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# Challenges towards carbon neutral energy systems

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- **Short to medium term challenges** – large scale integration of RES
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# EU energy strategy

## towards 2050

# Current energy system

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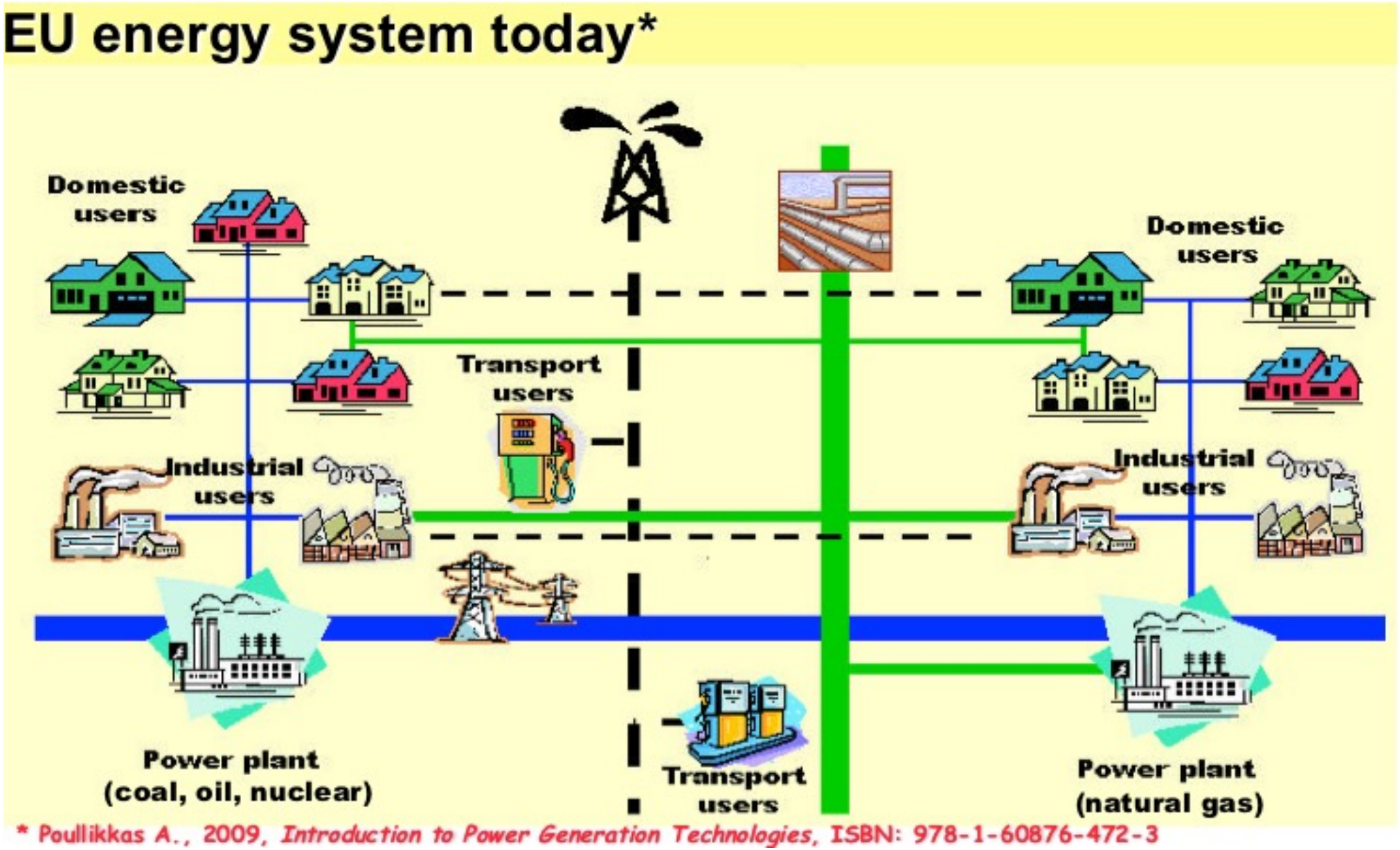

# Future energy systems (optimistic scenario)

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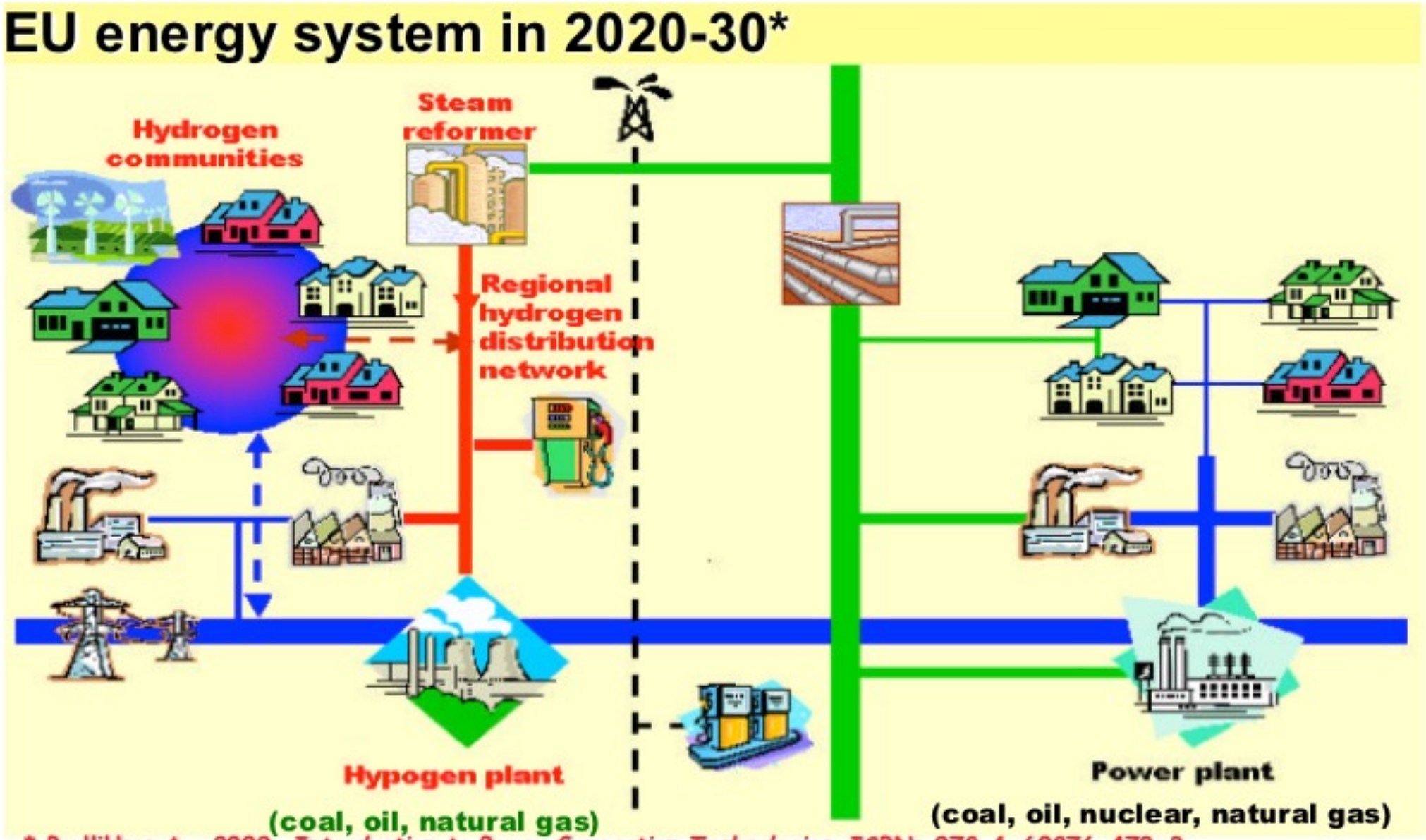

