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EU energy strategies towards sustainable energy systems

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- Challenges in electricity markets
- Energy cost

The need for sustainable technologies

Night lights in 2000

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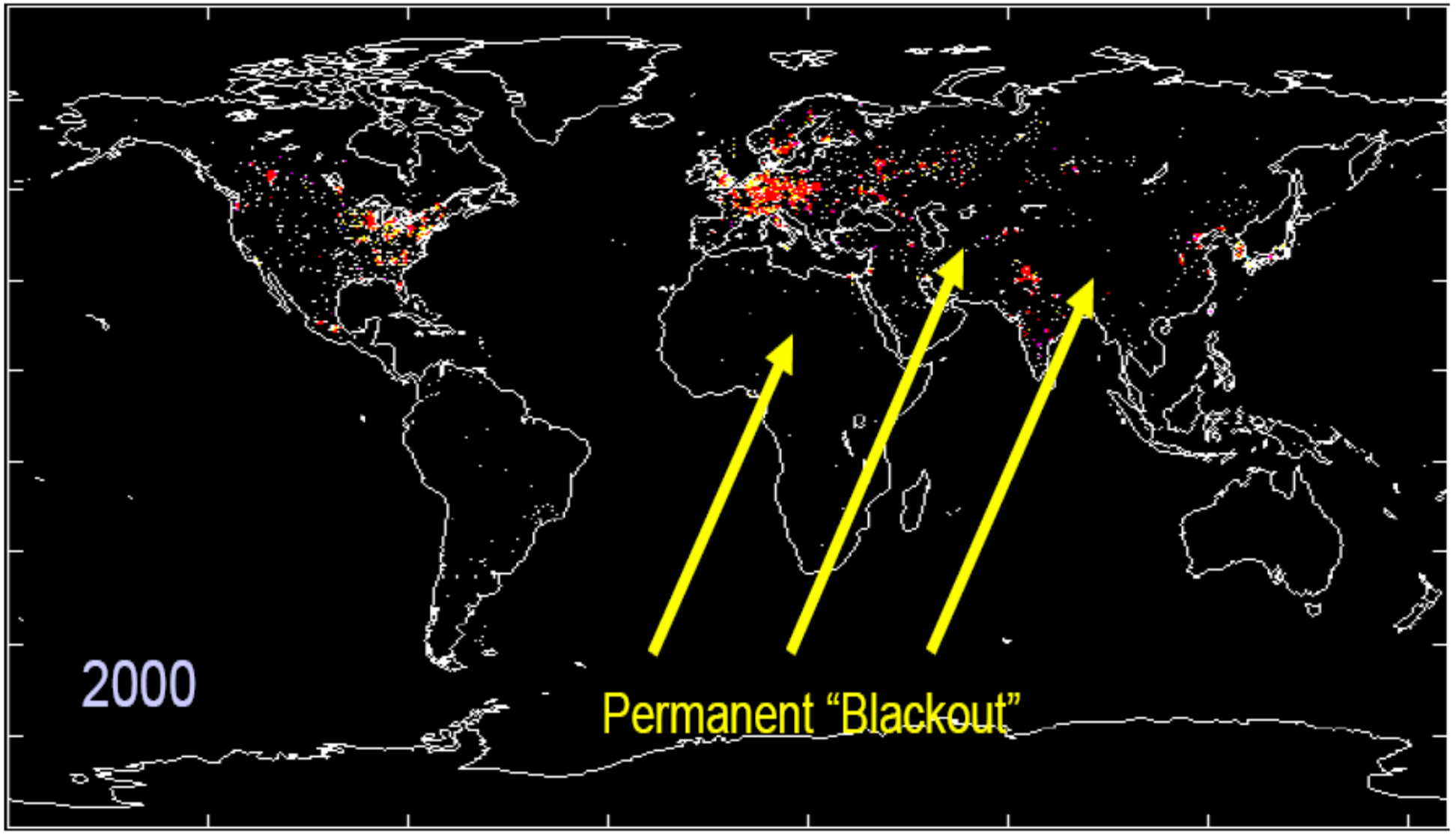

Source: e2050, 2006.

Night lights in 2070

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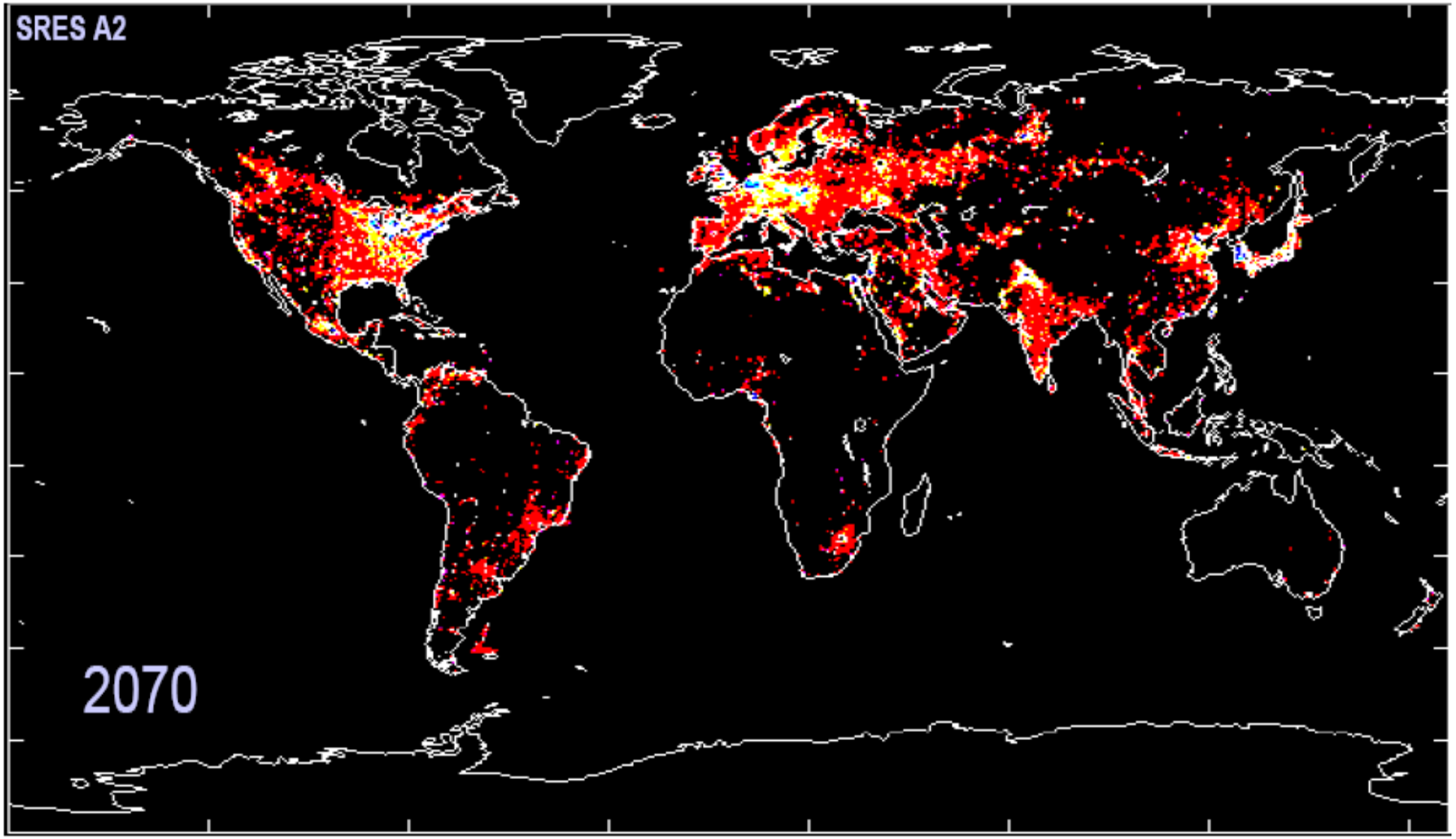

Source: e2050, 2006.

Global warming

today !

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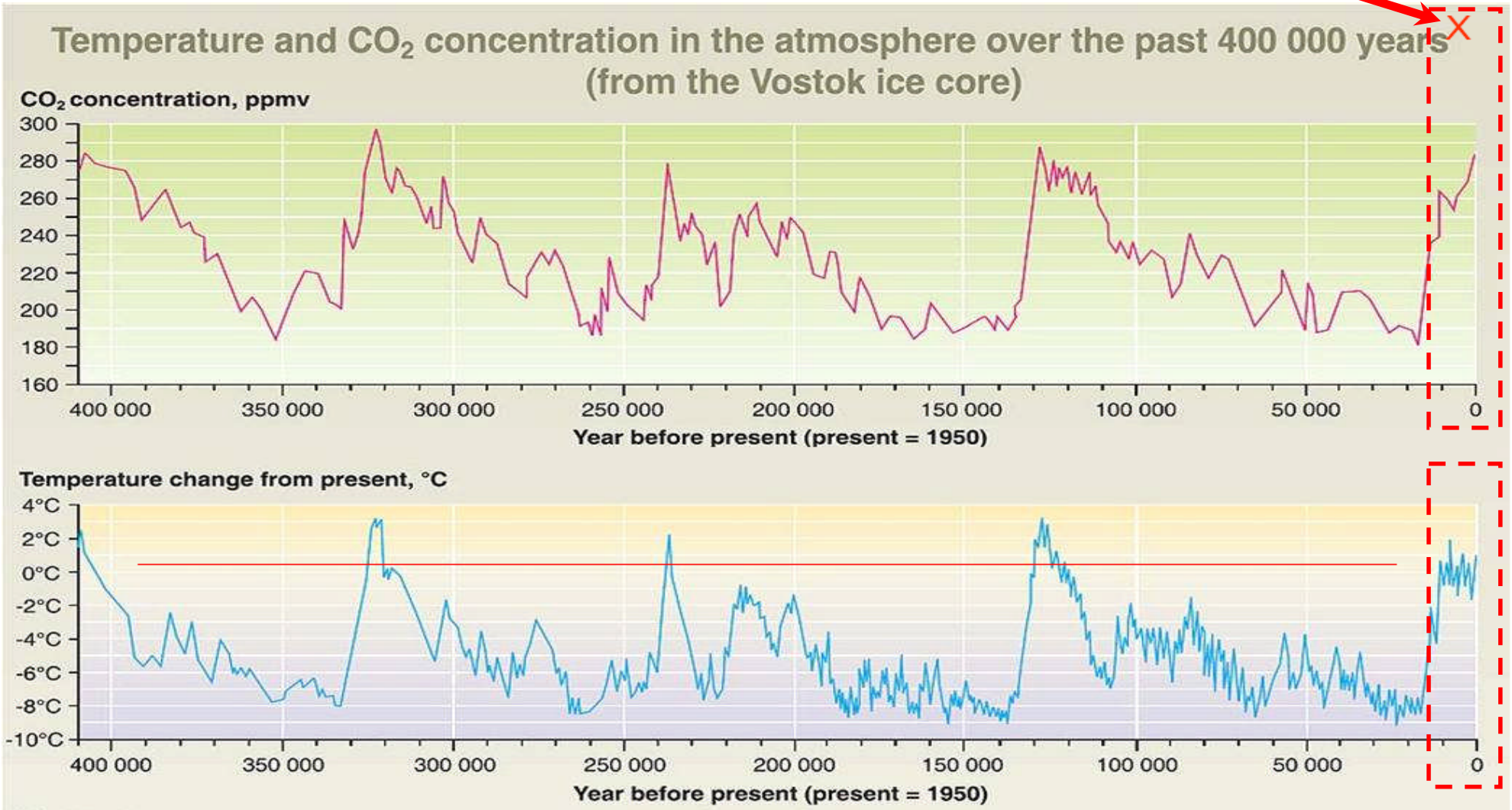
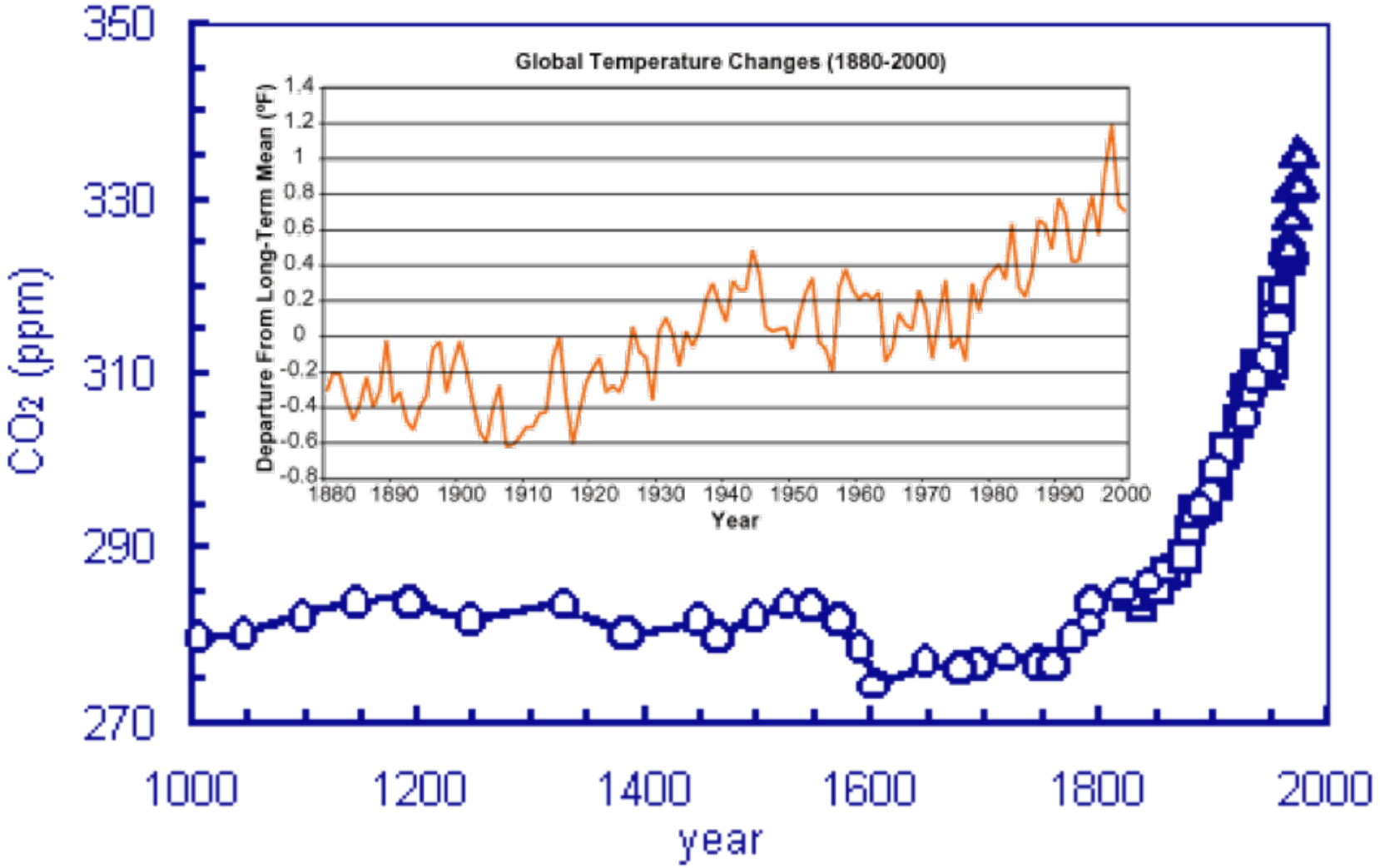


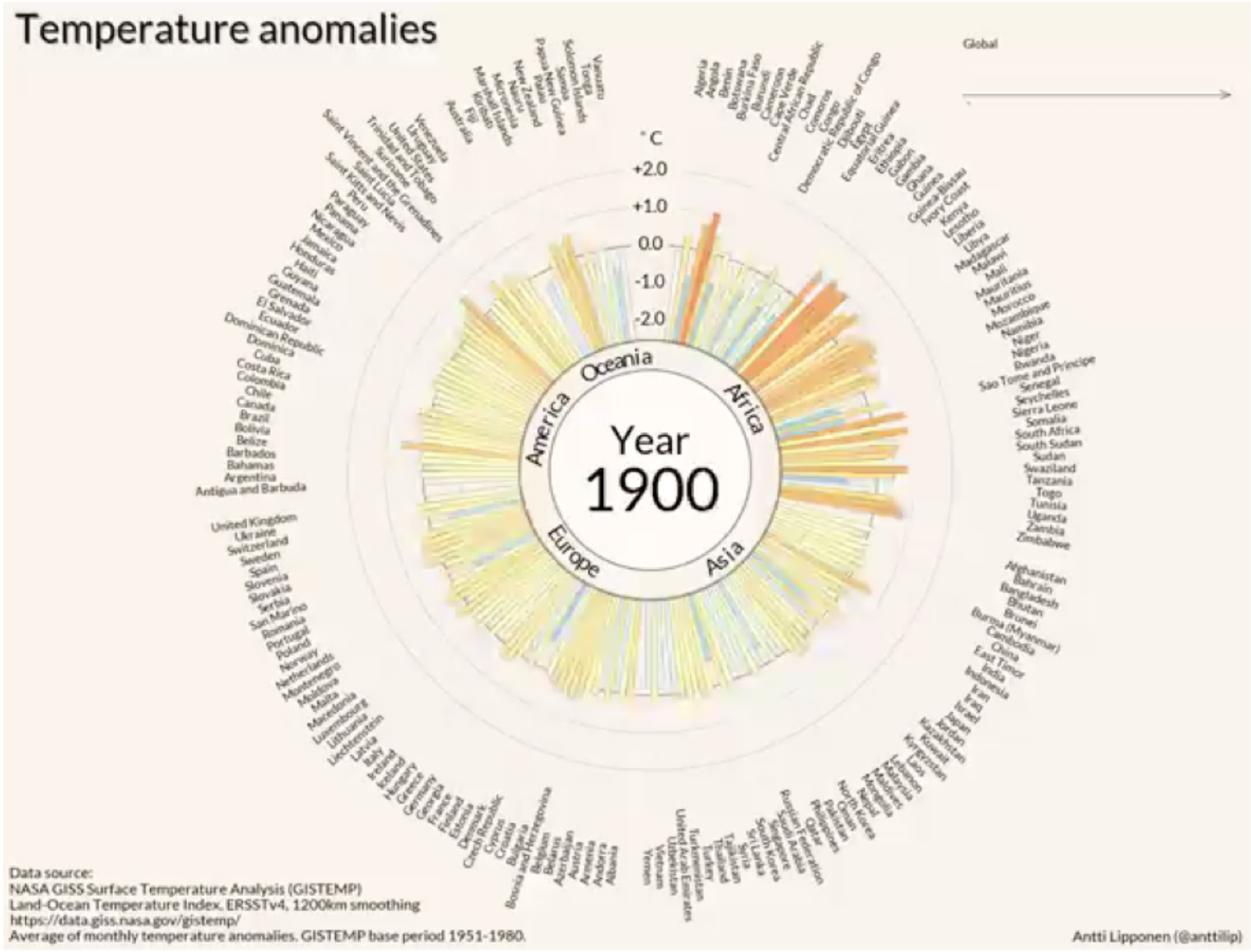
Source: J.R. Petit *et al*, Nature, 1999.

