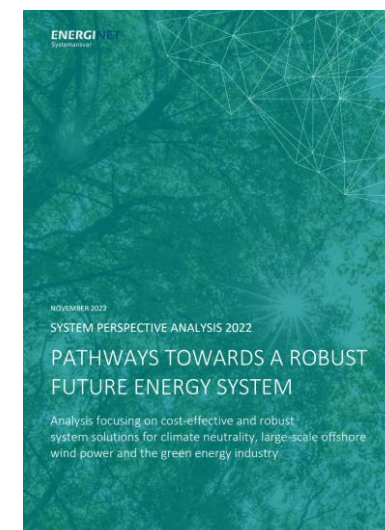


SYSTEM DEVELOPMENT TOWARDS A HIGHLY SECTOR COUPLED ENERGY SYSTEM – Strategy and R&D Roadmap for Denmark

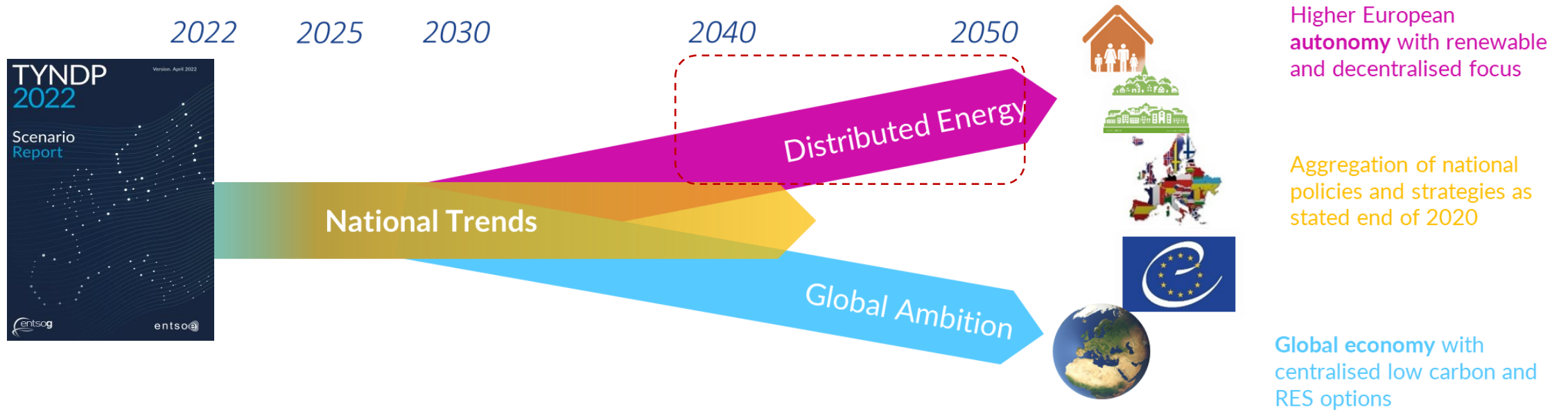
ESIG Spring 2023-03-30

Anders Bavnhøj Hansen (abh@Energinet.dk)
Chief Engineer
Energinet System Operator



See also material at link:
[System Perspectives towards a robust future energi system](#)