# Future energy systems (optimistic scenario)

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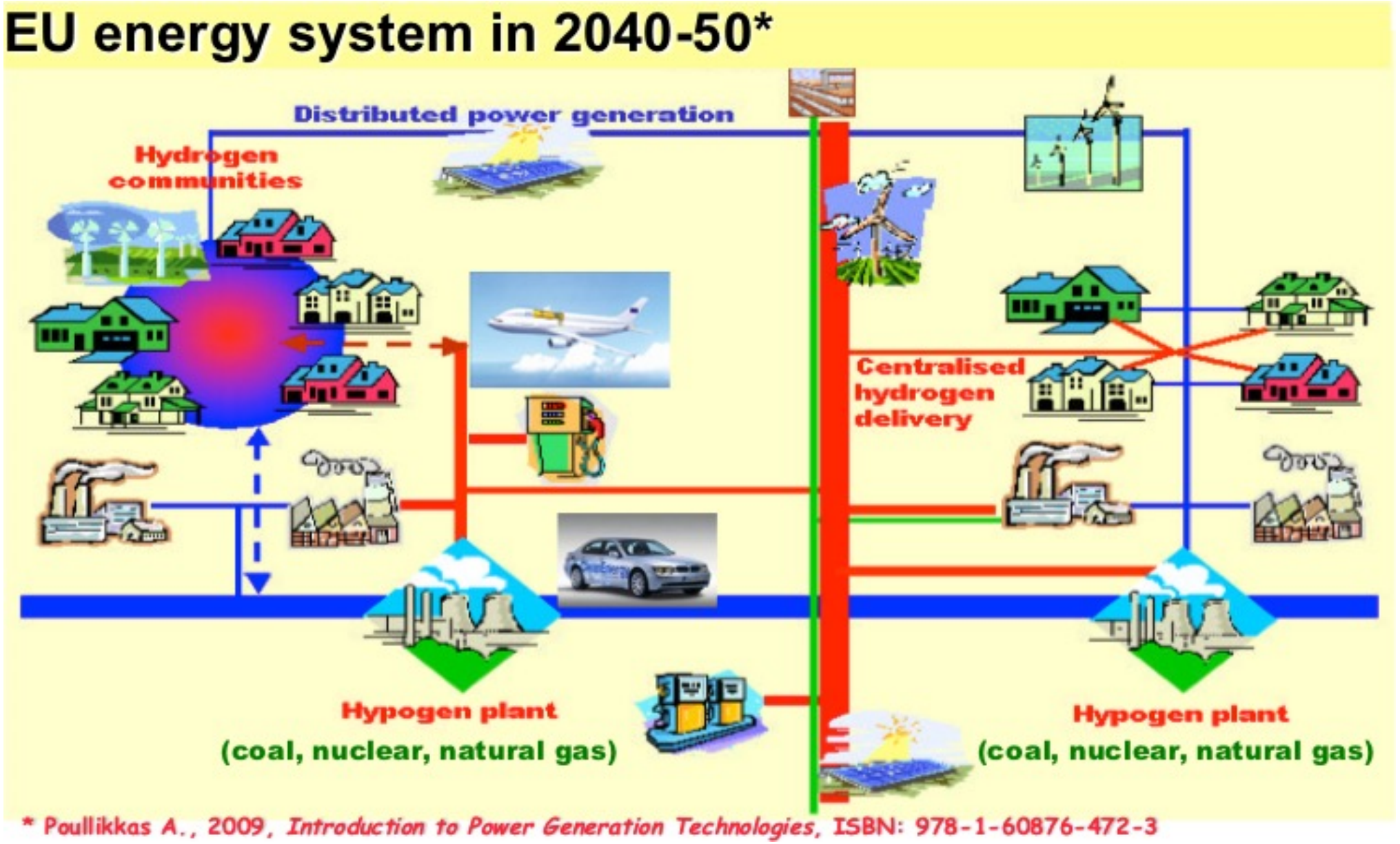
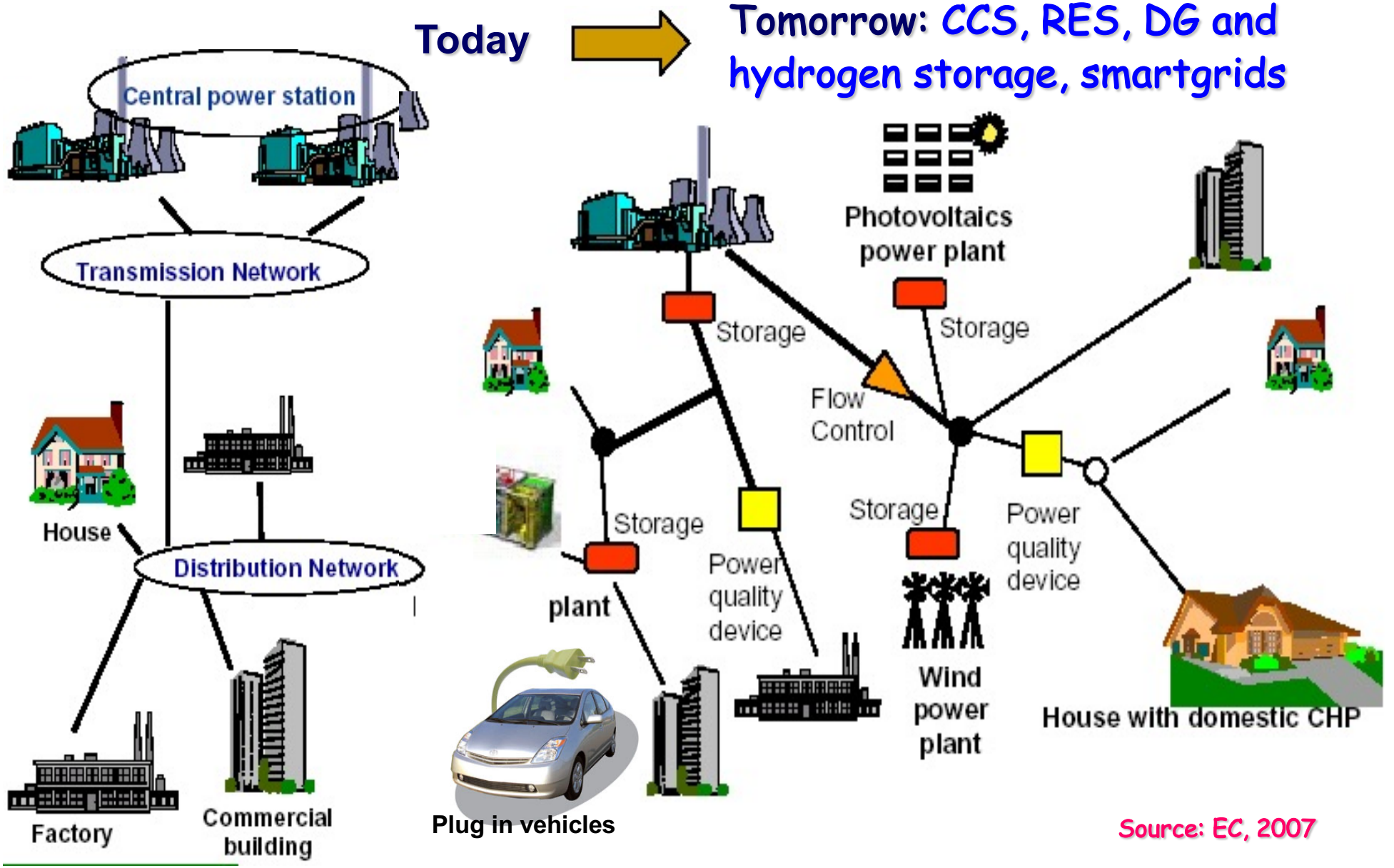