Global warming



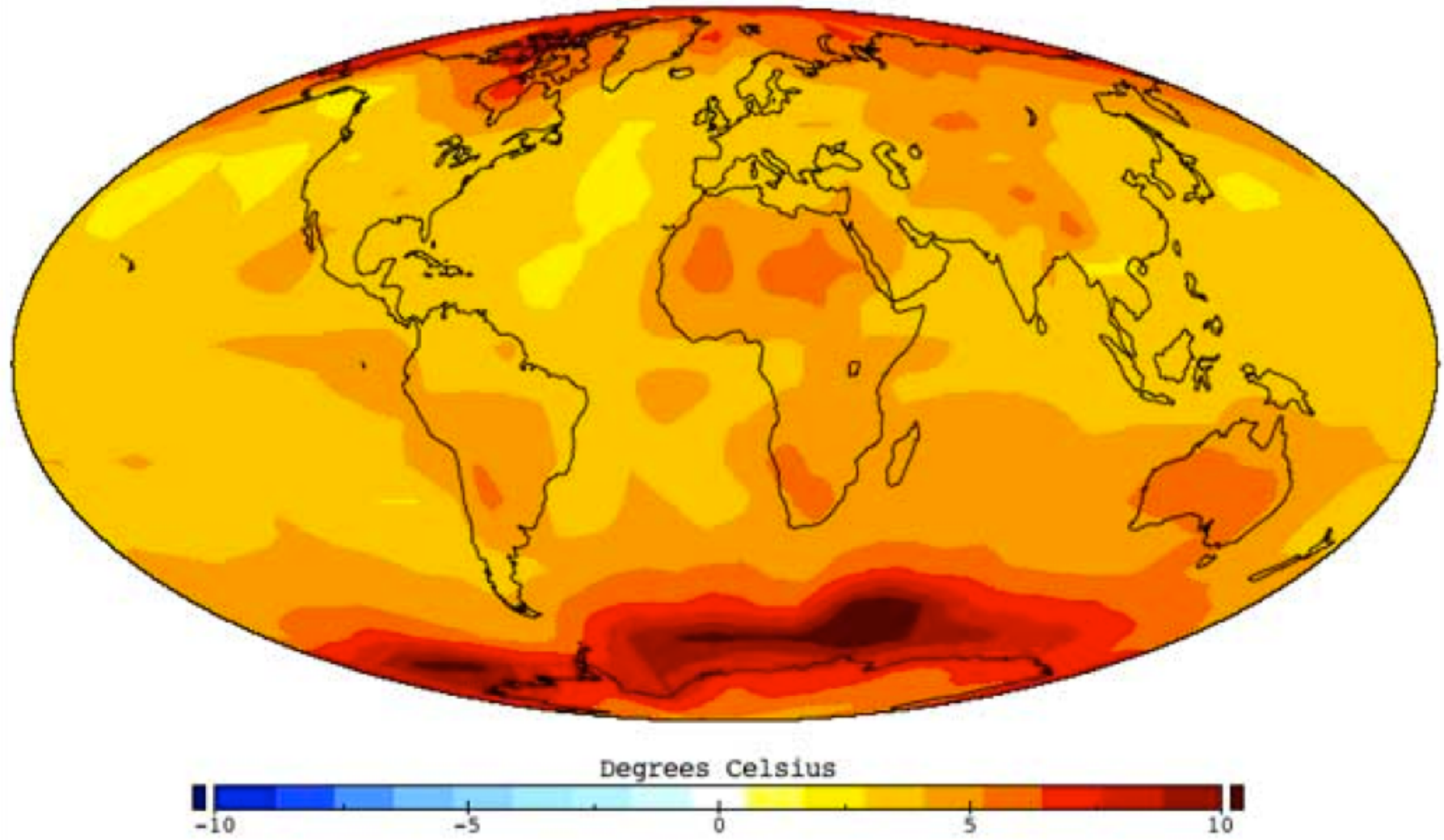
Source: U.S. National Climatic Data Center, 2001.

Temperature anomalies *



*** UN Environment, 2017.**

Increase of Earth global temperature 1960-2060



Source: NASA, 2010.

Sustainable energy

… provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs …

Sustainable technologies

… technologies that promote sustainable energy include renewable energy sources as well as technologies designed to improve energy efficiency …

EU energy strategy

Long term strategy

Future energy systems

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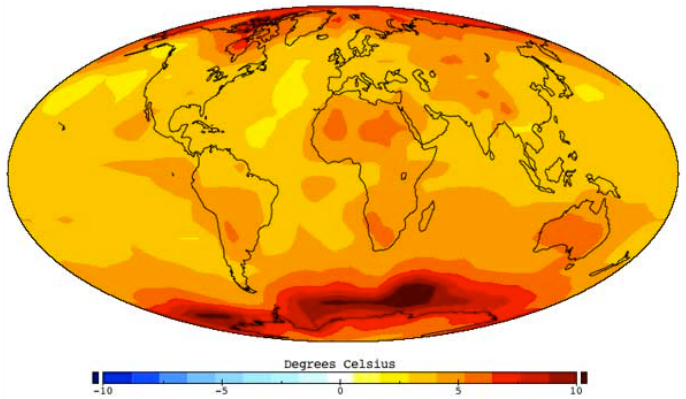
- **Climate change**

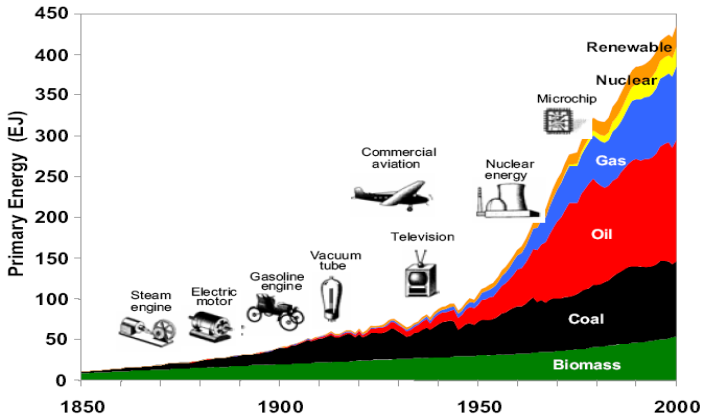


- **Third industrial revolution**

- **Future energy economics**

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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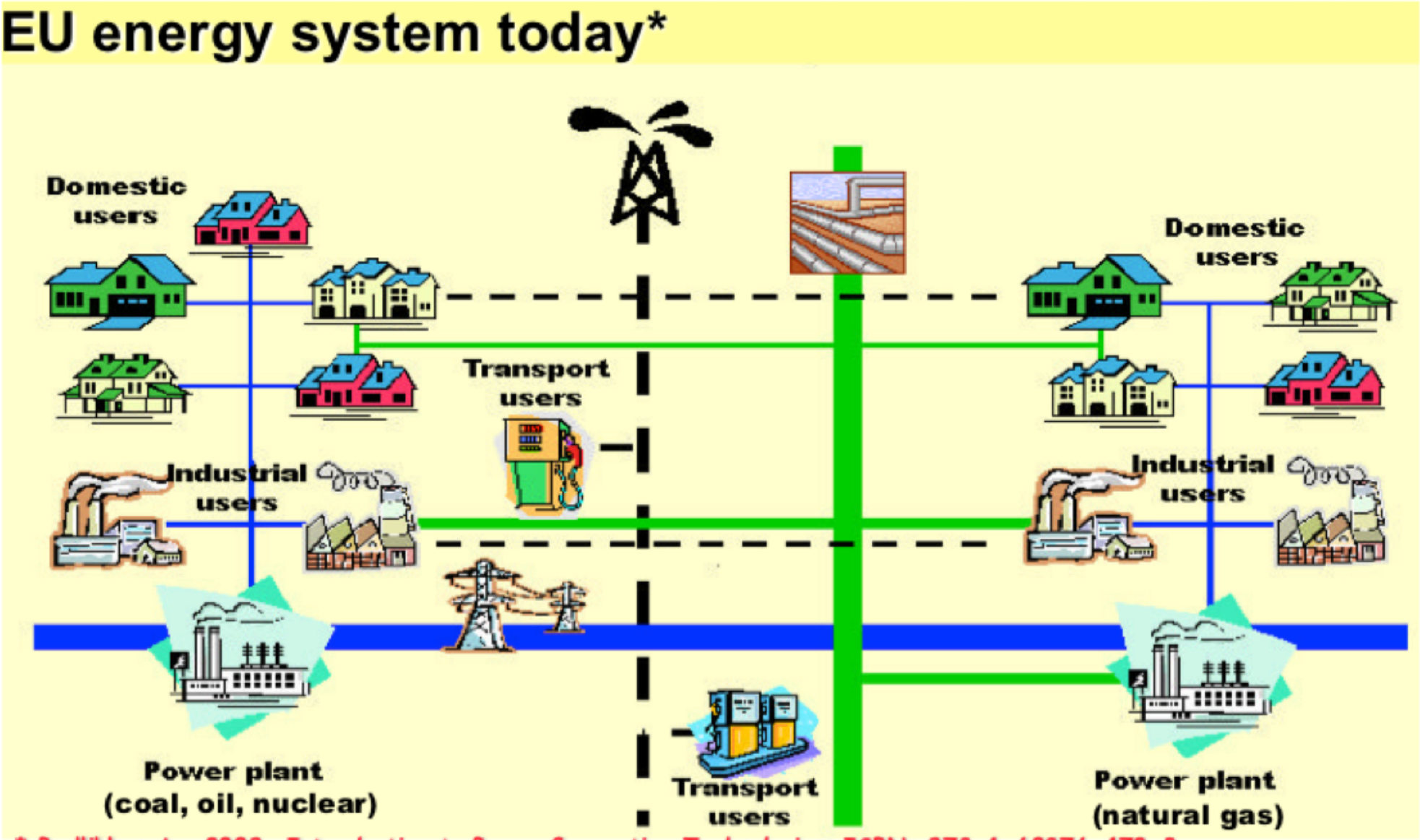
EU energy system today*



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

Future energy systems (optimistic scenario)

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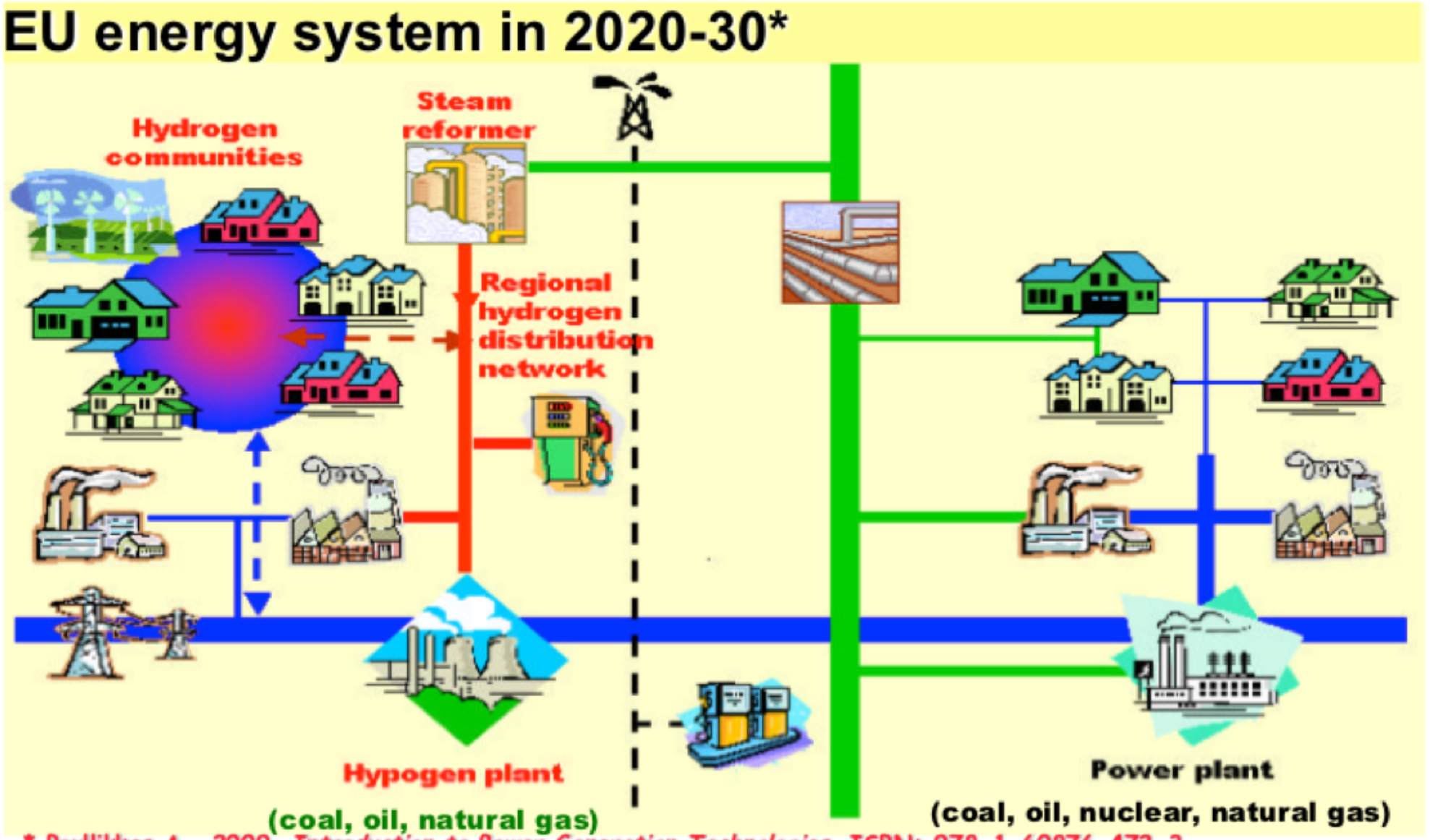

Future energy systems (optimistic scenario)