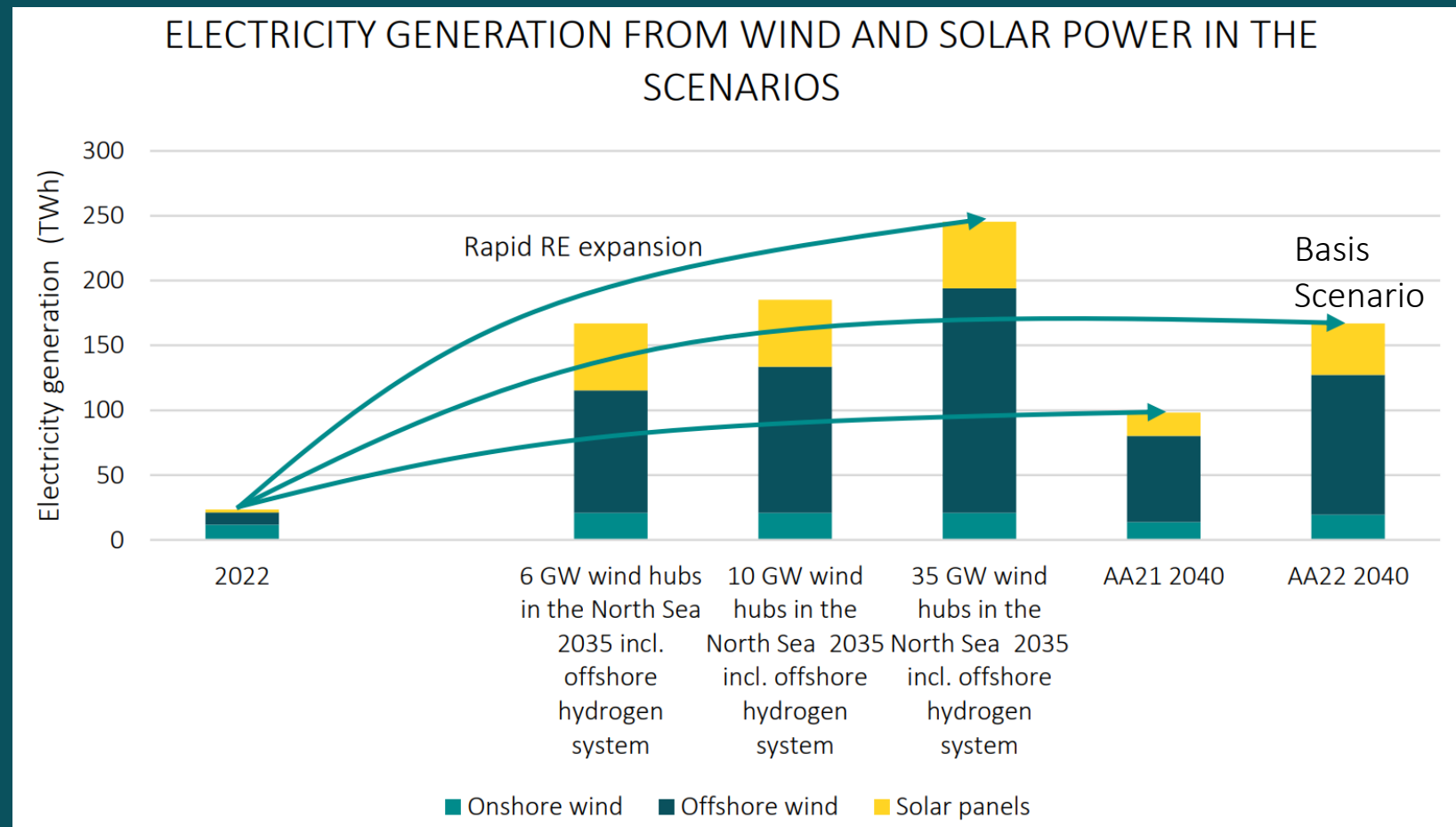
DK ANALYSIS USING EUROPEAN SCENARIOS AS A FRAMEWORK



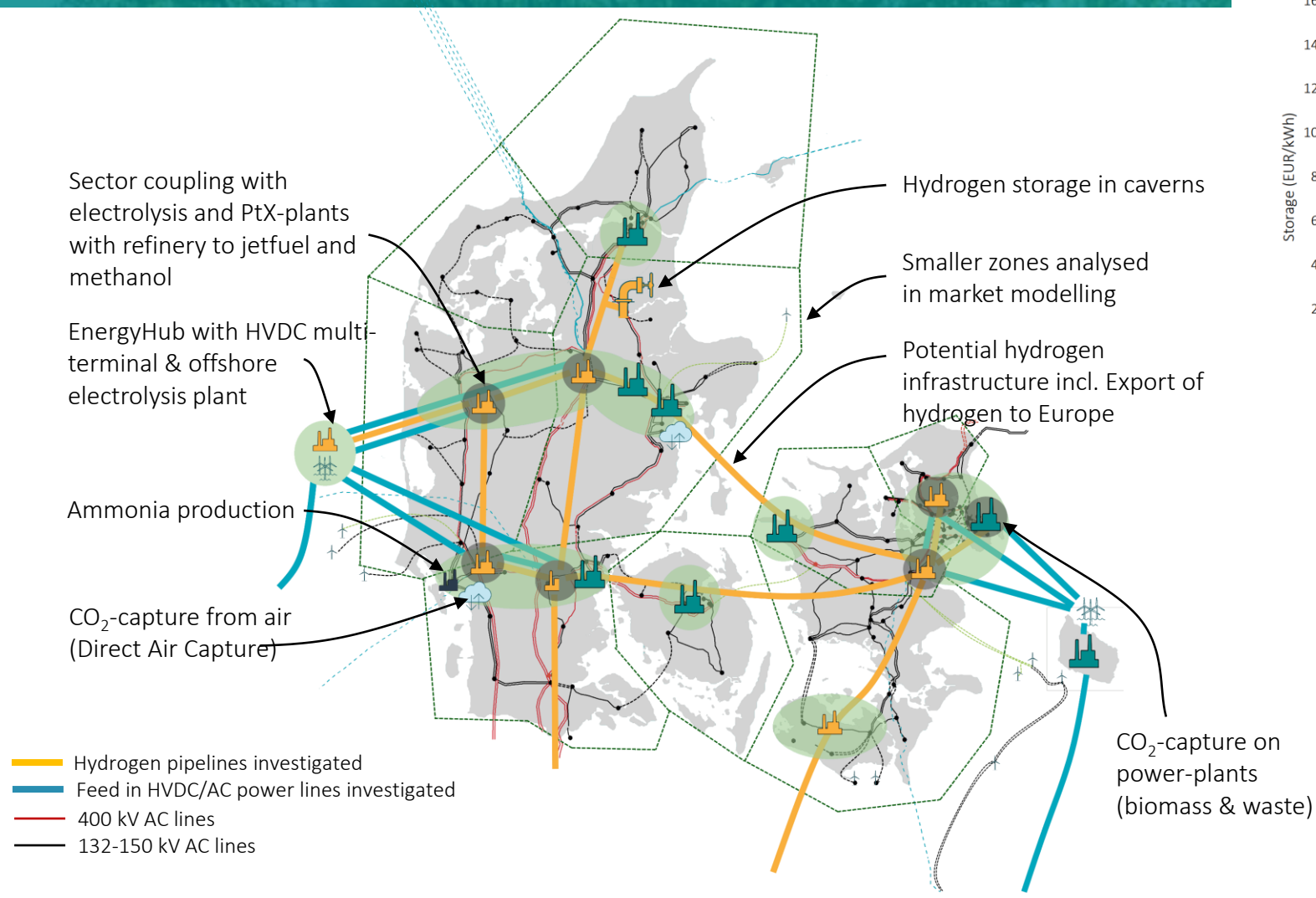
High focus on Distributed Energy in system perspective analysis

WIND AND SOLAR | THE SCENARIOS

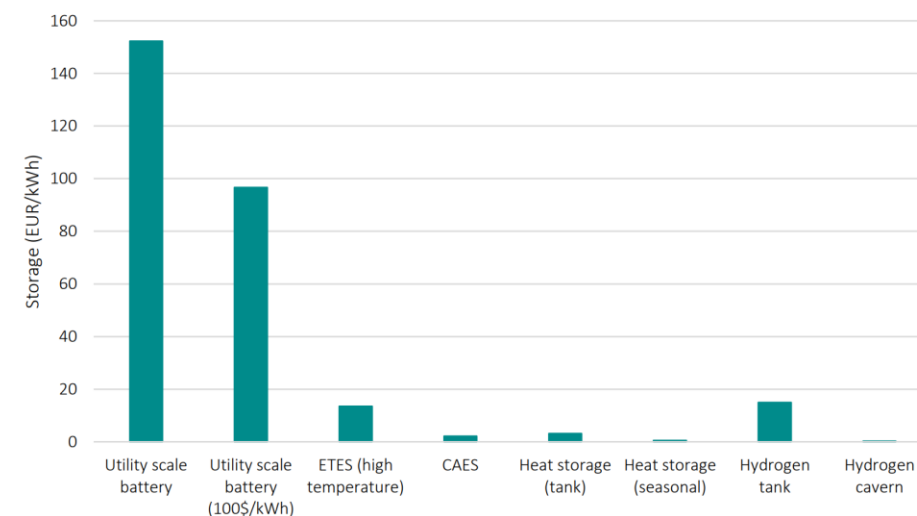
- Up to 35 GW offshore wind in the Northsea
- 35 GW solar