# Future power systems



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

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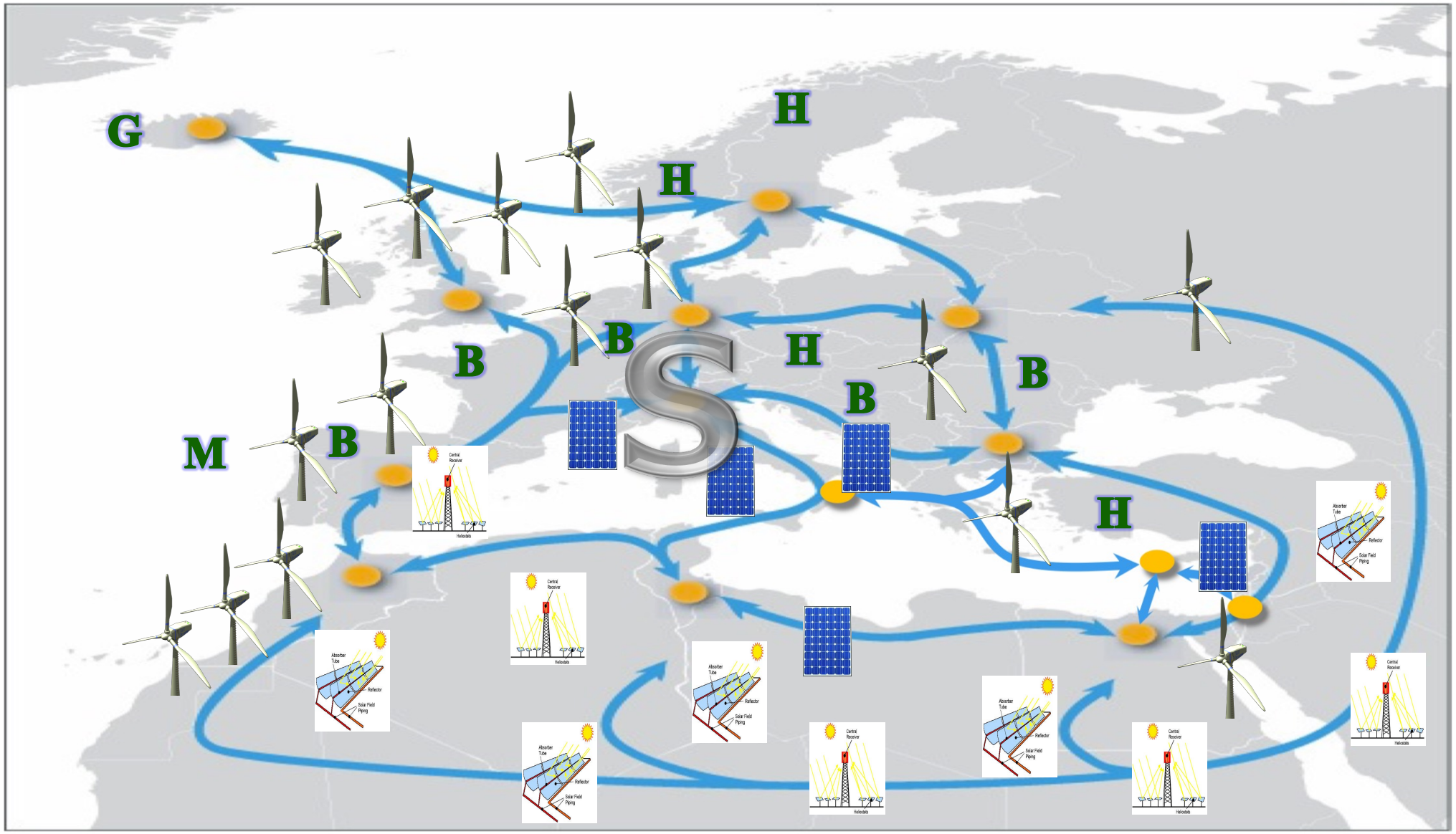


* Poullikkas A., 2013, *Sustainable Energy Development for Cyprus*, ISBN: 978-9963-7355-3-2

