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Plenary Talk

Future Sustainable Energy Systems – Moving Towards 2050

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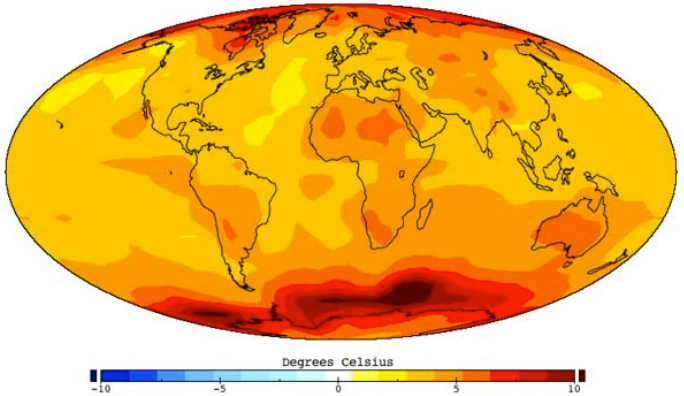
- **EU energy strategy**
  - **Long term strategy (2050)**
  - **Energy Union (2030)**
- **Challenges in electricity and natural gas markets**
- **Energy cost**

EU energy strategy

Long term strategy

Future energy systems

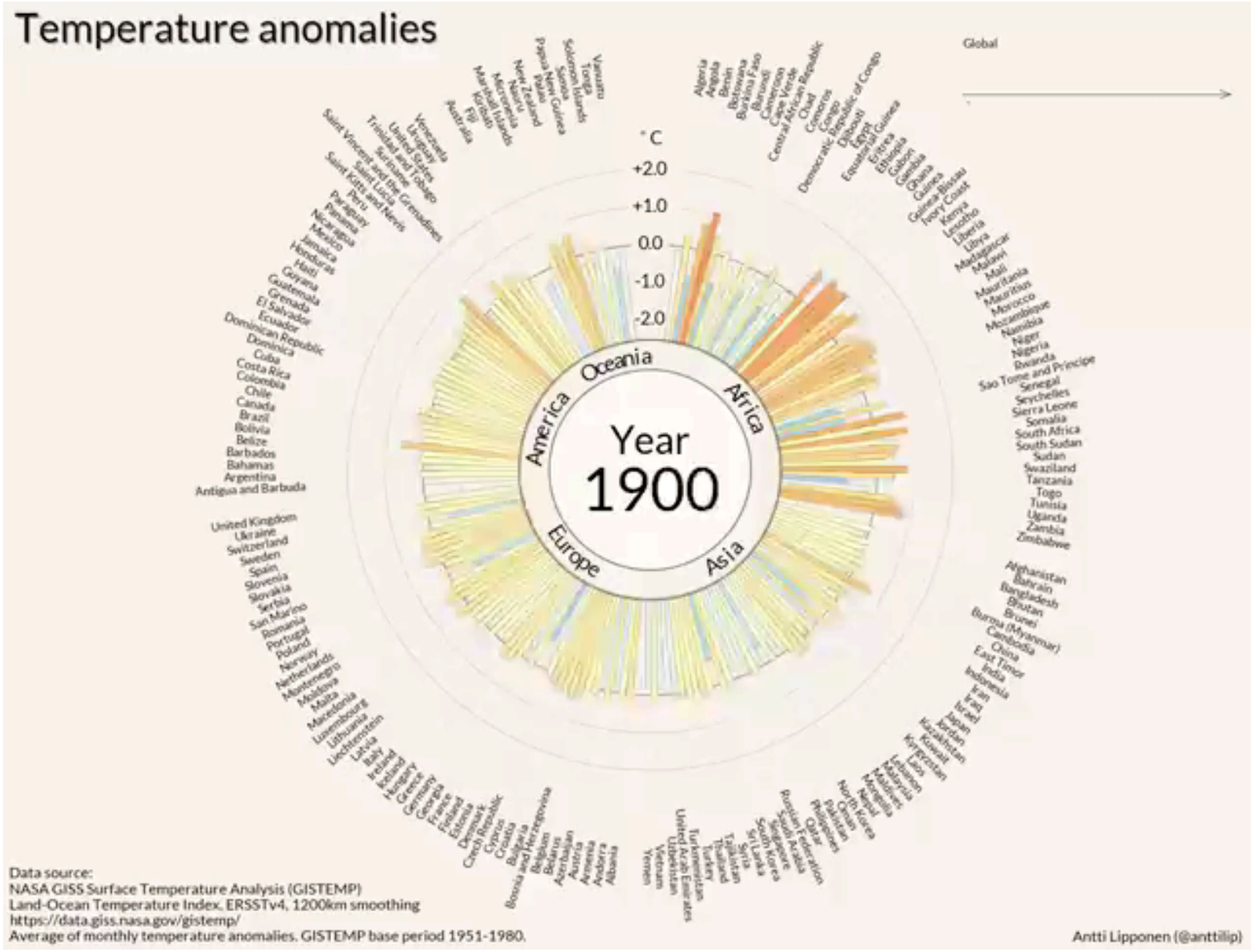
- **Climate change**



- **Third industrial revolution**

- **Future energy economics**

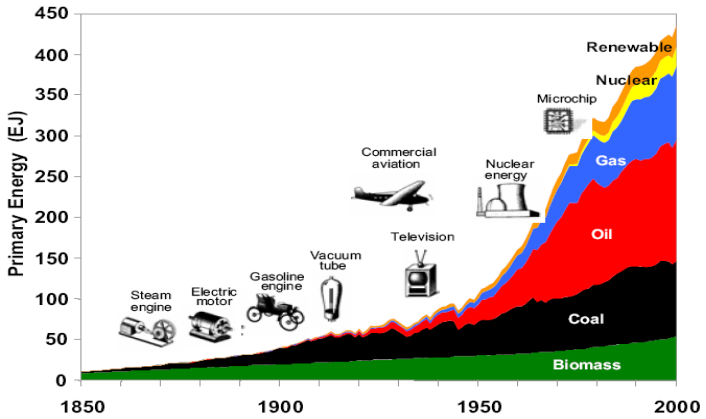
Temperature anomalies *



*** UN Environment, 2017.**

EU energy objectives

- greenhouse gas reduction
- sustainable production and consumption
- competition in electricity and natural gas markets
- security of supply



Our energy future?

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Decarbonisation:

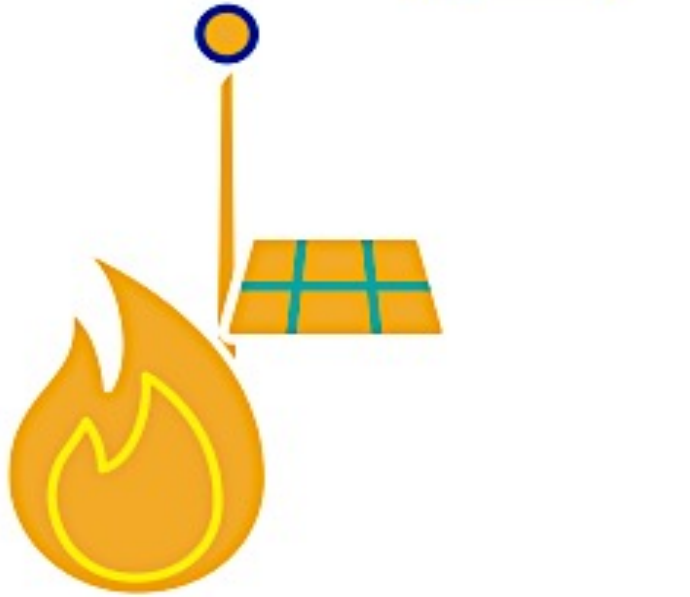
oil/coal-to-gas switch, renewable gas, wind and sun, carbon capture and usage

Decentralisation:

Solar panels, micro-CHPs/fuel cells, storage via power-to-gas and batteries

Digitalisation:

ICT for smart households and smart gas/electricity grids



- **Extrapolating developments of the past does not forecast the future**
- **Gas, wind and sun – providing Europe with clean heat, electricity and transport**

Current energy system

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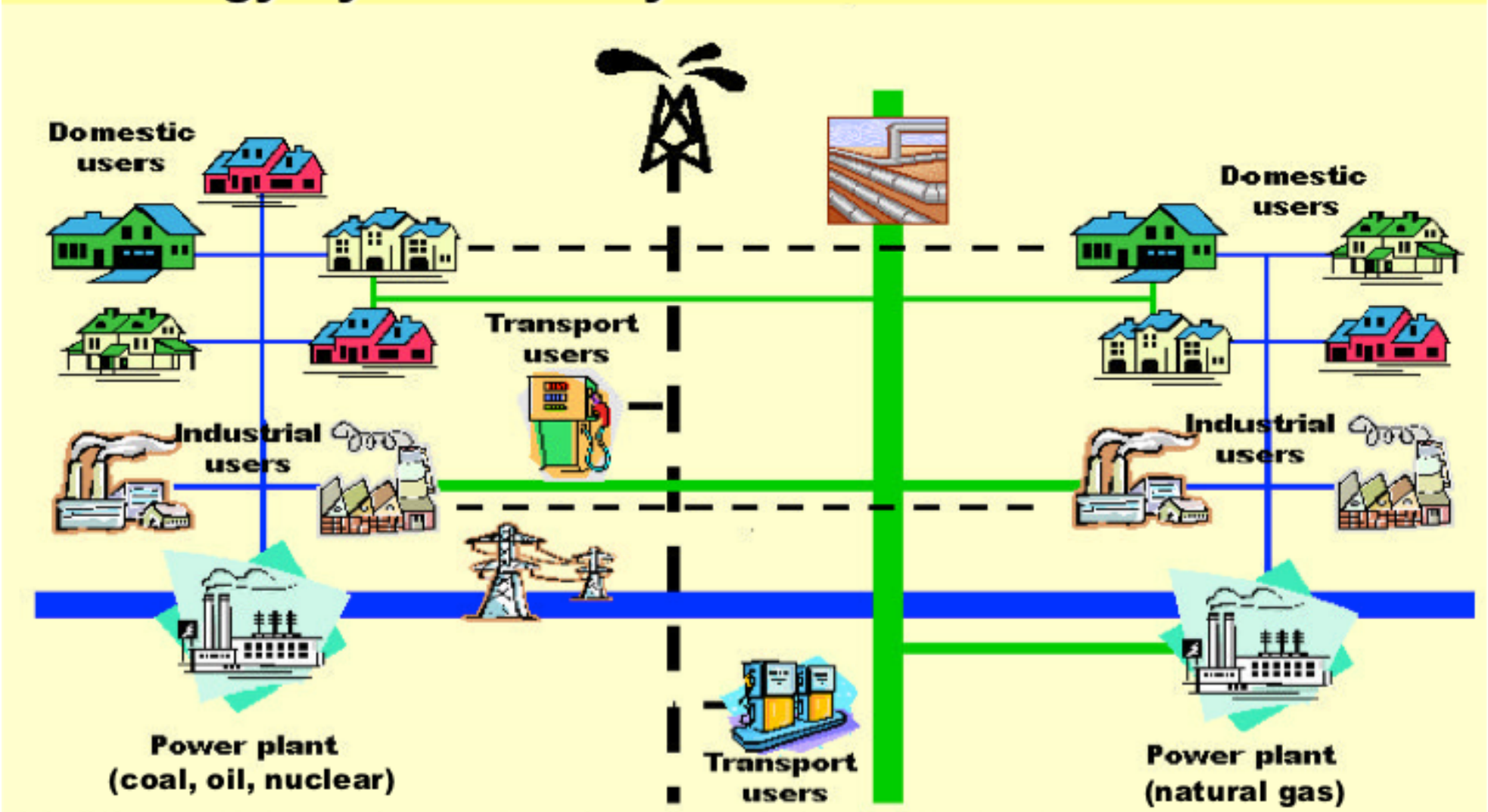
EU energy system today*



* Poullikkas A., 2009, *Introduction to Power Generation Technologies*, ISBN: 978-1-60876-472-3

Future energy systems (optimistic scenario)

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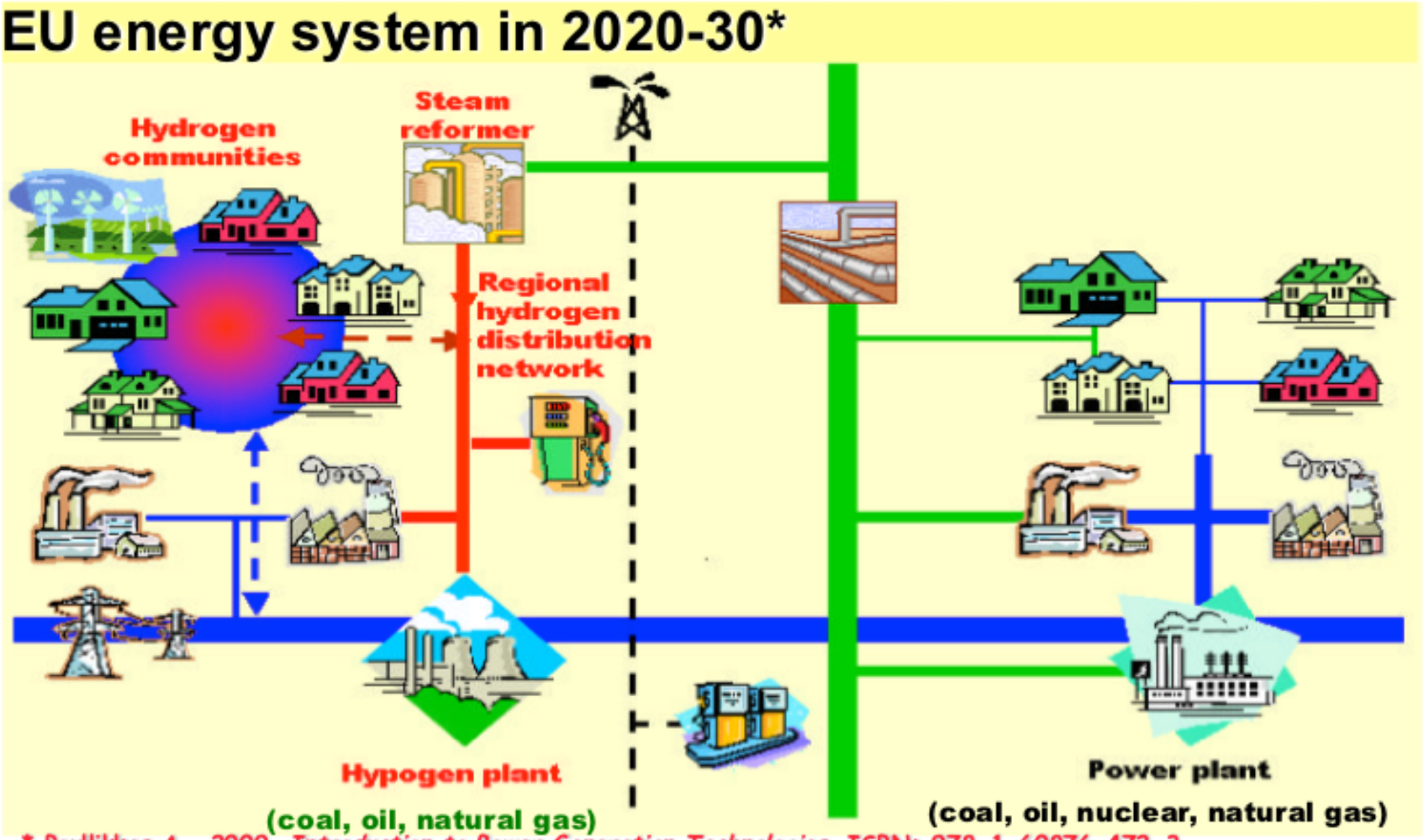

Future energy systems (optimistic scenario)