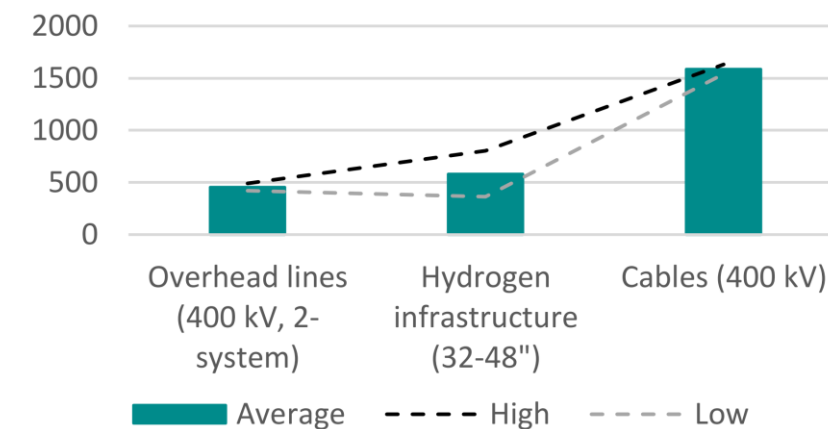
SYSTEM ANALYSIS OF SECTOR COUPLING



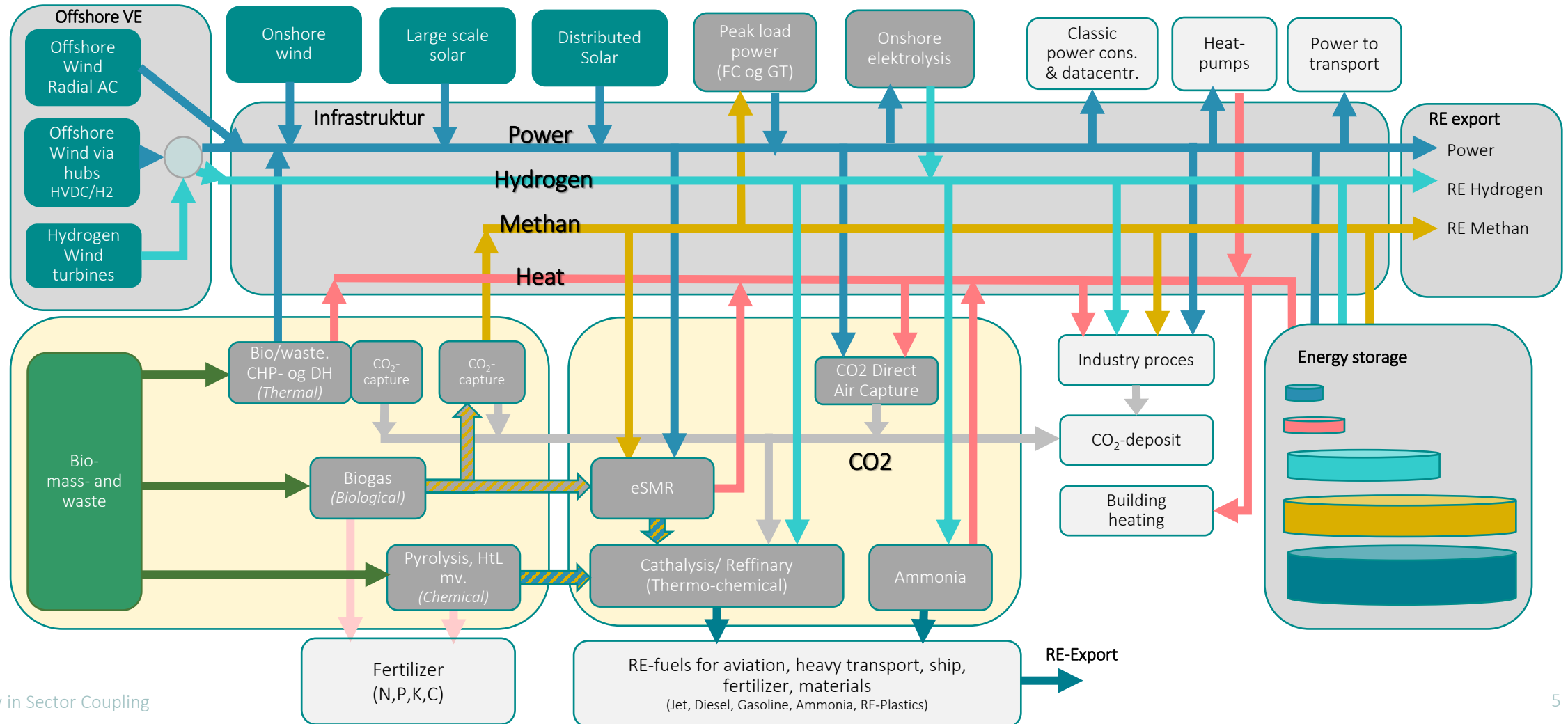
STORAGE COSTS (ENERGY PART)
(EXCL. DEVICES FOR CONVERSION)



