ENERGINET

Danish TSO Experience with interconnectors

Peter Markussen

Energinet Associated Activities

ENERGINET

THE ENERGY BACKBONE

We operate and develop the transmission grids and gas pipelines in Denmark

ENSURE BALANCE

We have the day-to-day and long-term responsibility for the overall electricity and gas system in Denmark

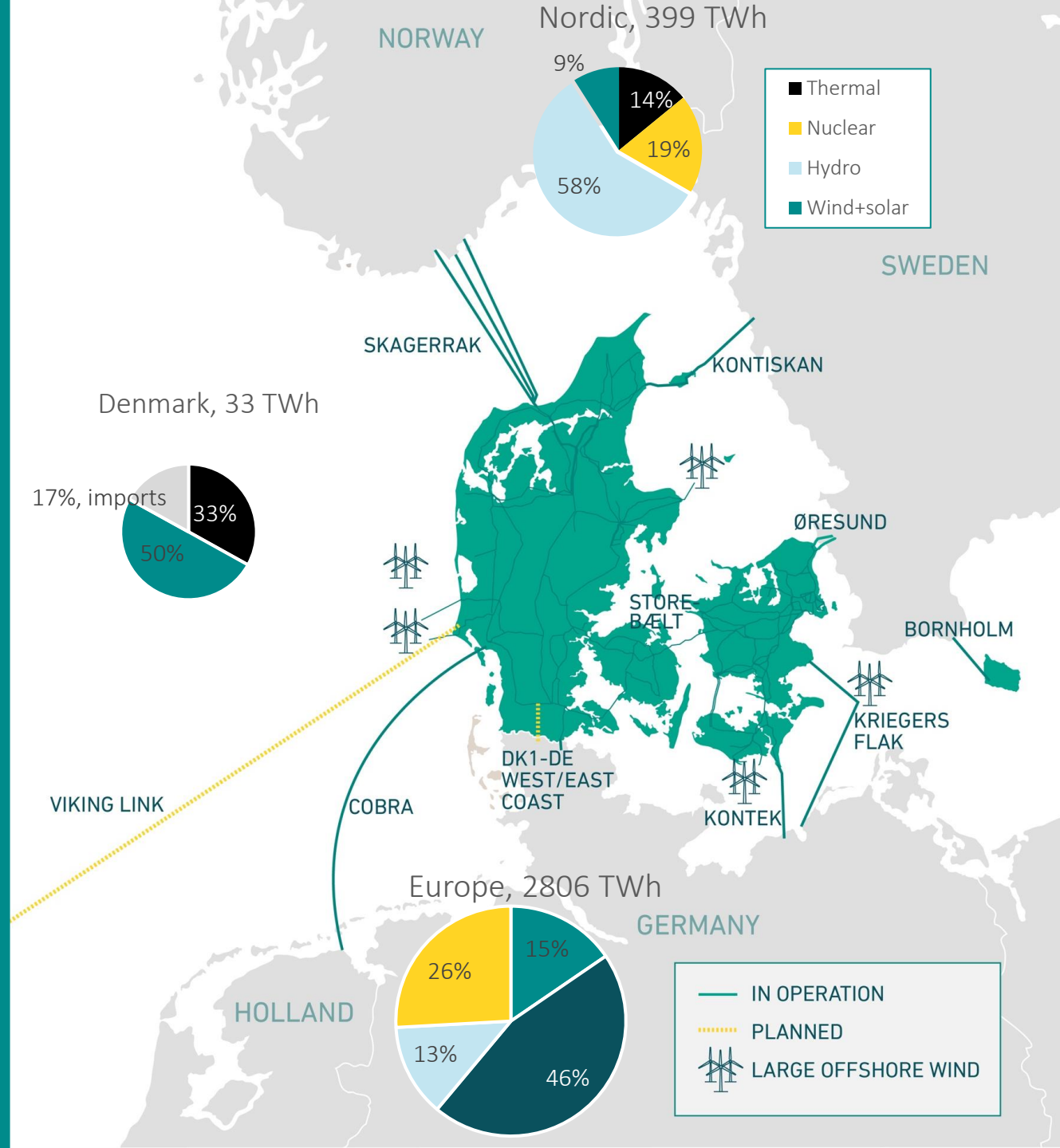
WORKING FOR THE SOCIETY

We are owned by the Danish Ministry of Climate, Energy and Utilities

.

