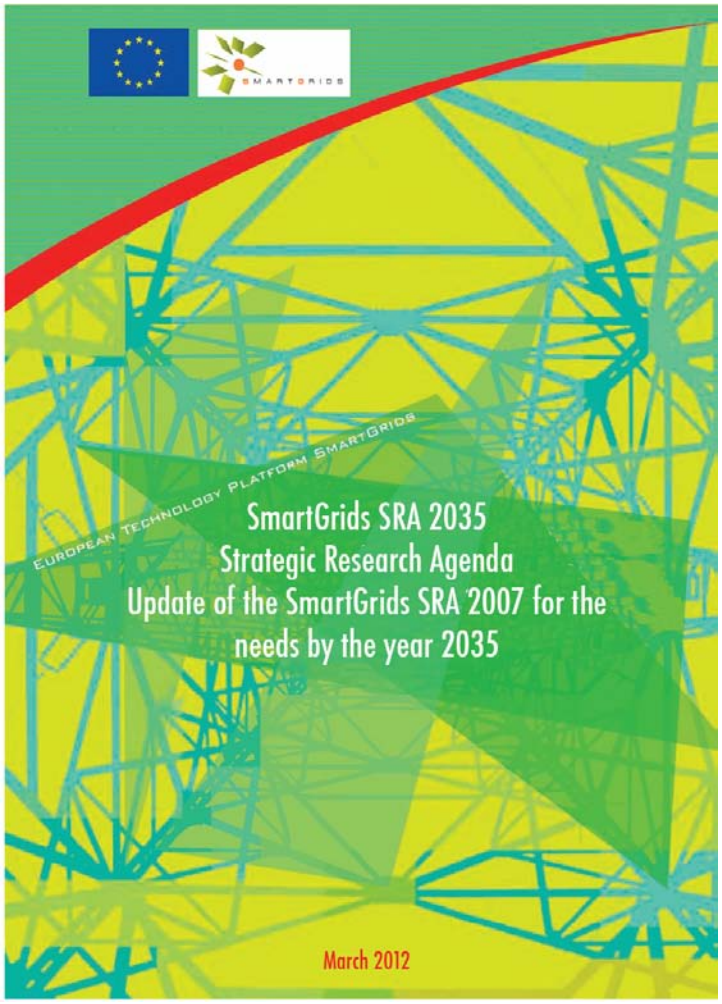

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Complexity architecture of smart grids (1)

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Complexity architecture of smart grids (2)

I) Technological-technical complexity

II) Social complexity

III) Economic complexity

IV) Sustainability complexity

I) Technology

- Technological-technical complexity

  a) Energy point of view (distributed generation (DG), demand side management (DSM))

  b) Topological (network) point of view (small-world, scale-free networks)

  c) Cyber point of view (Broadband Distribution PLC, Internet of things)

I) Technology
a) Energy

Research on new architecture of smart energy systems and networks

- mixed: large scale and scattered small scale generation
- transition of radial → meshed networks
- new type of power protection systems
- robustness of energy part of systems (double network power injection points)
- end-user intervention to demand side management
- power system security
- standardization

I) Technology
b) Network

- Architecture and dynamics of fused **power-cyber networks**
- Dynamics of new type of **power networks-** power flow control and optimisation under new conditions- emergence and chaotic behaviour
- Dynamics of **cyber networks** – data flow research and emergence and chaotic behaviour

I) Technology
b) Cyber

- Network fusion (power, cyber- Broadband DPLC) and systemic service
- Robustness (DPLC - only one fused network) or separate Energy – Cyber network
- Cyber security
- Standardization