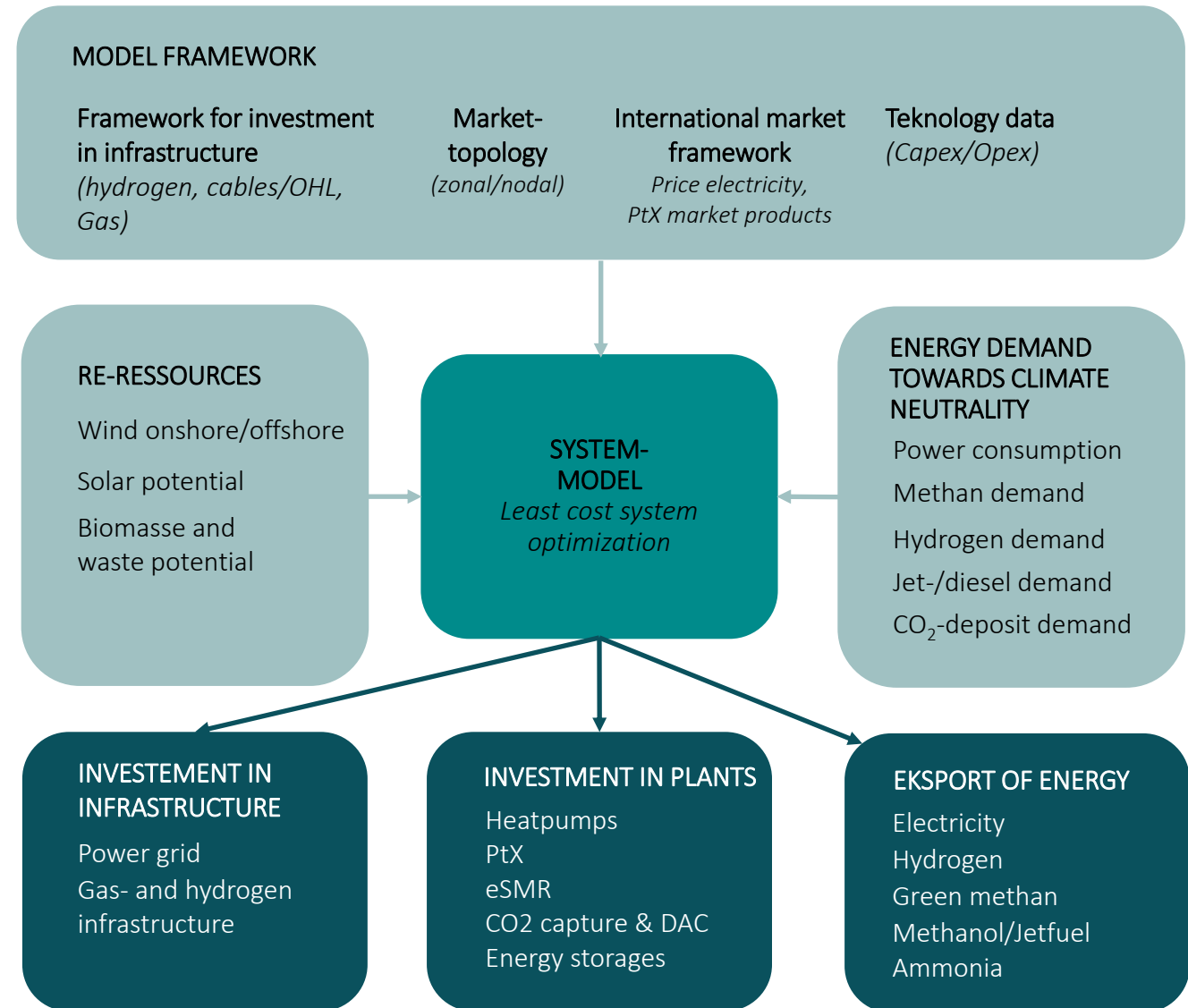
EUR/MW/km



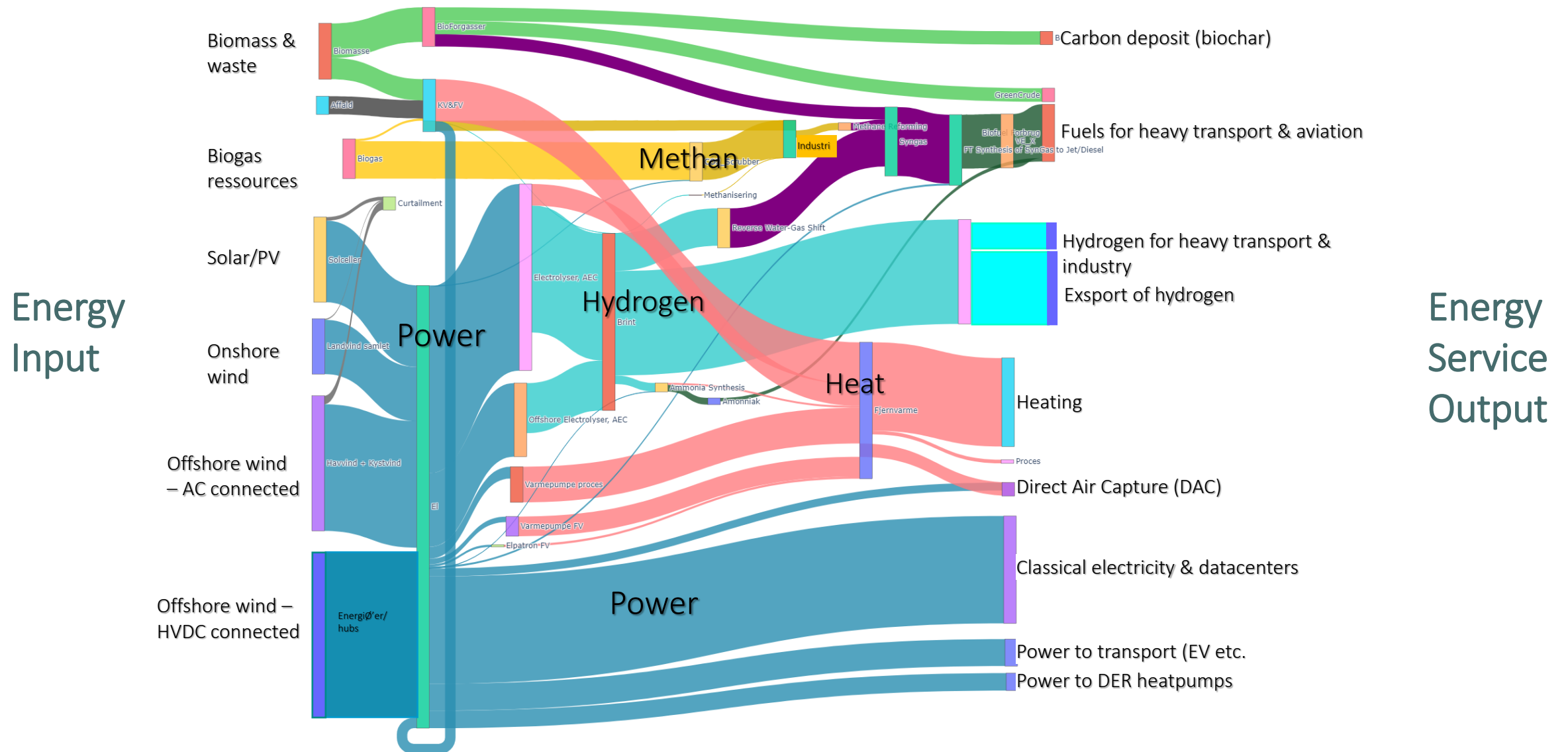
SECTOR COUPLING MODELLING



MODEL CONCEPT



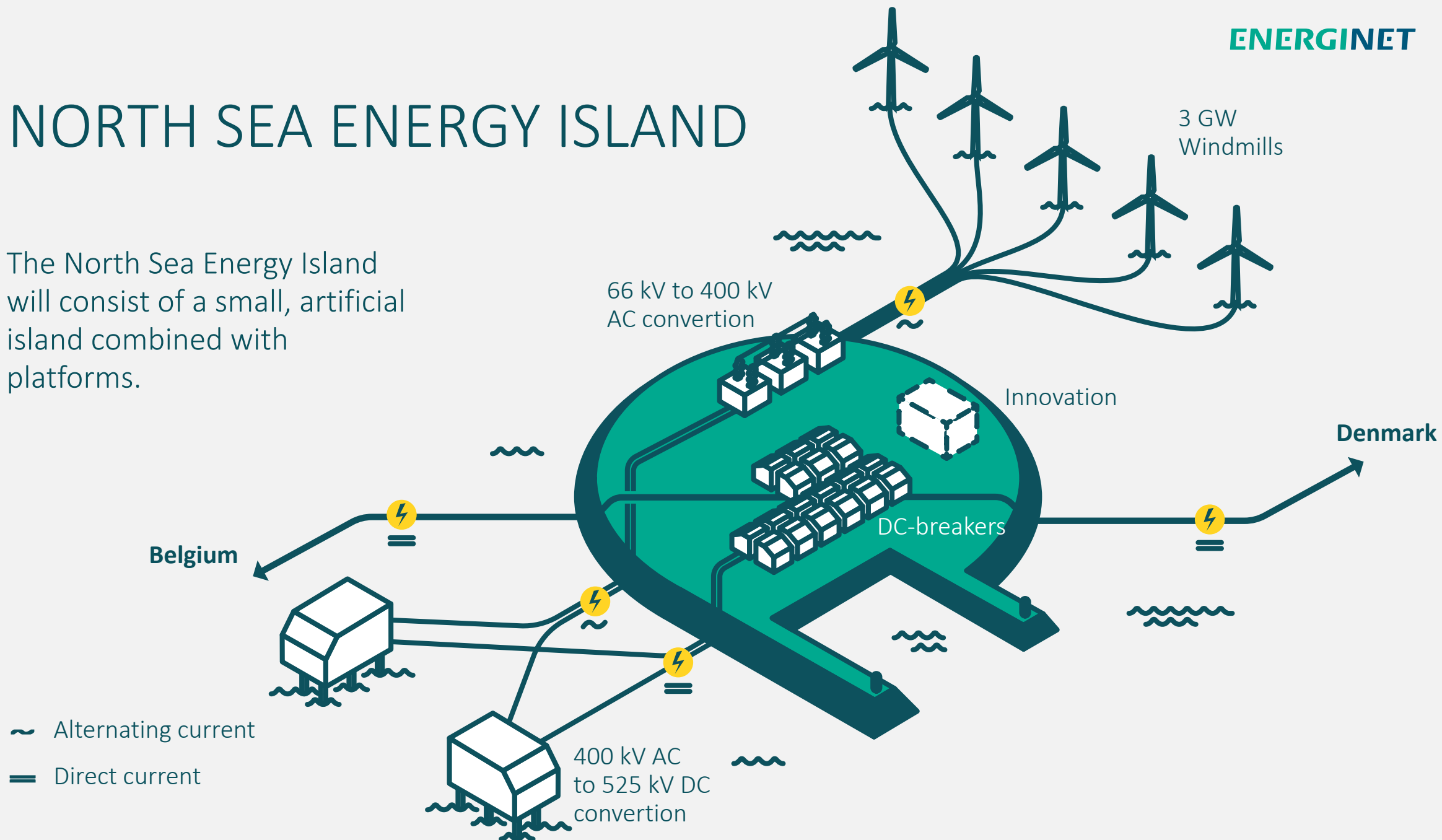
ENERGYFLOW – DENMARK SCENARIO 35 GW OFFSHORE IN DK NORTHSEA