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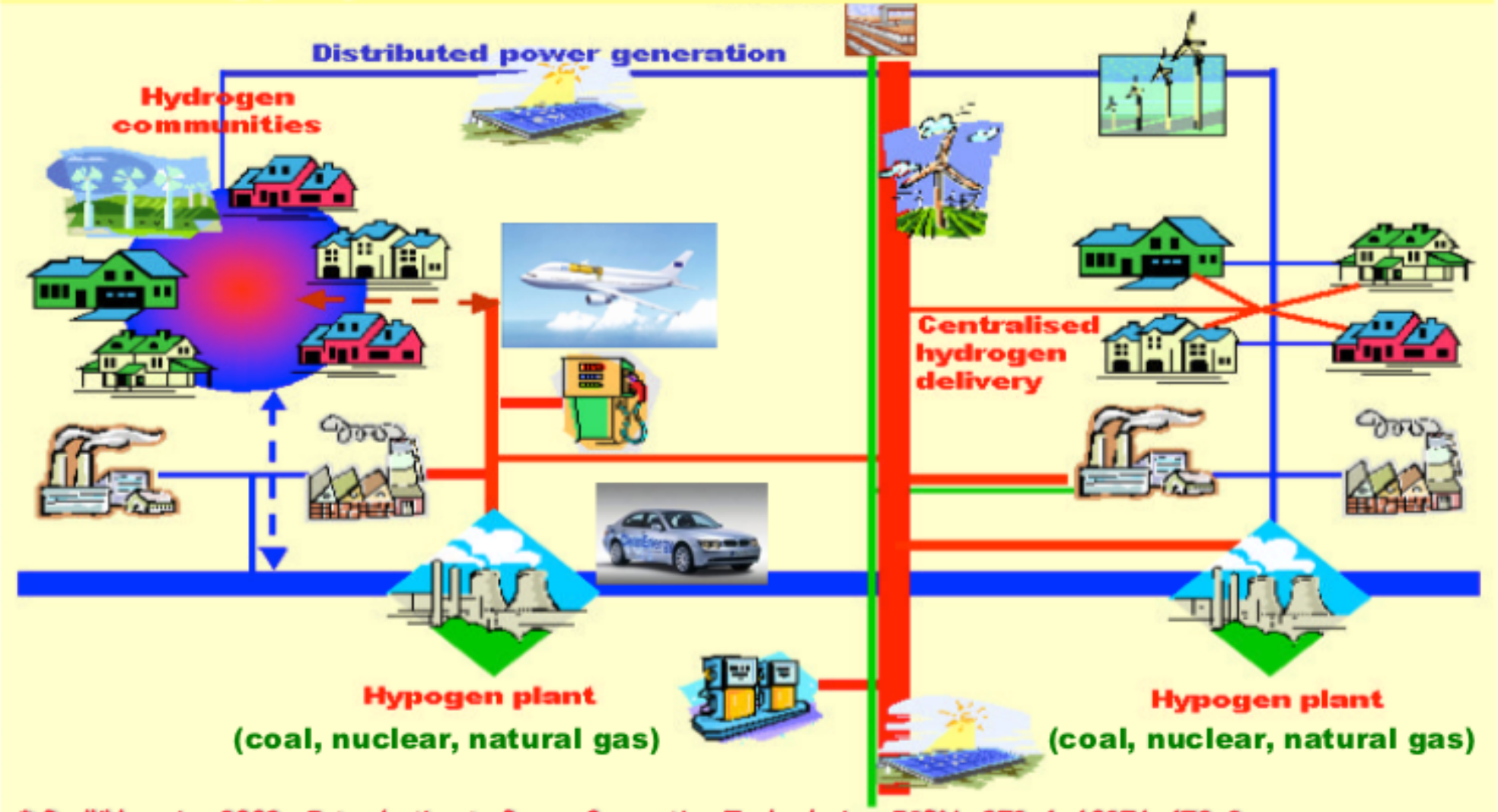
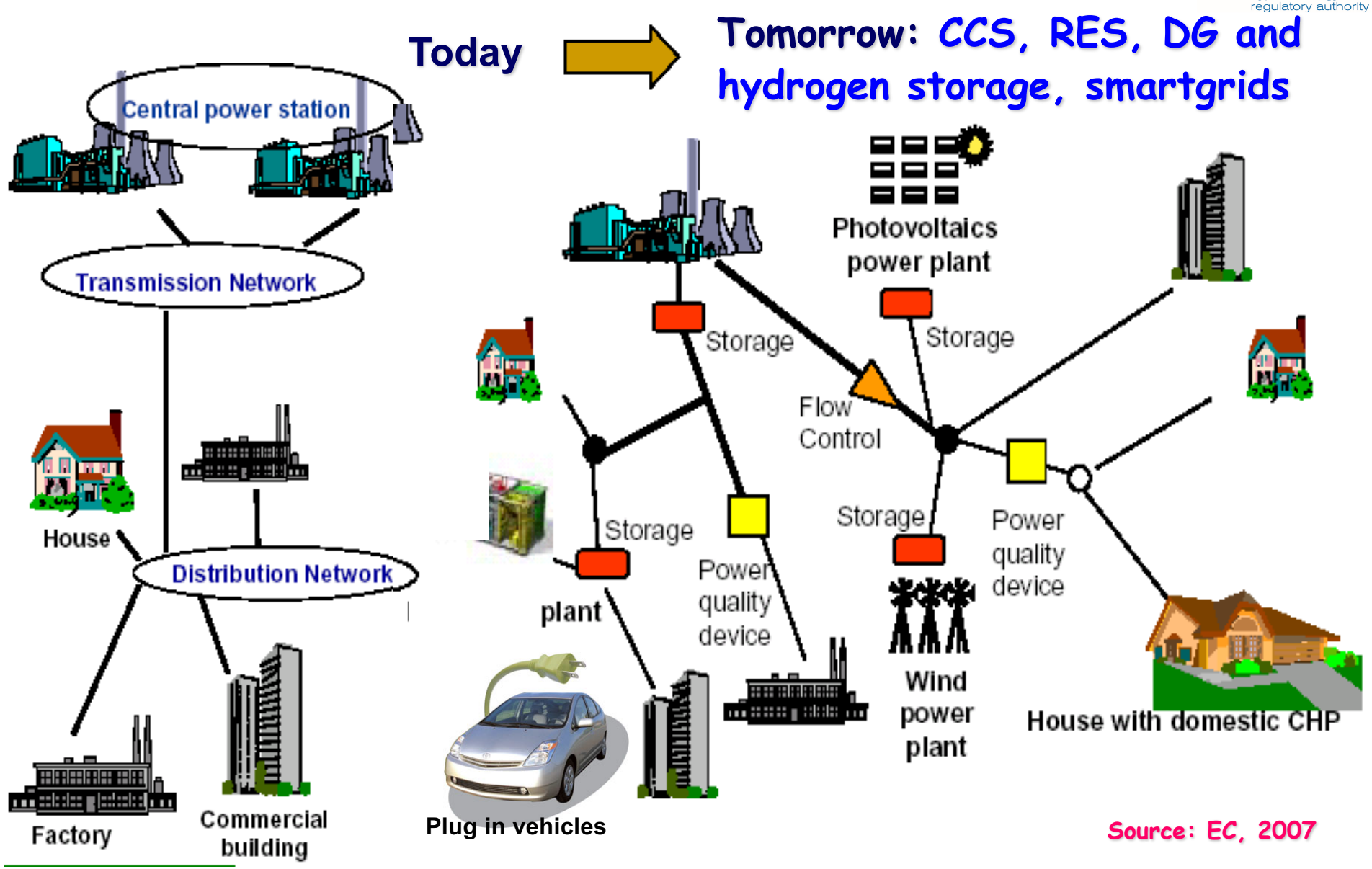
EU energy system in 2040-50*

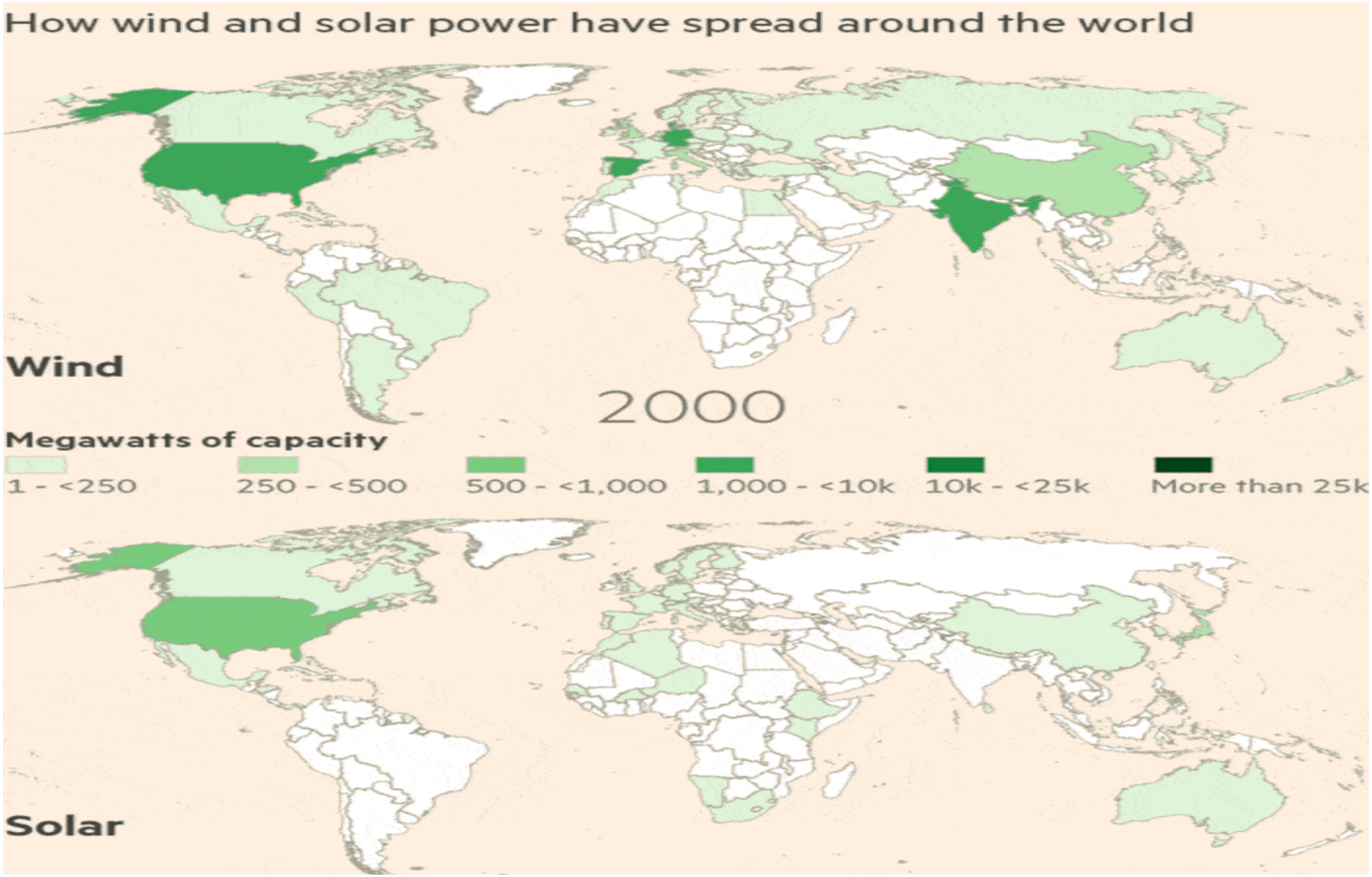


* Poullikkas A., 2009, *Introduction to Power Generation Technologies*, ISBN: 978-1-60876-472-3

Future power systems

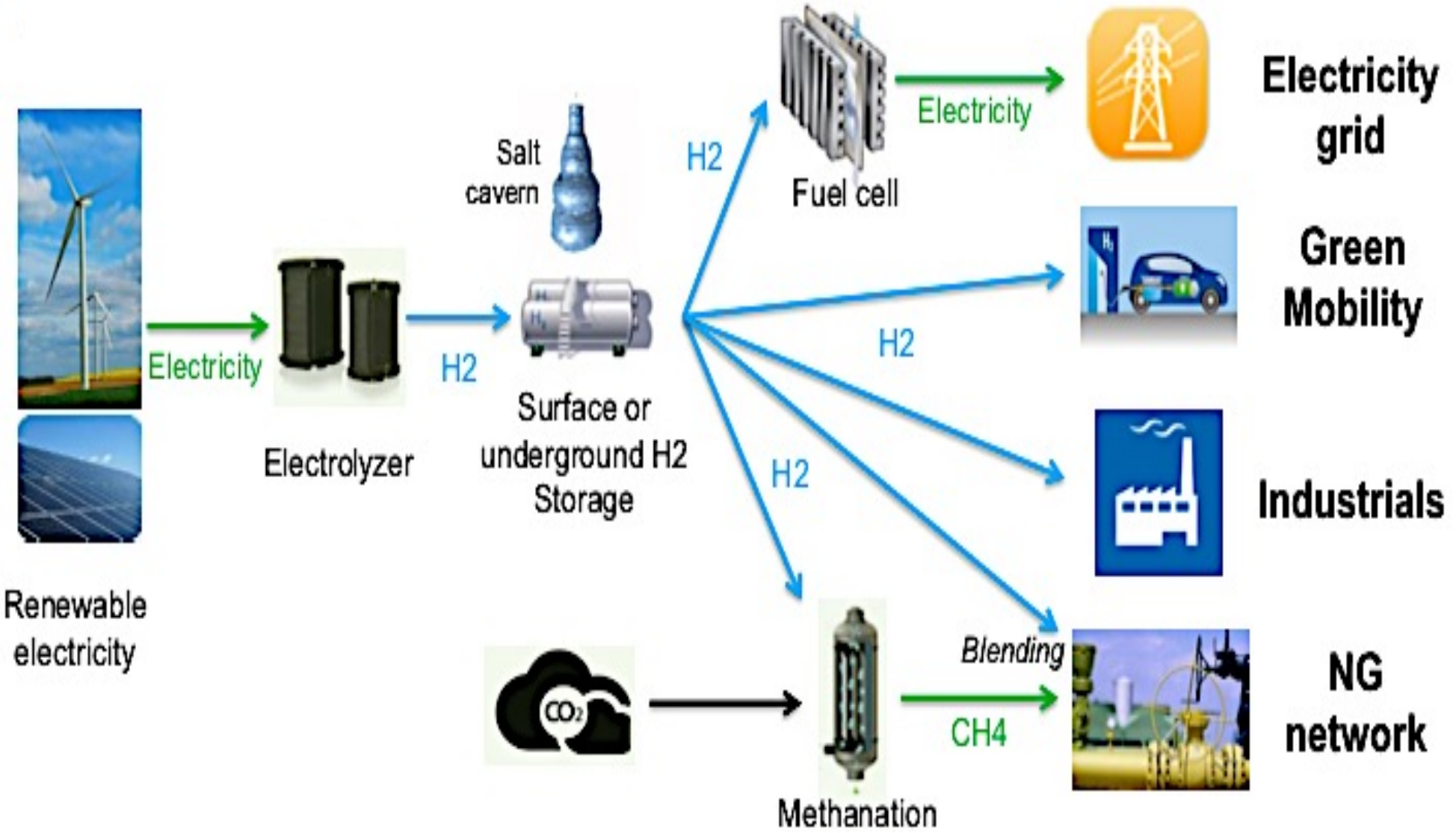


Development of wind and solar power *



* International Renewables Energy Agency

Hydrogen : an efficient vector in a decarbonized energy mix



End goal – the smart future

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The Super Smart Grid after 2050*
(may allow for 100% RES)