VISION

GREEN ENERGY FOR A BETTER WORLD



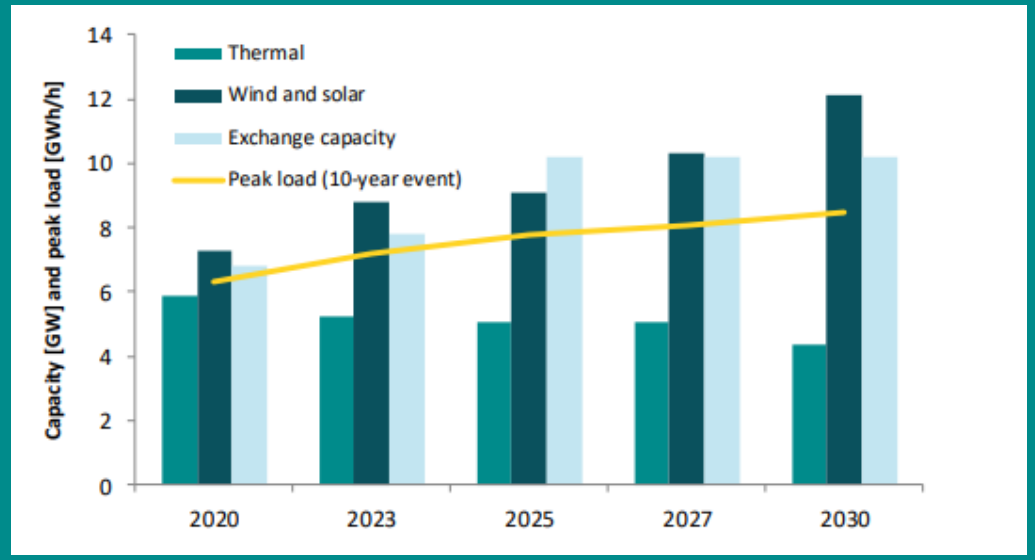
INTERCONNECTORS ARE IMPORTANT PART OF DANISH ELECTRICITY SUPPLY

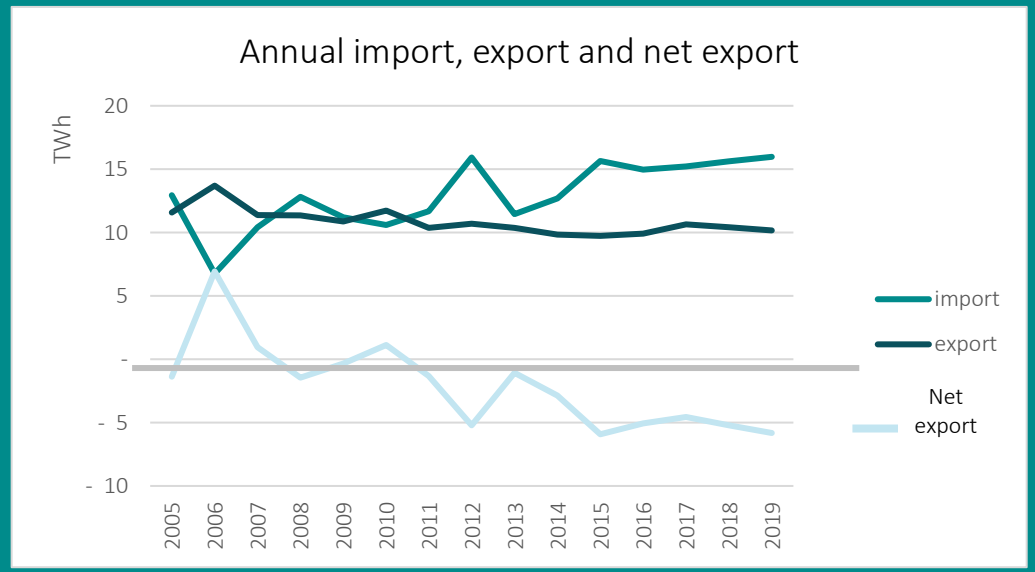
First AC connection to Sweden established in 1915 and HVDC to Norway in 1976