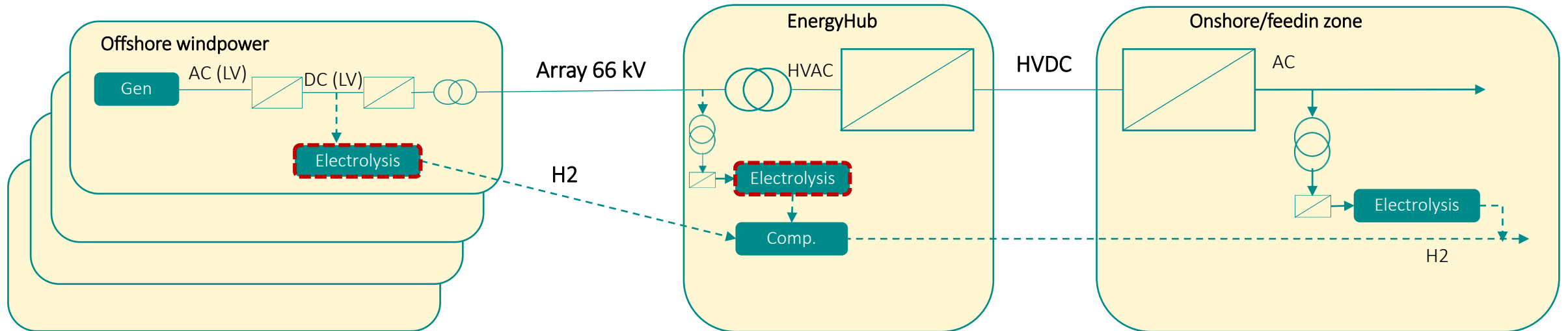
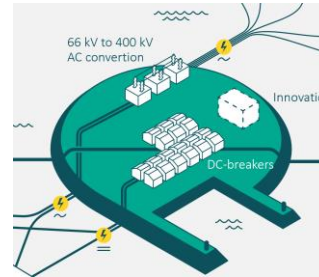
ENERGY HUBS IN A
SECTORCOUPLED PERSPECTIVE
(ONSHORE & OFFSHORE)

NORTH SEA ENERGY ISLAND

The North Sea Energy Island will consist of a small, artificial island combined with platforms.



