Seminar on how to establish RE centered grid system for carbon neutrality

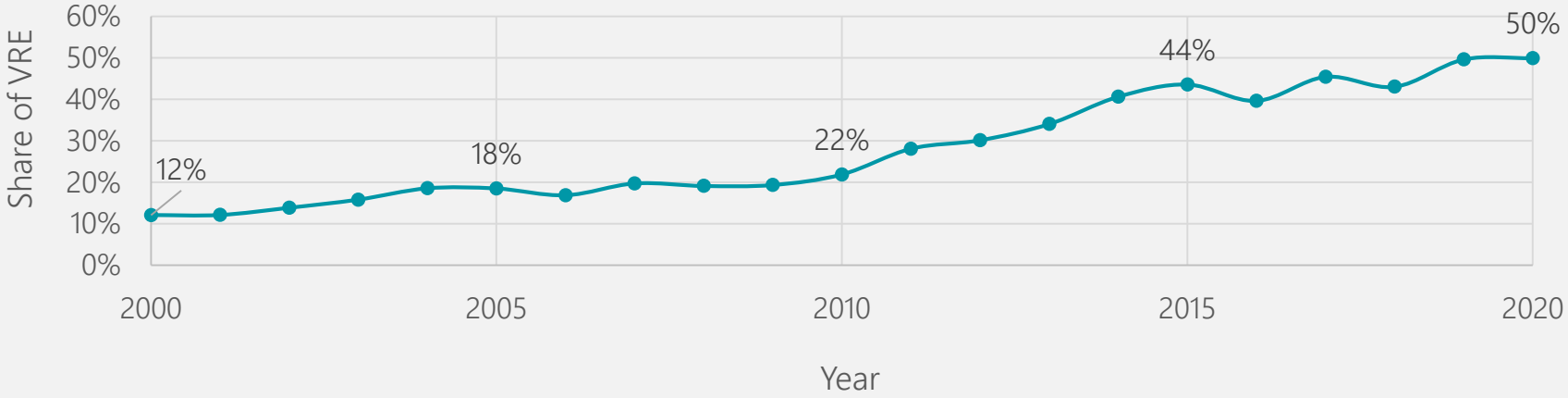
Danish Energy Agency

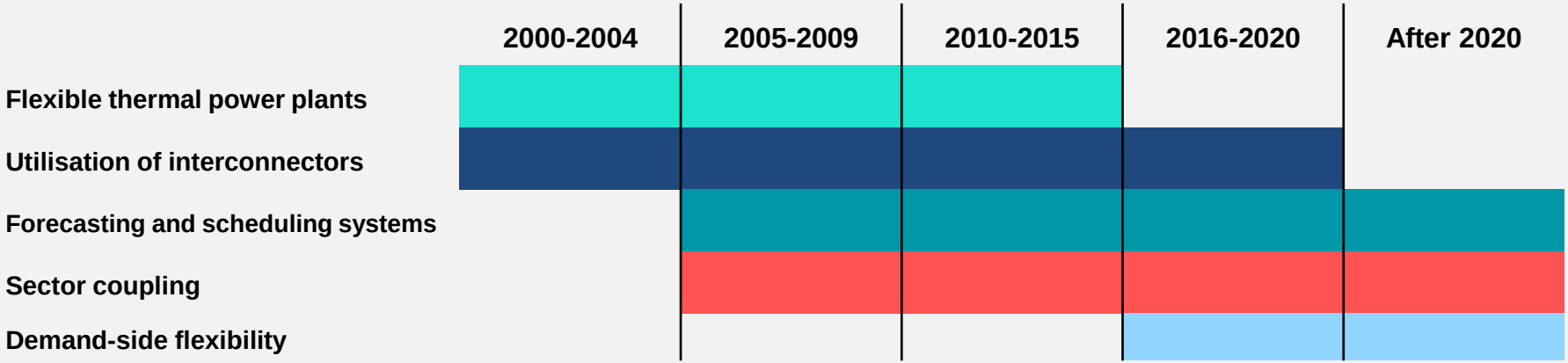
Brief introduction to the development of the power system relevant for renewables energy and current situation in Denmark