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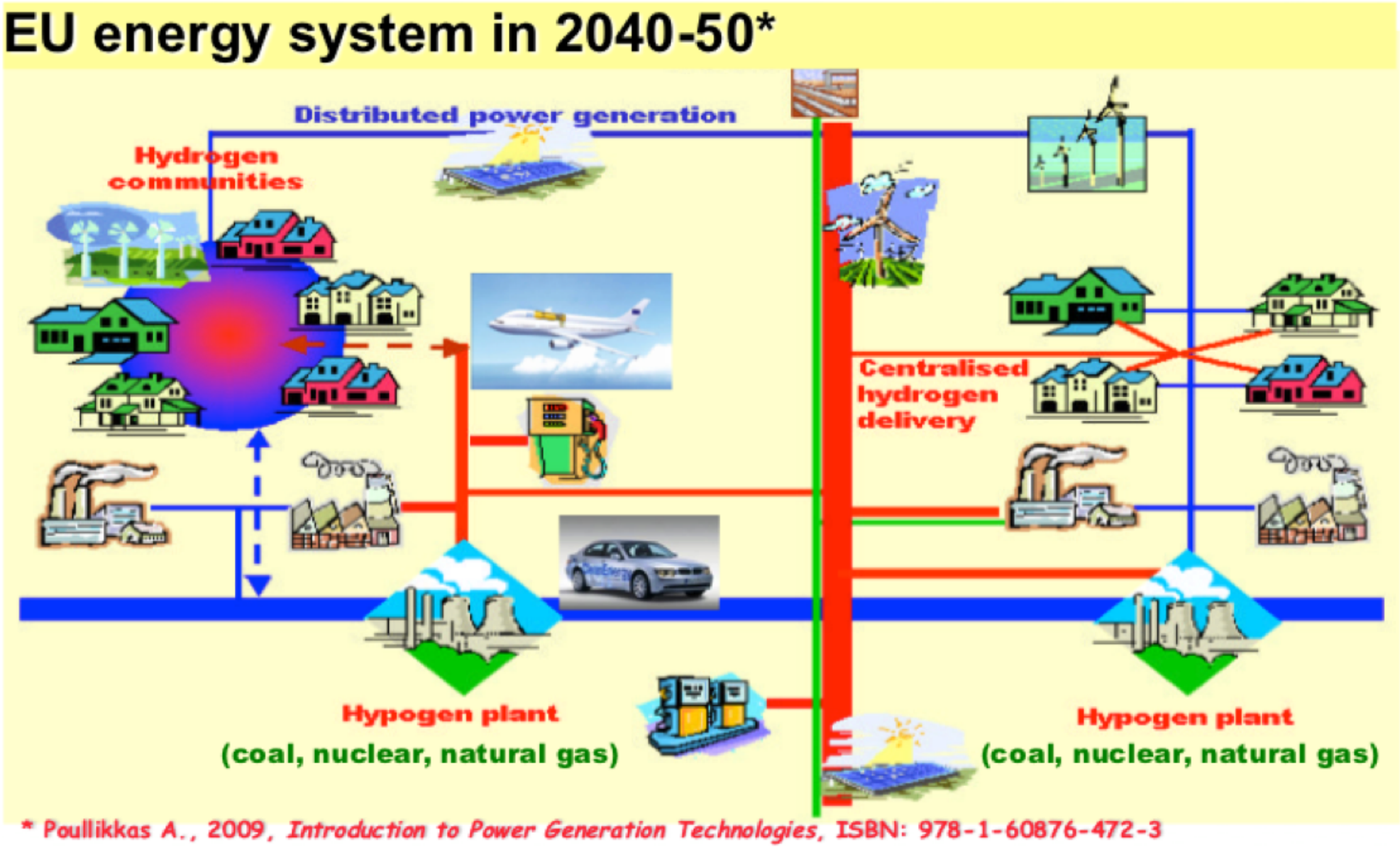
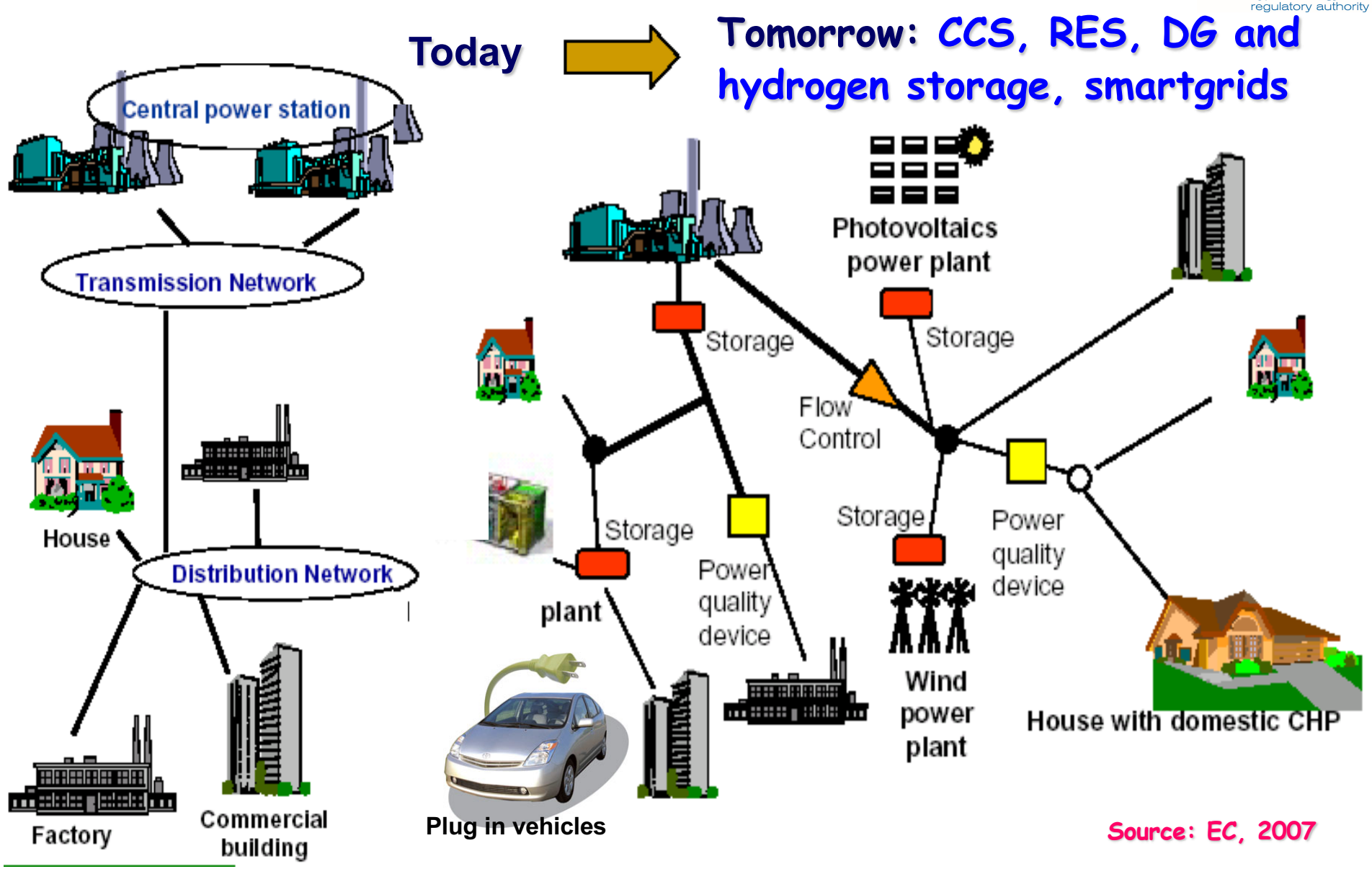
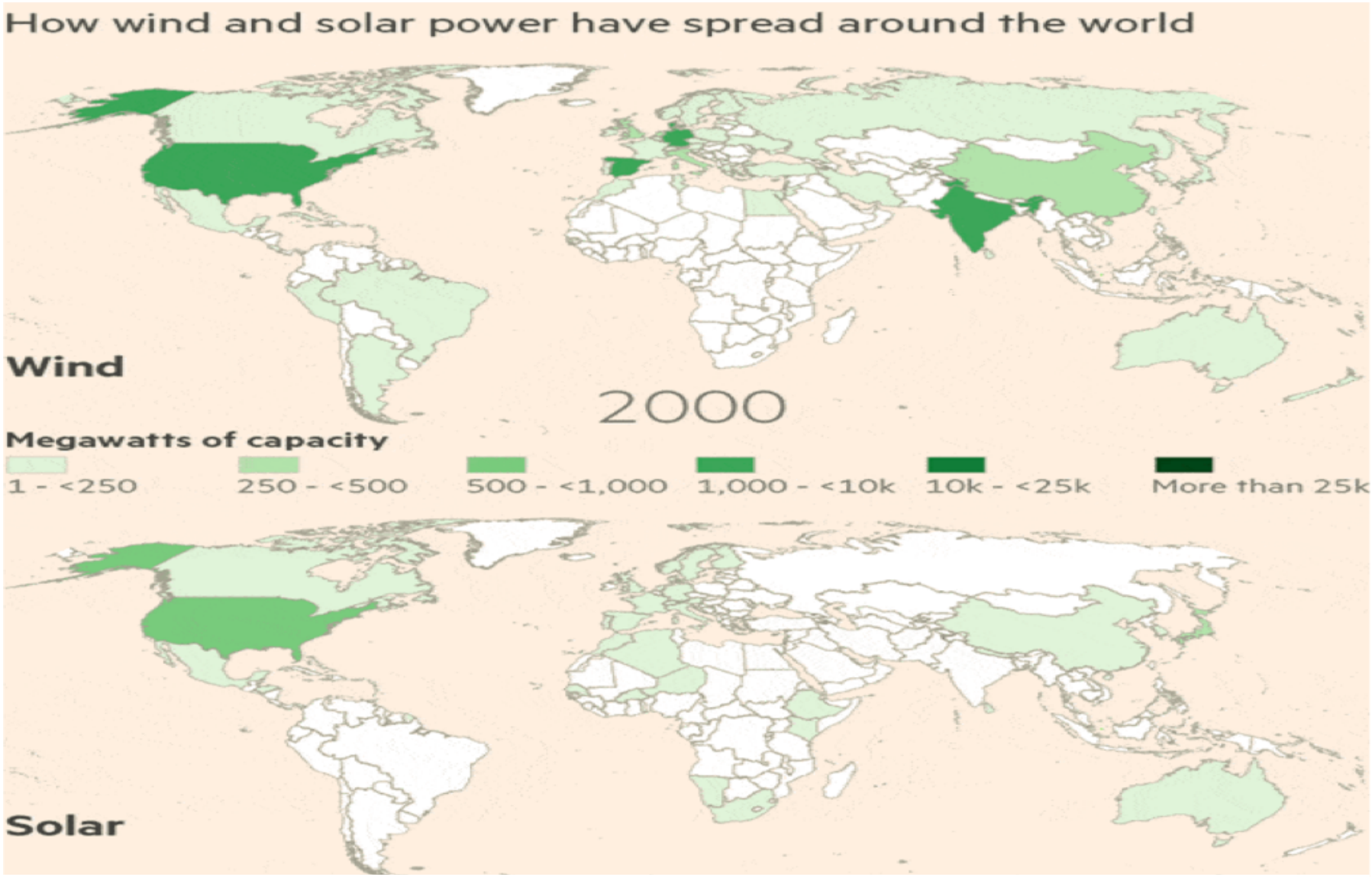


Future power systems

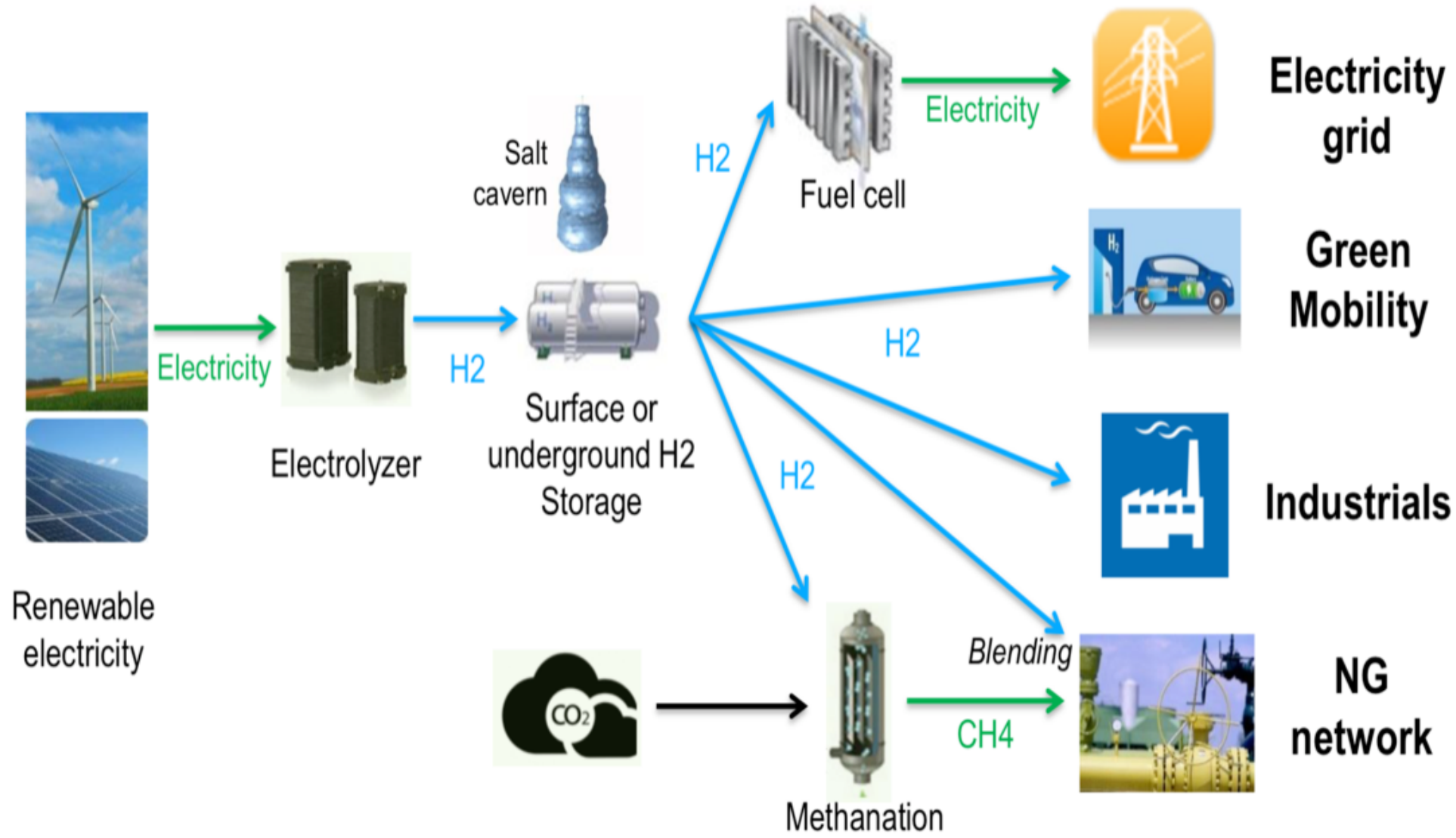


Development of wind and solar power *



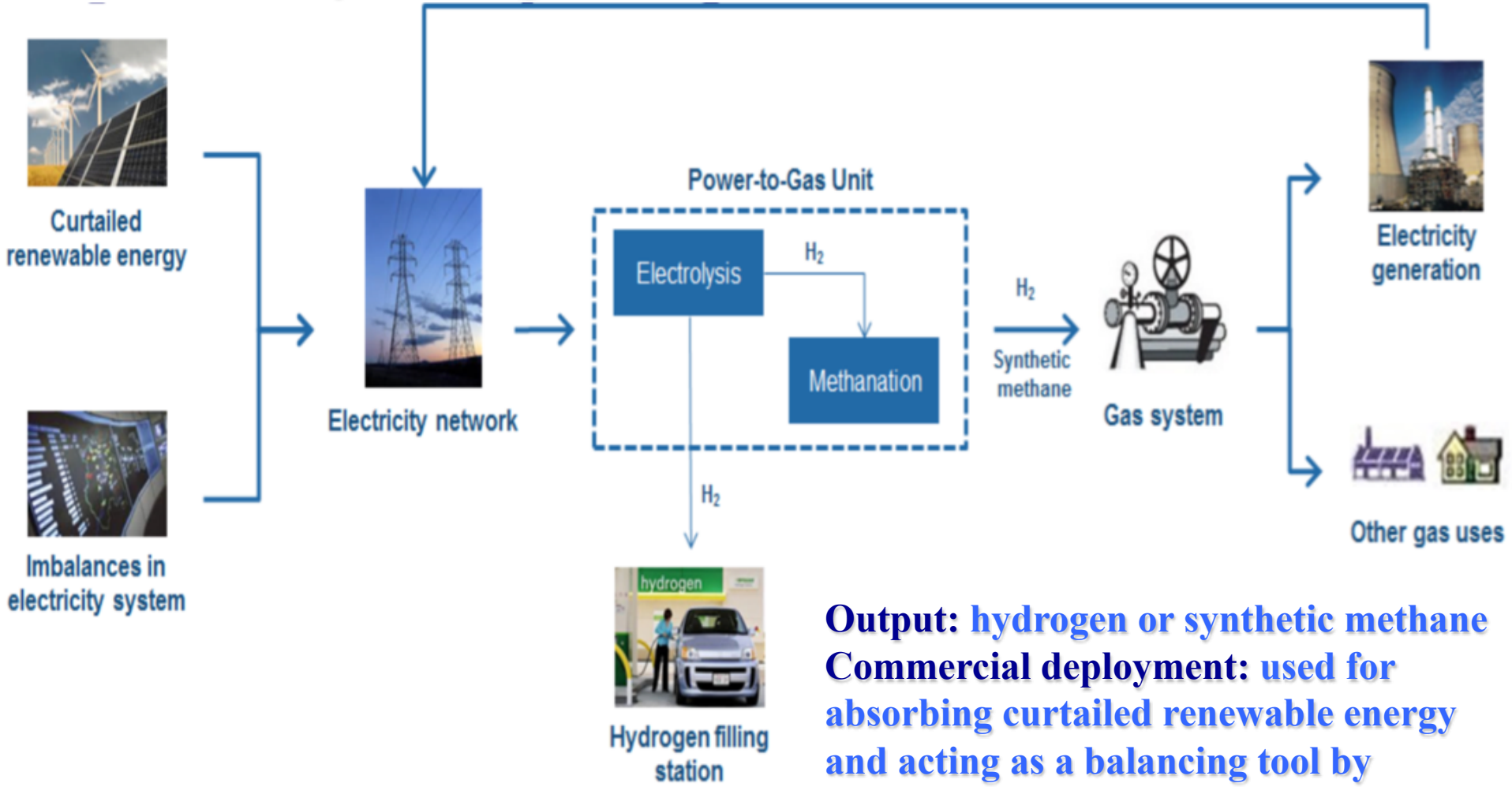
* International Renewables Energy Agency