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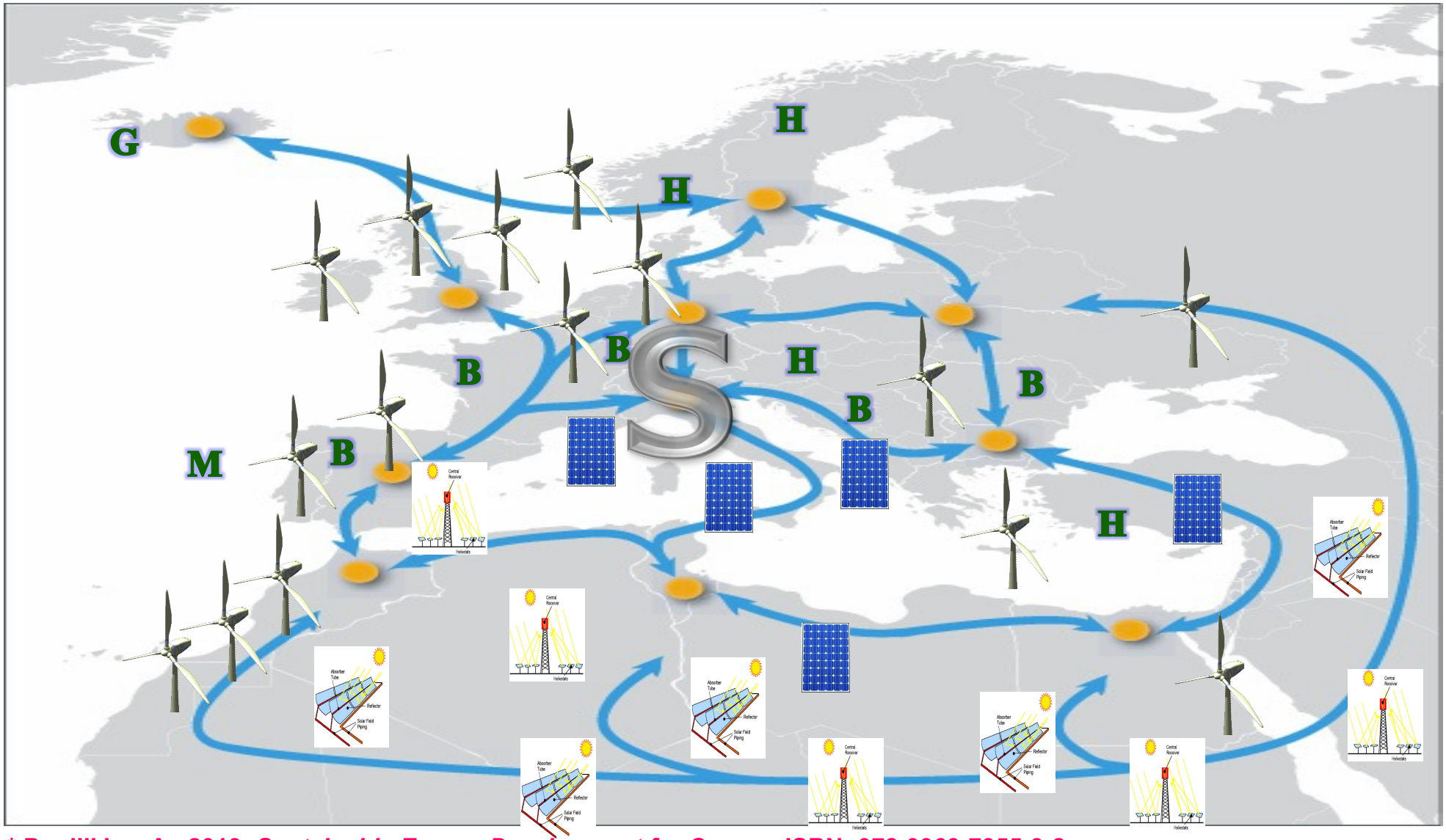
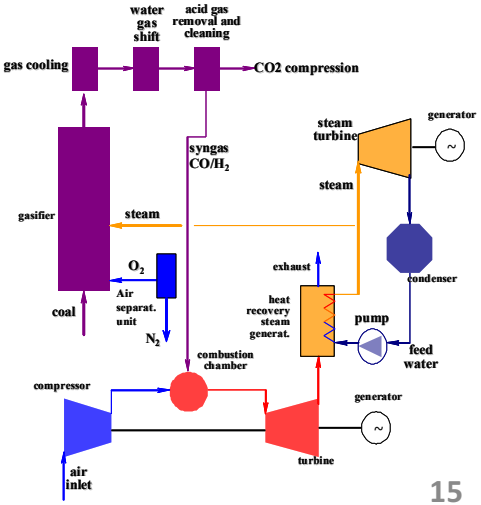


* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

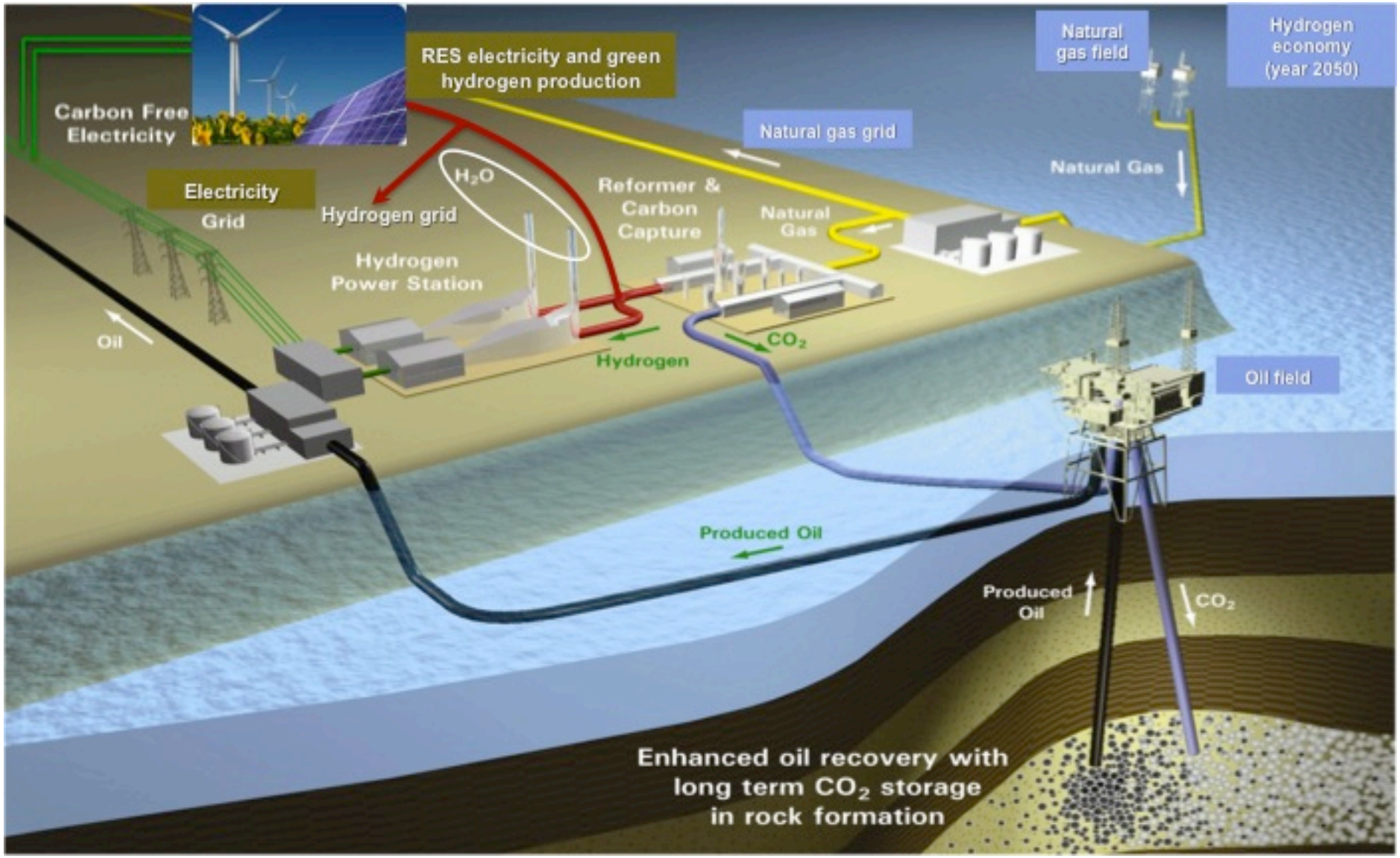
Long term EU energy strategy (2050)

- A vision of carbon free EU
- Main ingredients of future sustainable energy systems:
  - Large scale integration of renewable energy sources
  - Distributed generation
  - Carbon capture and storage
  - Smartgrids
  - Electric vehicles
  - Storage devices
  - Hydrogen



Development of new sustainable technologies and infrastructure

Towards hydrogen economy in 2050*



* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

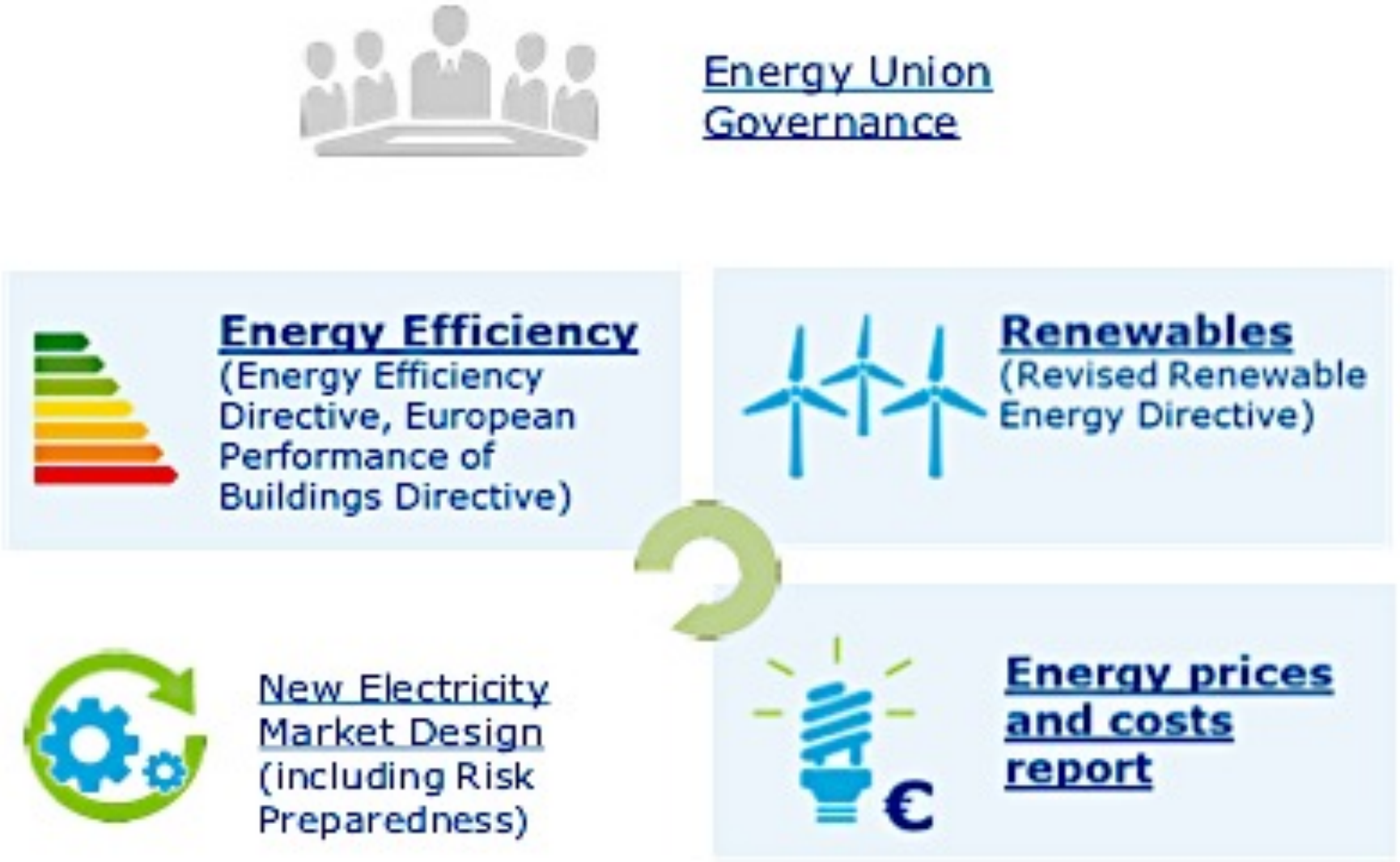
EU energy strategy

Energy Union

Energy Union

- a binding EU target of at least 40% less greenhouse gas emissions by 2030, compared to 1990
- a binding target of at least 27% of renewable energy use at EU level
- an energy efficiency increase of at least 27%
- the completion of the internal energy market by reaching an electricity interconnection target of 15%
- increase energy security (natural gas South Corridor)

Elements of Winter Package



- **A set of coherent measures**

Key aims of recent Winter Package

- To establish a common power market design across EU and to ensure the adequacy power systems
- To promote the better integration of electricity produced from RES into the market
- To advance energy efficiency, energy cleanliness and energy performance
- To implement rules on the governance of the Energy Union

Legislative proposals of Winter Package

- Proposals for a recast of the Internal Electricity Market Directive and Regulation
- Proposal for a recast of the Renewable Energy Directive
- Proposal for a recast of the ACER Regulation
- Proposal for a revised Energy Efficiency Directive
- Proposal for a Regulation on the Governance of the Energy Union
- …

Additional documents of Winter Package

- Large number of Communications
- Large number of Commission Regulations
- Large number of memos, factsheets, reports, impact assessments
- Other documents covering various topics, ranging from capacity mechanisms to eco-design, bioenergy sustainability, energy prices and costs, energy funding, innovation and transport

Electricity markets in Winter Package

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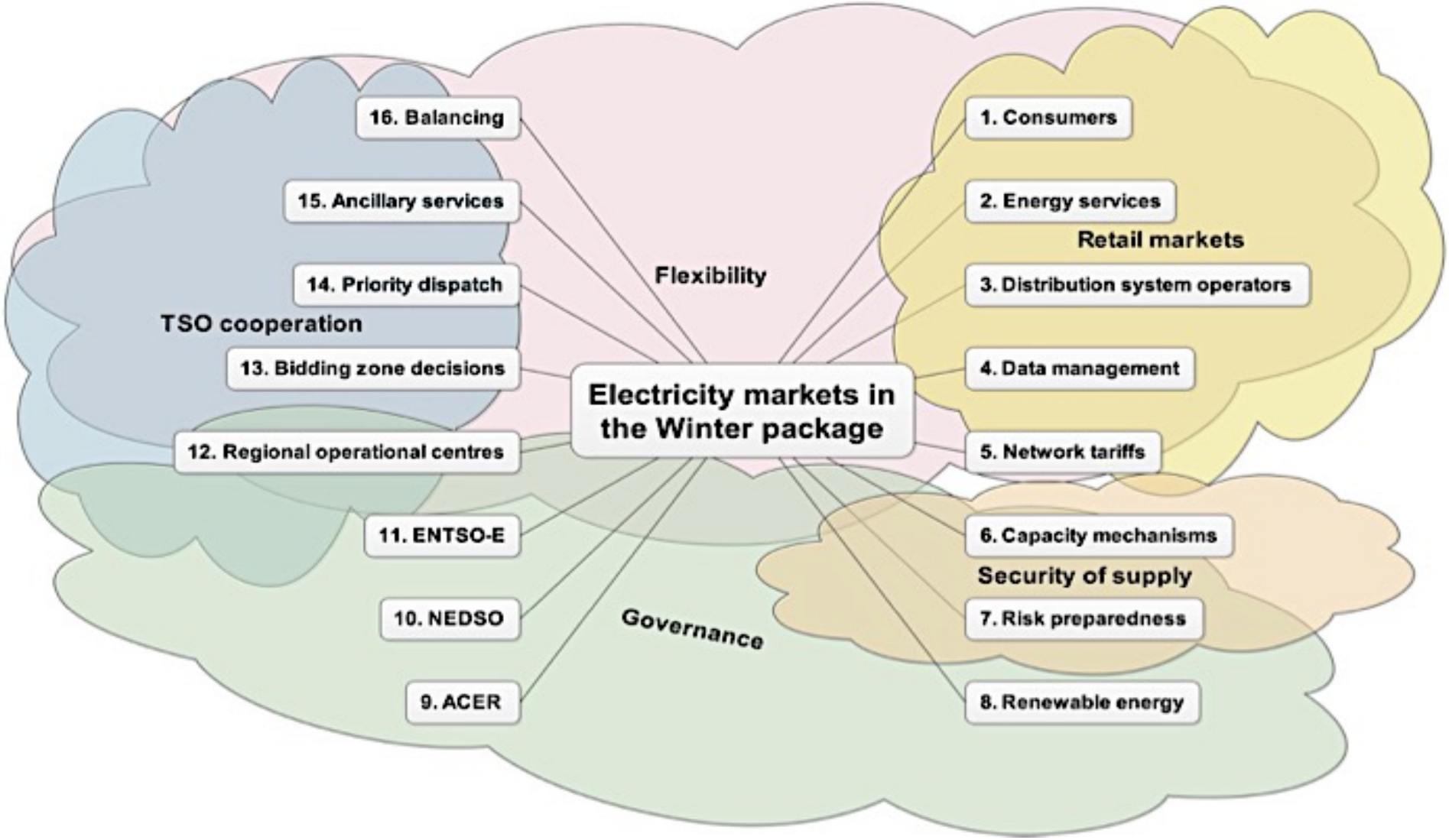