Hans Lyhne Borg, 17th May 2022

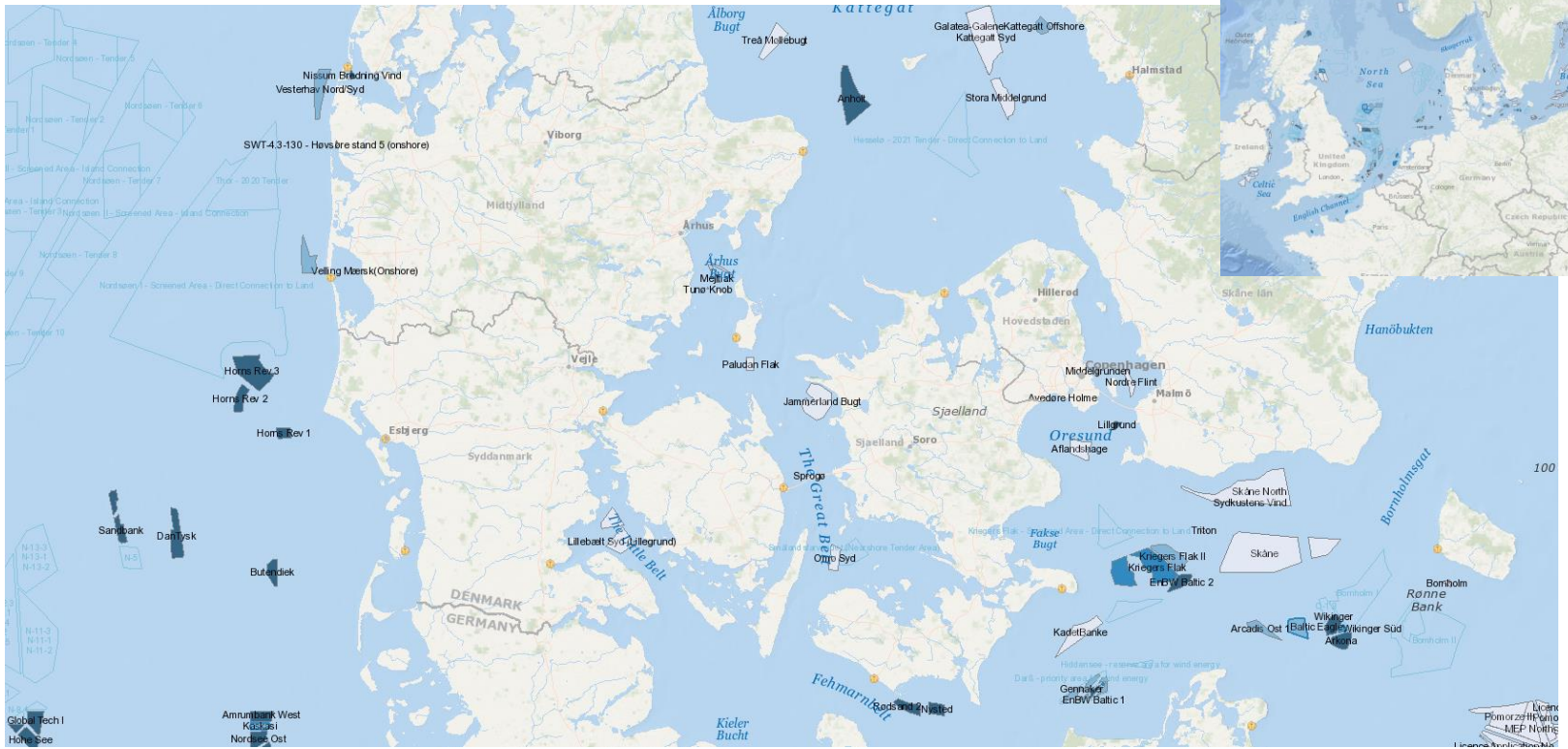
Development in Denmark and the increase of variable renewable energy