# Long term scenarios in Europe

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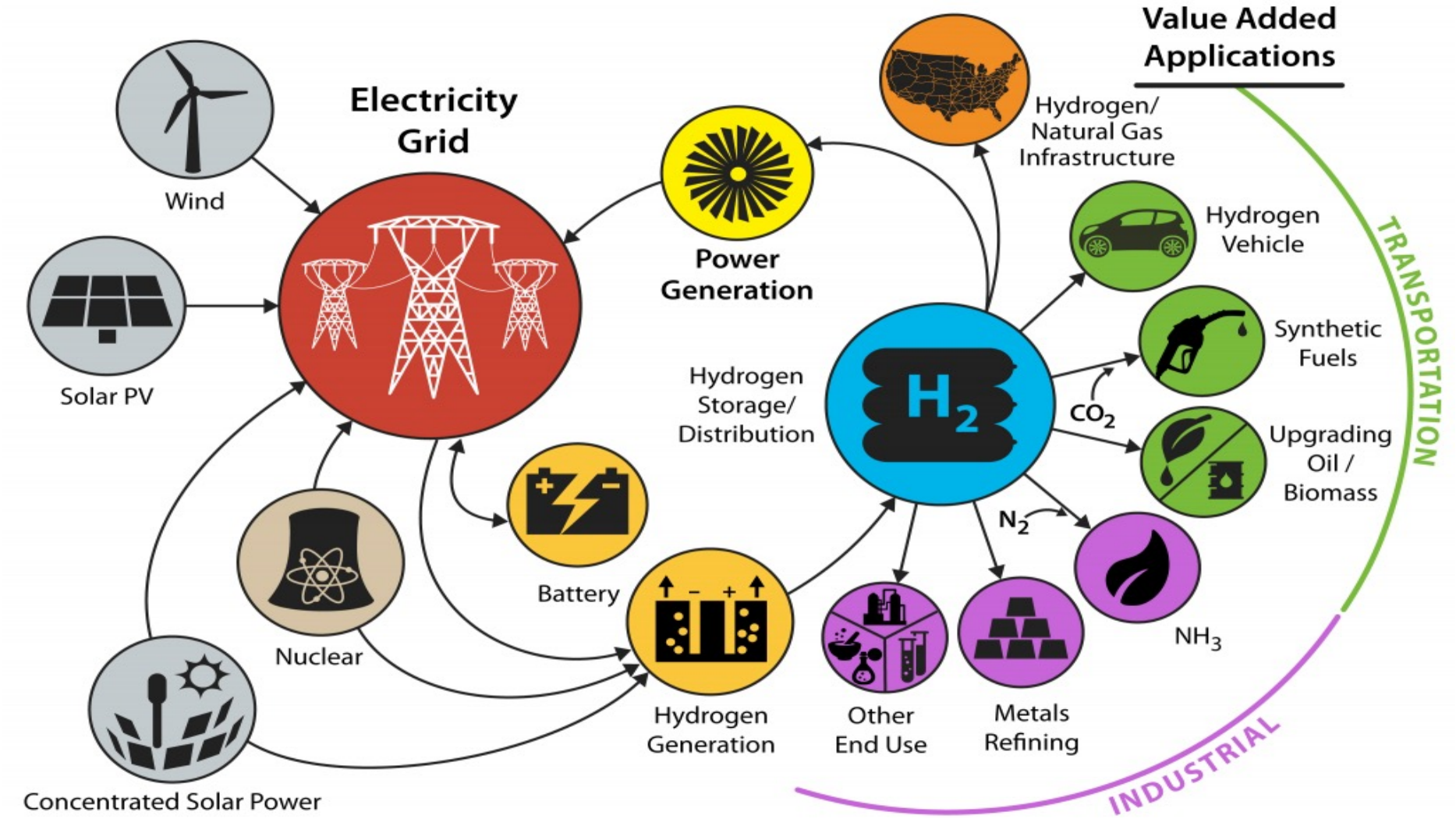
## Moving from Carbon economy to Hydrogen economy



# Energy transition for island systems

## Solutions for isolated systems

# Characteristics of isolated electricity systems*

- **High fuel costs**
  - ~ use of oil derivatives
- **Economies of scale cannot be adequately exploited**
  - ~ generation units cannot exceed a certain size since the loss of a unit would mean the loss of a high percentage of the entire system
- **Need to maintain high reserve capacity to ensure power system reliability**

**The smaller the electrical system size, the more the expenses will be**

* Poullikkas A., 2015, *Sustainable Energy Policy for Cyprus*, ISBN: 978-9963-7355-6-3

# The solution*

- **Increase system flexibility**
  - ~ integrate RES into electricity market
  - ~ use natural gas, storage and RES for power generation
  - ~ promote e-mobility (V2G technology - bidirectional flow of electricity between the electric car and the grid)
- **Establish electricity interconnections**
  - ~ with EU internal electricity market (the island of Cyprus is the only non-interconnected Member State)
- **Production of hydrogen** (energy carrier)
  - ~ from RES and natural gas

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

# CERA Energy Transition Regulatory Decisions

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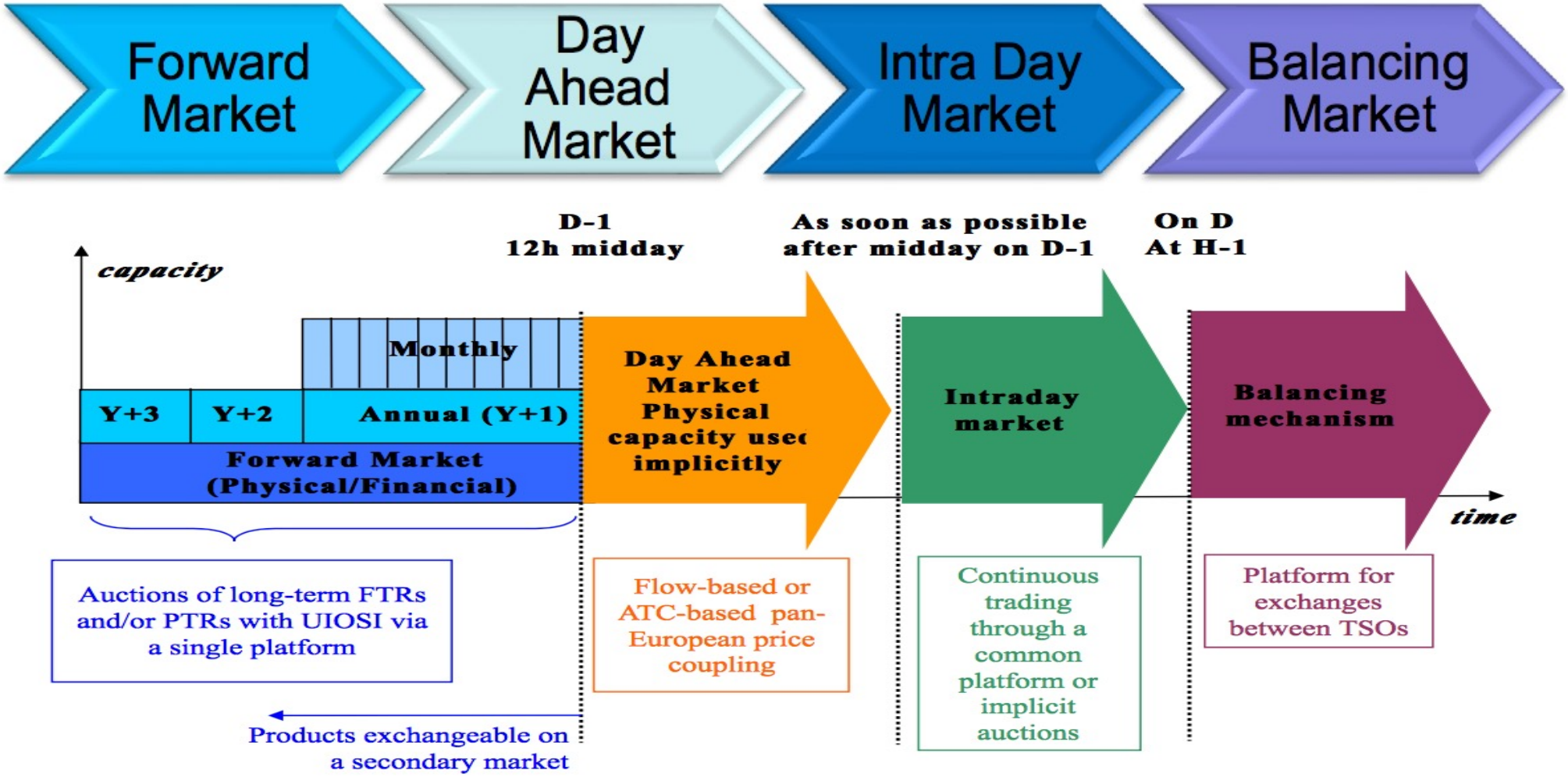
- **Regulatory Decision 01/2017 (ΚΔΠ 34/2017): A detailed schedule for the implementation of EU electricity market target model**
- **Regulatory Decision 02/2018 (ΚΔΠ 259/2018): The mass installation of an Advanced Metering Infrastructure including smartmeters to all electricity consumers**
- **Regulatory Decision 02/2019 (ΚΔΠ 204/2019): The establishment of basic principles of a regulatory framework for the operation of electricity storage systems in the wholesale electricity market**
- **Regulatory Decision 03/2019 (ΚΔΠ 224/2019): The redesign of the power grid to become smart and bi-directional in order to allow integration of large quantities of renewable energy sources in combination with energy storage systems**