Connecting electricity markets

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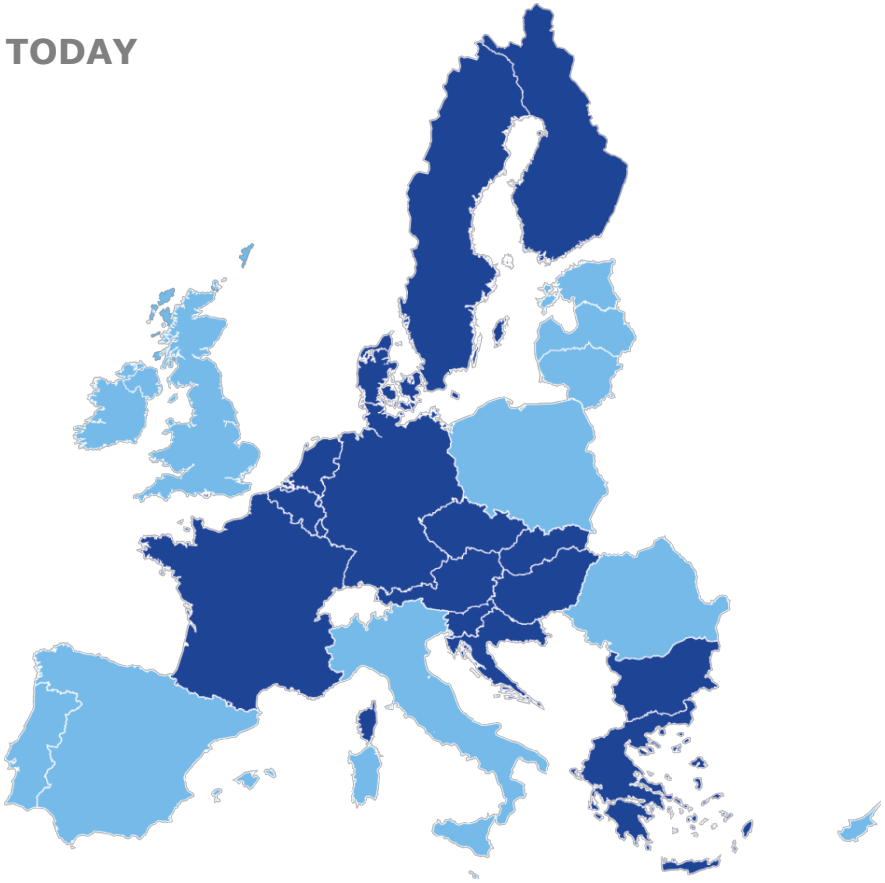
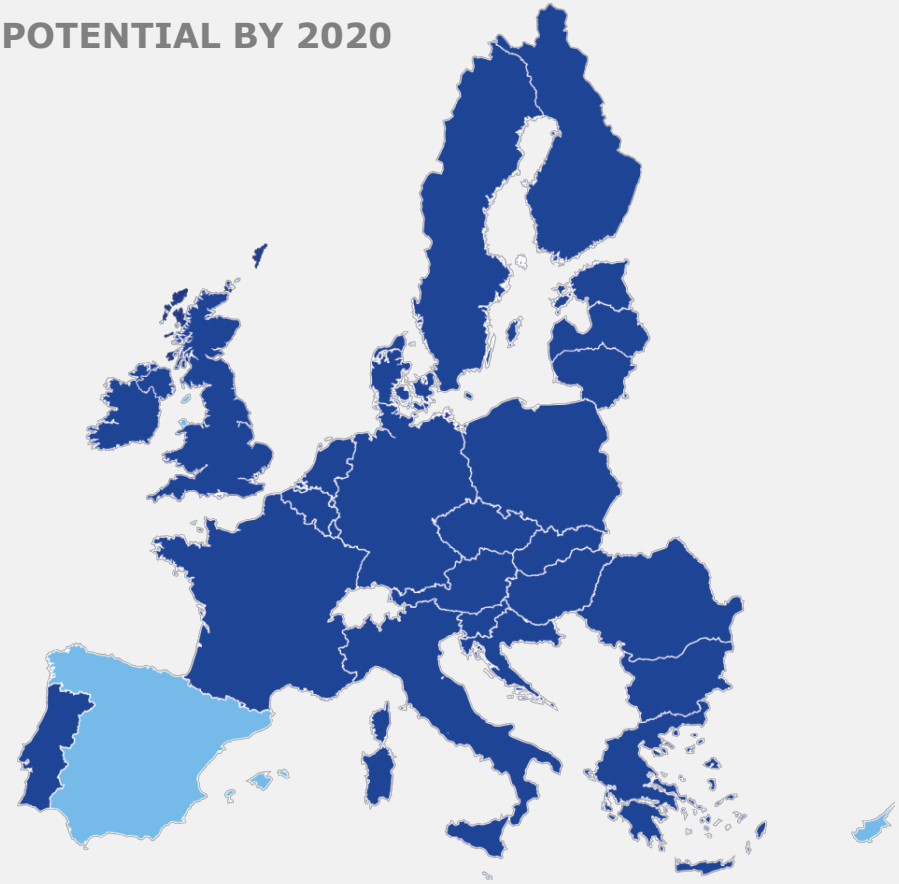
TODAY



Countries meeting the 10% **interconnection** target

Countries not meeting the 10% **interconnection** target

POTENTIAL BY 2020



Efforts need to be stepped up for those below the 10% target by 2020, mainly Spain and Cyprus, and in view of achieving the 15% target by 2030.

Challenges in electricity markets

Electricity market complexities*

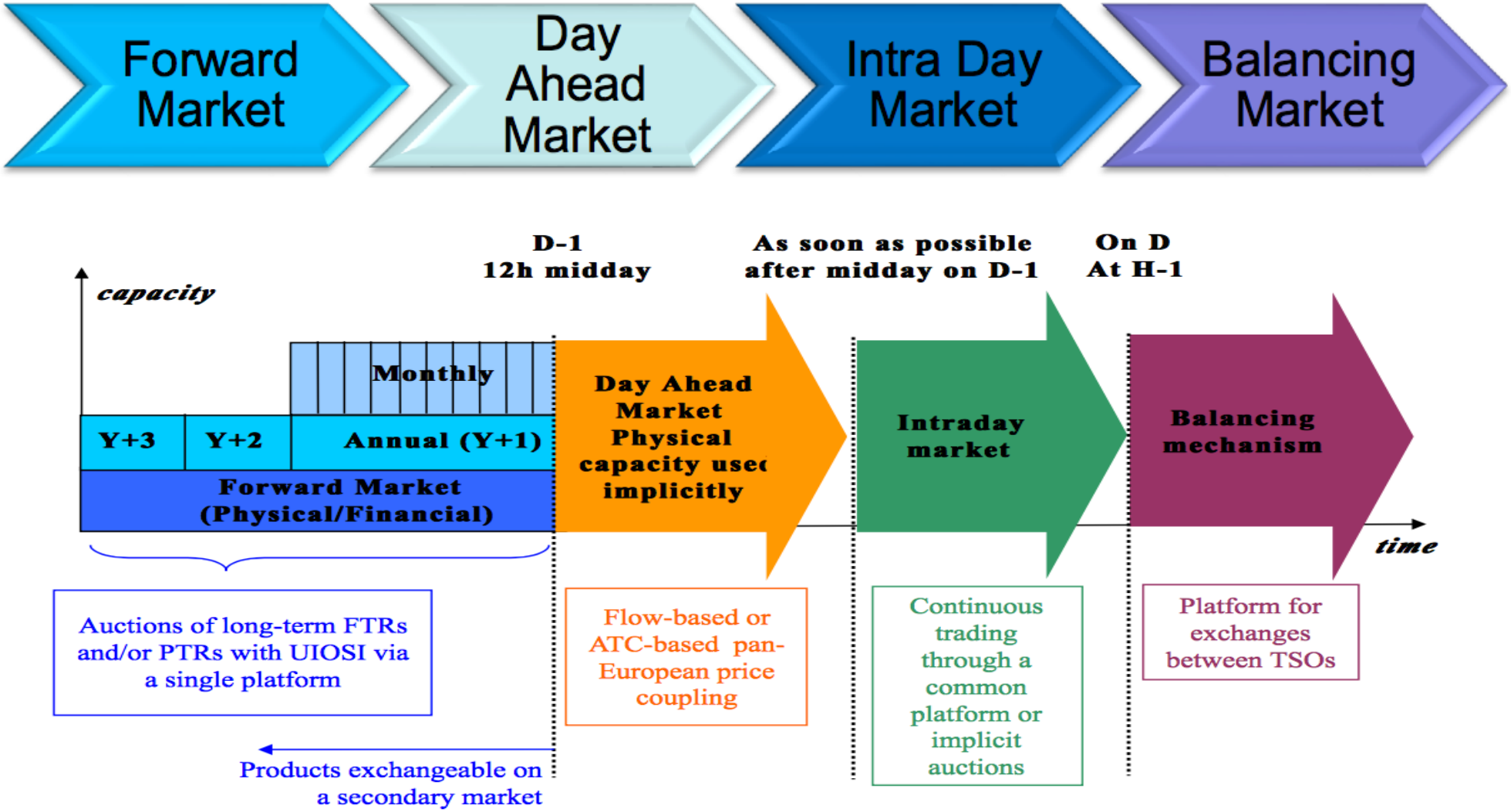
- **Energy market**
- **Power market (flow of energy)**
- **Ancillary services market**
  - **Reserve (spinning, cold, primary, etc.)**
  - **Voltage regulation**
  - **Frequency regulation, etc.**

*** Poullikkas A., 2016, *Fundamentals of Energy Regulation*, ISBN: 978-9963-7355-8-7**

Electricity markets current issues

- **Protection of the environment**
  - **Reduce primary emissions**
  - **Reduce greenhouse gas emissions**
  - **Develop alternative technologies**
- **Electricity markets open to competition**
  - **Increase in technologies efficiency**
  - **Reduce energy generation costs**

EU electricity market target model



The fundamental requirement of electrical power supply

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Get me what I want,

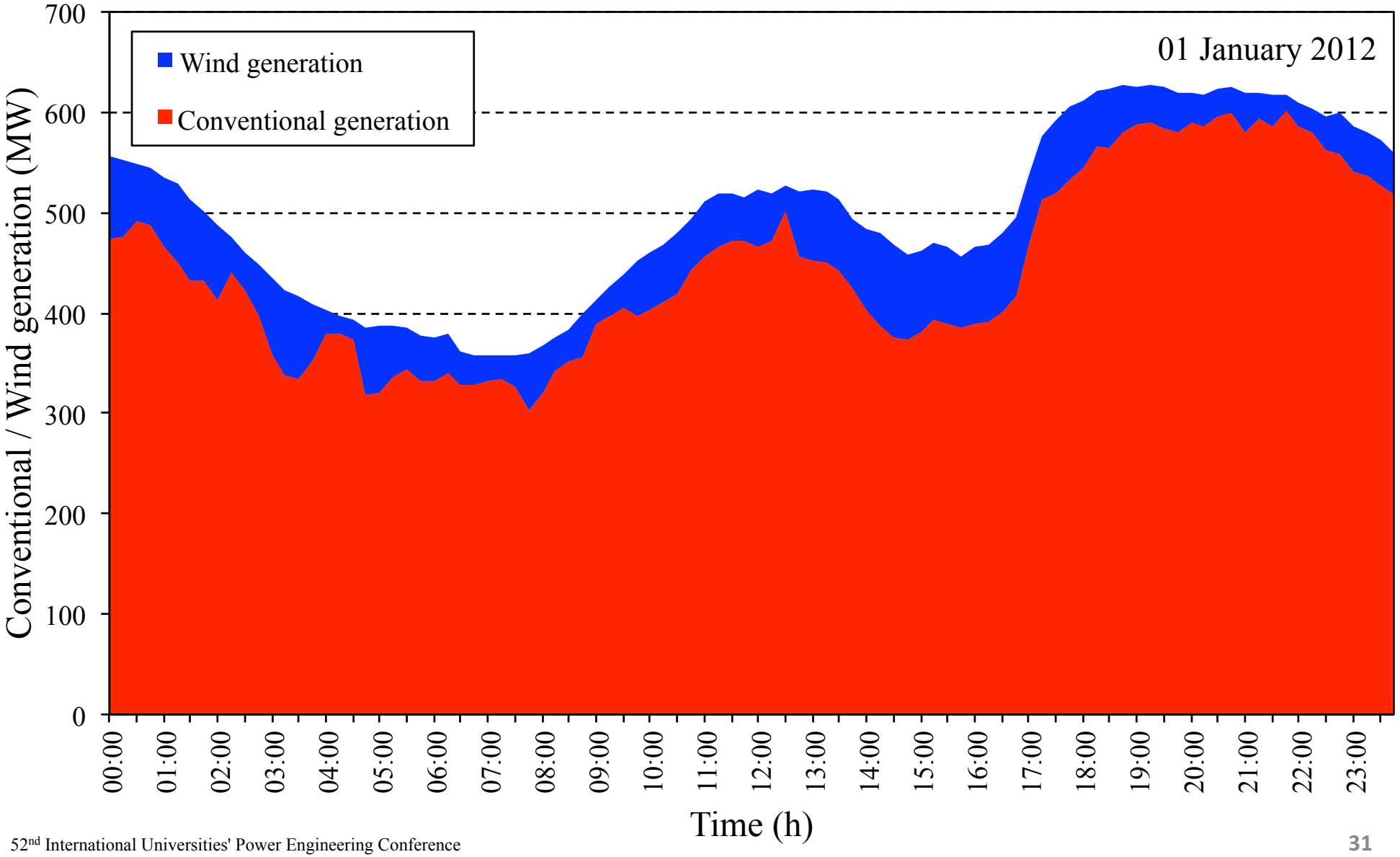
when I want it !!!

"Geeze. When the power's out there's nothing to play with around here."

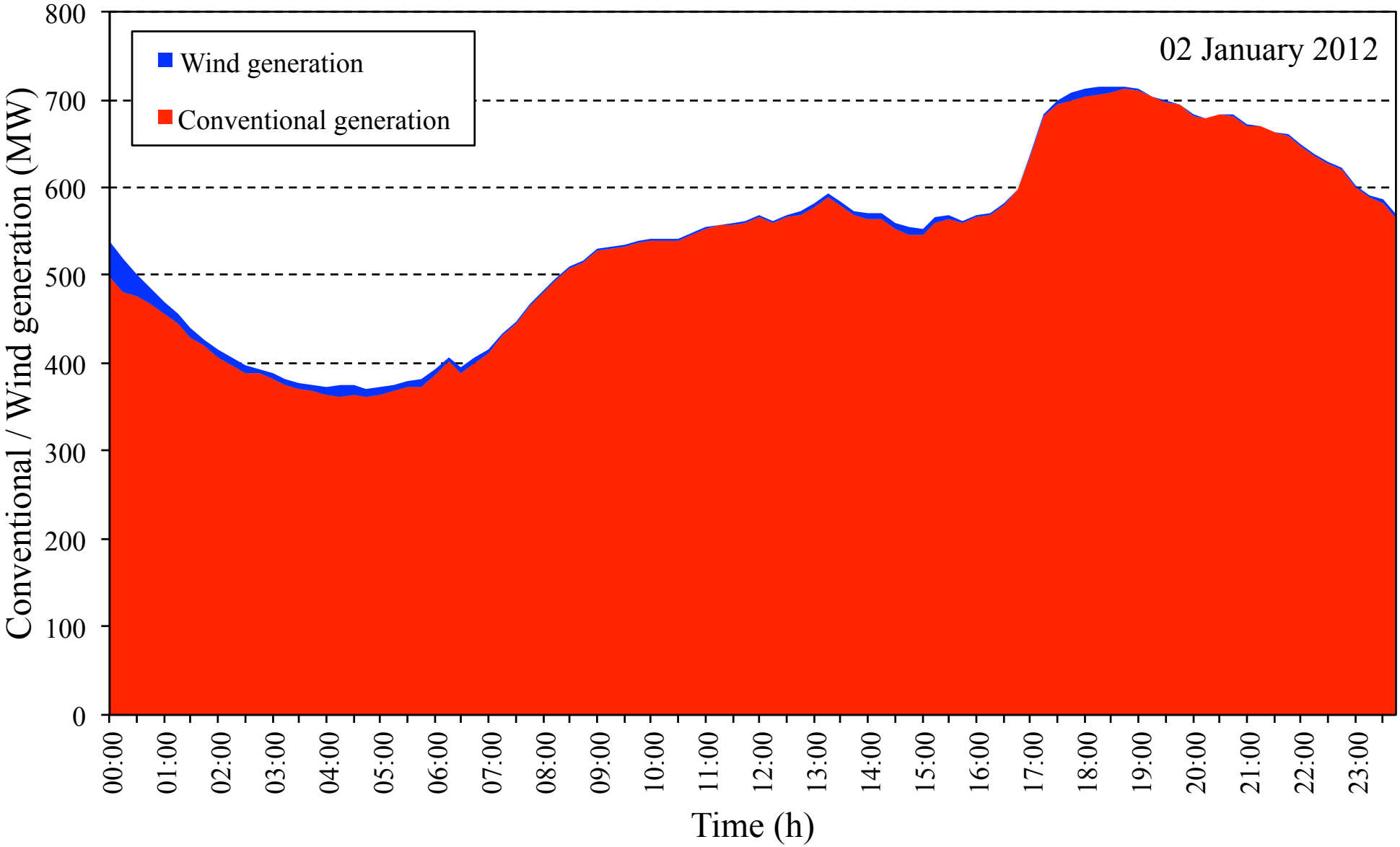
Intermittent energy source

- Any source of energy that is not continuously available
- May be quite predictable
- Cannot be dispatched to meet the demand of a power system
- For dispatching need storage