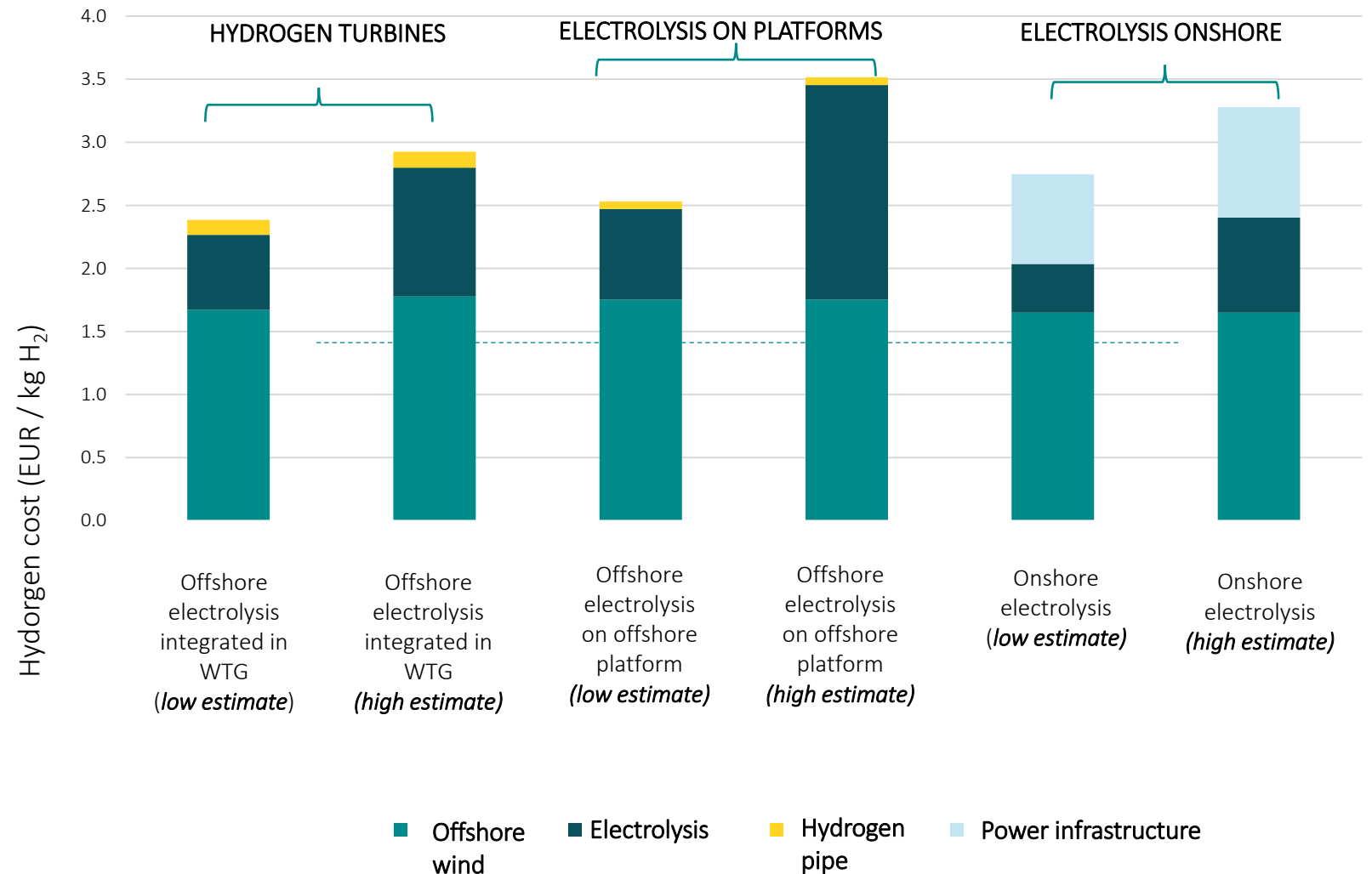
OFFSHORE ELECTROLYSIS POTENTIAL INVESTIGATED



CONCEPTS FOR ELECTROLYSIS CONNECTED TO OFFSHORE HUBS

Hydrogen production cost without additional benefit from electricity production

Hydrogen production cost 2030 (LCOH)
100 KM from coast (EUR/KG H₂) CAPEX (30 Years, 4 %) + OPEX

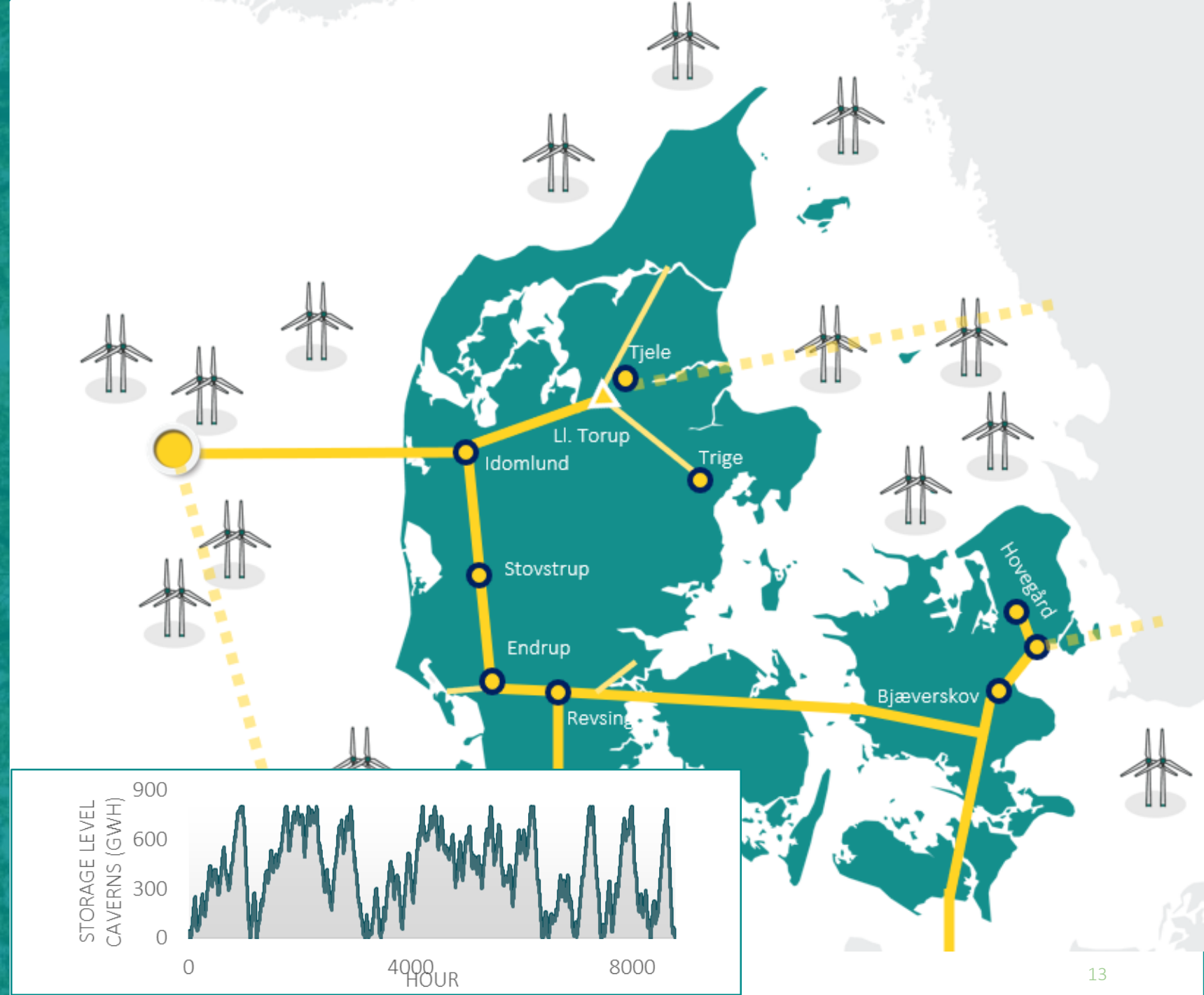
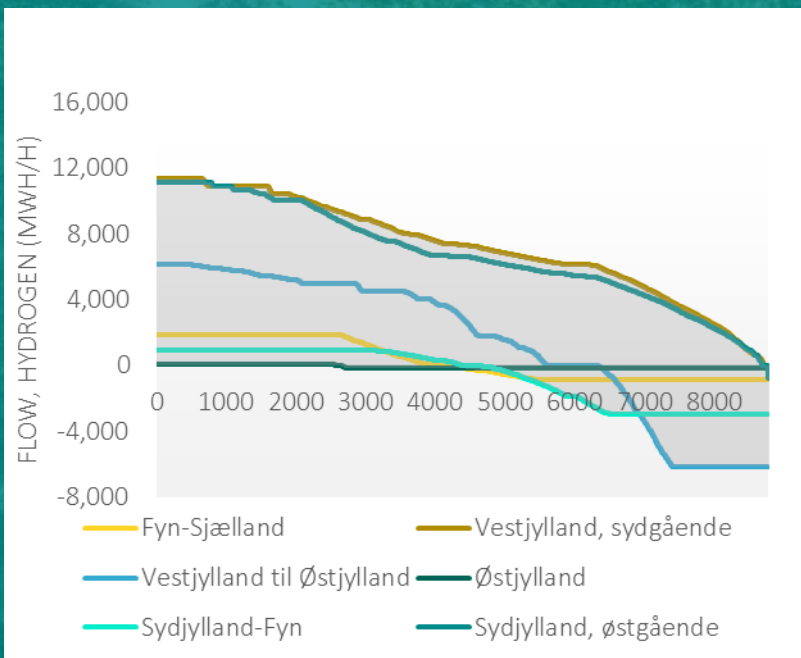