Exchange capacity expected to increase in the future

From seasonal to hourly flexibility from exchange of electricity :

- Reduce end consumer electricity price
- Security of supply from balancing, sharing reserves and ressource adequacy
- Efficient integration of renewables





BUSINESS CASE FOR INTERCONNECTOR

Approval based on socio economic benefit

Business case setup

- Optimization of investment (technology choice, capacity, timing, onshore connection, routing, internal grid investments)
- Tenderdesign (lots), multi contract or EPC
- Comparison with alternative investments and impacts

Regulation

- Regulated or merchant
- Non-proft, cap and floor regime, tariff, other incentives
- Grid codes for connection and operations

Energinet owned interconnectors financed by loans from Danish National Bank and depreciated based on technical life-time (30/40 year)

Energinet (benefit/costs effecting accounts)	Socio economic variables (not affecting Energinet acounts)
Congestion rent/fee	Net consumer/producer surplus
Net effect on costs for reserves and balancing	Net effect on security of supply
Other ancillary services/capacity markets	Net effect on costs for balancing
Investment costs	Net effect on support for renewables
Operation costs/spare parts etc.	Increased competition
Grid loss/Transit income	Net environmental impact
Funding	Other socio economic impacts (jobs, electrification etc.)

VIKING LINK

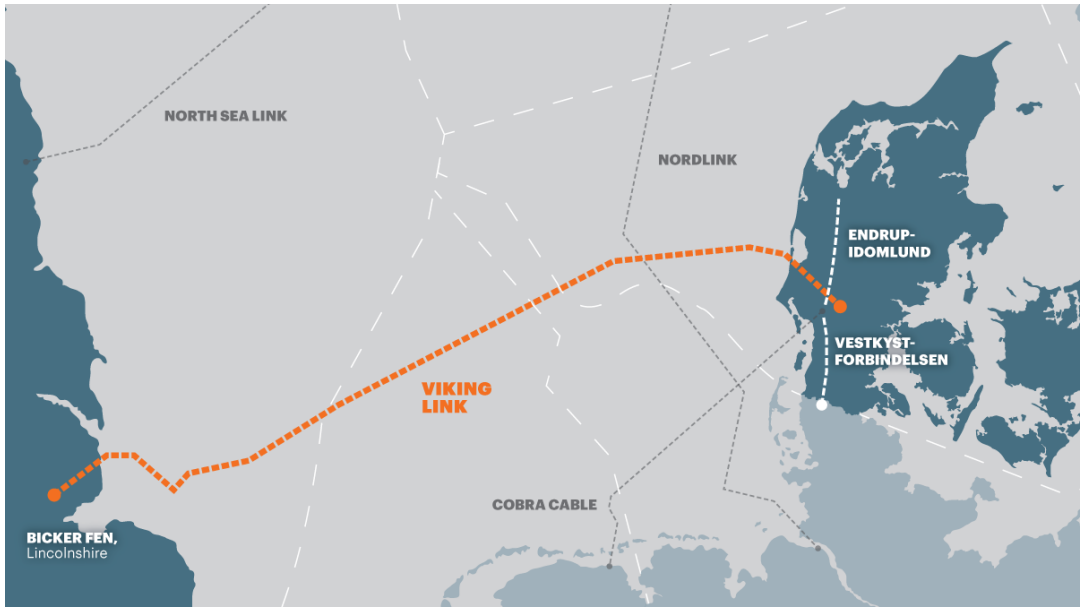
Main value driver:

- Higher electricity price in UK than in Denmark (thermal power in UK and hydro/wind in Nordic system)
- Capacity market and ancillary service benefits in the UK (limited effect in DK as already covered by other interconnectors)
- Internal grid extension part of Danish business case
- Costs and income shared between National Grid and Energinet

Source: figures are based on public available information and recalculated to illustrate difference in socio economic and Energinet impact and may differ from final business case