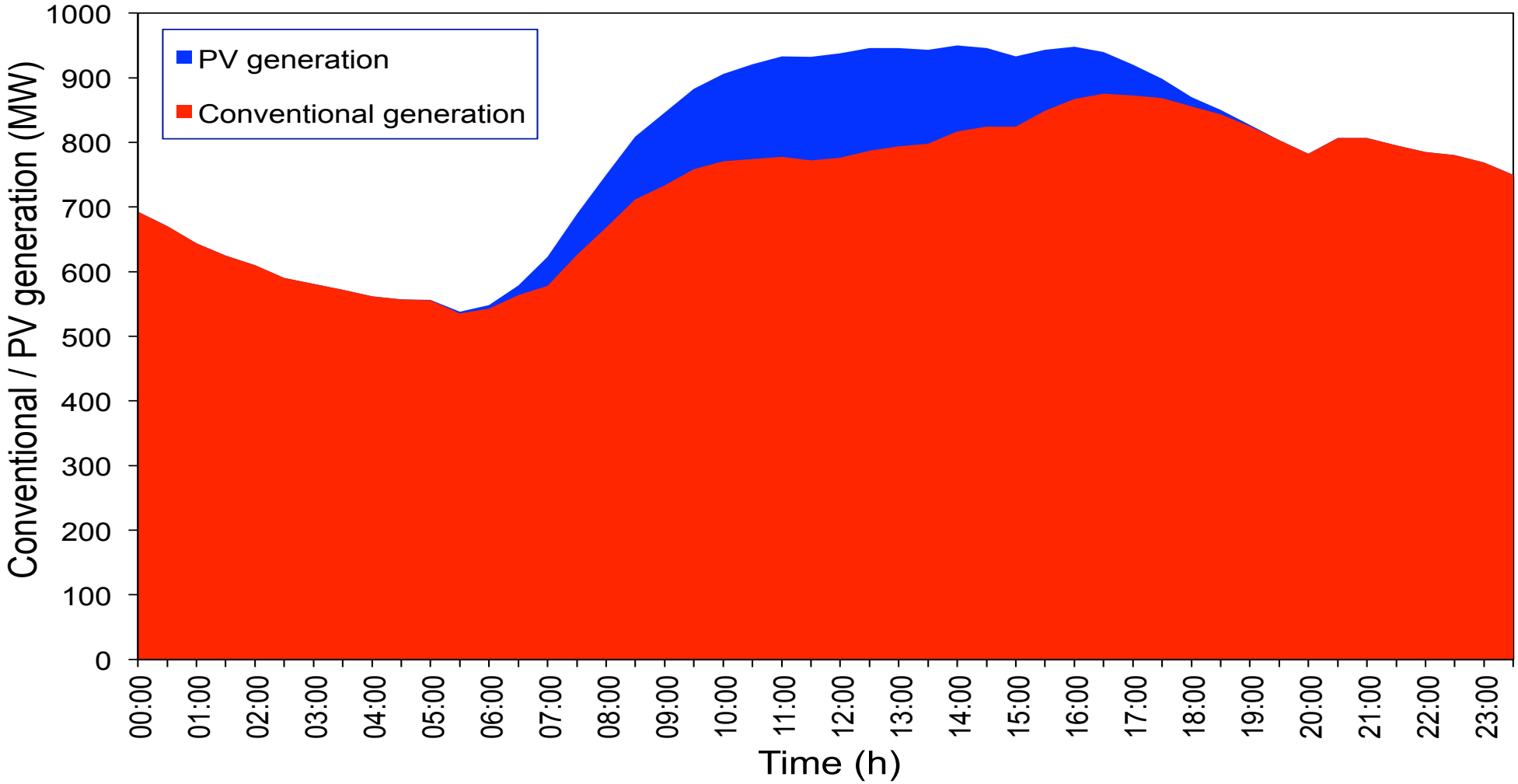
Wind generation (in Cyprus)



Wind generation (in Cyprus)

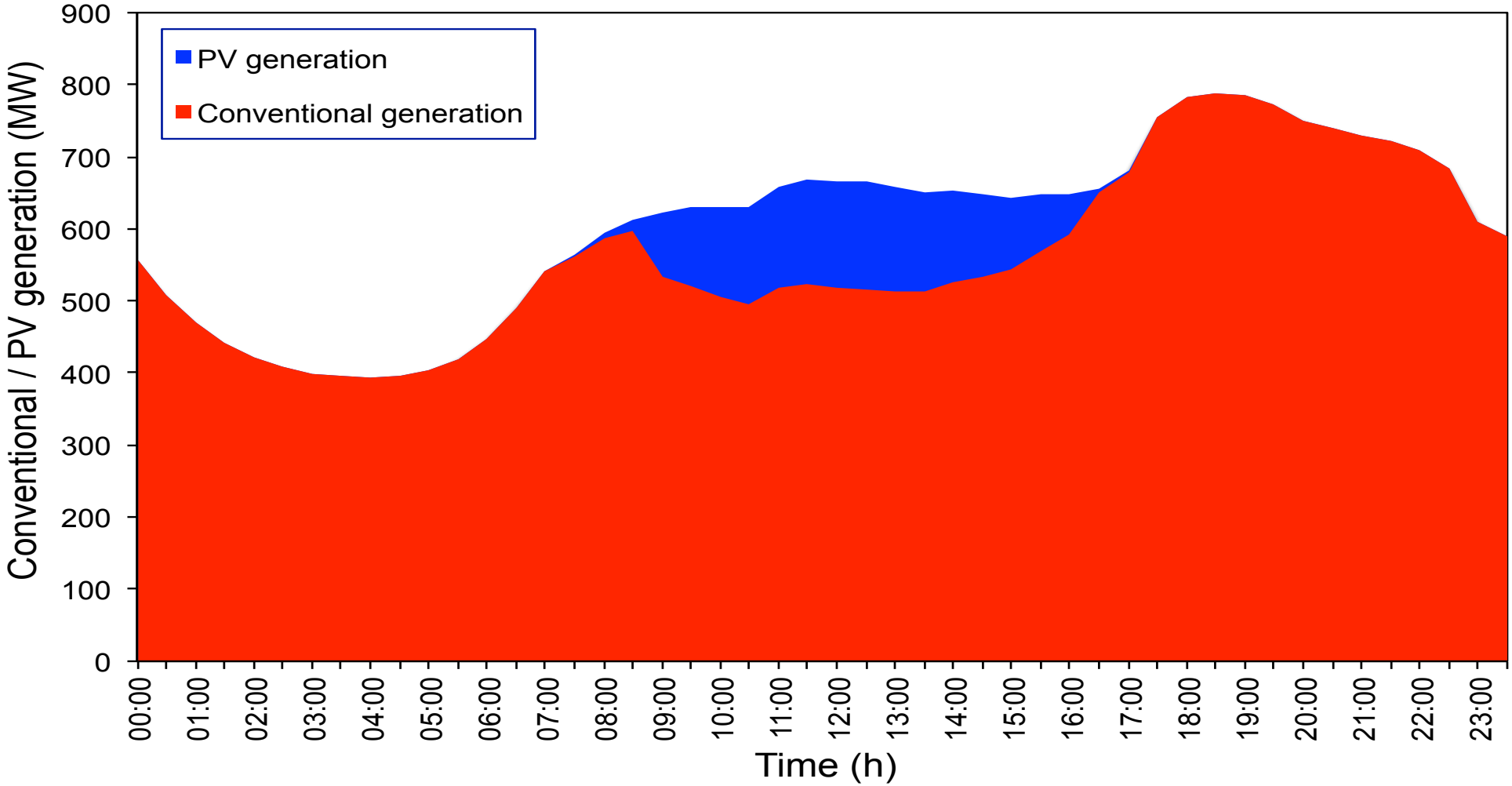


Example of PV generation during Summer time*



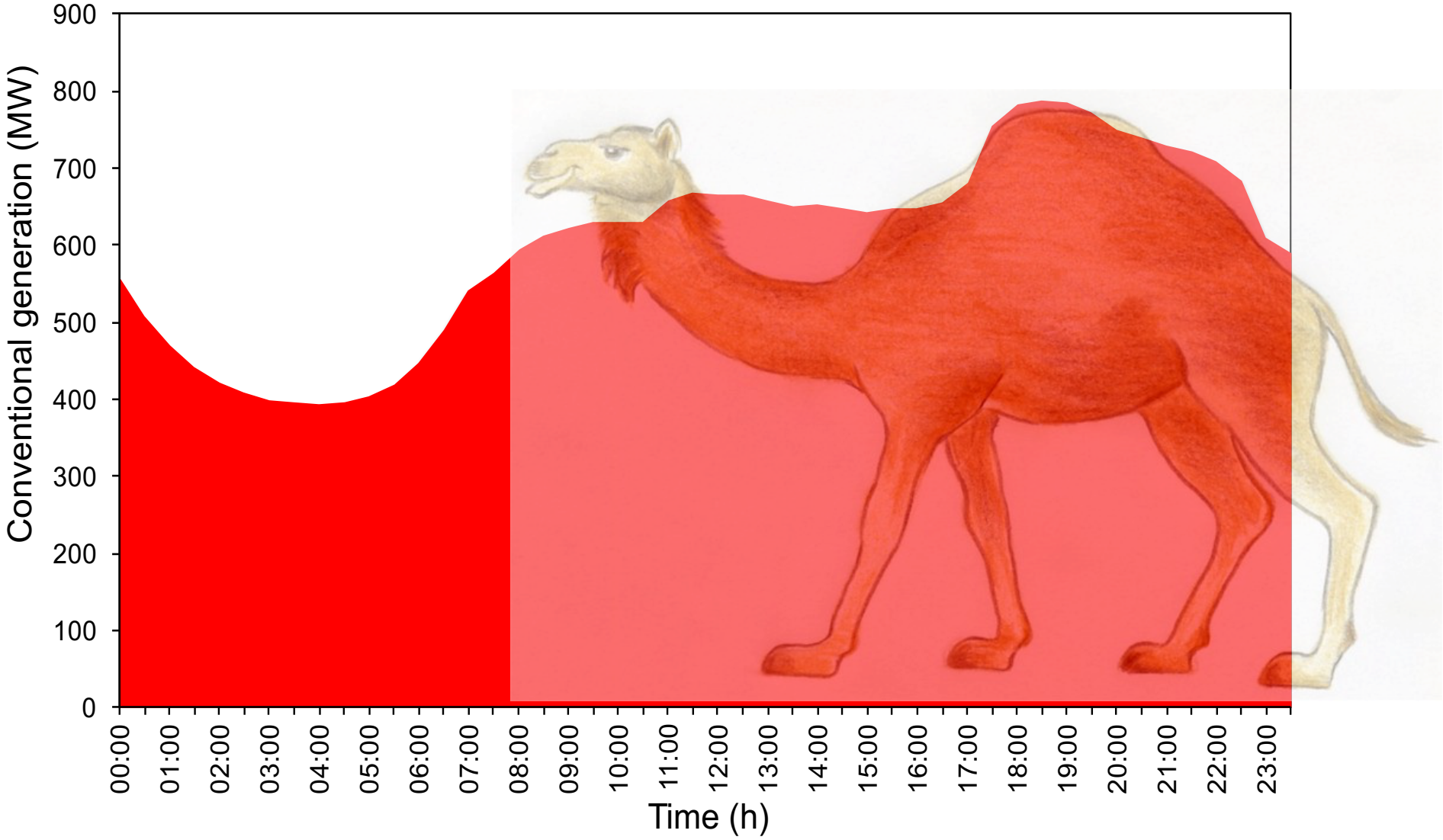
* Poullikkas A., 2009, "Parametric cost-benefit analysis for the installation of photovoltaic parks in the island of Cyprus", *Energy Policy*

Example of PV generation during Winter time*



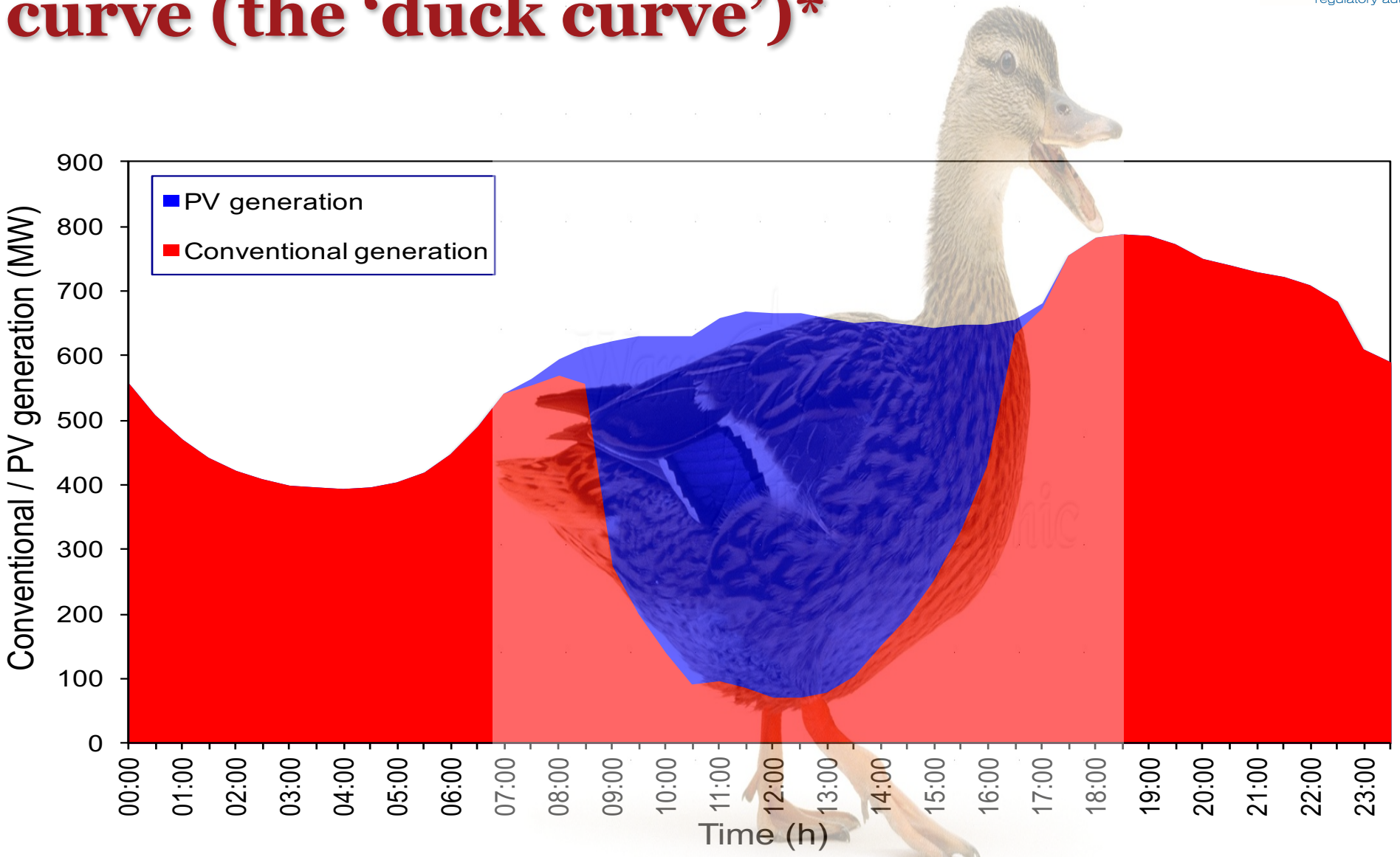
* Poullikkas A., 2009, "Parametric cost-benefit analysis for the installation of photovoltaic parks in the island of Cyprus", *Energy Policy*