Hydrogen : an efficient vector in a decarbonized energy mix



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

End goal – the smart future

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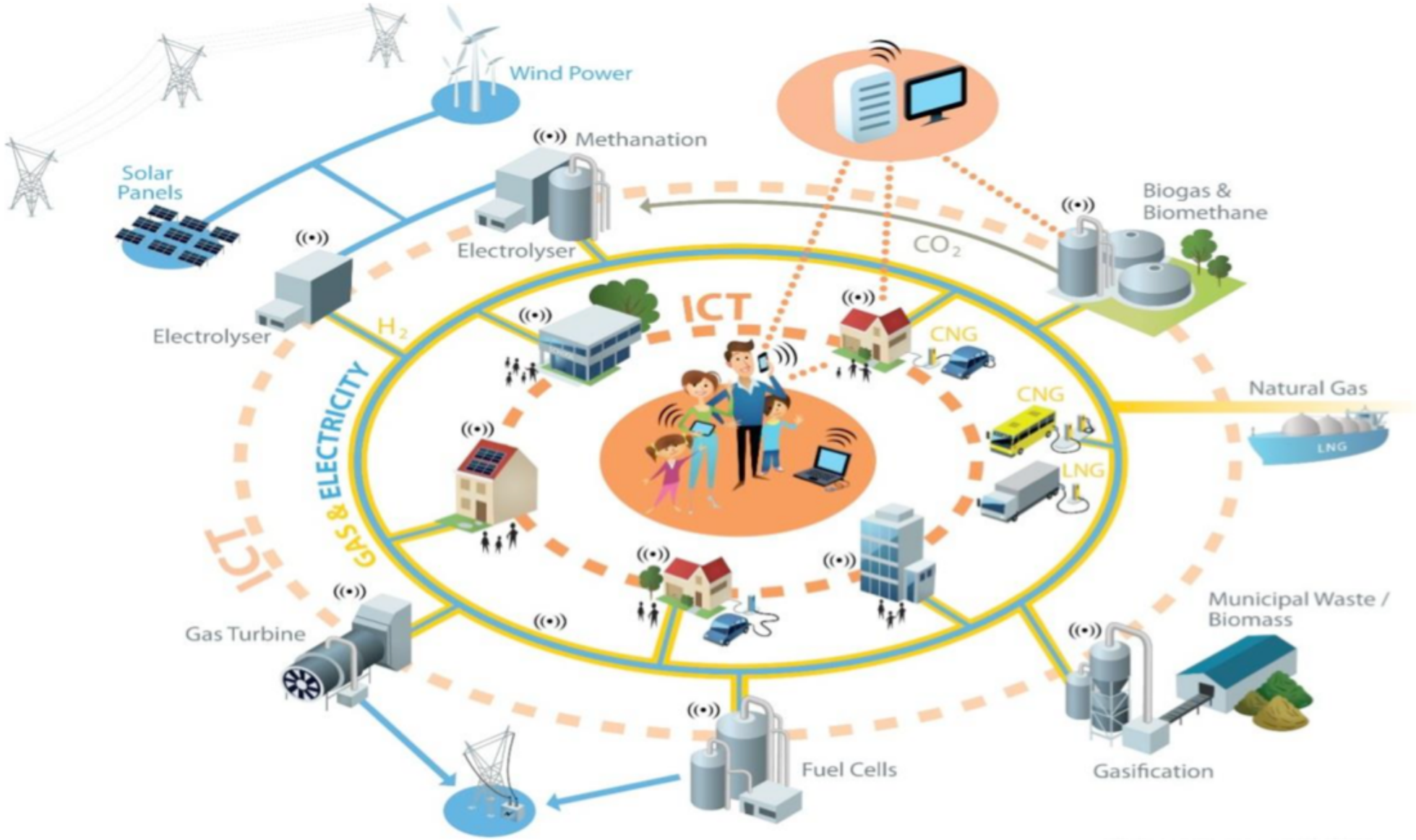

The Super Smart Grid after 2050*
(may allow for 100% RES)

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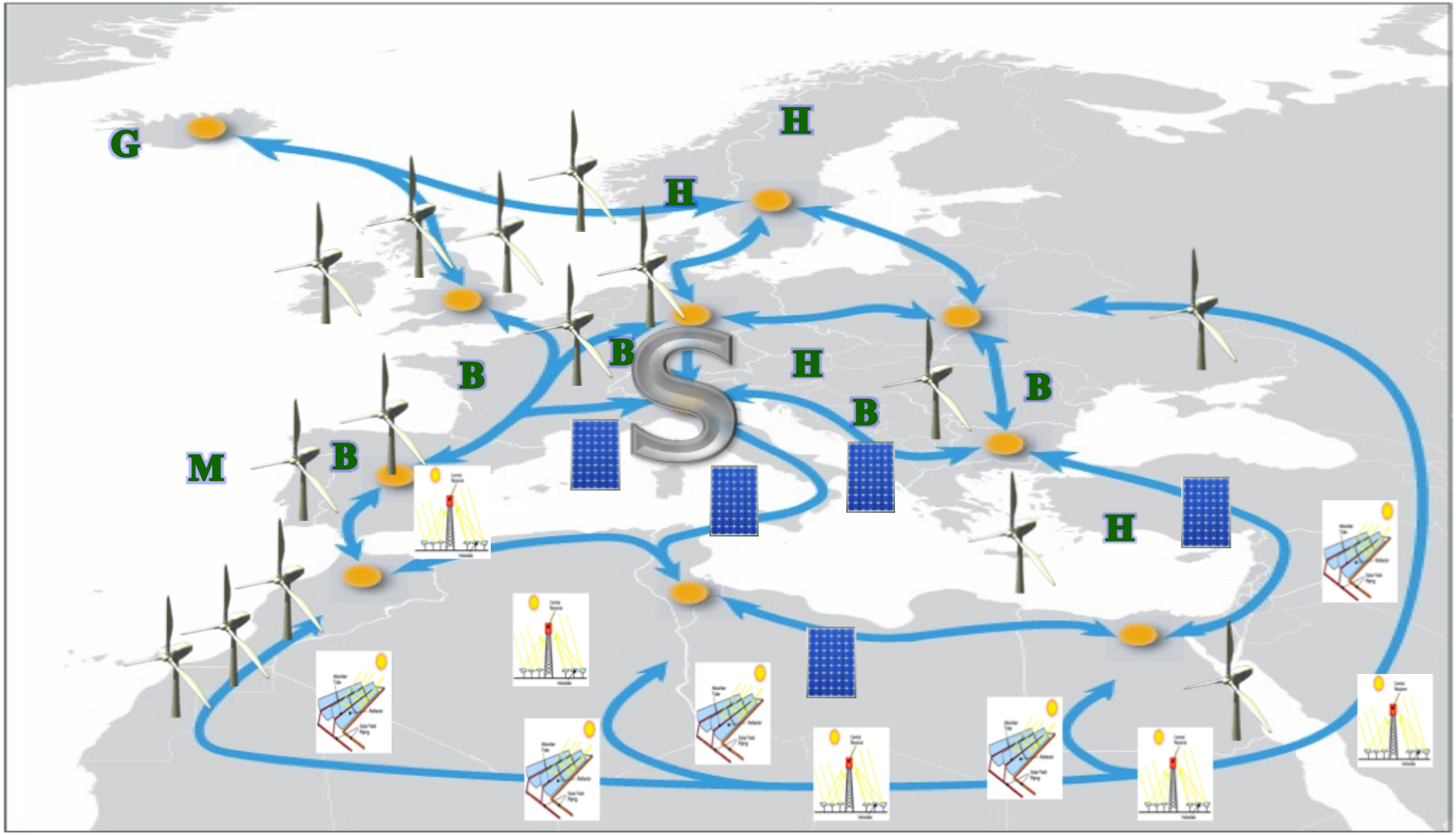
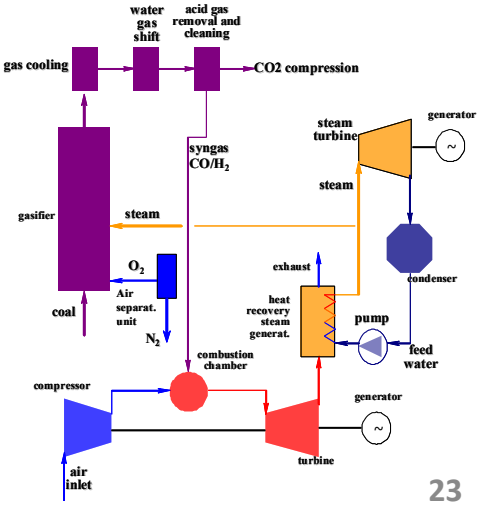


* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

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*

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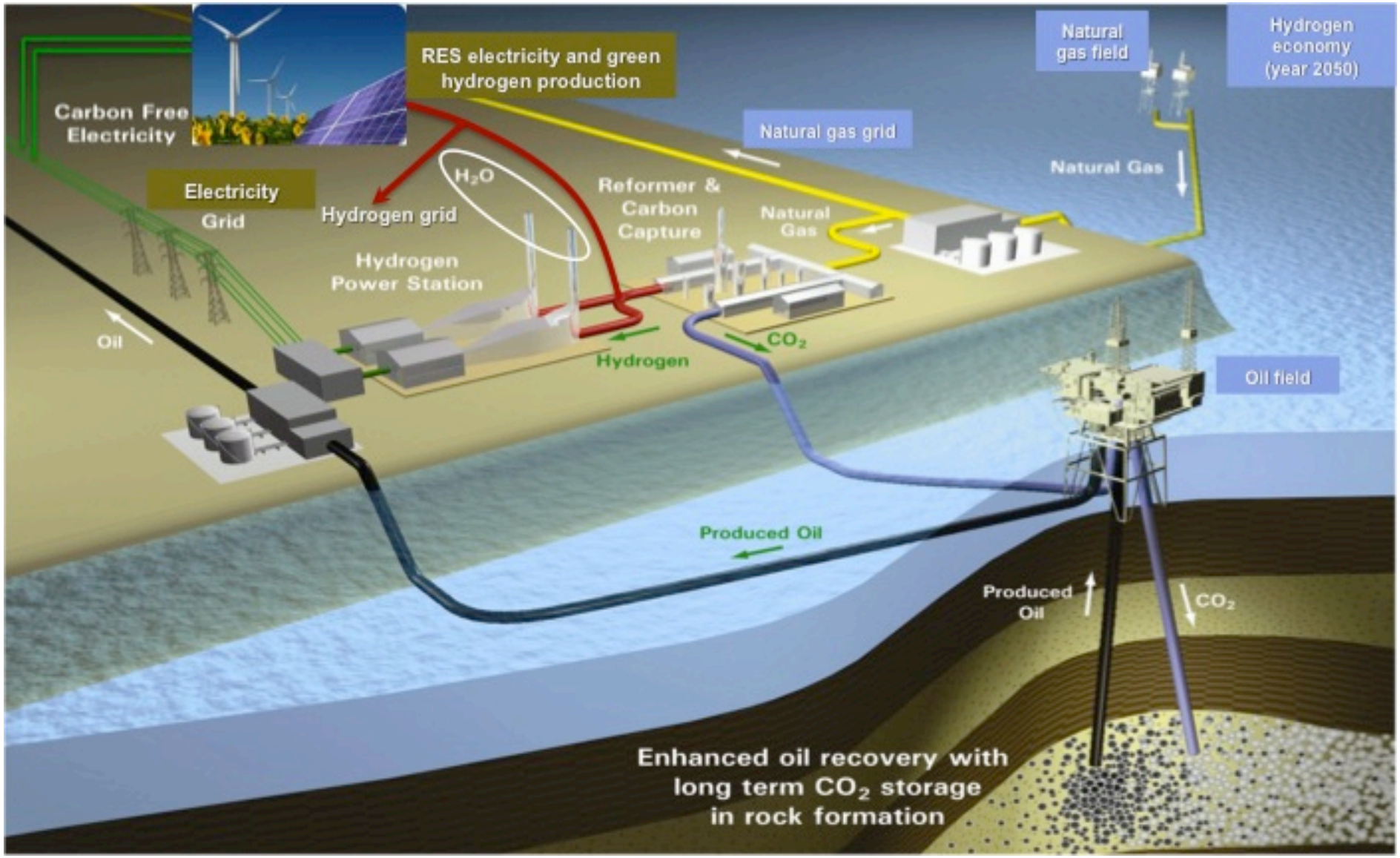
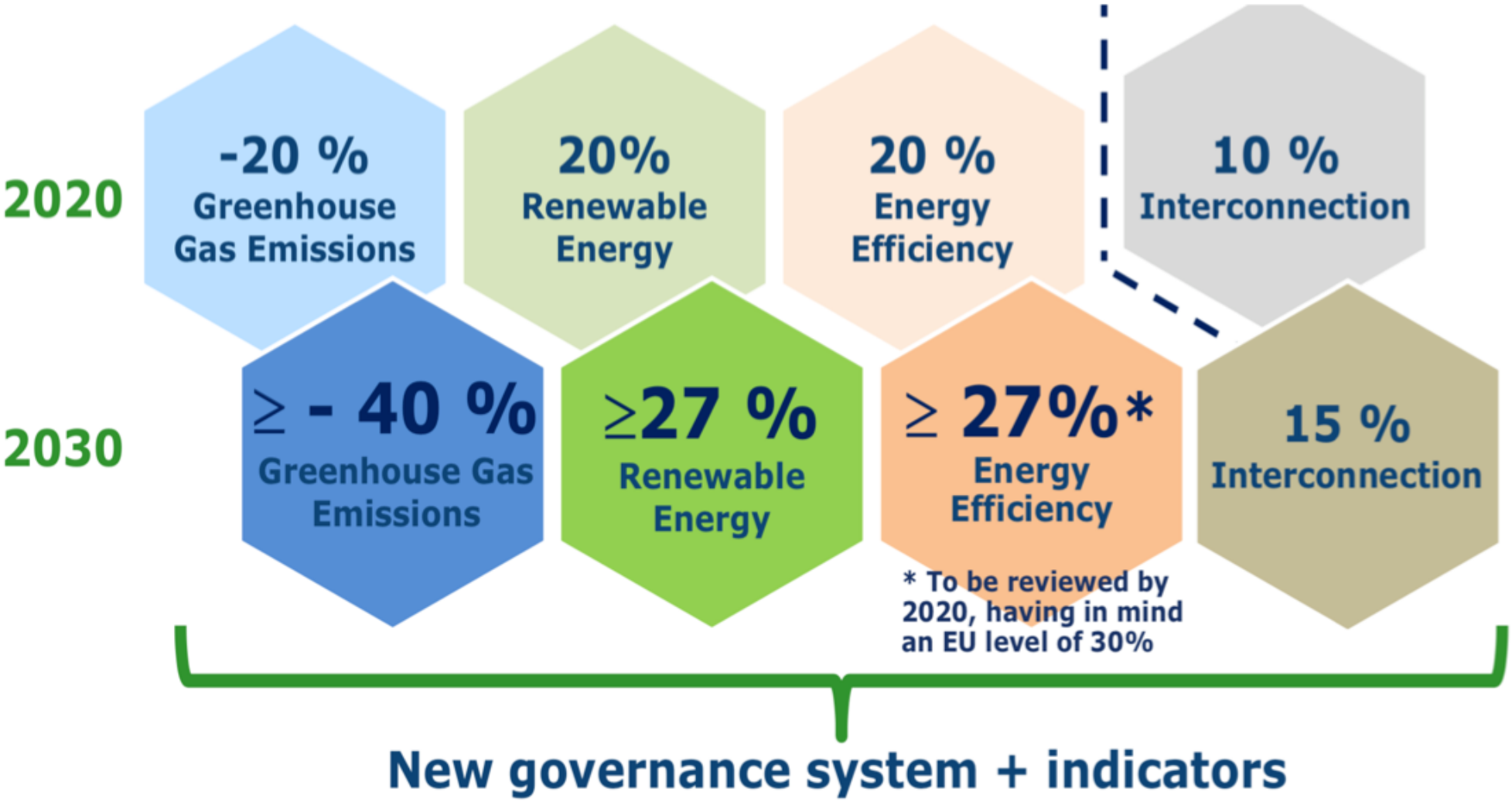


* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

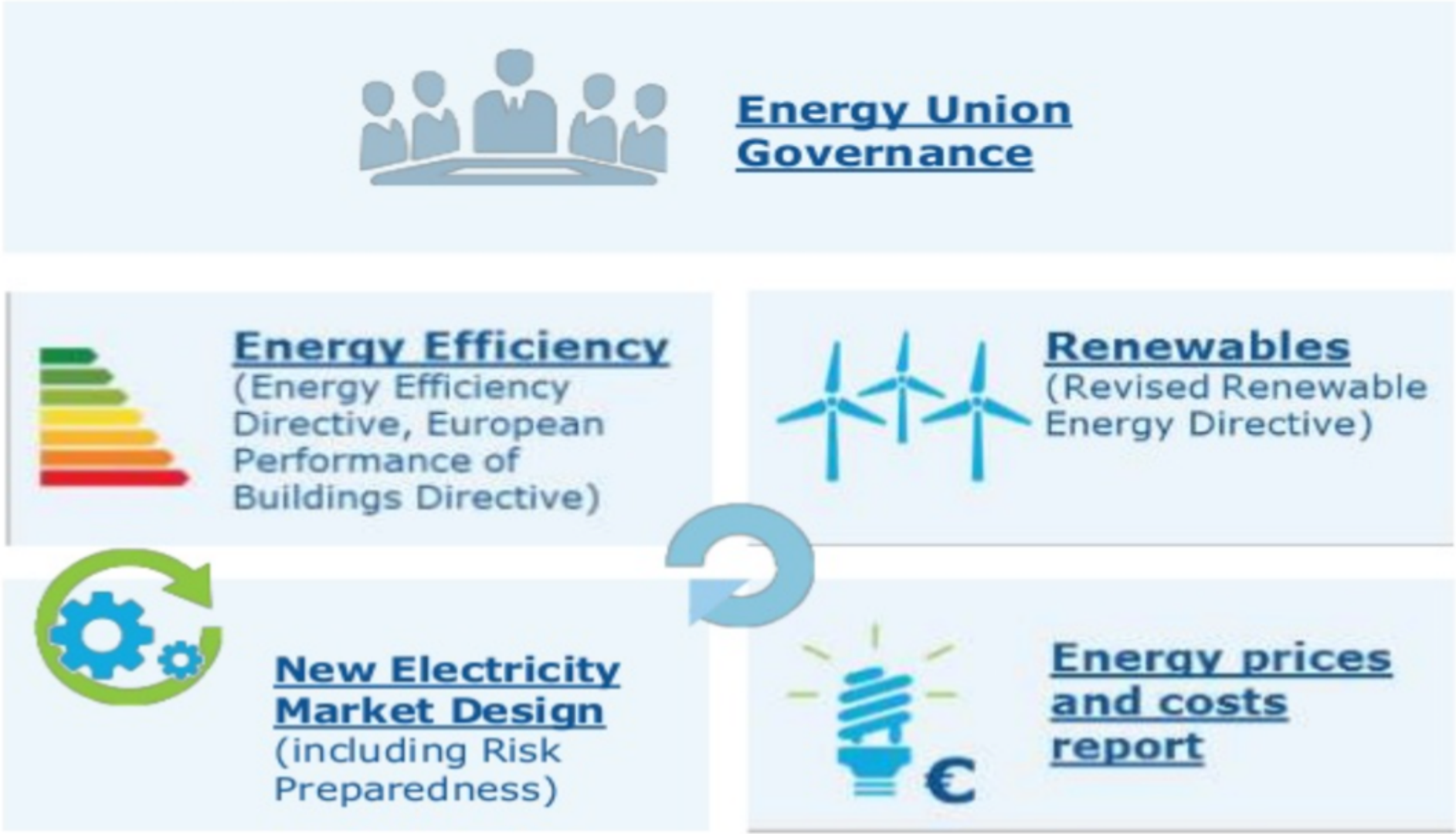
EU energy strategy

Energy Union

Energy Union targets



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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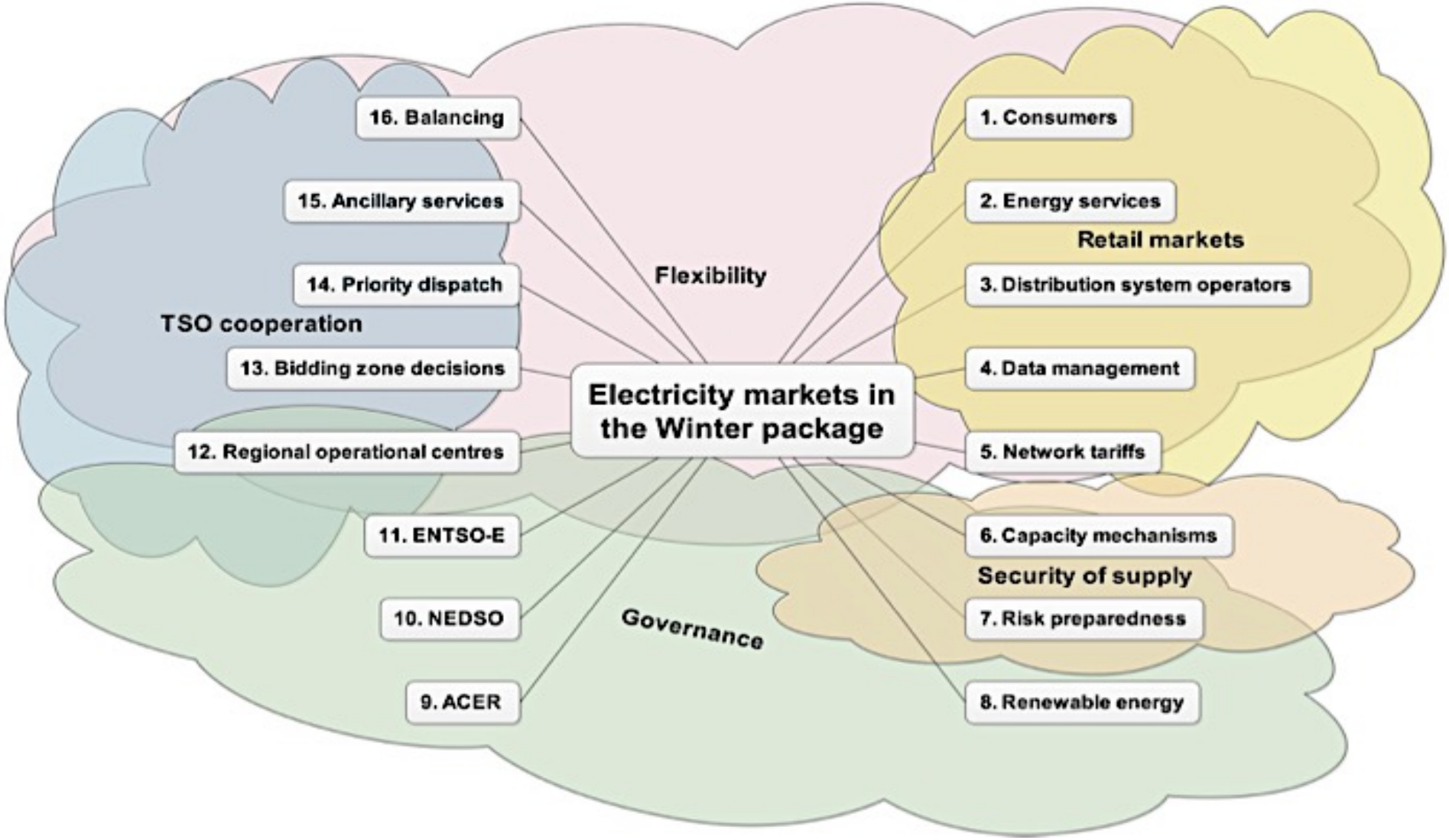

Connecting electricity markets

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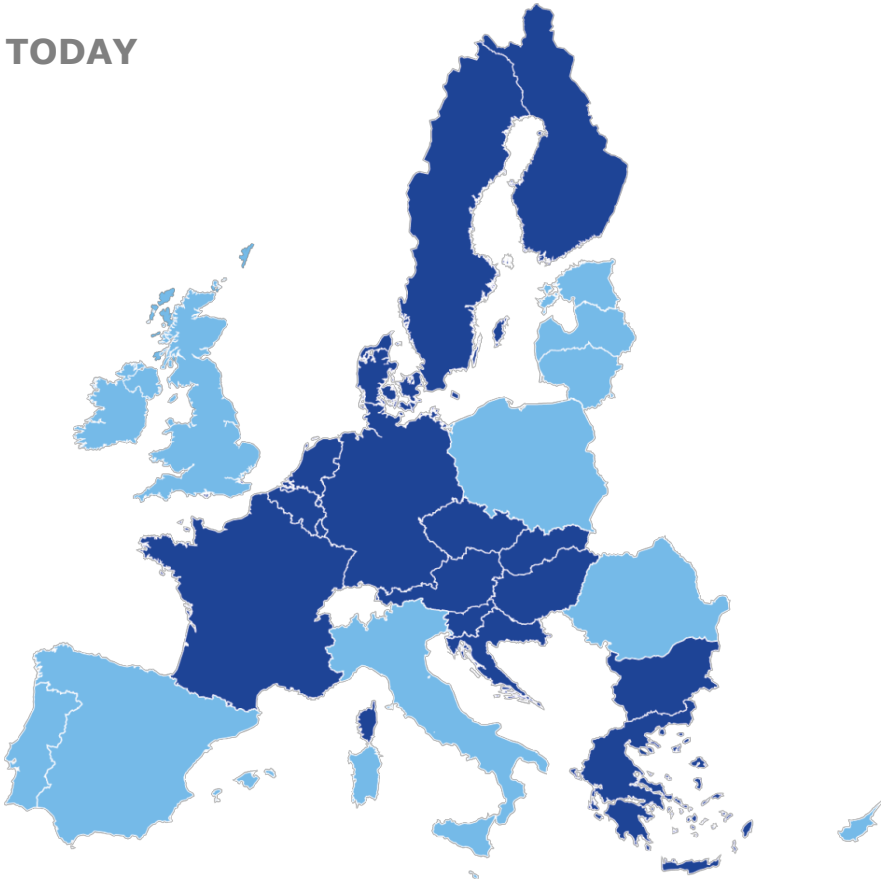
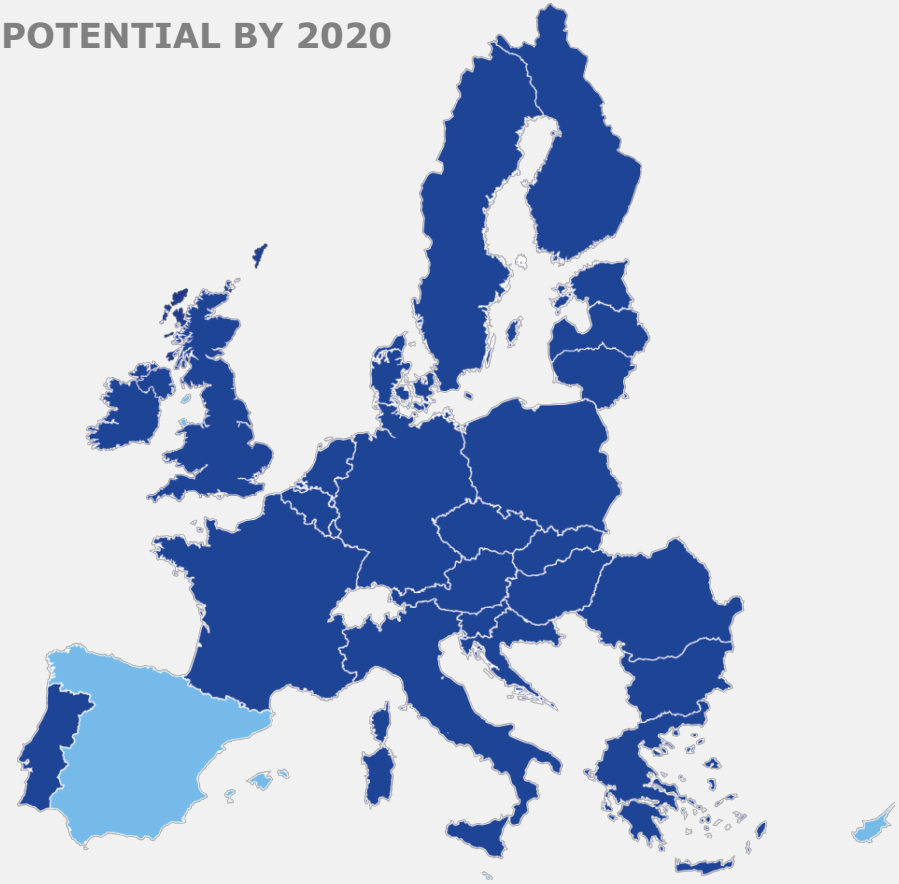
TODAY



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

What is a power system?

- Largest and most complex manmade system
- Electrical power is somewhat like the air we breath
  - We think about it only when it is missing
- PS should be operated with the goal of achieving:
  - Highest reliability standards
  - Lowest operation cost
  - Minimum environmental impacts

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**

Electricity market functions

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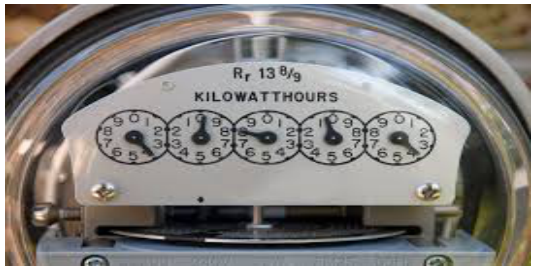
- **Generation** (competition)

- **Transmission** (monopoly)

- **Distribution** (monopoly)

- **Supply** (competition)



Competition *vs* monopoly

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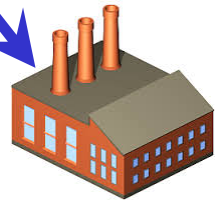
Transmission grid