# Short to medium term challenges

## Large scale integration of RES

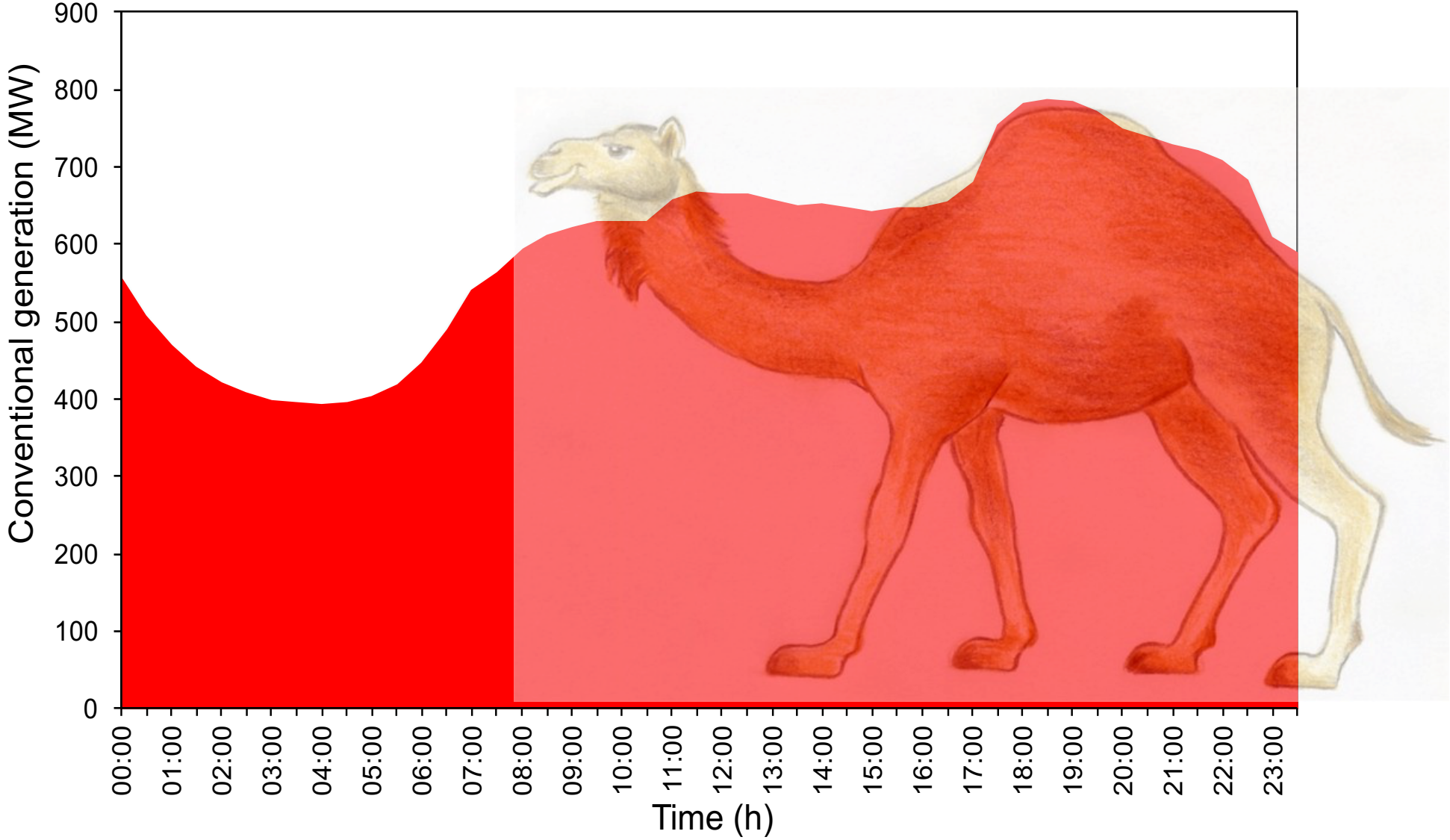
# EU electricity market target model




# Integration of RES*: LCOE *vs* Reliability

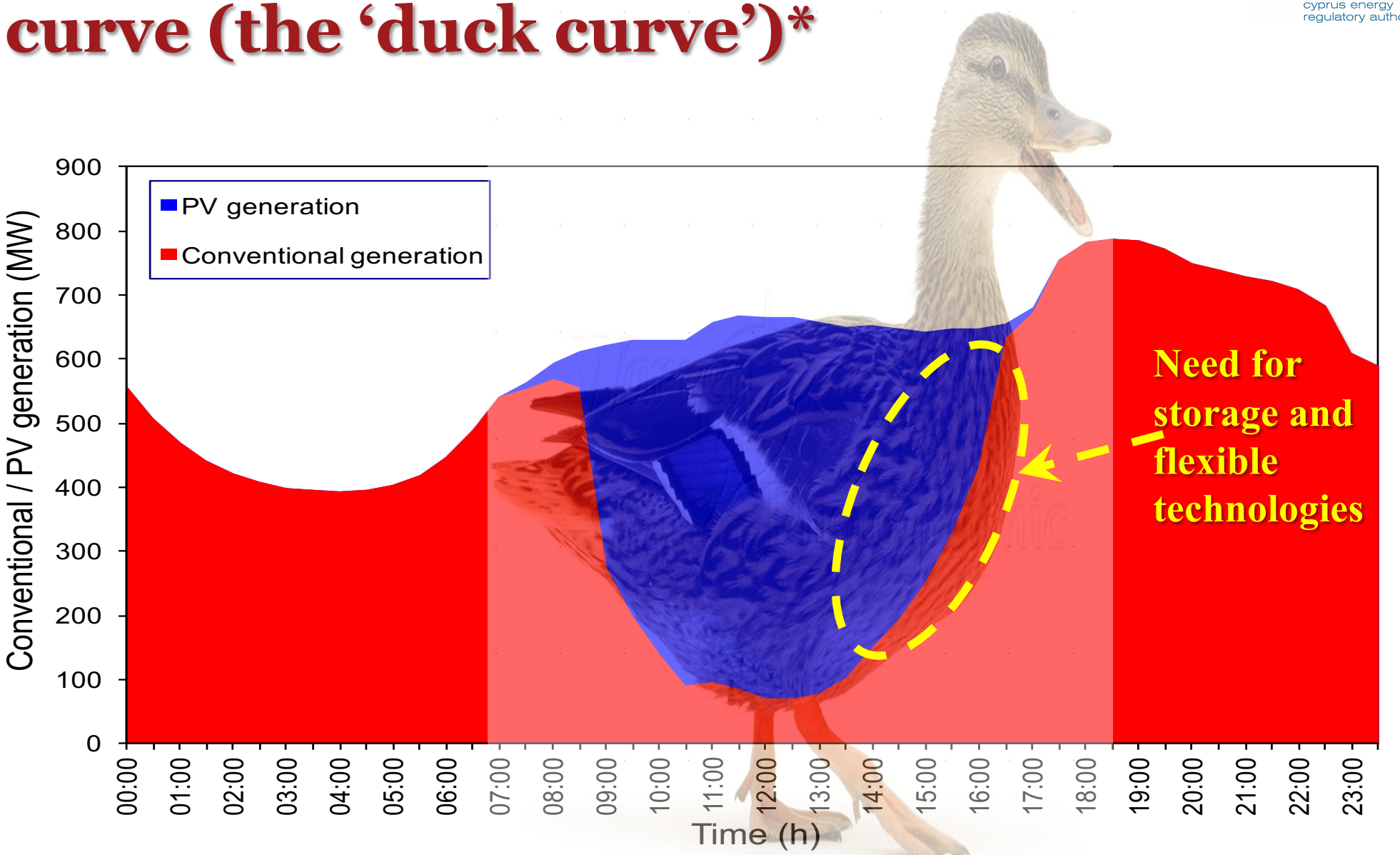
* Nicolaidis P., Chatzis S., Poullikkas A., 2018, "Renewable energy integration through optimal unit commitment and electricity storage in weak power networks", *International Journal of Sustainable Energy*