Daily load curve (the 'camel curve')*



* Poullikkas A., 2016, "From the 'camel curve' to the 'duck curve' on electric systems with increasing solar power", *Accountancy*

Effect of PV generation on load curve (the 'duck curve')*



* Poullikkas A., 2016, "From the 'camel curve' to the 'duck curve' on electric systems with increasing solar power", *Accountancy*

Storage is the missing link

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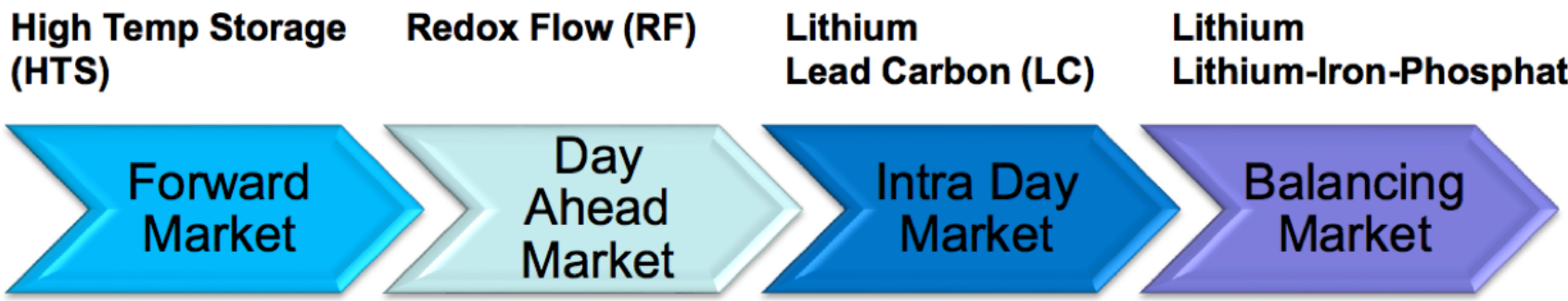

Advantage HTS:
- Very large storage
- 80% DOD
- Electricity, heat and AC generation
- Lowest Cost
- Minimum space
- 50 years LT

Disadvantage:
No fast response
E-Efficiency 40%
H-Efficiency 40%

Size: 3 - 50MWh

Advantage RF:
- Large storage
- 50-70% DOD
- High Power
- Lower cost
- No memory effect
- 15 to 20 years LT

Disadvantage:
Low Energy Density
No fast response
Efficiency < 80%

Size: 1 - 10MWh

Advantage LC:
- Large storage
- 50-70% DOD
- High power
- Lower cost
- Efficiency > 85%
- 10-15 years LT

Disadvantage:
Medium Energy Density
High Weight
Efficiency 80%

Size: 0,1 - 10MWh

Advantage Lithium:
- Fast response
- Quick Service
- 80% DOD
- High Power
- Efficiency > 95%
- No Memory effect
- Highest energy density
- 15 to 20 years LT

Disadvantage:
High Cost

Size: 0,1 - 10MWh

Challenges in natural gas markets

Pathways to low emissions

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Why gas is perfectly suited to play a pivotal role in the energy mix of the future

1. Gas is clean

In the UK, gas produces less than half as much CO2 per KWh than electricity

2. Gas is scalable

Gas is sufficiently abundant to continue to meet a large share of European and global energy demand

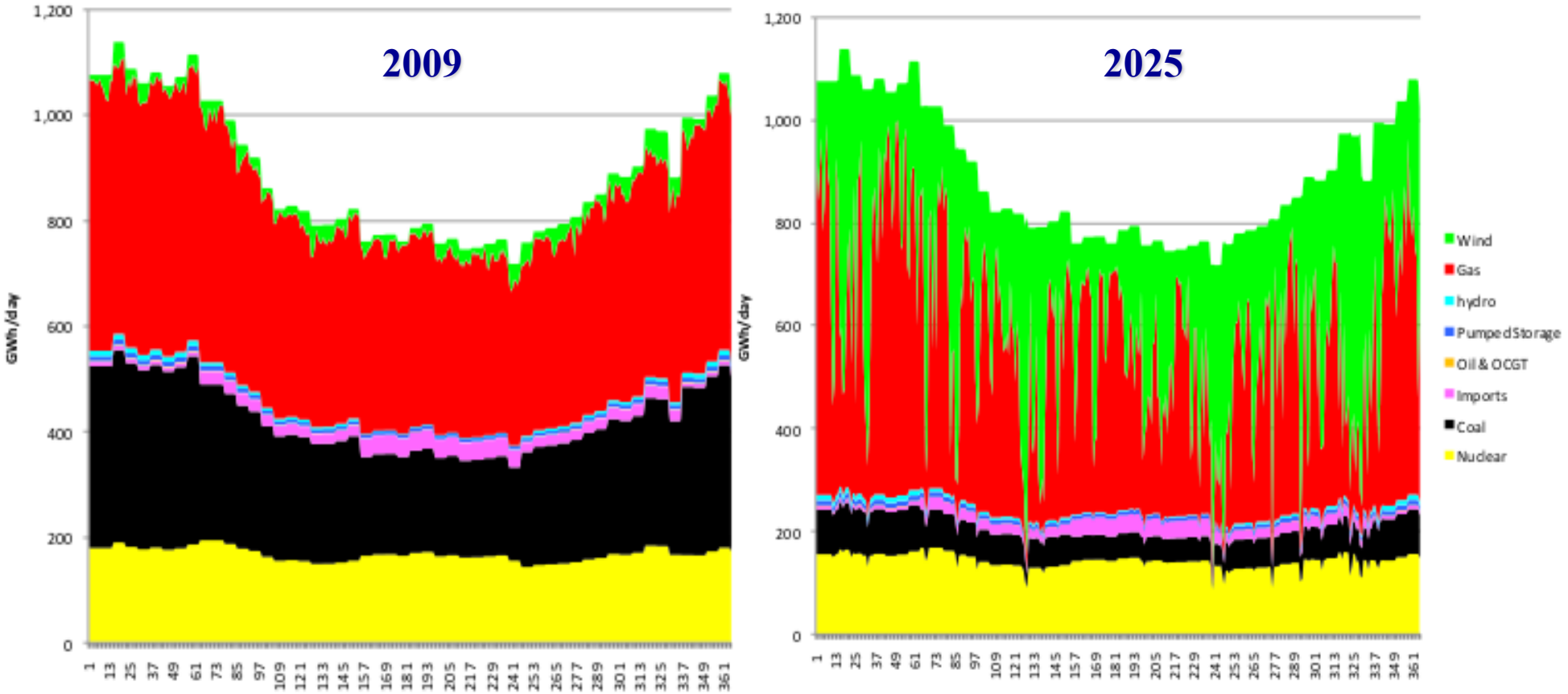
3. Gas is flexible

Gas can quickly meet short term fluctuations in power demand where other power sources can not

3. Gas technology is improving

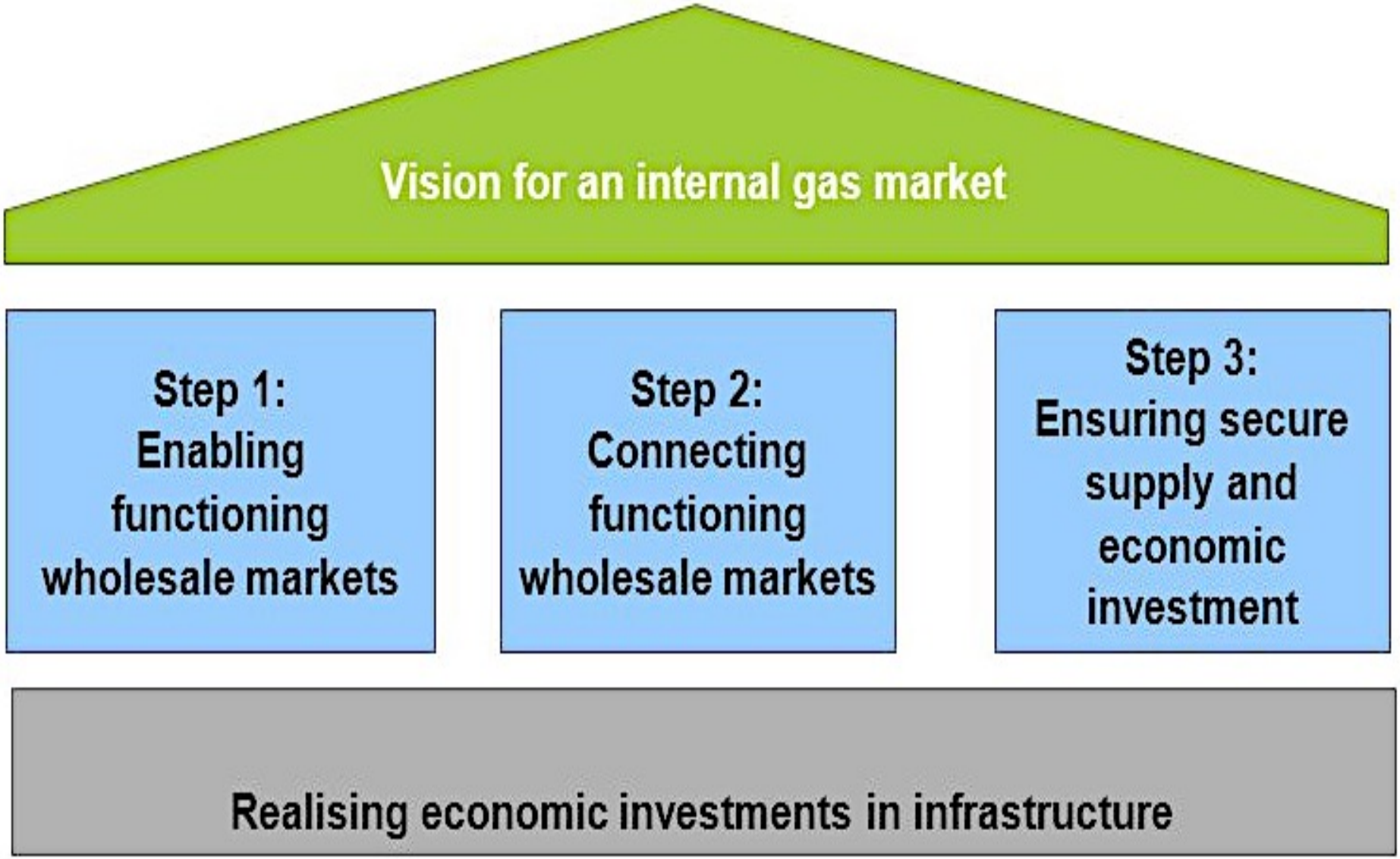
Gas technological improvements are driving energy efficiency gains

Gas is a pillar of renewable energy (power production in UK*)



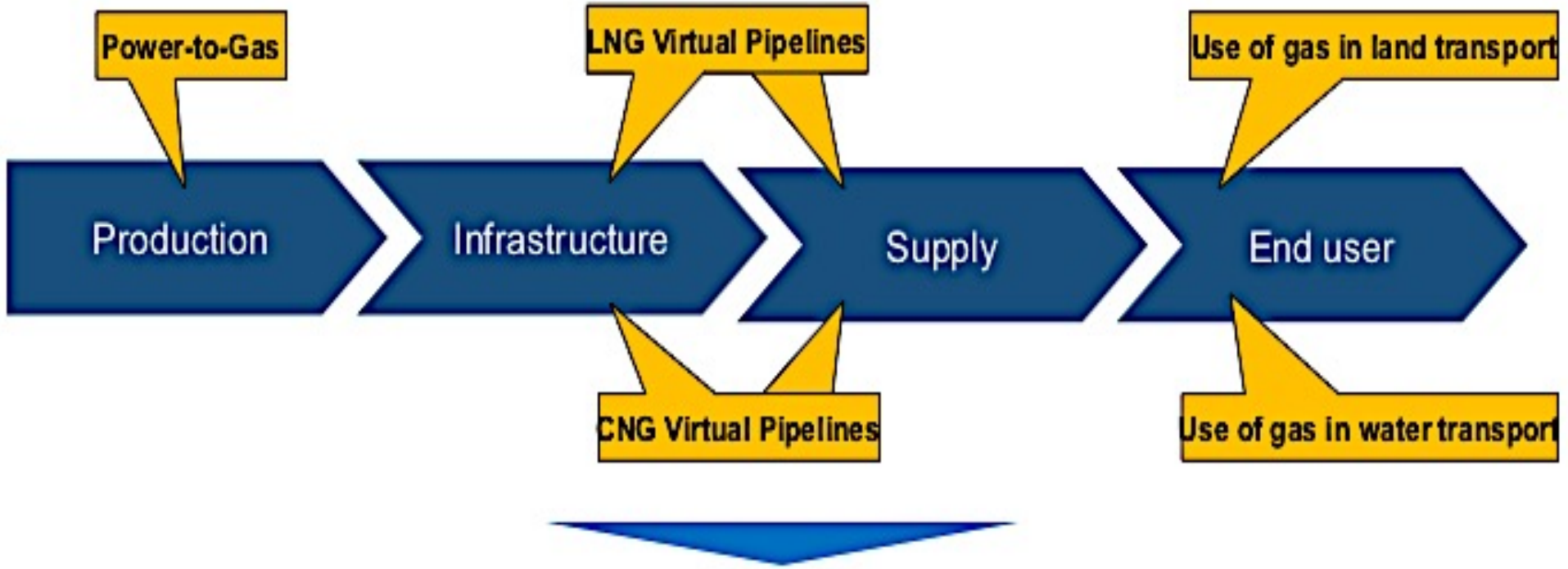
* H.V. Rogers, 2011, *The Impact of Import Dependence and Wind Generation on UK Gas Demand and Security of Supply to 2025*, The Oxford Institute For Energy Studies

EU gas market target model



EU gas market target model

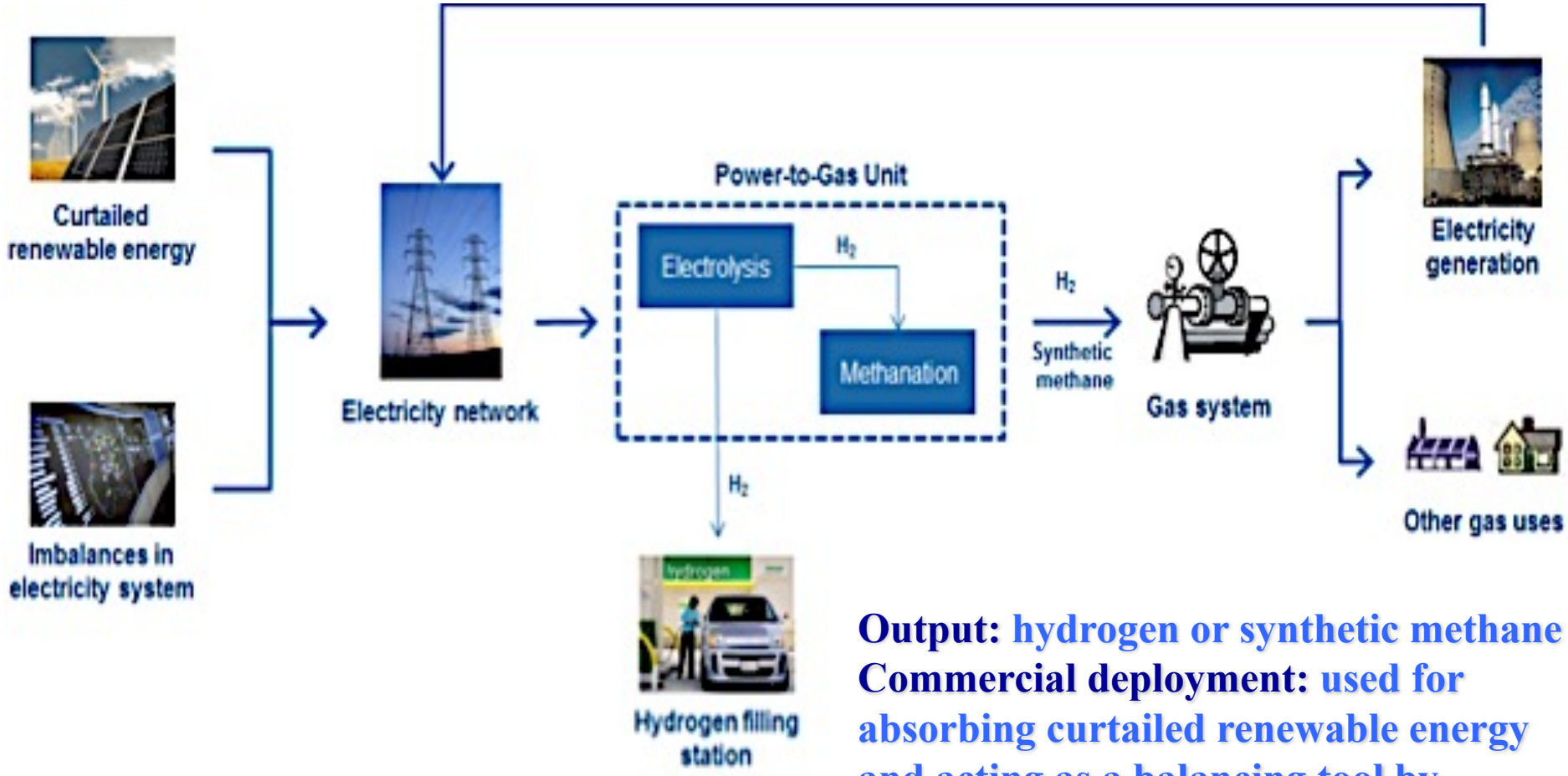
- **The new uses for gas have different roles across the gas supply chain**