ENERGINET

Viking Link: 1400 MW HVDC (SVC technology and 750 km)
West coast: 1000 MW AC connection to Germany.
Commissioning expected 2023 (Energinet board approval in 2015)



NPV, mill. US$ (2015 prices)	Socio economic	Energinet
Benefit:	**2179**	**1830**
Congestion income	1684	1684
net producer surplus	349	
other benefits	145	145
Costs	**1323**	**1312**
investment	1047	1047
operation/outage	197	169
other costs	79	96
Net benefit	**856**	**518**

Average influence on end consumer power price in Denmark (US$/MWh)	
spot price	1,7
tariff	-1,2
Public Service Obligation	-0,8
Total	**-0,3**
Reduced curtailment, 2030:	78 GWh

GREAT BELT

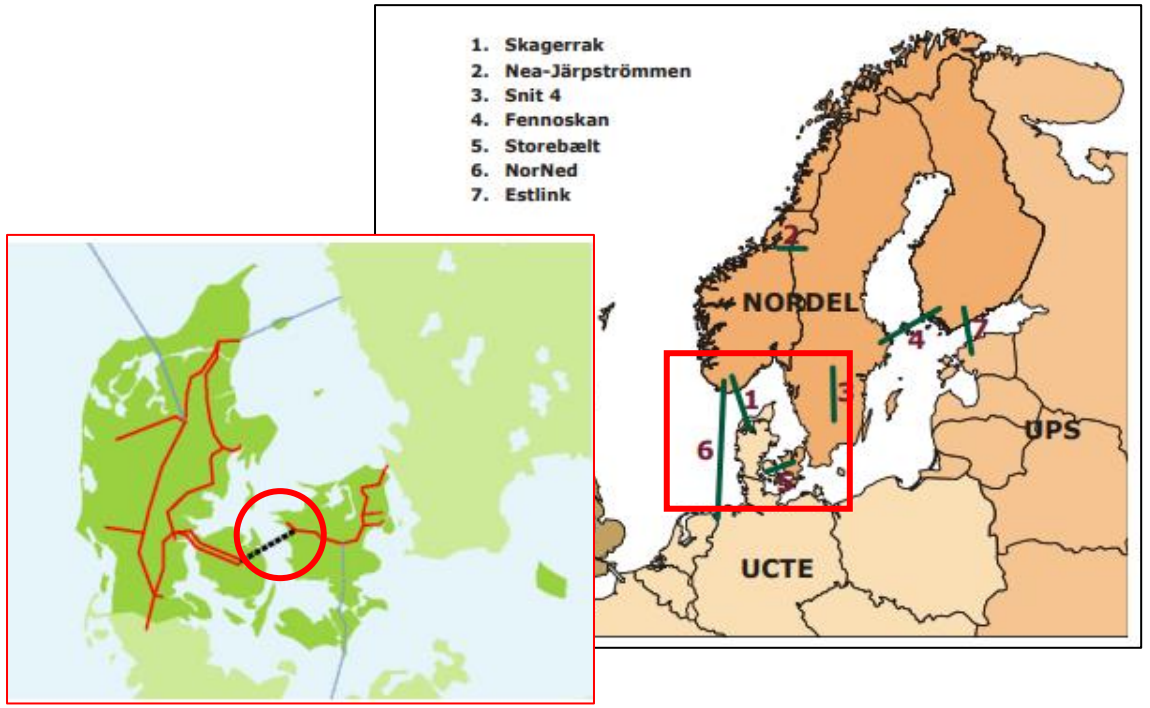
Main value driver:

- Part of Nordic grid development plan to strengthen robustness and security of supply
- Improving security of supply from sharing of reserves, ressource adeqaucy and balancing
- Internal Danish HVDC link between Eastern and Western Denmark - two different synchronous areas
- Limited price difference and expected flow from West to East Denmark

Source: figures are based on public available information and recalculated to illustrate difference in socio economic and Energinet impact and may differ from final business case