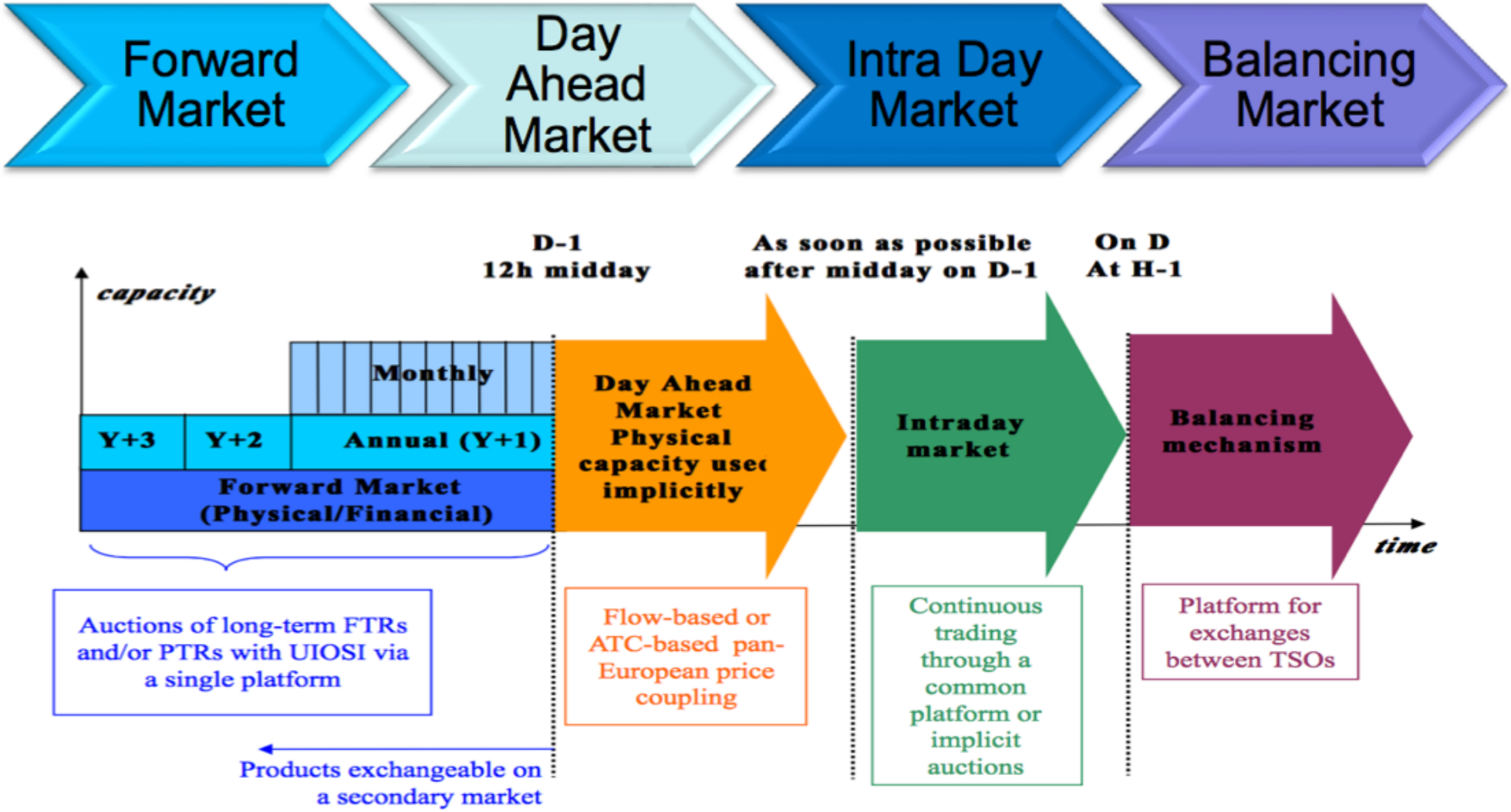


Distribution grid



EU electricity market target model



The fundamental requirement of electrical power supply

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Get me what I want,

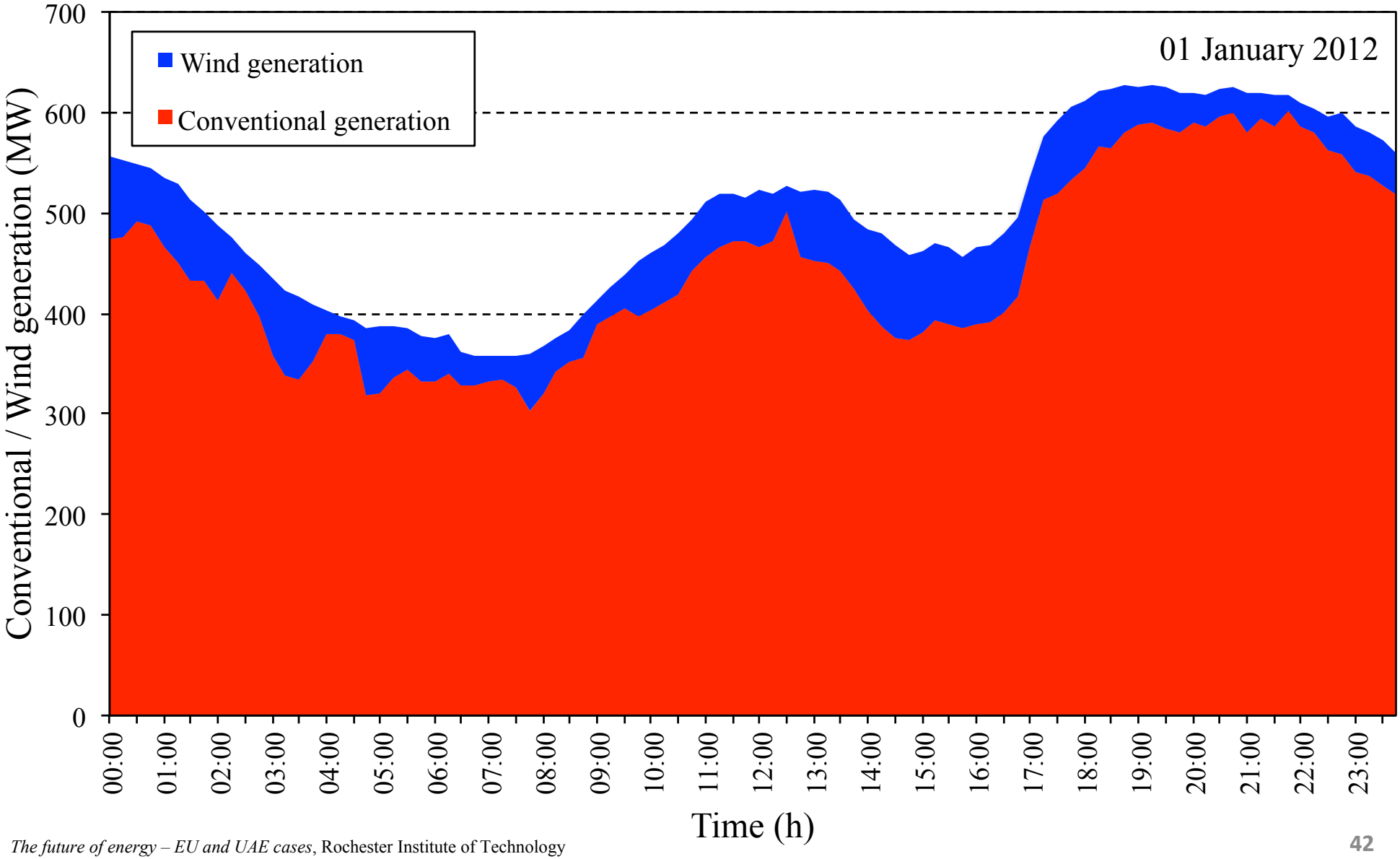
when I want it !!!

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

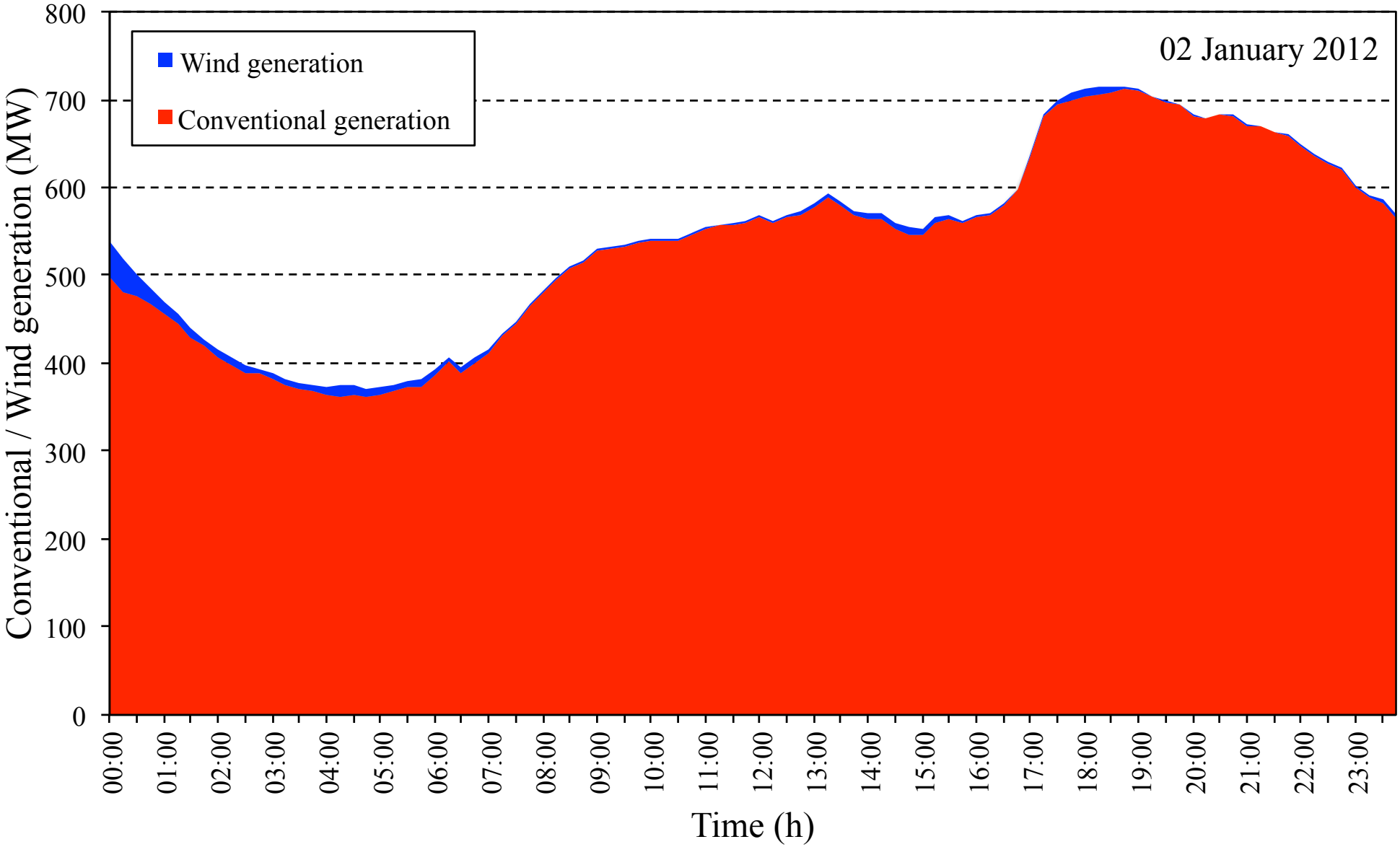
Intermittent energy source

- 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

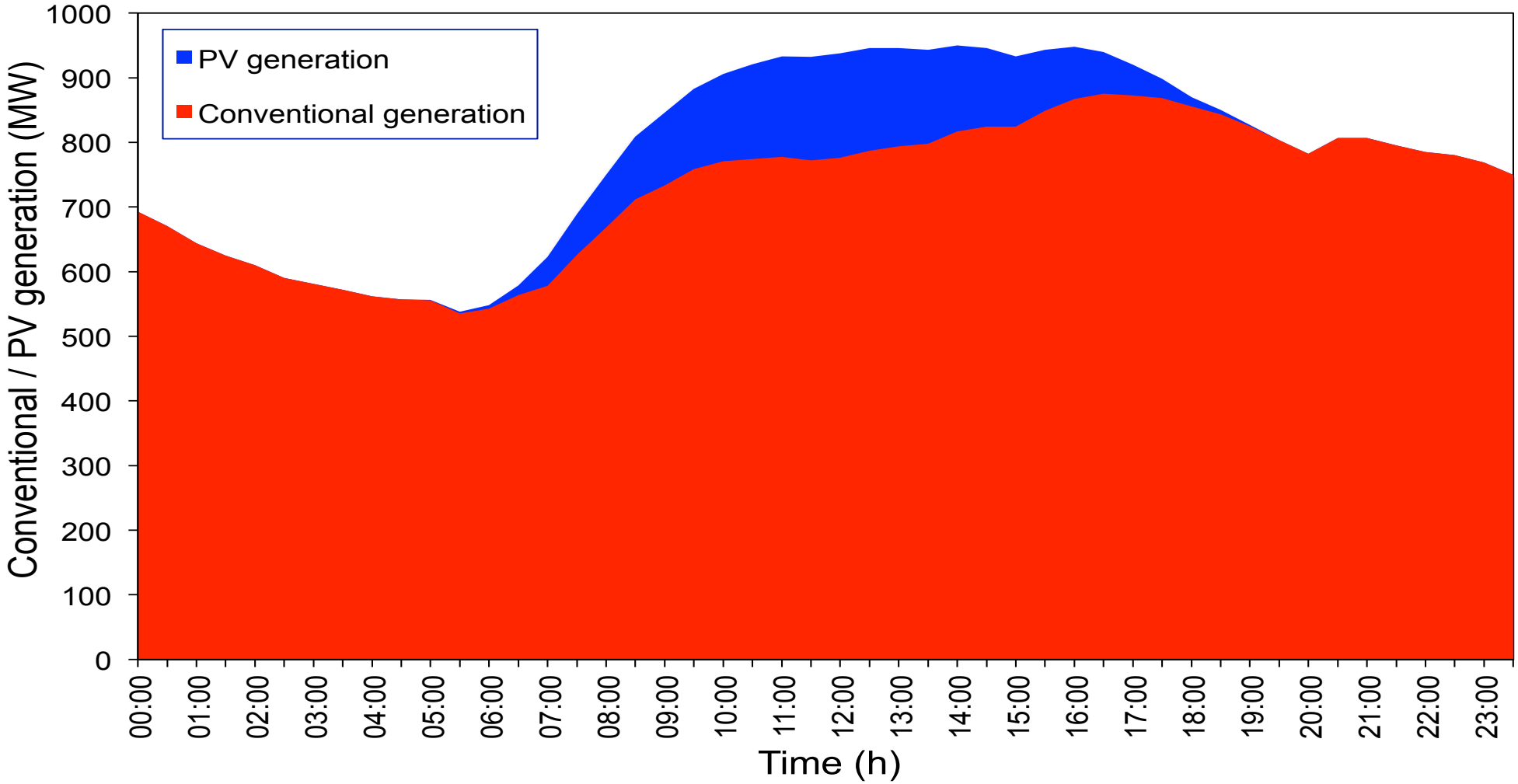
Wind generation (in Cyprus)



Wind generation (in Cyprus)

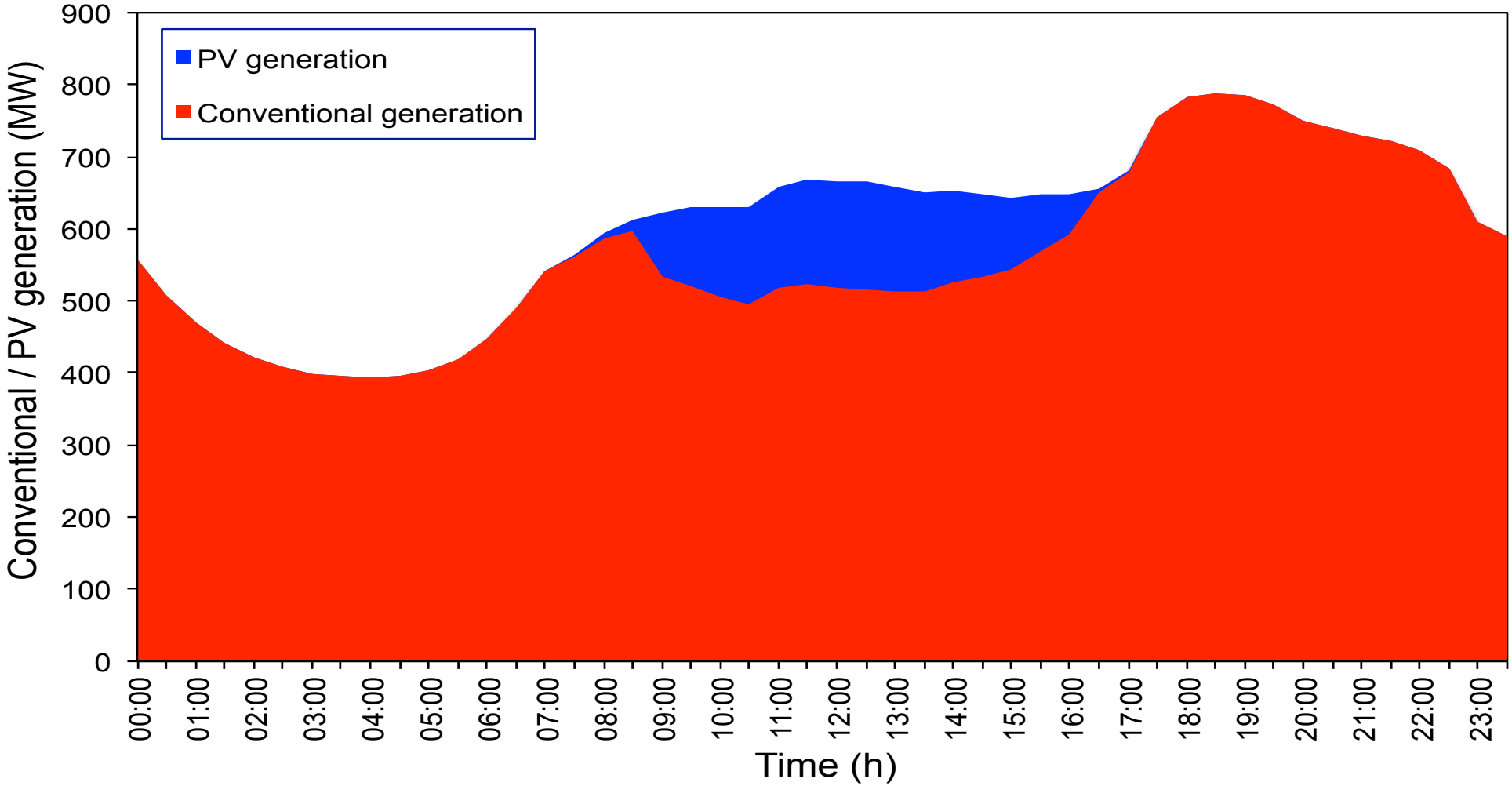


Example of PV generation during Summer time*



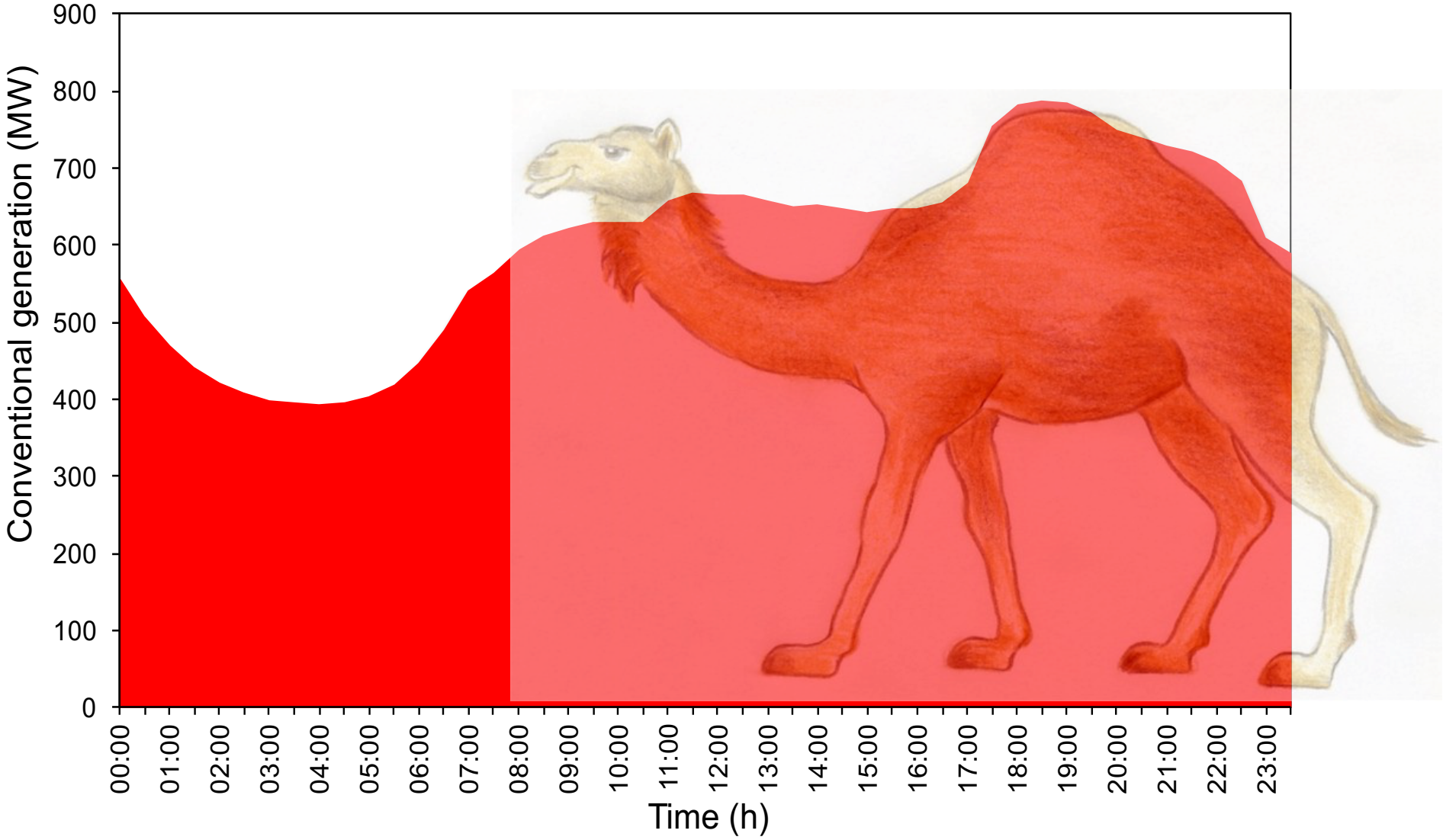
* Poullikkas A., 2009, "Parametric cost-benefit analysis for the installation of photovoltaic parks in the island of Cyprus", *Energy Policy*