Virtual pipelines are closely related to the development of the use of gas in the transport sector, particularly in the case of LNG

Power-to-Gas (P2G)

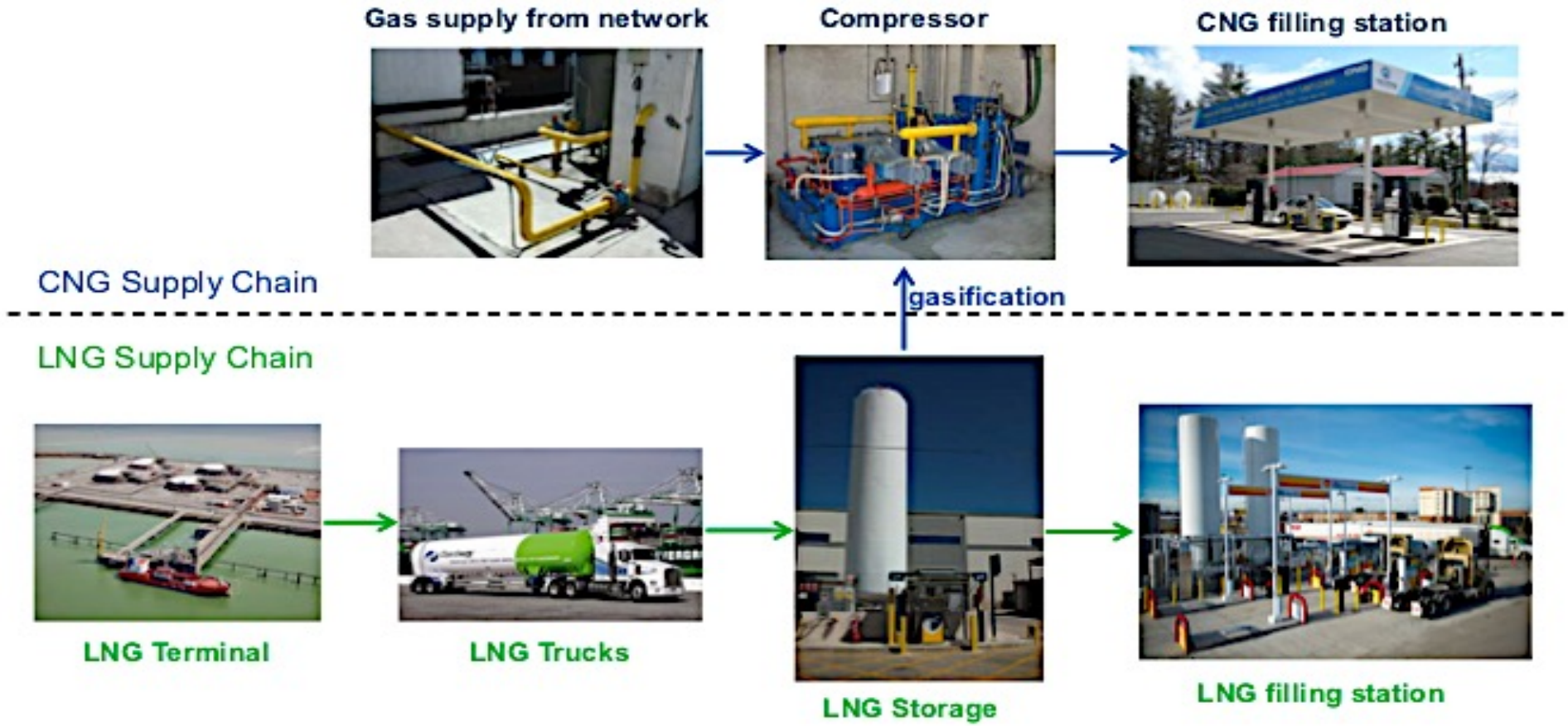
- energy storage technology linking the electricity and gas infrastructure



Output: hydrogen or synthetic methane
Commercial deployment: used for absorbing curtailed renewable energy and acting as a balancing tool by electricity TSOs

Virtual pipelines

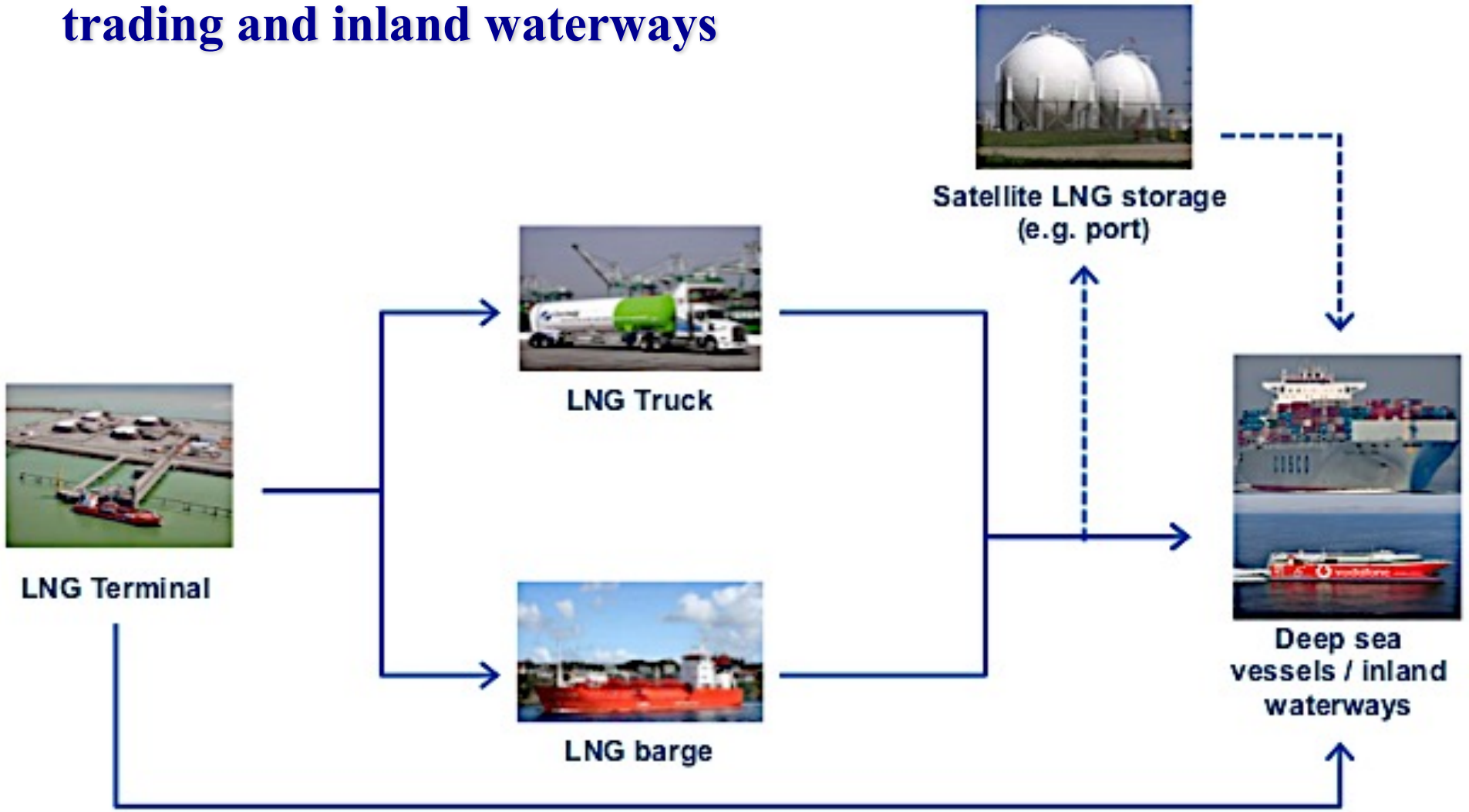
- **LNG stations are supplied through trucks**
- **CNG stations are supplied either from the network or with LNG (L- CNG)**



Virtual pipeline: the supply chain transporting natural gas to final consumers in the form of CNG or LNG, using road and sea means of transportation, such as trucks, vessels and rail

LNG bunkering

- **Supply chain is the same for applications in deep-sea trading and inland waterways**



LNG bunkering options: Ship-to-Ship (STS), Truck-to-Ship (TTS), Terminal-to-Ship (TPS)

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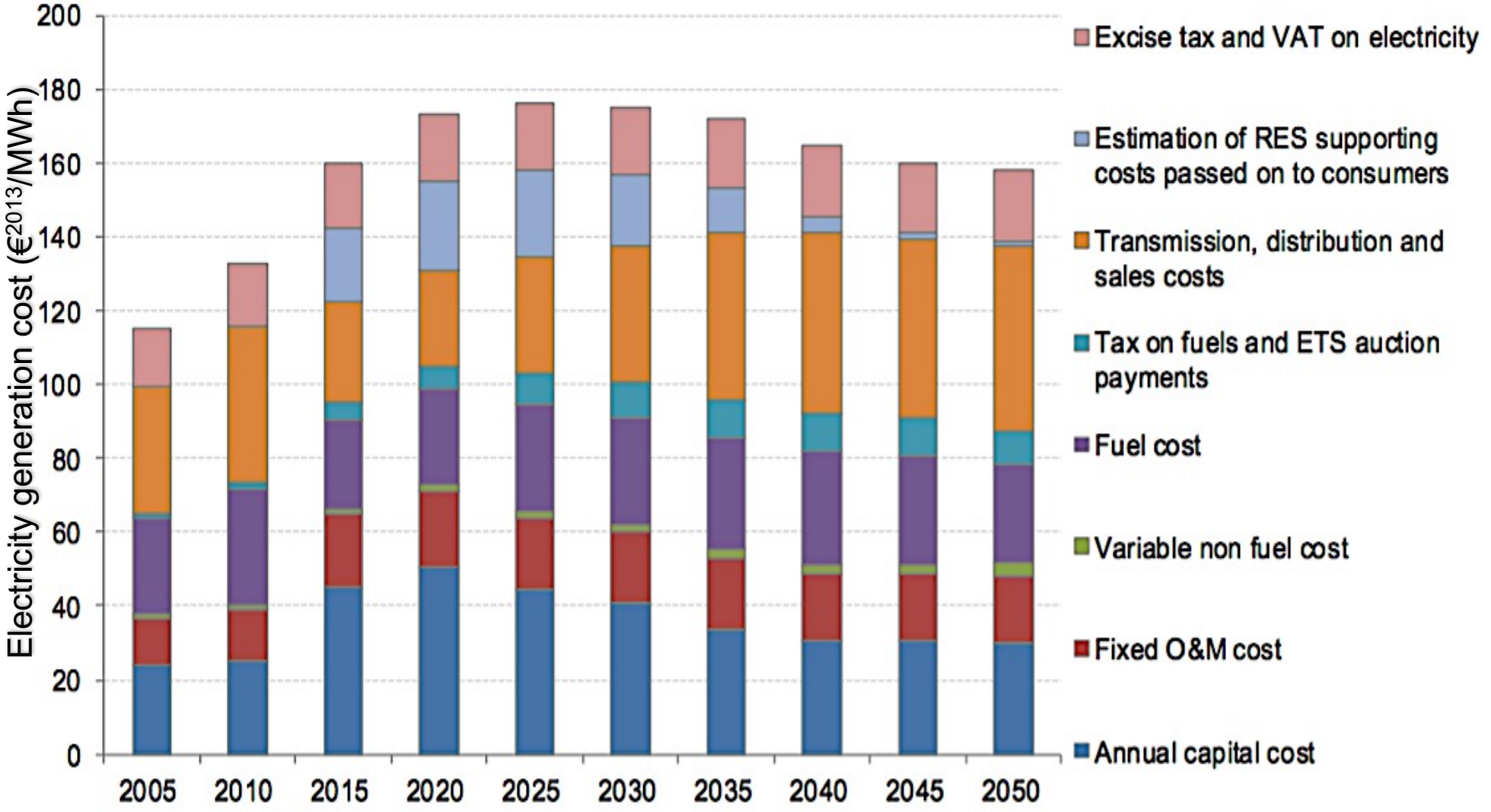
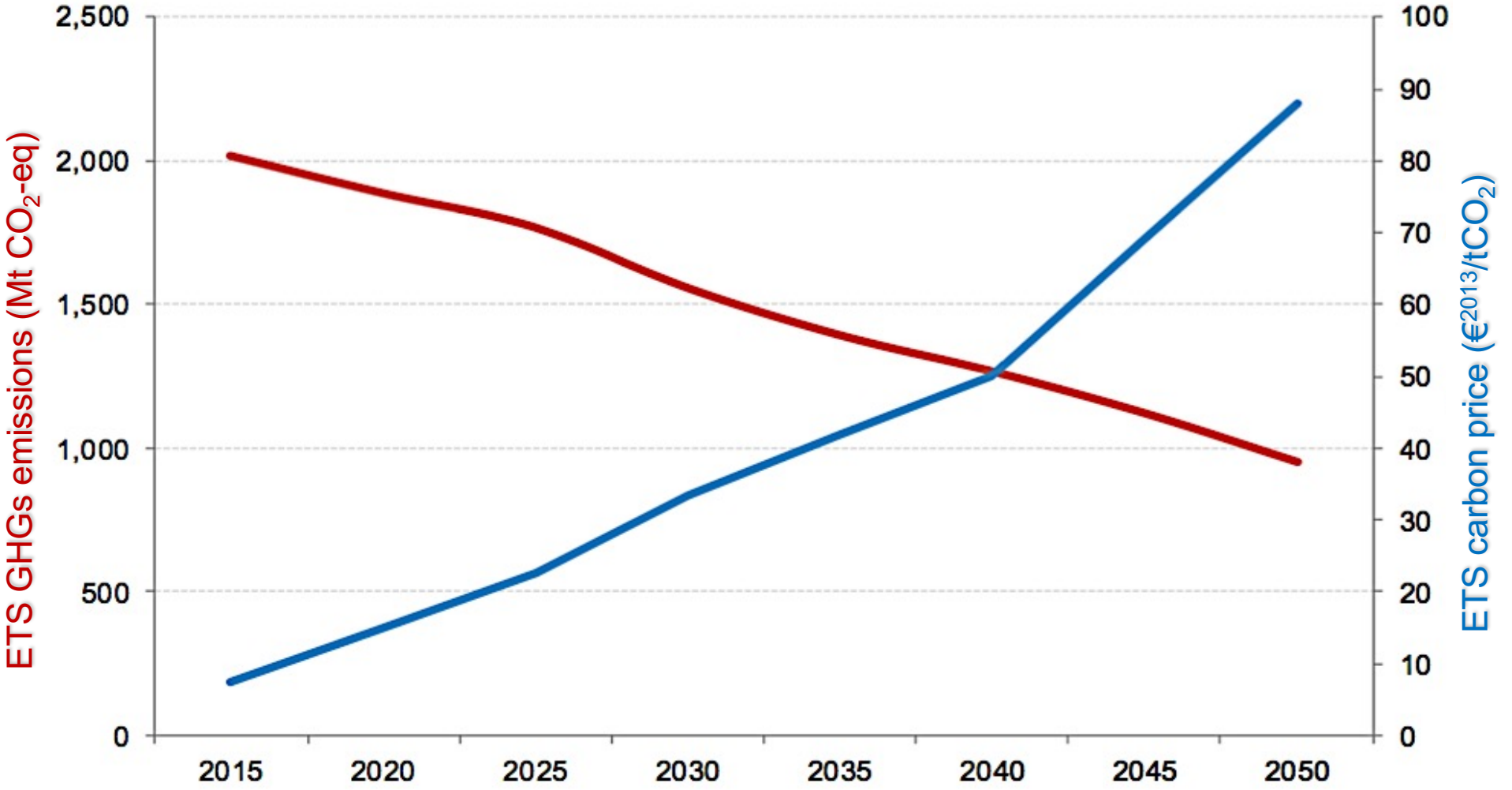
Energy cost