ENERGINET

Great Belt: 600 MW HVDC (LLC technology and 57 km)
Commissioned 2010



mill. US$ (2005)	Socio economic	Energinet
Benefit:	**609**	**245**
Congestion income	14	14
net producer supplus	138	0
security of supply	365	231
other benefits	92	0
Costs	**508**	**508**
investment	452	452
operation/outage	55	55
other costs	0	
Net benefit	**102**	**-263**

APPROVAL OF BUSINESS CASE

ENERGINET

Energinet approval process of interconnectors (appr. 2-4 years and investment execution 5-8 years):

Political agreement DK/other TSO → Creation of BC → Executive committee Energinet → Energinet Board → Danish Energy Agency → Minister of Supply, Energy & Climate

Law about Energinet prescribes major investments to be approved by Ministry of Climate, Energy and Supply before tenders.

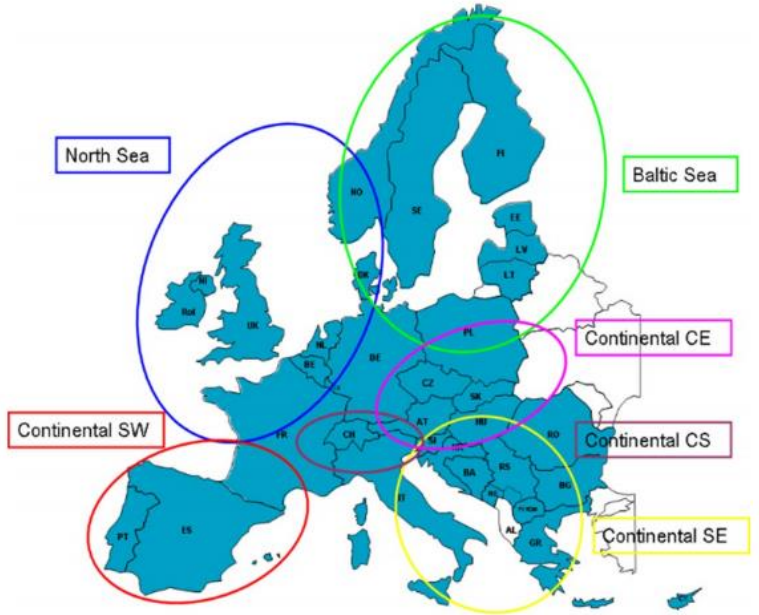
Criteria for approval:

- Overall positive socio economic business case for Denmark, connecting TSO and neighbouring countries
- All consents and national/international approvals for investing TSO's achieved
- Investment costs after tender in line with business case

Coordination of European, regional and national transmission grid planning in 2-year continuous process (TYNDP: Ten years national grid plan, Planning the future grid - TYNDP (entsoe.eu))

Project of Common Interest (PCI) : accelerate approval processes and consents and possible funding of development costs

European and regional transmission grid planning



MAIN PRINCIPLES FOR HVDC OPERATION

CONNECTION

EU grid codes

Active power control and frequency support

Reactive power control and voltage support

FRT capability

Control (ie. oscillation)

Power system restoration

OPERATION AND MAINTENANCE

Shared or delegated responsibility (outsource)

Maintenance strategy, ie strategic spare parts

Insurance

Portfolio optimization of interconnectors

SYSTEM OPERATION

Capacity availability (market rules)