# 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*

# Medium to long term challenges

## The role of interconnections and hydrogen

# Regional primary energy sources

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## Indigenous energy sources

# Gas reserves in SE Mediterranean region*

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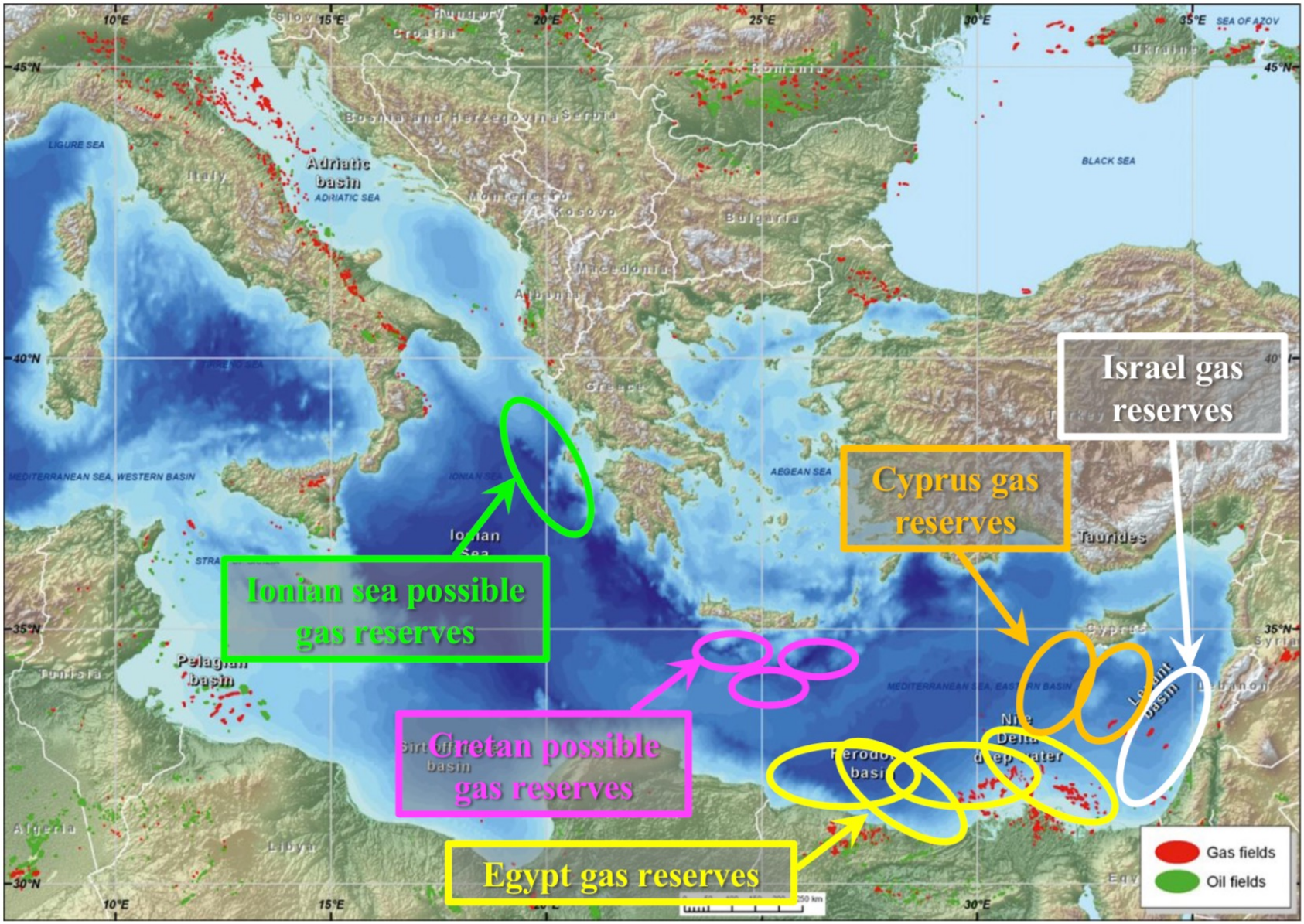


* A. Belopolsky, *et al.*, 2012, "New and emerging plays in the Eastern Mediterranean", *Petroleum Geoscience*