5 main categories of flexibility and role of the market





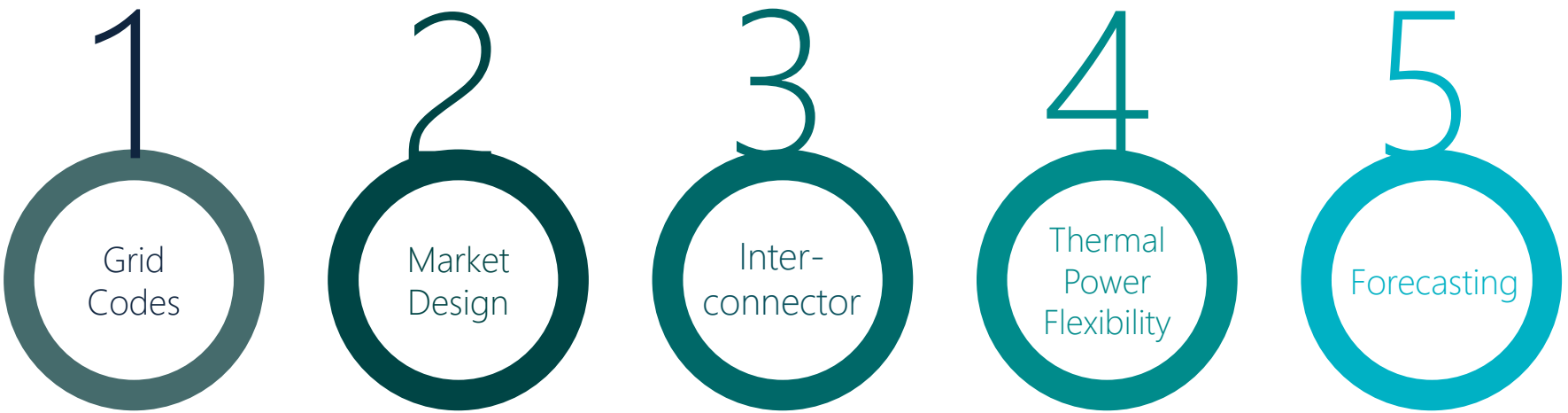
Offshore wind farms in Denmark | Existing capacity of approx. 2.3 GW



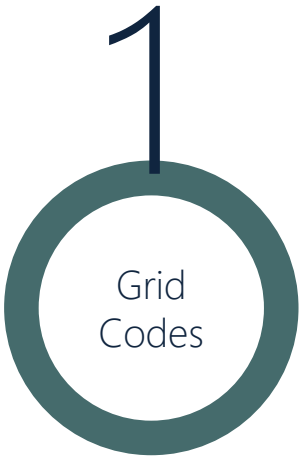
Offshore wind farms in Denmark | Share learnings and experiences

Project	Commissioning	Capacity (MW)	Voltage level	Learning
Horns Rev 1	2002 (operation)	160	150 kV	First large scale OSW grid connection
Nysted/Rødsand 1	2003 (operation)	166	132 kV	Transformer cooling design
Horns rev 2	2009 (operation)	209	150 kV	Incorporated large number of experiences from HR 1
Rødsand 2	2010 (operation	207	132 kV	Landfall in difficult area and voltage control in weak grid
Anholt	2013 (operation)	400	220 kV	First rolling commissioning of wind turbines
Horns rev 3	2019 (operation)	406,7	220 kV	Transfer of components to optimize proces
Kriegers Flak	2021 (operation)	604,8	220 kV	Combined grid solution to Germany
Near shore	2023 (construction)	350	66 kV	First large POC on-shore
Thor	2024-2027 (planning)	1000	220 kV	First tender with POC on-shore, SEA and Flidar
Energy Islands - Bornholm	2030 (decided)	Up to 3000	TBD	First hub connection/HVDC multiterminal and with island of Bornholm as hub
Energy Island - North Sea	After 2030 (decided)	Up to 10000	TBD	First hub connection with establishment of energy island. Maybe with PtX

Five Main Solutions in Denmark



Five Main Solutions in Denmark



EU - ONE MARKET, ONE POWER SYSTEM

Common rules and technical standards are necessary to achieve better market integration, efficient and secure system operation.