Example of PV generation during Winter time*



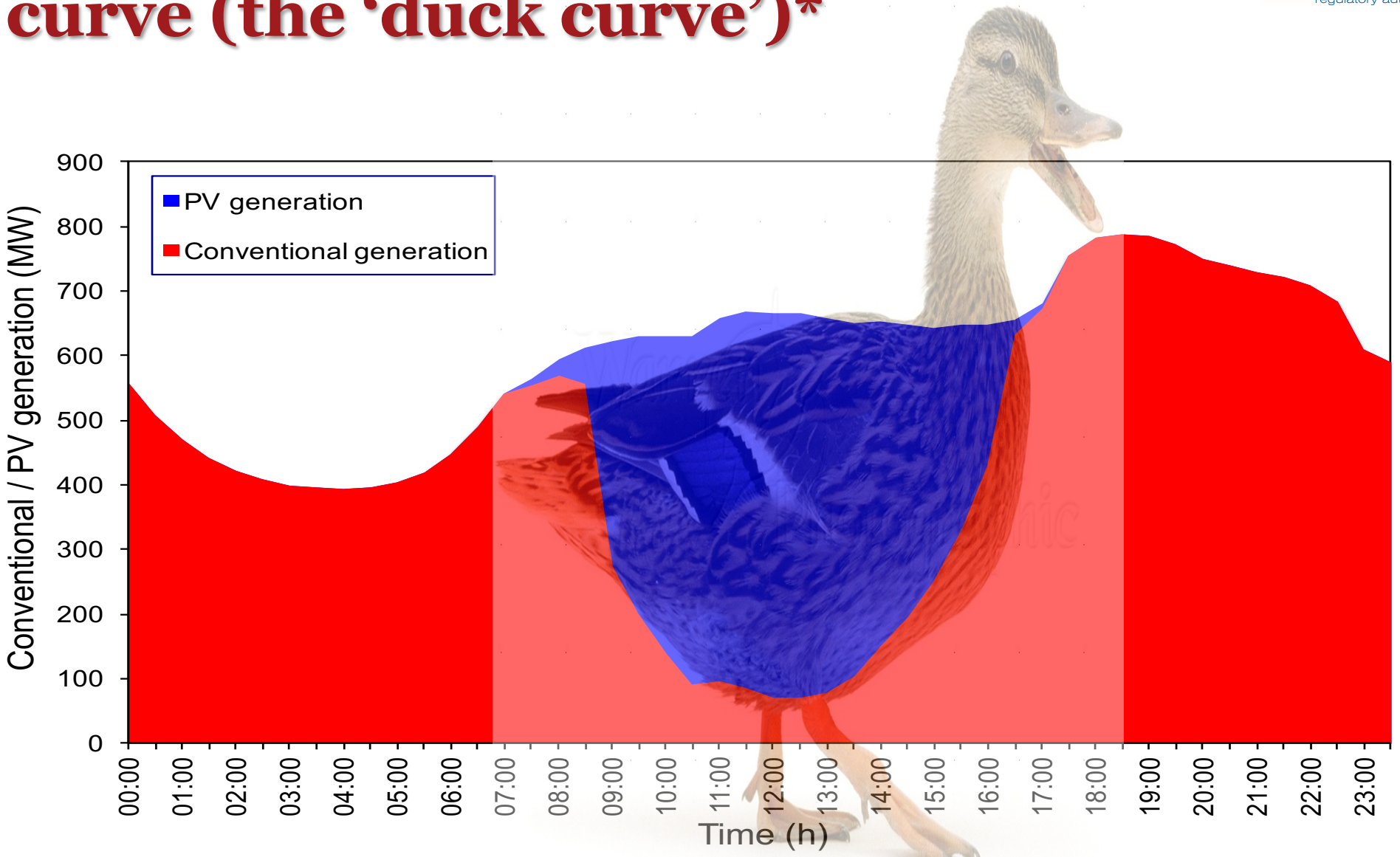
* **Poullikkas A., 2009, "Parametric cost-benefit analysis for the installation of photovoltaic parks in the island of Cyprus", *Energy Policy***

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

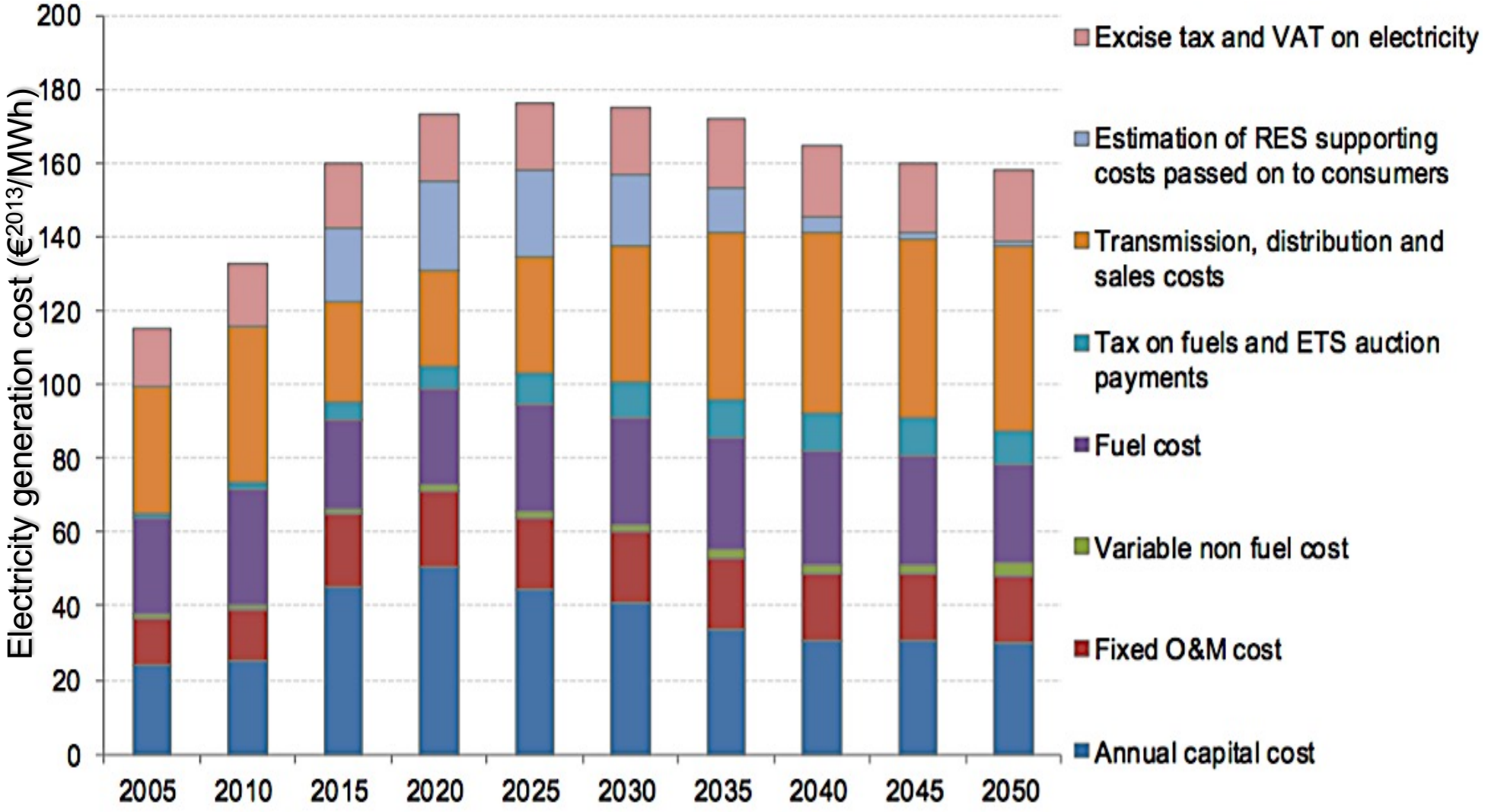
Advantage Lithium:
- Fast response
- Quick Service
- 80% DOD
- High Power
- Efficiency > 95%
- No Memory effect
- Highest energy density
- 15 to 20 years LT