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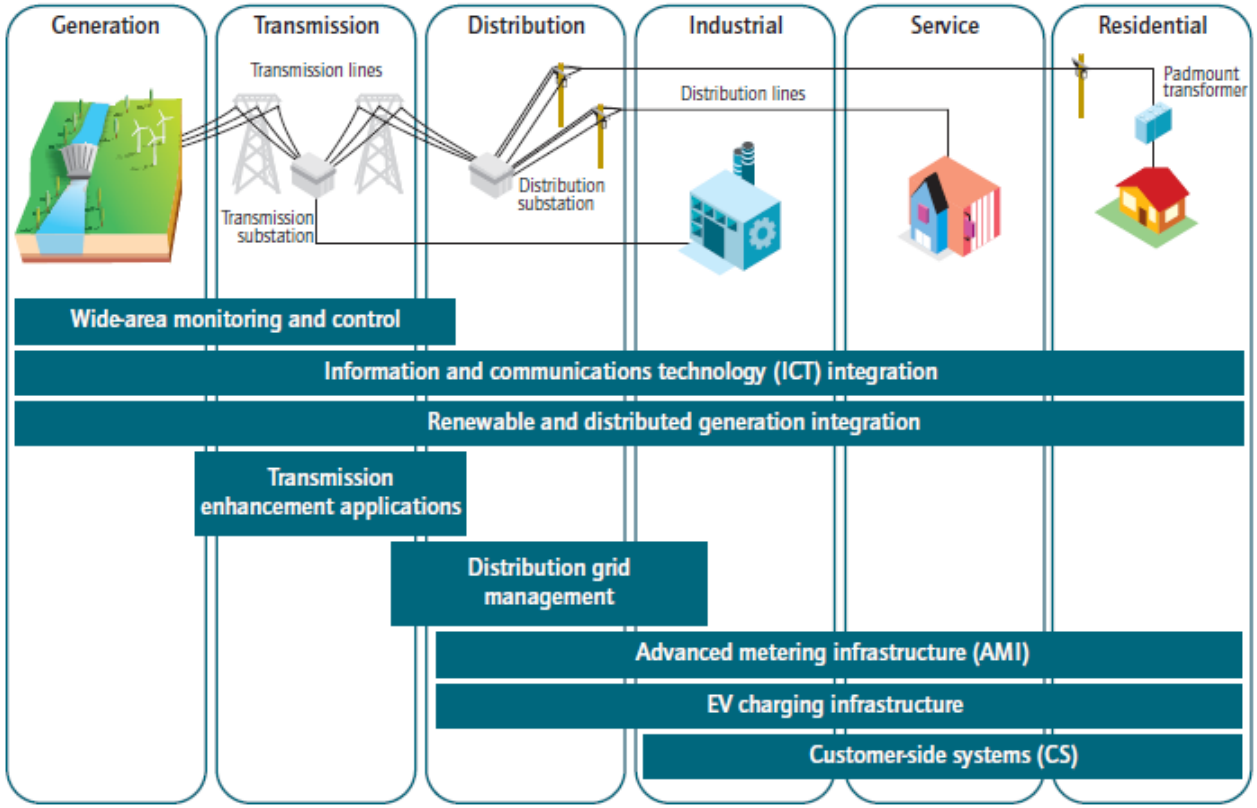
