

# Off-shore wind and Interconnectors

David Newbery  
*University of Cambridge*

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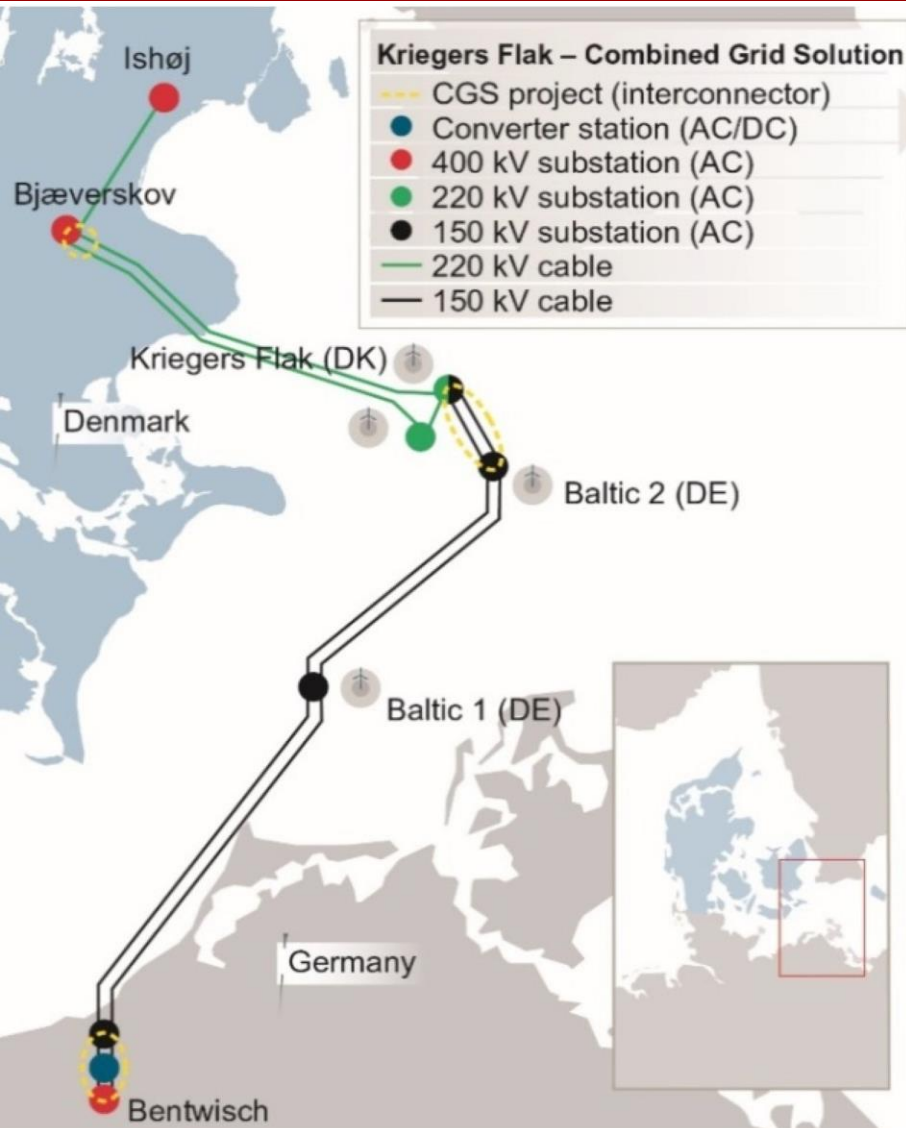
- Case for and problems of combining OWF & ICs
- Example: Kriegers Flak due Q2 2020

Q1 What **incentive changes** helpful to encourage OWF and IC developers to coordinate?

Q2 How should such changes be **introduced**?  
(Avoiding a hiatus to projects in progress)

Q3 How to conduct effective stakeholder **engagement** with many competing objectives?