Disadvantage:
High Cost

Size: 0,1 - 10MWh

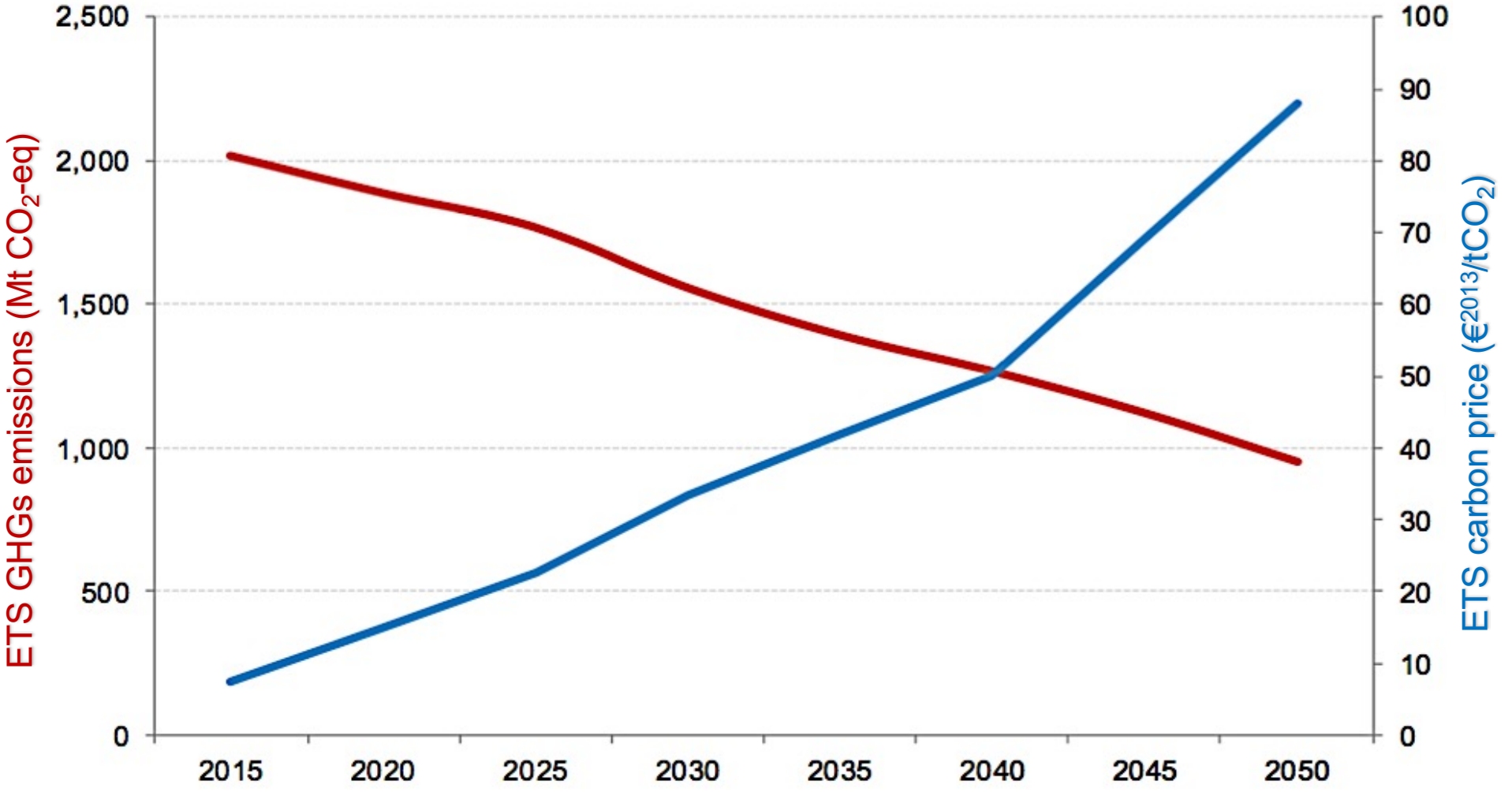
Energy cost

EU reference scenario 2016



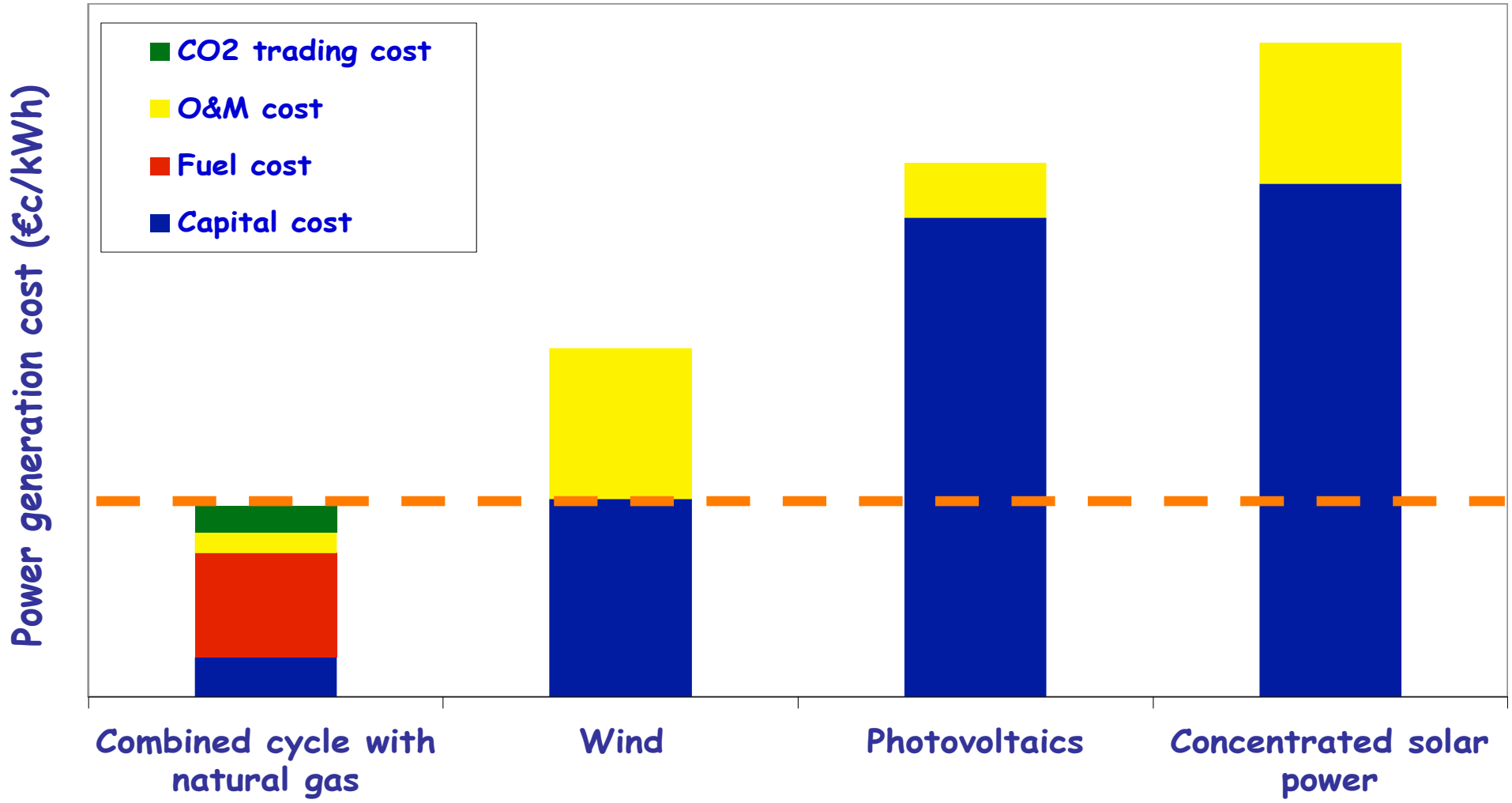
Source: PRIMES

EU reference scenario 2016



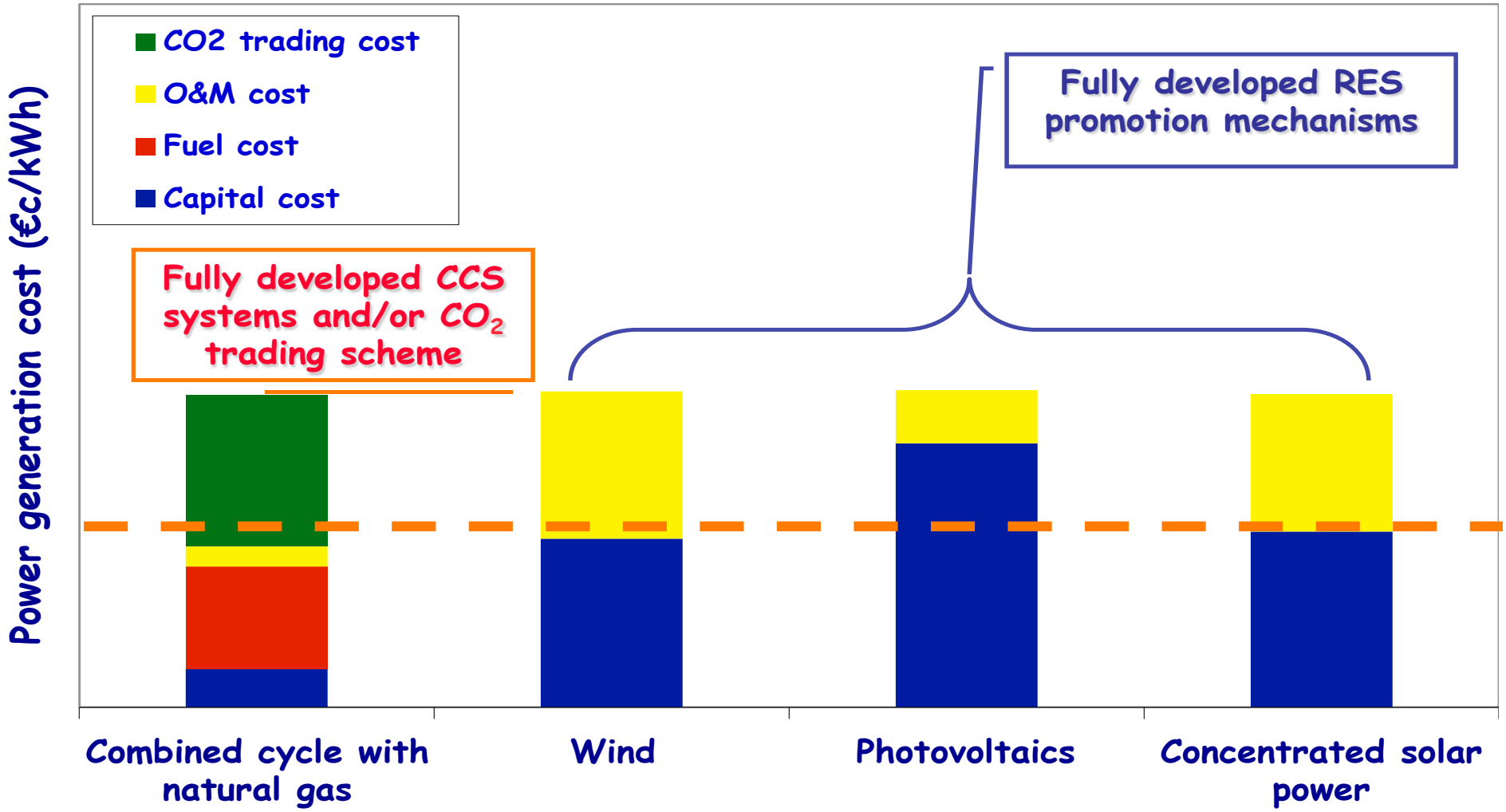
Source: PRIMES, GAINS

Power generation cost (year 2010)*



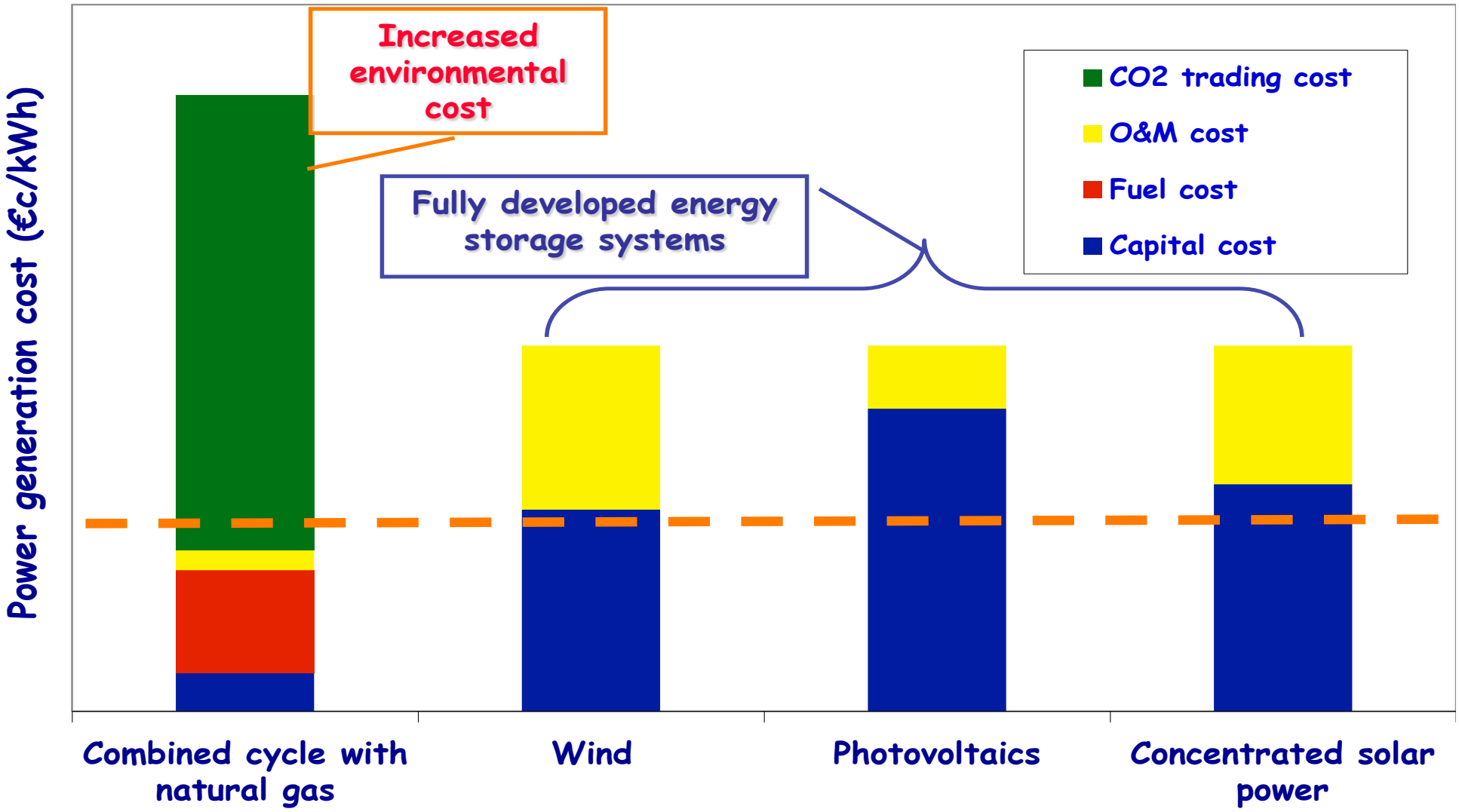
* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

Power generation cost (year 2020-30)*



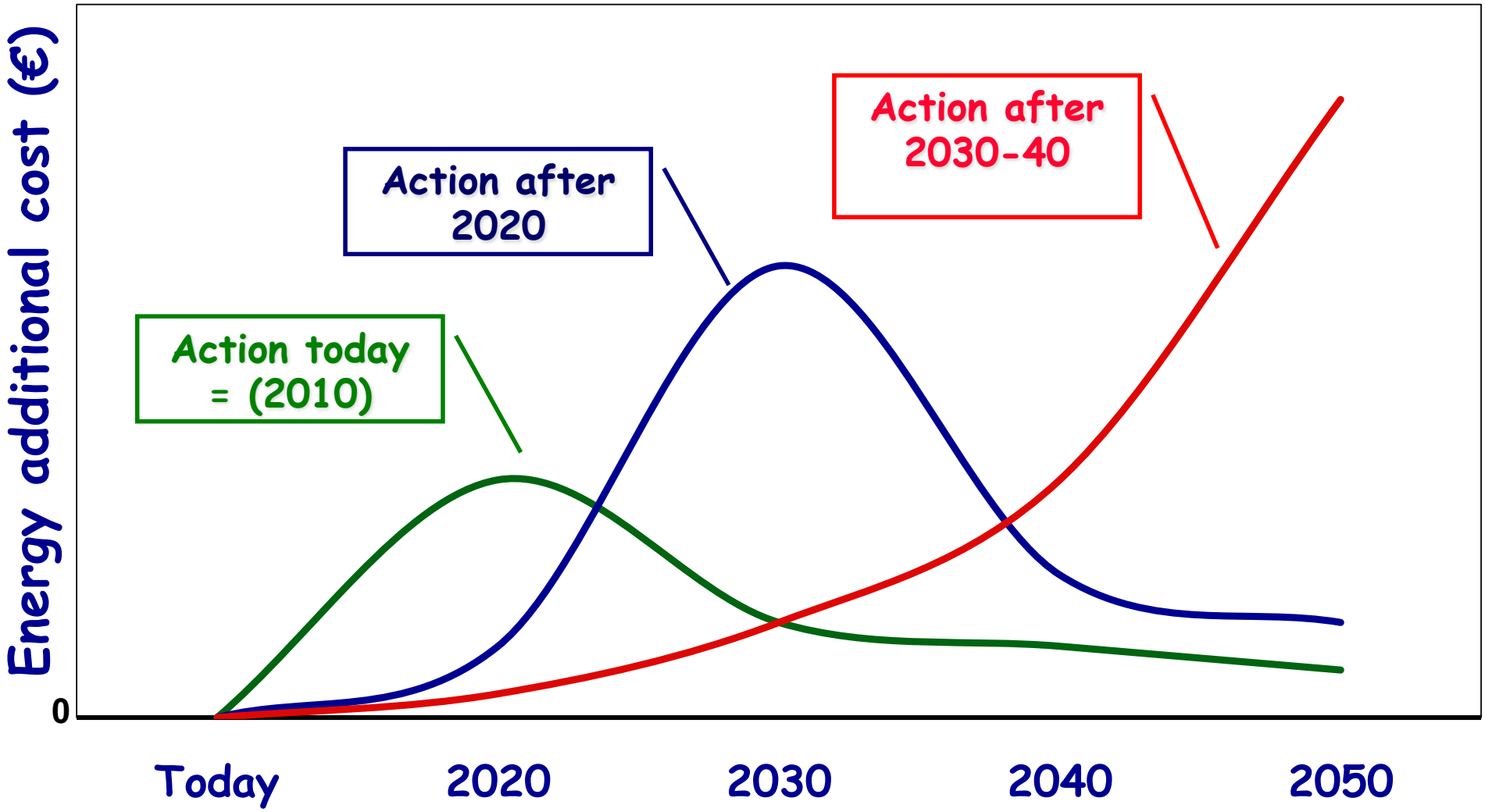
* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

Power generation cost (year 2040-50)*



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

Future energy cost* (for EU only)



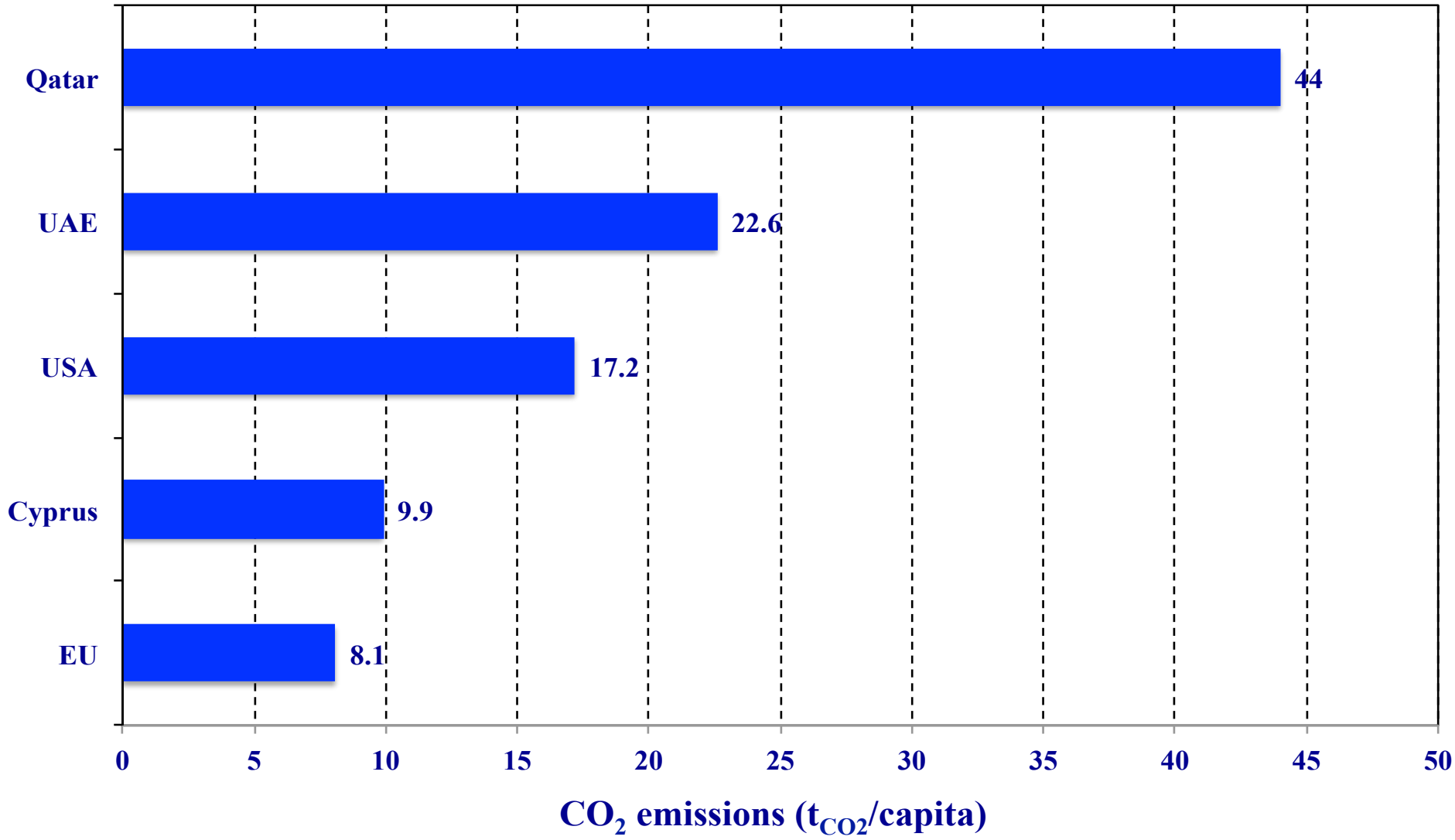
* Poullikkas A., 2010, "The cost of integration of renewable energy sources", *Accountancy*

Panel discussion

Main energy challenges for UAE

- Increase in population
- Increase in electricity demand
- Increase in CO_2 emissions
- Depletion of energy sources – Natural gas
- Electricity tariffs heavily subsidized

CO_2 emissions



Electricity tariffs in UAE*

Emirate	User type	Tariff (US$c/kWh)	Comments
Abu Dhabi	National	1.36	Flat rate
	Non-national	4.08	Flat rate
	Industrial	4.08	Flat rate
	Commercial	4.08	Flat rate
Dubai	Residential	5.45	Below 2000kWh/month
		12.12	Above 2001kWh/month
	Industrial	5.45	Below 10000kWh/month
		12.12	Above 10001kWh/month
	Governmental	5.45	Below 10000kWh/month
		12.12	Above 10001kWh/month

* Poullikkas A., Gadalla M., 2013, "Assessment of solar electricity production in United Arab Emirates", *International Journal of Sustainable Energy*

Next steps

ρυθμιστική αρχή ενέργειας κύπρου
cyprus energy regulatory authority

First steps towards the development of UAE sustainable energy strategy

- **Horizon up to 2060**
- **Integration of sustainable technologies***
- **Use of net-metering for domestic PV systems****
- **Use of auctioning schemes for new power capacity**
- **Use of hydrogen after 2030**
- **Hydrogen production*****
  - **Nuclear power**
  - **Solar technologies**

* Poullikkas A., Zueter A.F., Dirar M.H., , 2015, "Prospective scenarios for the adoption of sustainable power generation technologies in United Arab Emirates", *International Journal of Sustainable Energy*

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*** Babu B.S., Orhan M., Poullikkas A., 2013, "Mitigation of Environmental Impact via an Integrated Hydrogen production system based on solar and nuclear energy sources in U.A.E.", *Proceedings of the 4th International Conference on Renewable Energy and Sources and Energy Efficiency*