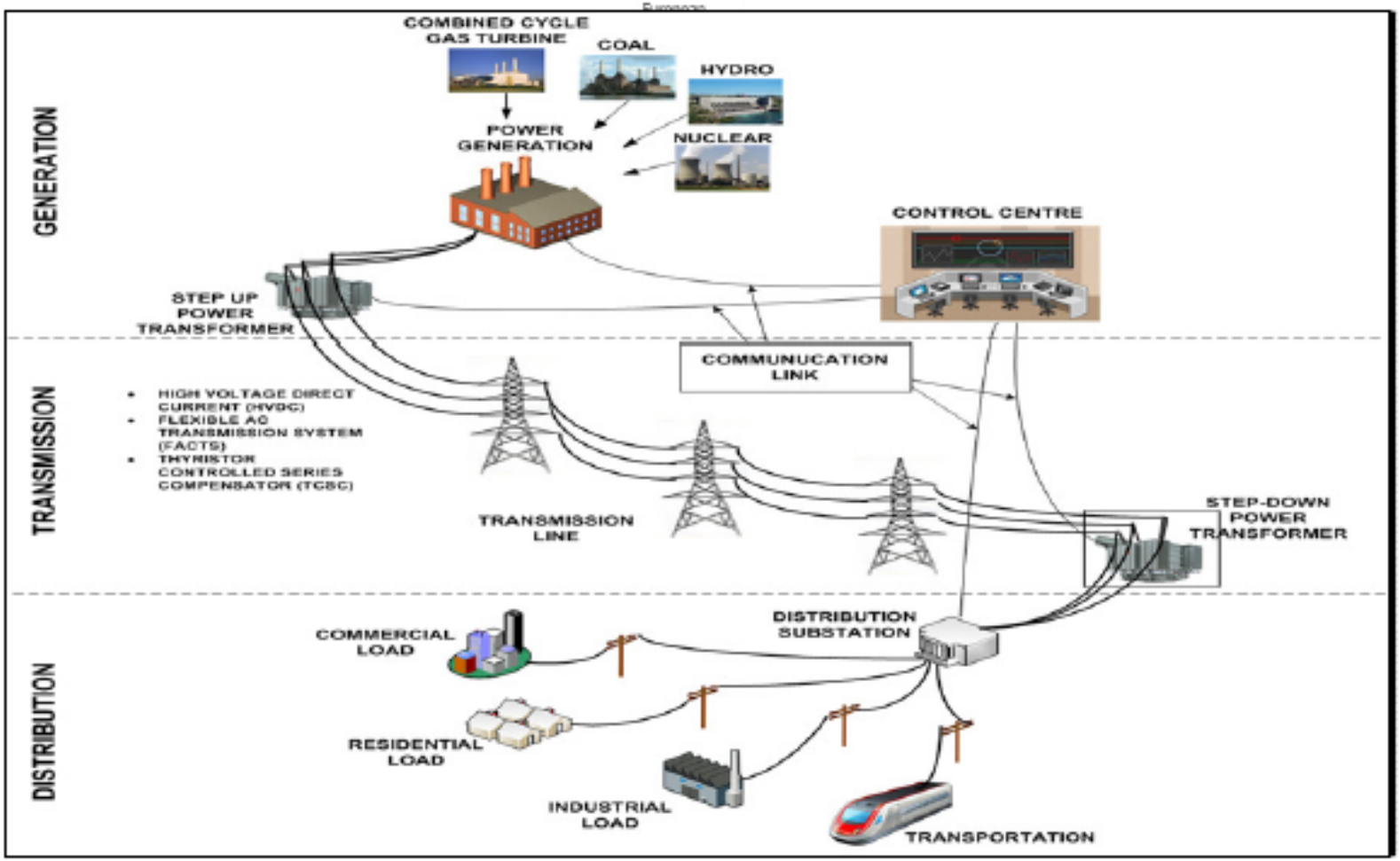
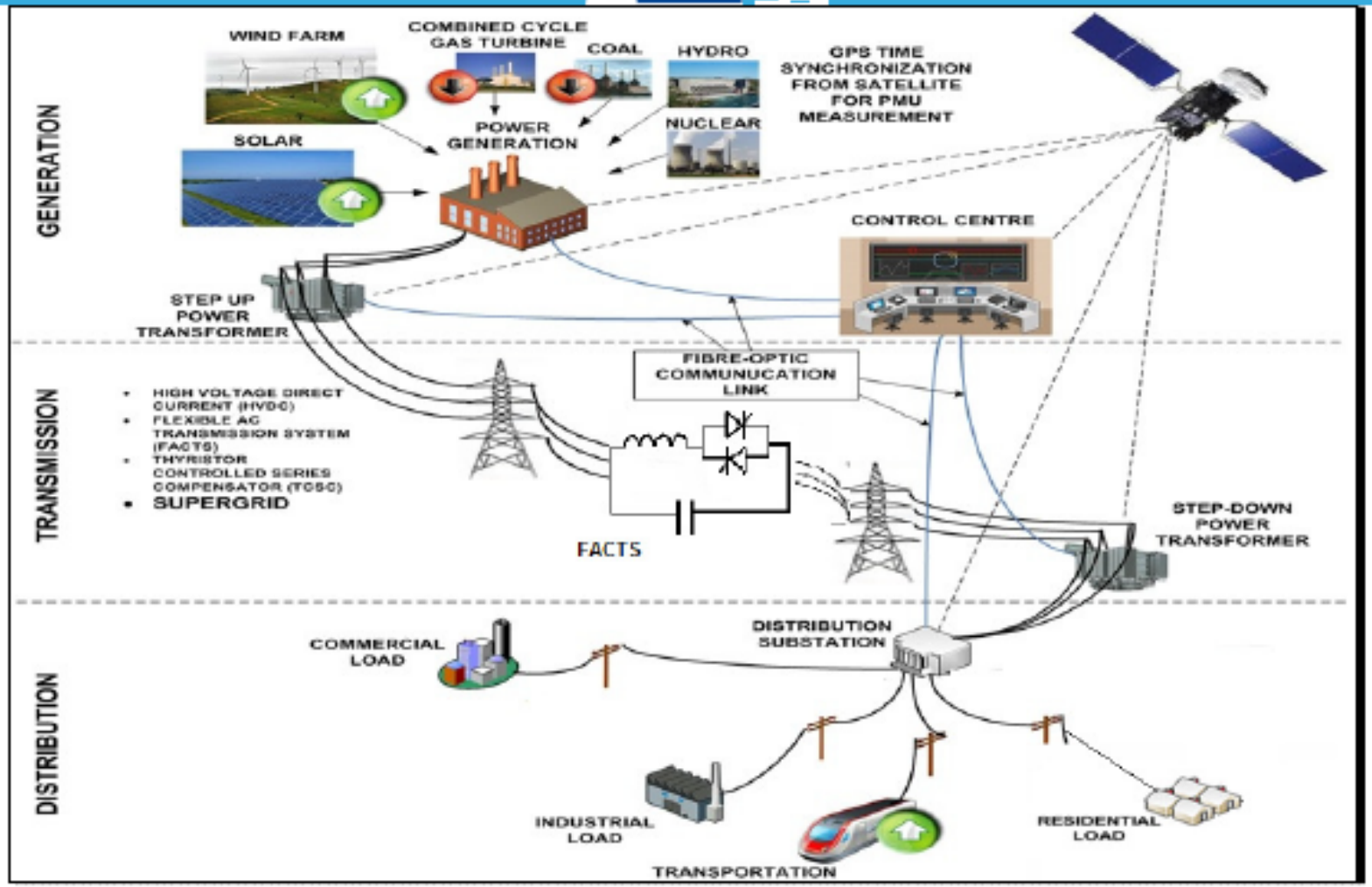
Smart grid technology areas