Financial/physical transmission rights

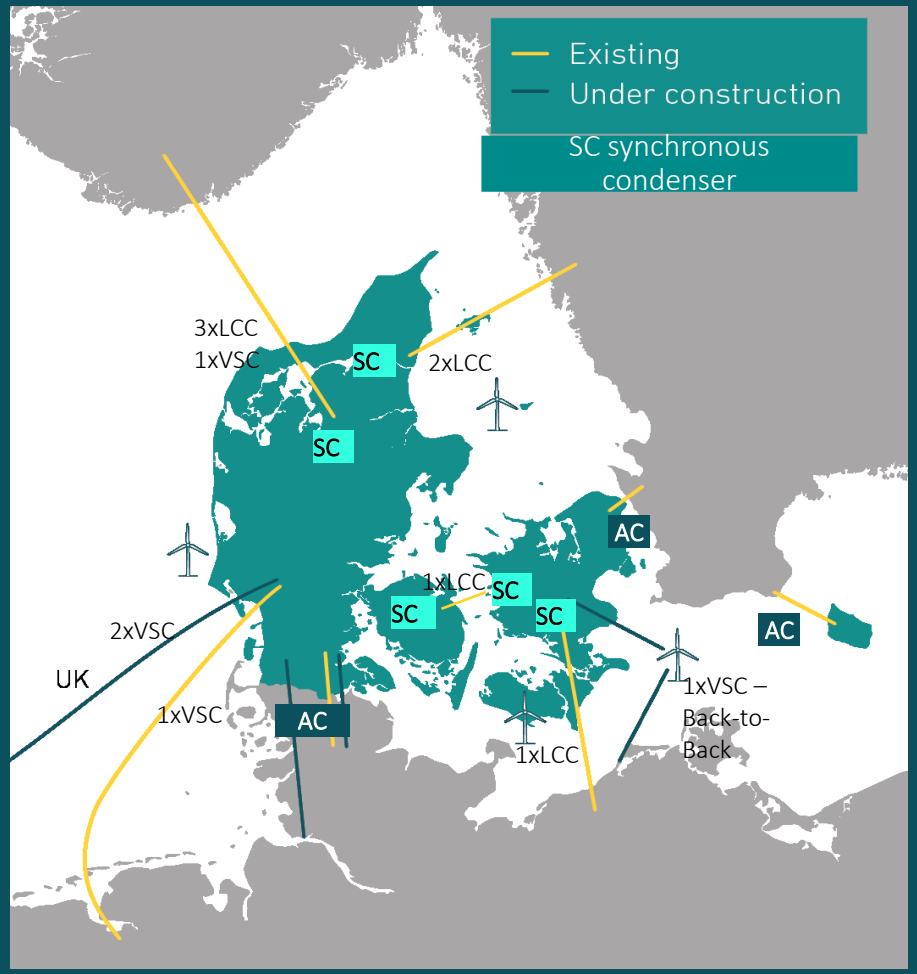
Ancillary services

Outage coordination

Ramping restrictions

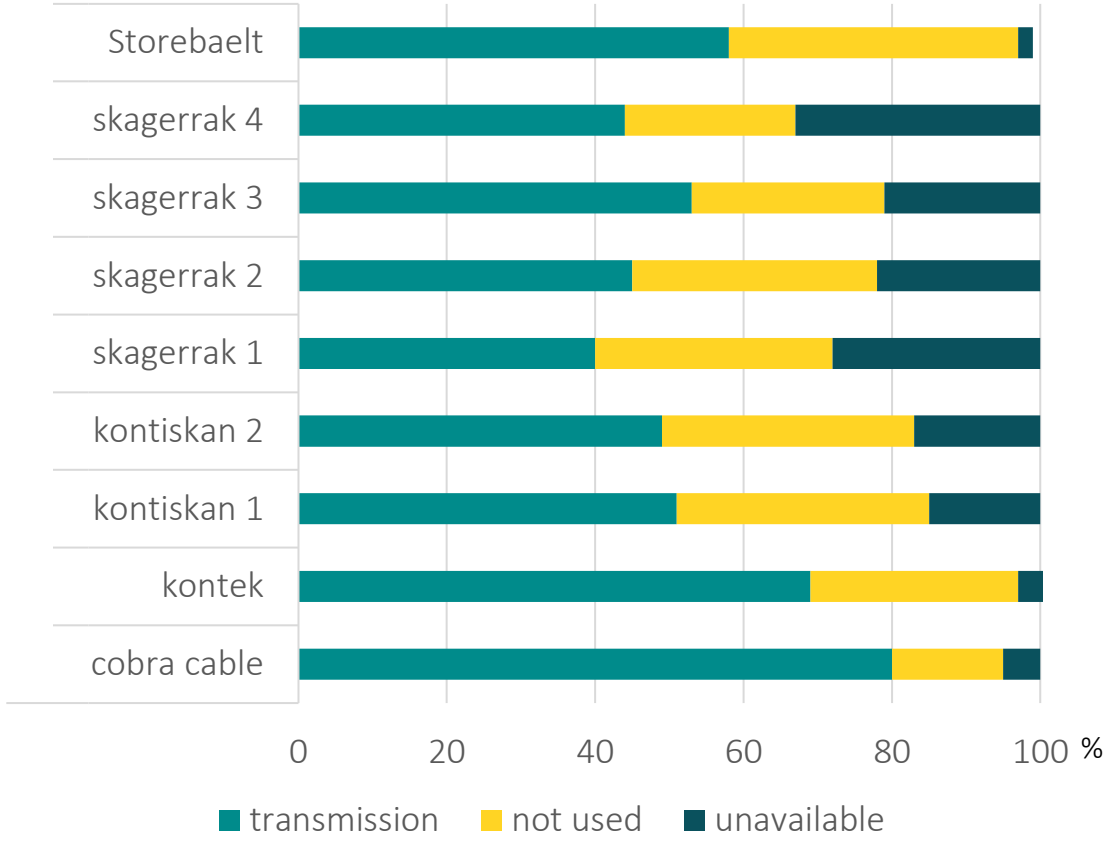
Communication

INVESTMENT IN SYNCHRONOUS CONDENSERS TO IMPROVE ROBUSTNESS IN SYSTEM WITH HIGH SHARE OF HVDC AND RENEWABLES



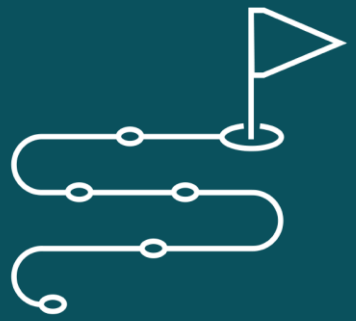
ENERGINET

AVAILABILITY AND UTILIZATION OF DANISH INTERCONNECTORS IN 2019



Interconnectors decisive for efficient integration of renewables and part of long term energy policy and planning

Adapt regulation to reflect socio economic benefit in business case



Approval process, consents, procurement, construction takes 8-10 years in total – focus on value creation in all parts

Operations to be carefully integrated in approval process and project execution