HYDROGEN INFRASTRUCTURE AS PART OF SECTOR COUPLED SYSTEM

INVESTMENT IN HYDROGEN INFRASTRUCTURE

- Hydrogen pipes are invested from a cost efficient optimization
- Scenario up to 35 GW North sea analysed



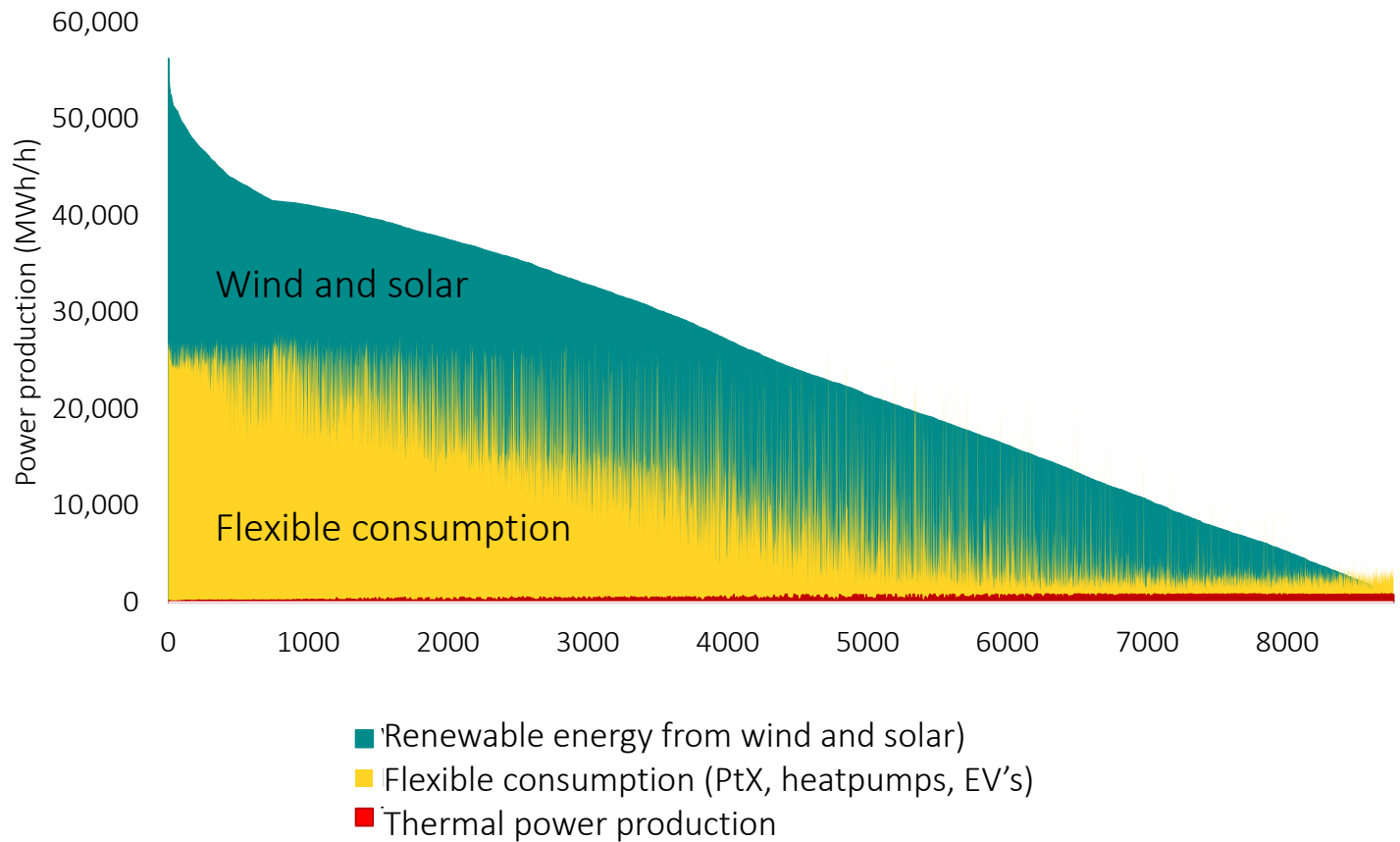


DEVELOPMENT OF POWER SYSTEM AT LARGE SCALE RE TOWARDS A CLIMATE NEUTRAL SYSTEM

WIND AND SOLAR DOMINATES POWER PRODUCTION IN 2035 SCENARIO

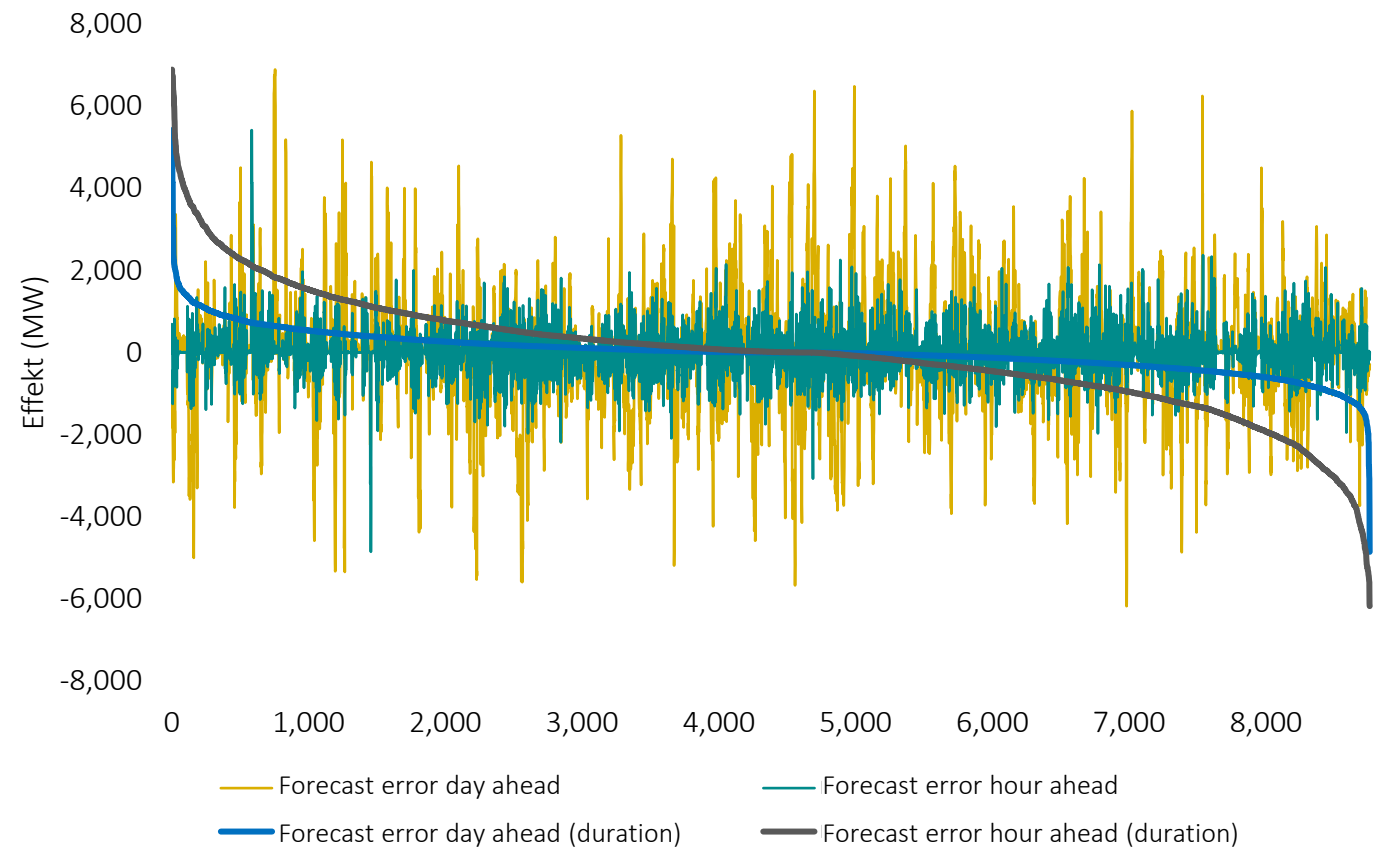
- Thermal power production very low in many hours during the year
- Flexible power consumption a very large balancing resource to ensure stability
- System stability and Gridforming capability from Power Electronic Interfaced Devices

POWER PRODUCTION AND FLEXIBLE CONSUMPTION
(SCENARIO WITH 35 GW OFFSHORE WIND IN NORTHSEA)



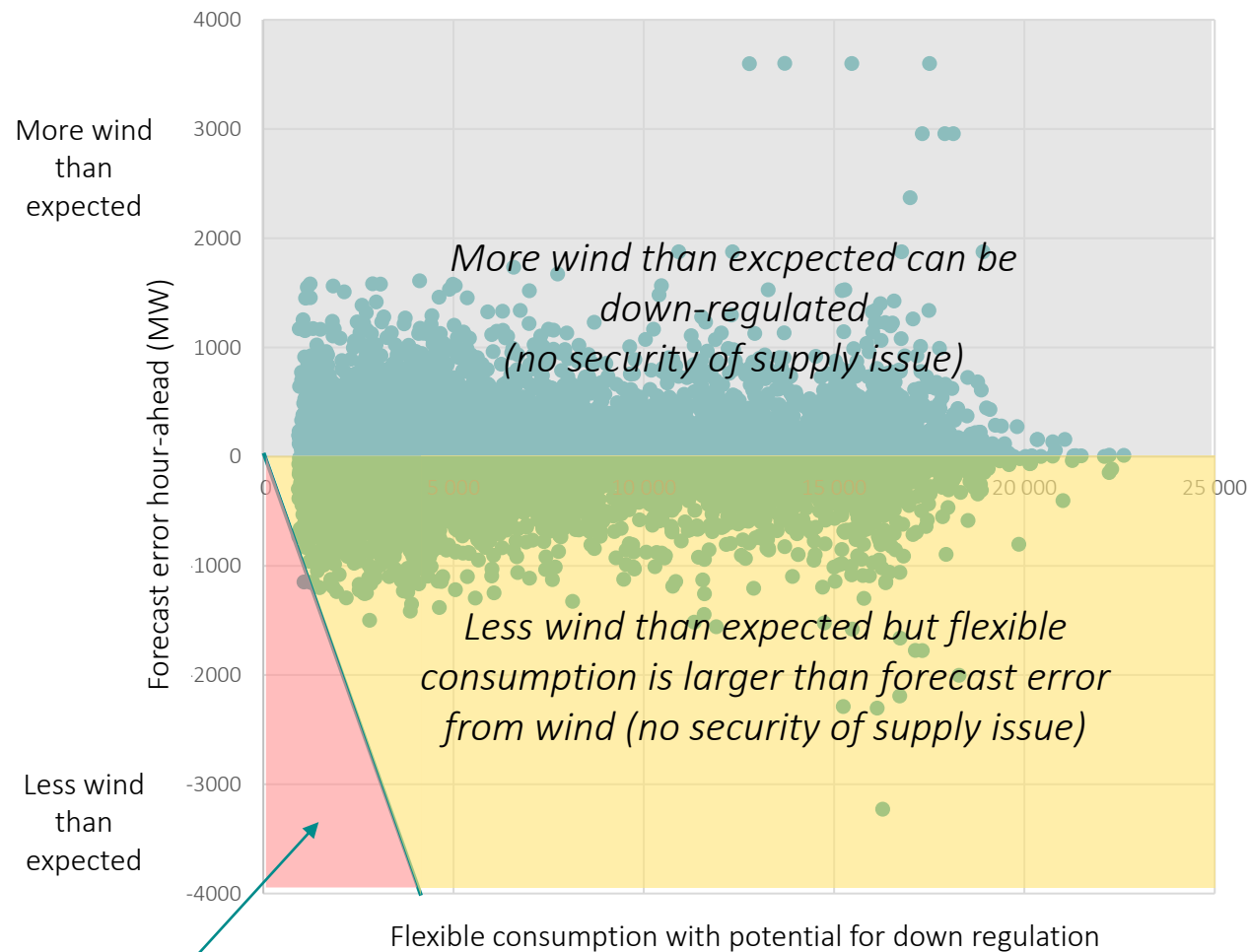
BALANCING OF FORECAST-ERROR FROM LARGE SCALE OFFSHORE WIND

EXAMPLE – FORECAST ERROR FROM OFFSHORE WIND
(Day ahead and 1 hour before operations time in scenario with 6 GW hubs in the
Nordsea (climate year 2008))



BALANCING OF FORECAST-ERROR FROM LARGE SCALE OFFSHORE WIND

ACCESS TO FLEXIBLE POWER CONSUMPTION VERSUS FORECAST ERROR FROM
OFFSHORE WIND (hour-ahead case)