Electricity Network 20 years back



Electricity Network Today



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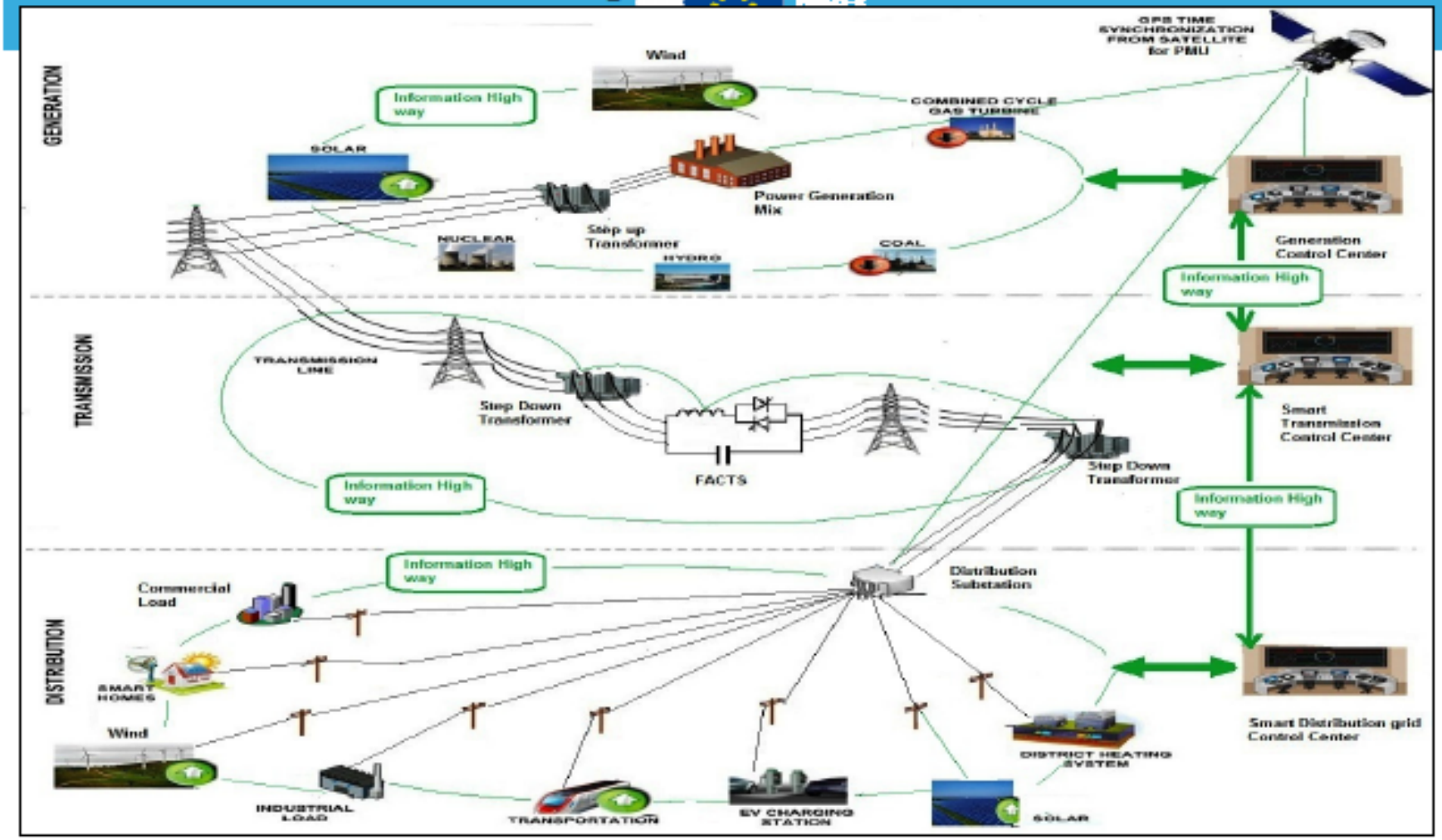
And 20 years in future



II Social

New social complexity

- New role of end users (grater impact)
- New type of end users (prosumers)