# Wind potential in SE Mediterranean region*

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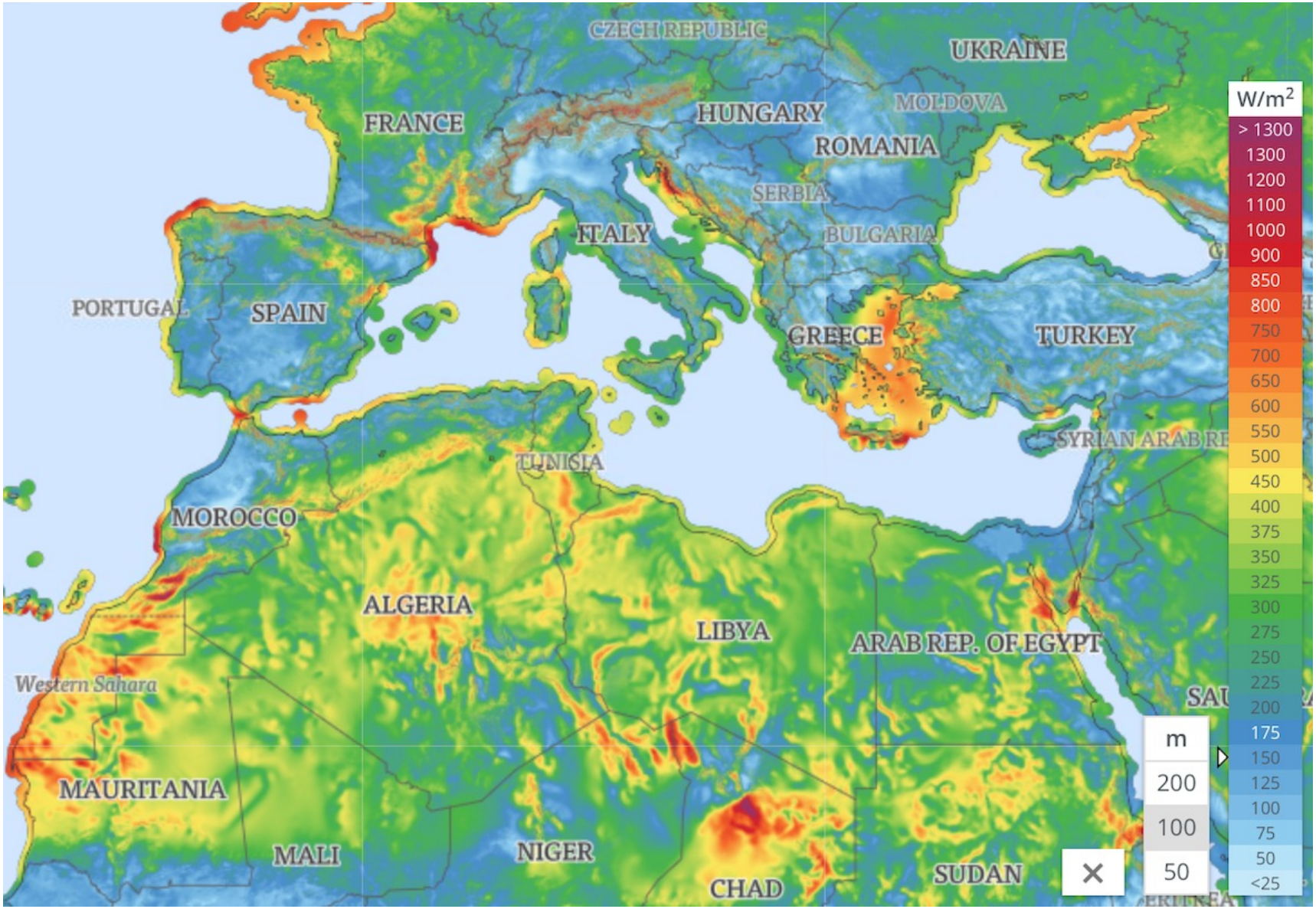


* The Global Wind Atlas (https://globalwindatlas)

# Solar potential in SE Mediterranean region*

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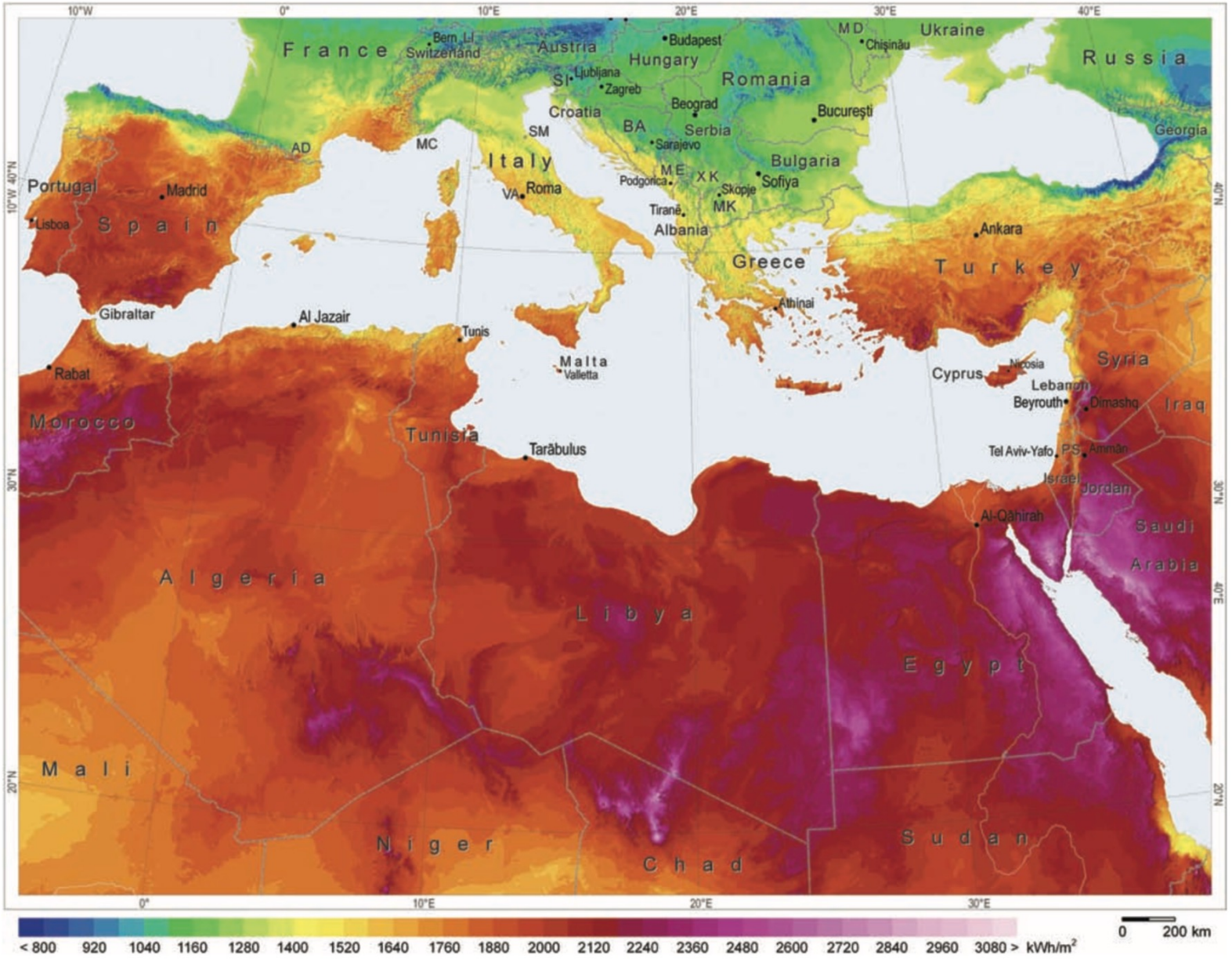
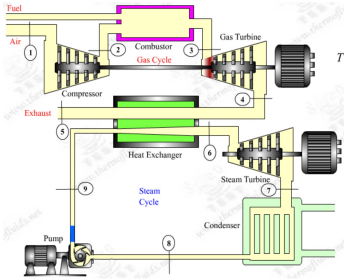



* Easac & Pihl, Erik. (2011). Concentrating Solar Power: Its potential contribution to a sustainable energy future

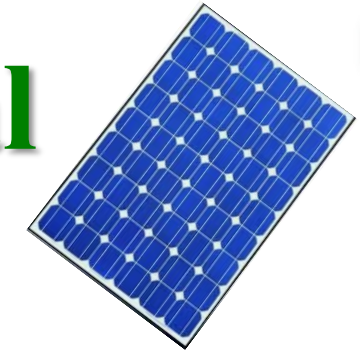
# Main indigenous energy sources in SE Mediterranean region