CONNECTION | MARKET | OPERATION

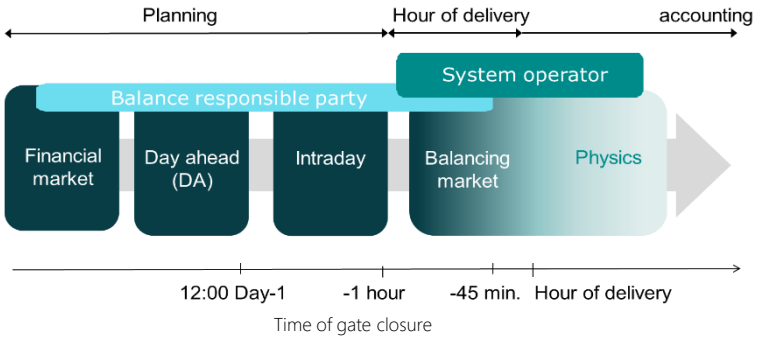
Lead by ACER Agency for the Cooperation of Energy Regulators entsoe

Five Main Solutions in Denmark

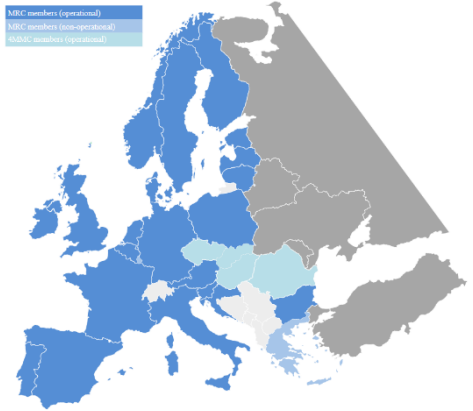
A PERFECT MARKET HAS PERFECT COMPETITION

Nordic electricity market is the most harmonized cross-border electricity market in the world, as a result of many years of merger activities.

Overview of nordic power markets



EU Single Day-ahead Coupling



Source: Energinet (left), Entso-E (right)

Five Main Solutions in Denmark

3

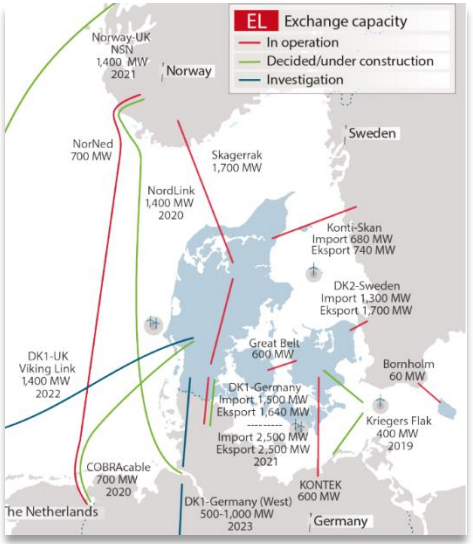
Inter-connector

TRANSMISSION IS NECESSARY HARDWARE FOR POWER BALANCING

Denmark will have a total capacity of 10-11 GW of interconnectors to five different countries in 2022

STRONG GRIDS ENABLE

- Optimal utilization of generation capacity (merit order dispatch)
- Balancing in larger diversified areas
- Sharing of reserves
- Flexibility