- Energy data as personal data
- Energy conscious end user
- Future scarcity of energy resources
- New way of life (smart home, teleworking etc.)
- Self organisation

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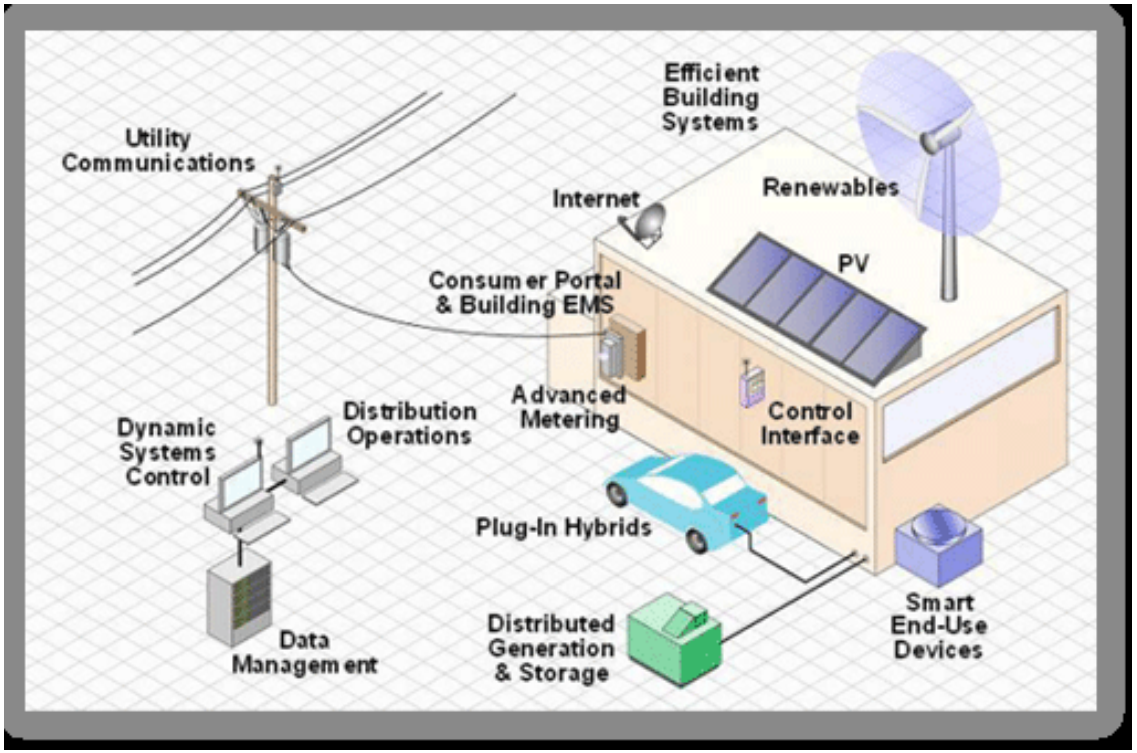
Smart grid
End user layer