EU reference scenario 2016



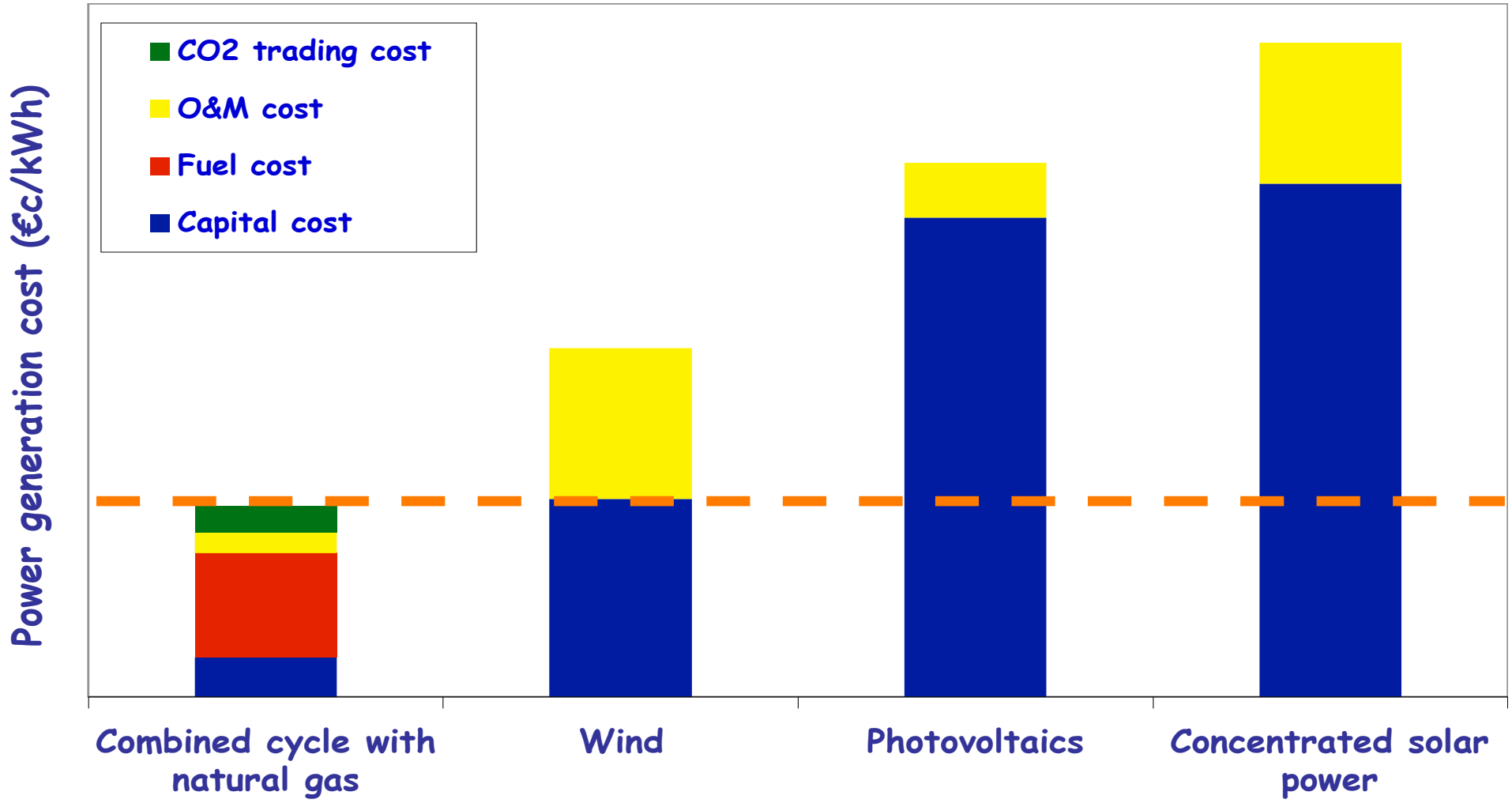
Source: PRIMES

EU reference scenario 2016



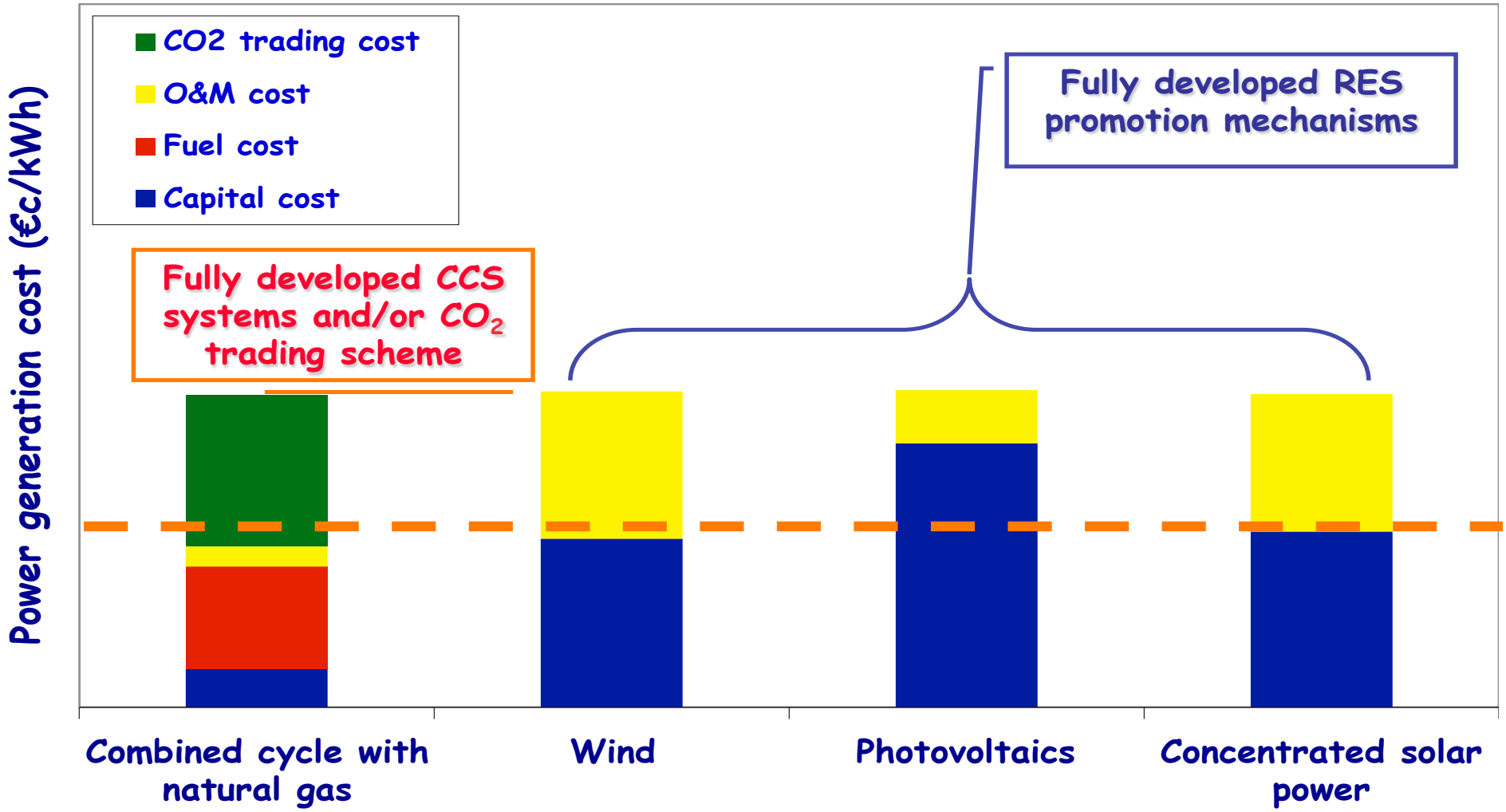
Source: PRIMES, GAINS

Power generation cost (year 2010)*



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

Power generation cost (year 2020-30)*



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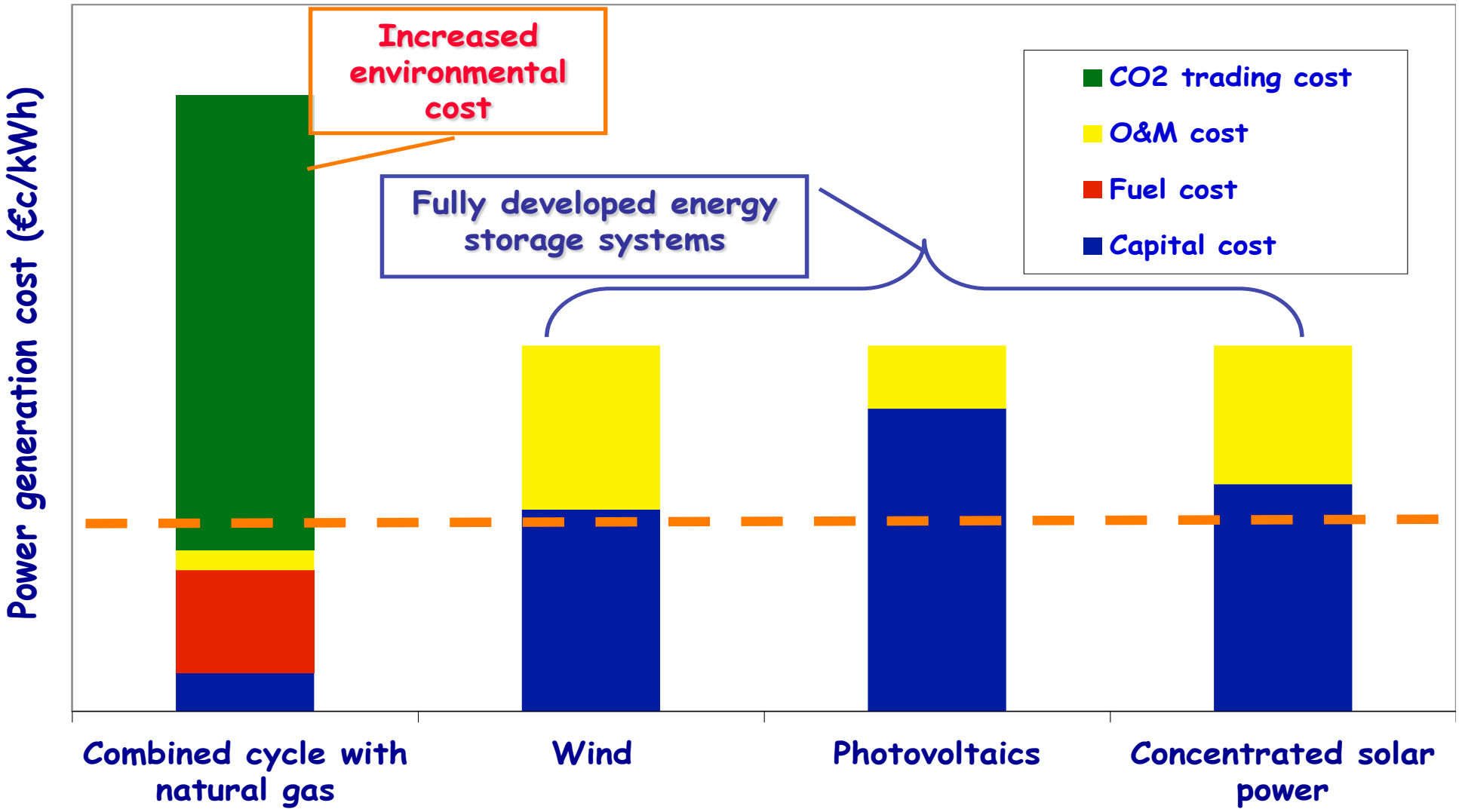
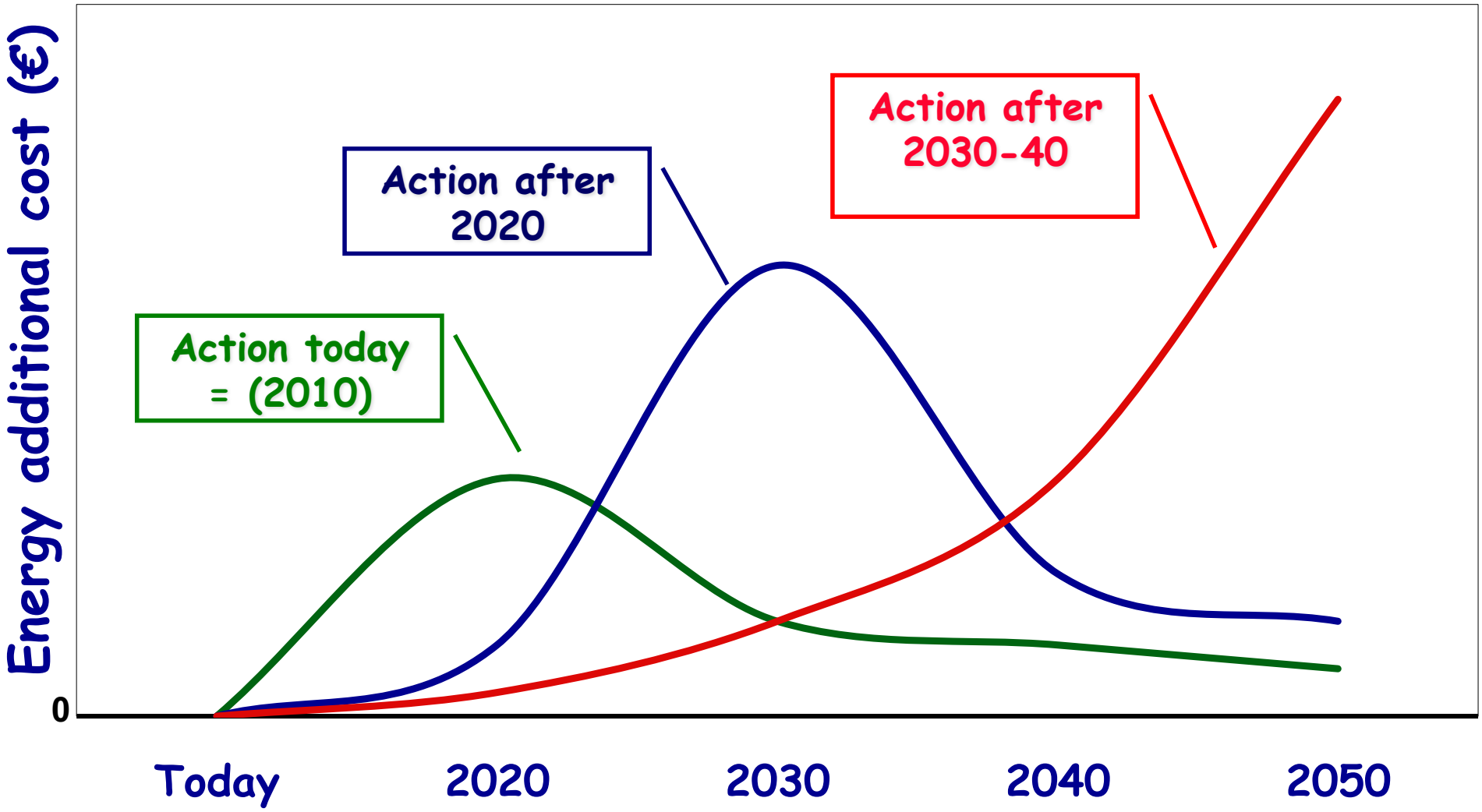
Power generation cost (year 2040-50)*



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

Future energy cost* (for EU only)



* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*