International transmission links between Denmark and nearly electricity markets

Source: DEA

Five Main Solutions in Denmark

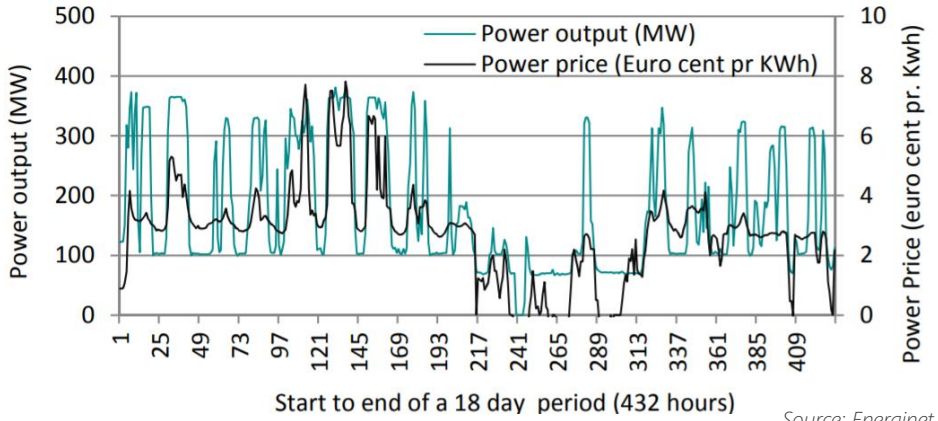
4

Thermal power Flexibility

DEFINITION OF FLEXIBILITY IN DENMARK

The ability to handle variability and uncertainty in generation and demand while maintaining satisfactory reliability

Large-scale CHP output and hourly prices



Source: Energinet

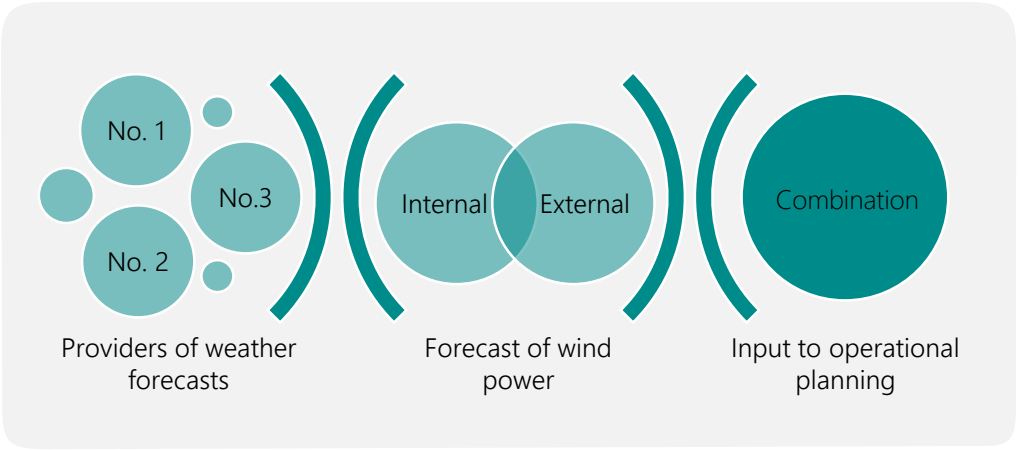
FLEXIBLE THERMAL POWER PLANTS

- Ramping rate
- Minimum output
- Warm starts
- Overload
- Heat accumulators and electric boilers

Five Main Solutions in Denmark

DENMARK USES MULTIPLE FORECASTS

Forecasts are provided from one year ahead until five minutes ahead



Source: Energinet

CURRENT FORECASTS COVER

- Wind power
- Decentralized production
- Transmission loss
- Consumption
- Flow on tie-lines
- Solar power

Due to the oil crisis, Denmark had car-free Sundays from 25 November 1973 to 10 February 1974

- Denmark was hit by an oil crisis in 1973 that limited our import of oil. We were highly dependent on oil for both electricity production, heating and transportation. More than 99% of the energy supply came from imported fossil fuels – mainly oil.
- The crisis was so bad that the winter of 1973-74, we needed to implement car-free Sundays in order to be able to have enough oil to also heat our houses.
- In the 1970s, the oil crisis forced us to change our perspective on energy…as climate change does now.

Thank you for your attention

경청해 주셔서 감사합니다

Danish Energy Agency