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III Economy

Complexity of new type of energy economy

- **local energy communities** as complex systems
- **new stakeholder mix models** (power producers, prosumers, power network operators, cyber net providers, energy communities, regulators and policy makers) – their interplay as a complex system
- **economy energy models** (internalisation of costs) as a complex system (emergency, chaotic models??)

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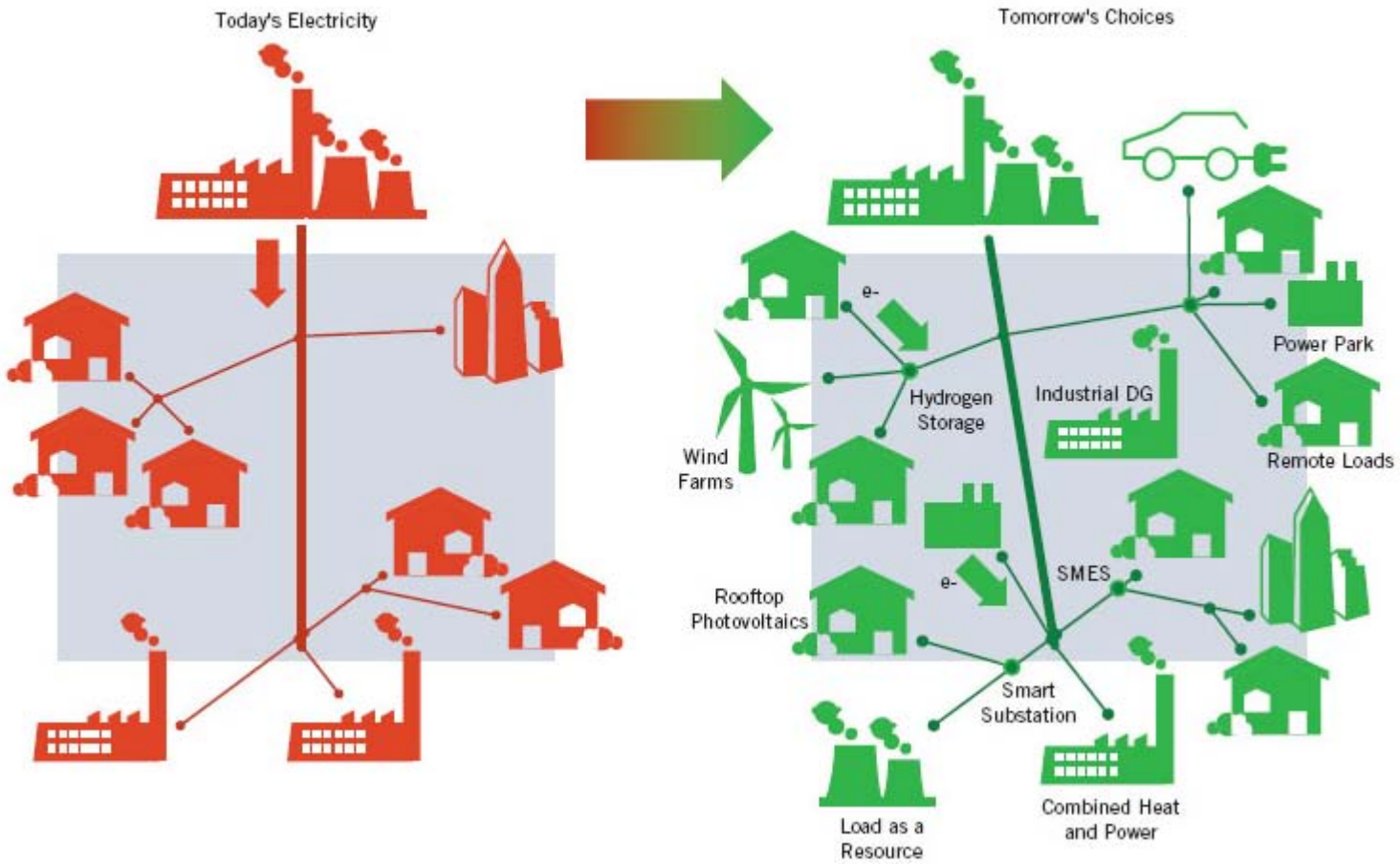
Grid Modernization