HVDC technology and technical standards develops continously for stable operation of electricity systems with HVDC

QUESTIONS

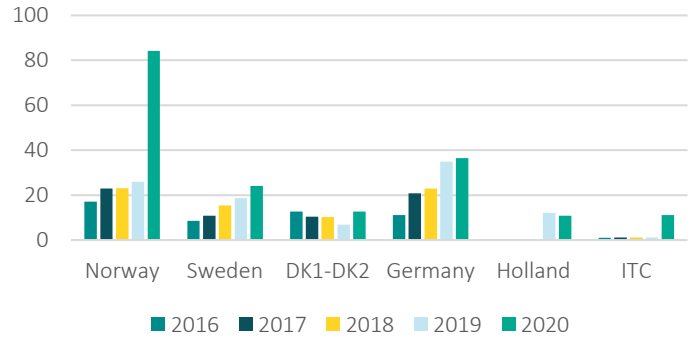
Contact: Peter Markussen, PMR@energinet.dk

DANISH INTERCONNECTORS

	Commissioned	Technology	Capacity, MW	Length, km
Cobra	2019	VSC	700	325
Kontek	1995	LCC	600	160
Kriegers Flak CGS	2020	AC/VSC back-to-back	400	240
Kontiskan 1+2	1988/2008	LCC	370/370	150
Skagerrak 1-4	1976/1977/ 1993/2015	LCC/VSC	236/236/ 478/ 700	212
Storebælt	2010	LCC	600	57
Øresund	1951/1964/1973/1985 (2020)	AC (132 kv/400 kv)	1700*	36
DK1-DE (east coast)	1957/2020	AC (220 kv/400 kv)	2500*	-
Viking link	2023	VSC	1400	750
DK1-DE (west coast)	2023	AC (400 kv)	1000*	-

**export capacity*

Energinet share of congestion income from interconnectors, mio. Euro



	Total
2016	51
2017	66
2018	73
2019	100
2020	179