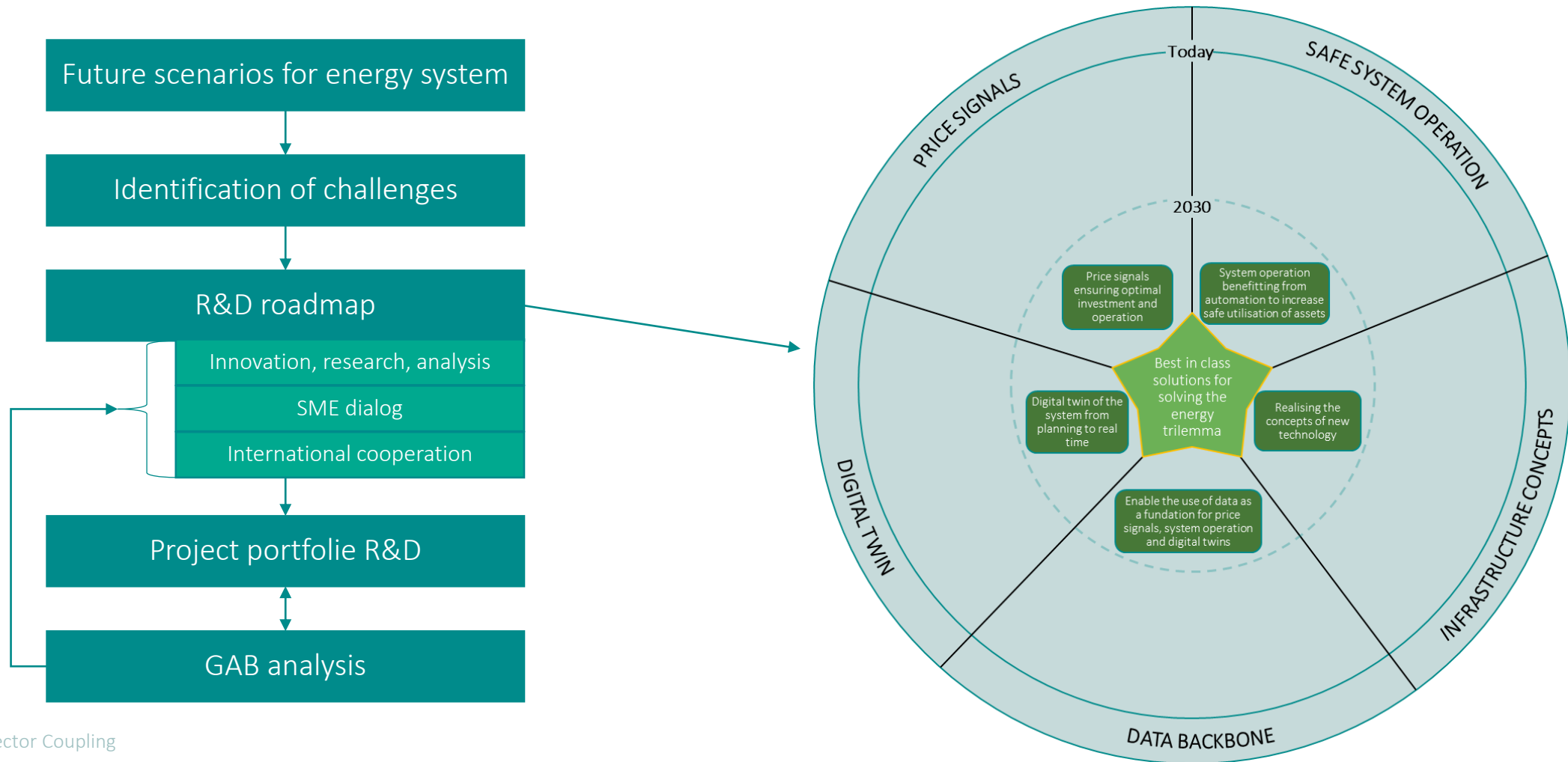


Need for upregulation from power-plants or eg. Battery storages



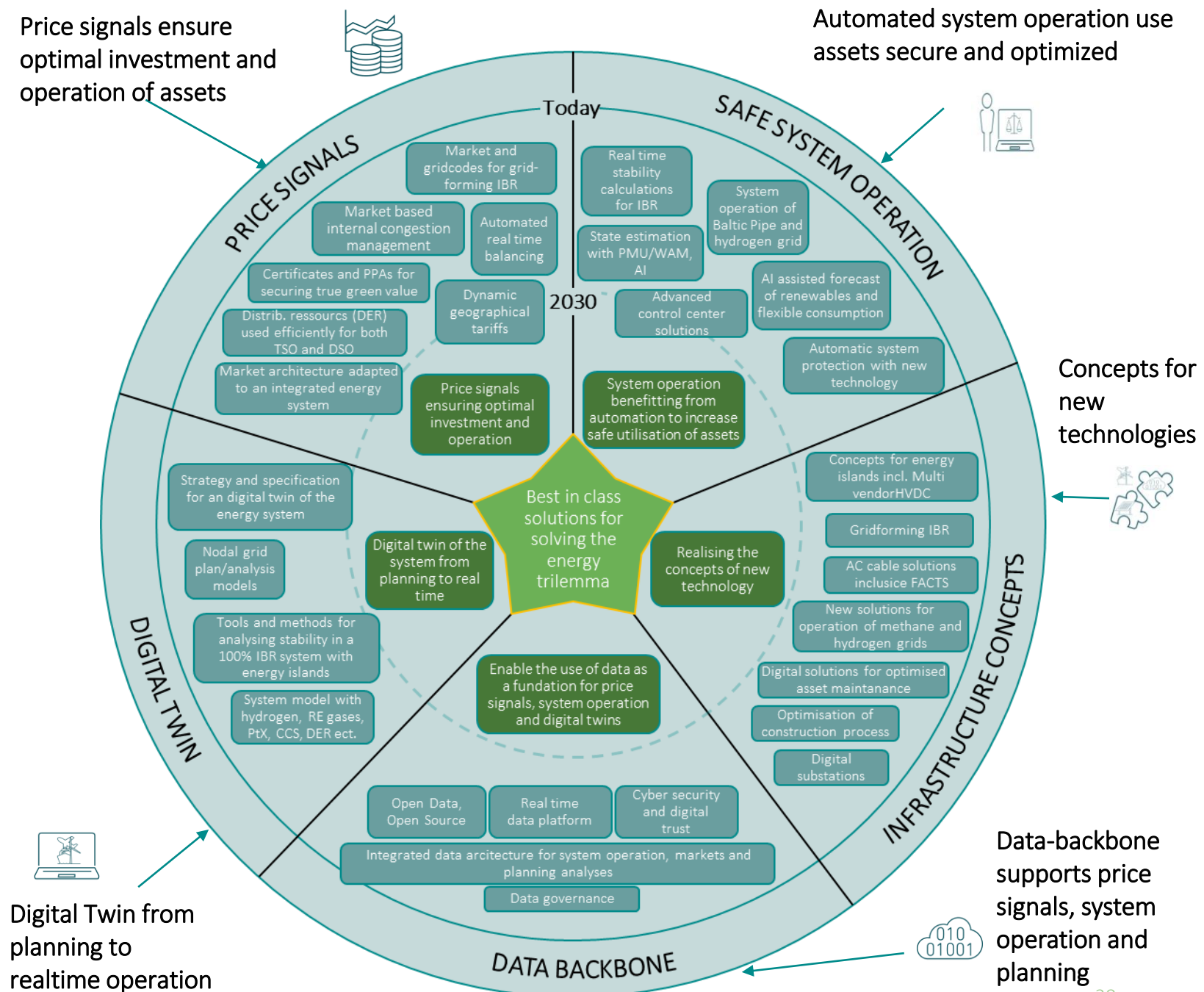
RESEARCH AND DEVELOPMENT (R&D ROADMAP)

FROM SCENARIO ANALYSIS TO R&D ROADMAP



R&D ROADMAP

- Overview long term system development key areas
- Figure shows selected development areas



KEY TAKE AWAYS FROM THE ANALYSIS



Scenarios towards 35 GW offshore DK Northsea and 35 GW PV analysed



Co-optimisation in planning, design and operation of power and hydrogen essential



Hydrogen system can reduce need for overhead power lines



Large scale storage of hydrogen essential for security of supply



Potential for offshore hydrogen infrastructure and electrolysis on offshore hubs and wind-turbines



A need for close coupling of market and physics to harvest synergies from sector coupled system

R&D focus areas identified



entsoe

GLOBAL PST
CONSORTIUM



A photograph of two white wind turbines on a grassy dune. The turbine on the left is in the foreground, partially obscured by tall grass. The turbine on the right is further back. The ocean is visible in the background under a blue sky with some clouds. The text "Thanks for attention" is overlaid in the center.

Thanks for attention