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IV) Sustainability

Complexity of sustainability - EU goals by 2020

- **Green gas reduction - 20%**
- **Renewables – 20%**
- **Energy saving- 20%**

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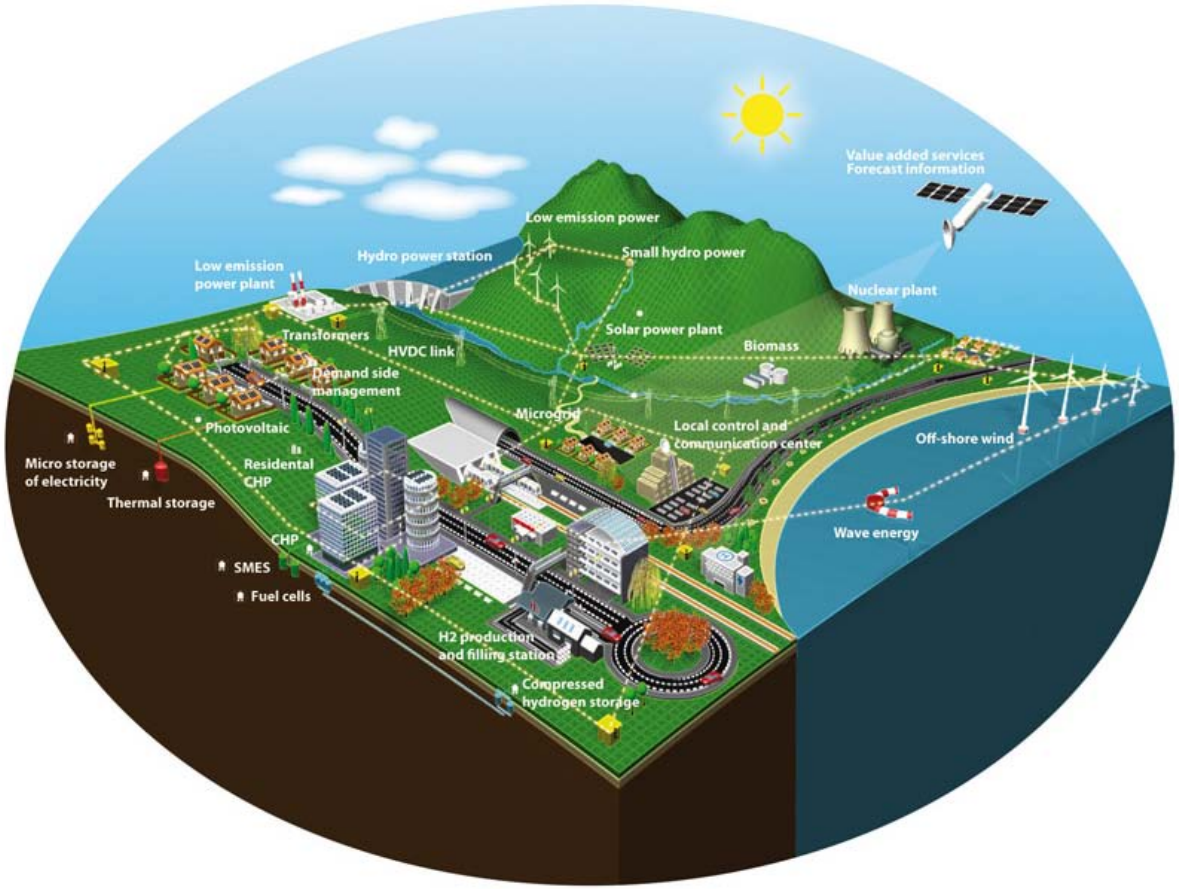
Future sustainable eco system