- Natural gas




- Wind potential

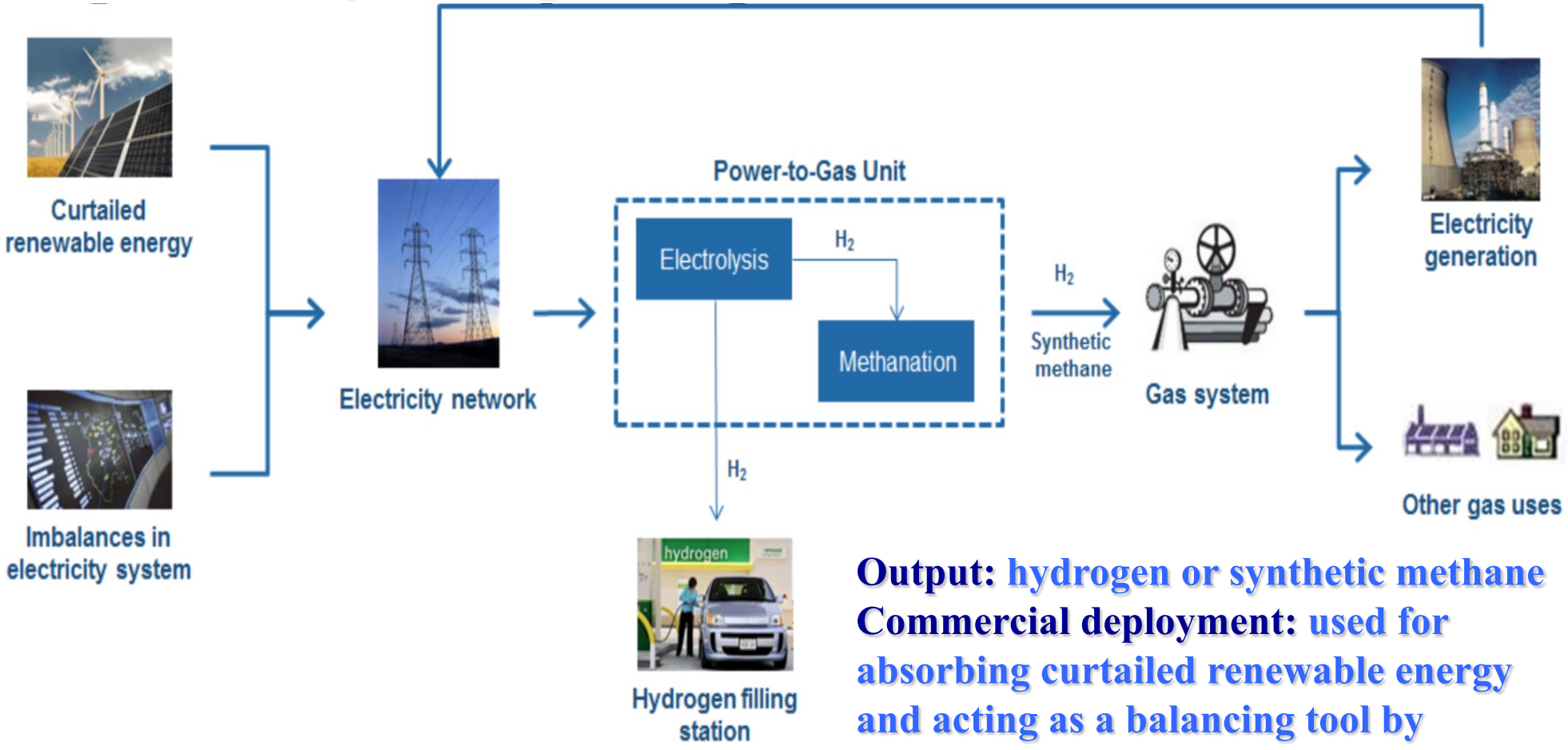
- Solar potential



hydrogen

# 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

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

# Target-setting for Cyprus' transition to hydrogen economy*

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| Target | Year | | |
|---|---|---|---|
| | 2030 | 2040 | 2050 |
| Greenhouse gases | -30% | -75% | -100% |
| Renewable energy sources | 30% | 75% | 100% |
| Electrical interconnections | 50% | 65% | 80% |

**Cyprus could set a long-term goal of reducing greenhouse gas emissions by 100% by 2050 !**

* Poullikkas A., 2020, *Long-term Sustainable Energy Strategy: Cyprus' Energy Transition to Hydrogen Economy*, ISBN: 978-9925-7710-0-4

# Energy transition by 2050

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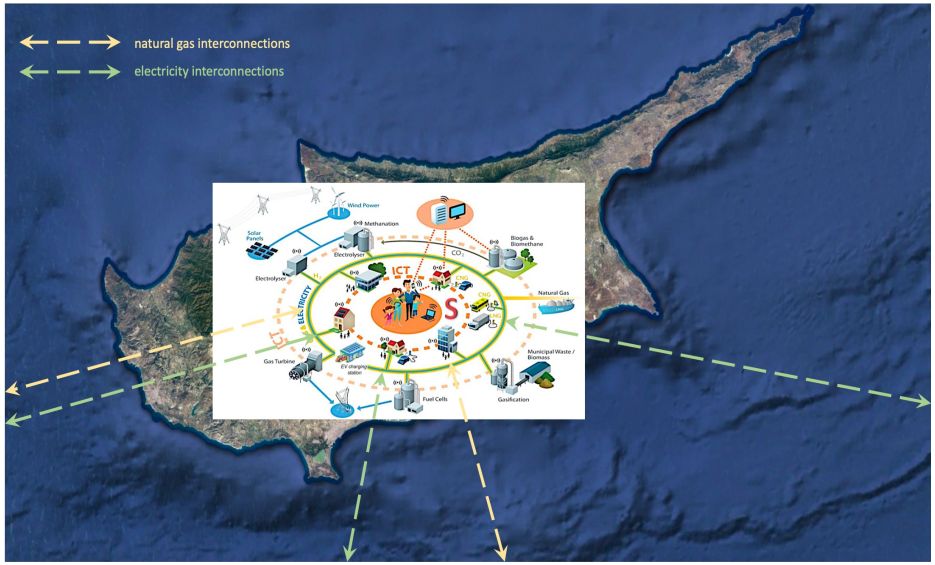
## Cyprus' energy system:

- smart and digitised
- flexible
- decentralised
- electrically interconnected
- interconnected gas and/or hydrogen pipelines




## Integration:

- hydrogen in all energy sectors
- renewable energy sources
- storage energy systems
- electric mobility

**Transition of Cyprus from the current carbon economy to hydrogen economy by the year 2050**

# Development of regional energy strategy ?

- **Horizon up to 2060**
- **Development of strategic plan for SE Med region:**
  - ~ **Electrical interconnections**
  - ~ **Pipeline interconnections (or virtual pipelines)**
  - ~ **Integration of sustainable technologies and storage**
  - ~ **Use of hydrogen after 2030**
  - ~ **Hydrogen production**
    - From natural gas
    - From renewables
- **Energy exporters to EU**