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Covered

I) Technological-technical complexity

II) Social complexity

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IV) Sustainability complexity

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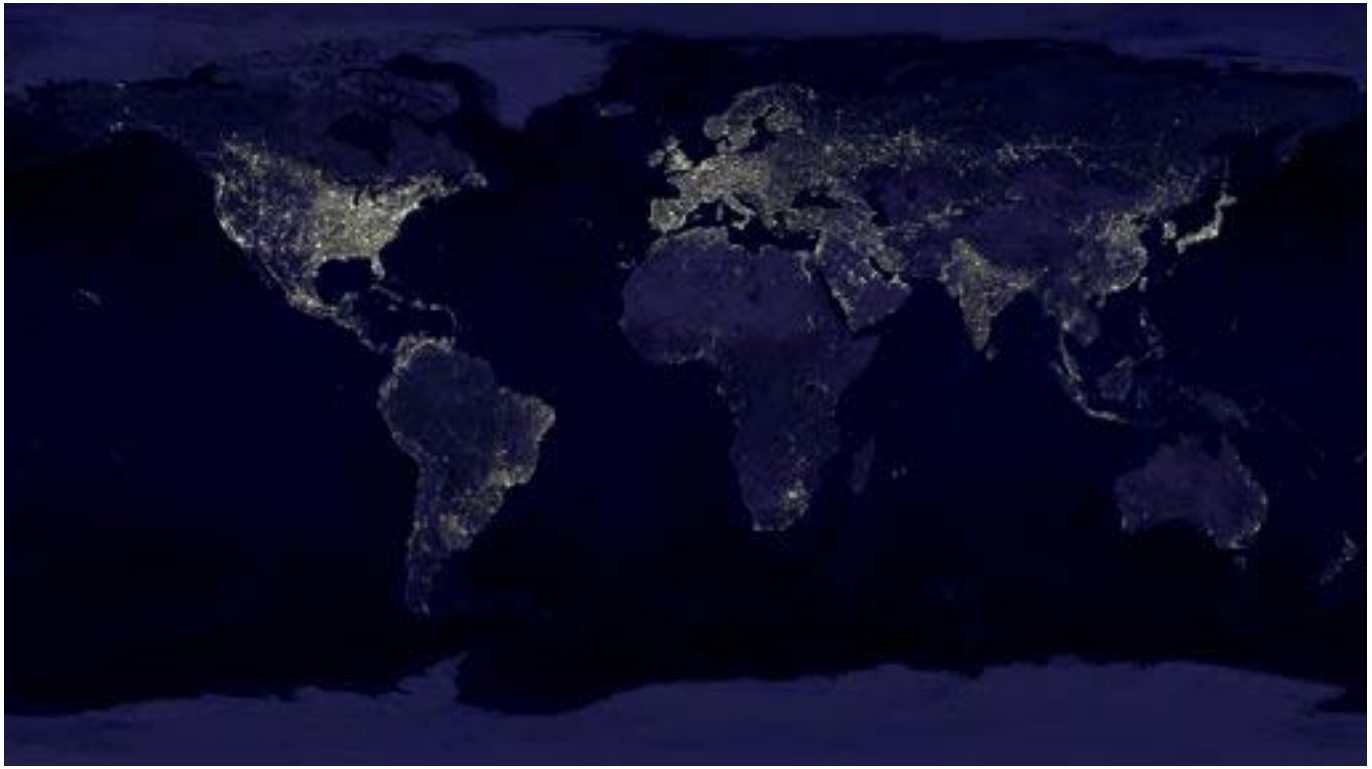
Thank you



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