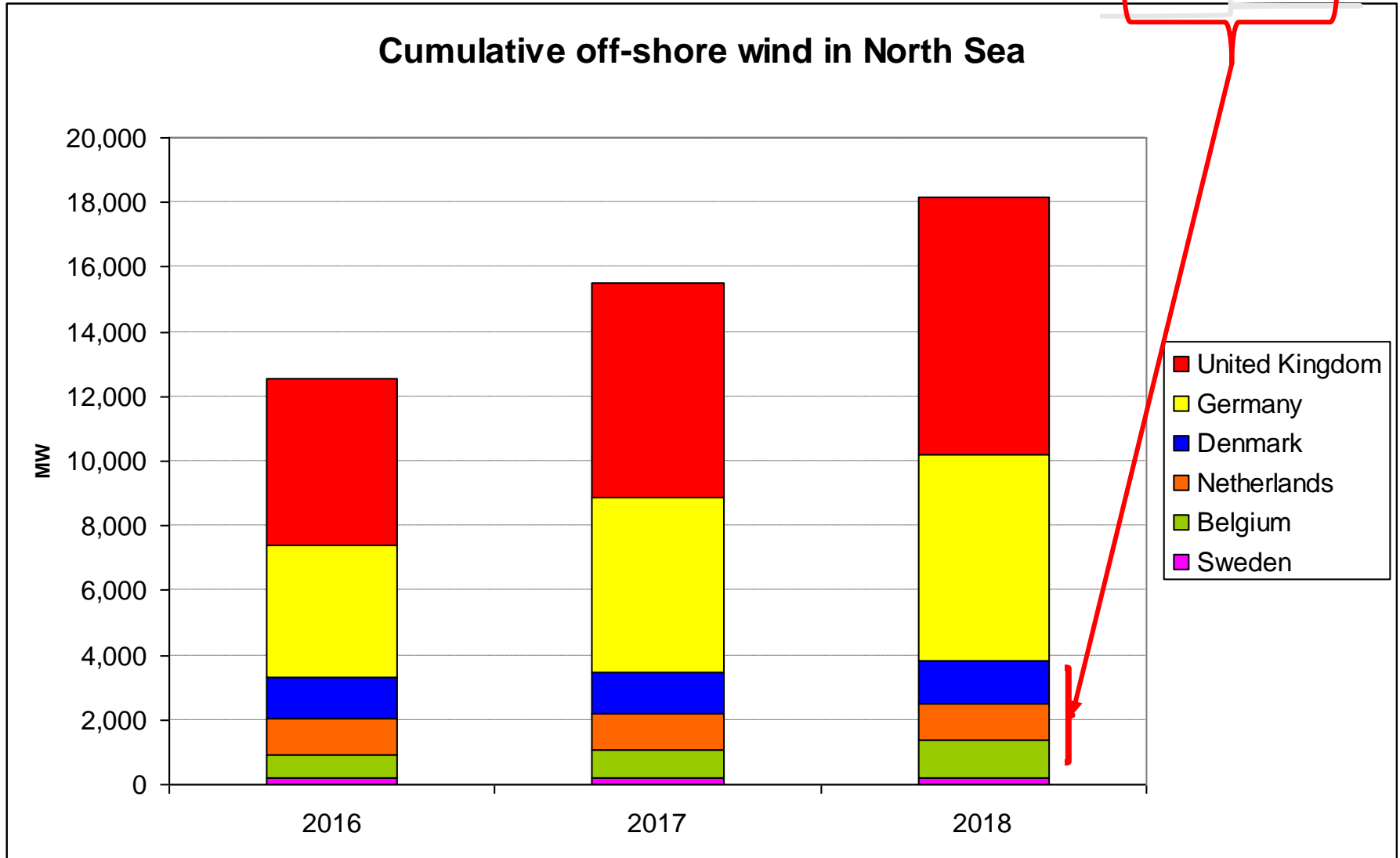
# Kriegers Flak 9 years from OWF to IC



**600 MW DK OWF+288MW+48MW (DE), 400 MW IC.** All links to shore are AC but not synchronised. One VSC converter transforms AC from the Nordic interconnected system to DC. The other Back to Back (BtB) converter in Bentwisch in Germany transforms DC back to AC - adapted to the Continental Europe Synchronous Area. When the hybrid interconnector is in operation, the German wind farms (Baltic 1 & 2 – BA1 & BA2) will run synchronous to the Nordic but will feed into the German grid through the BtB. Interconnection is expected for launch in Q2 2020. **Master Control Unit is the key**

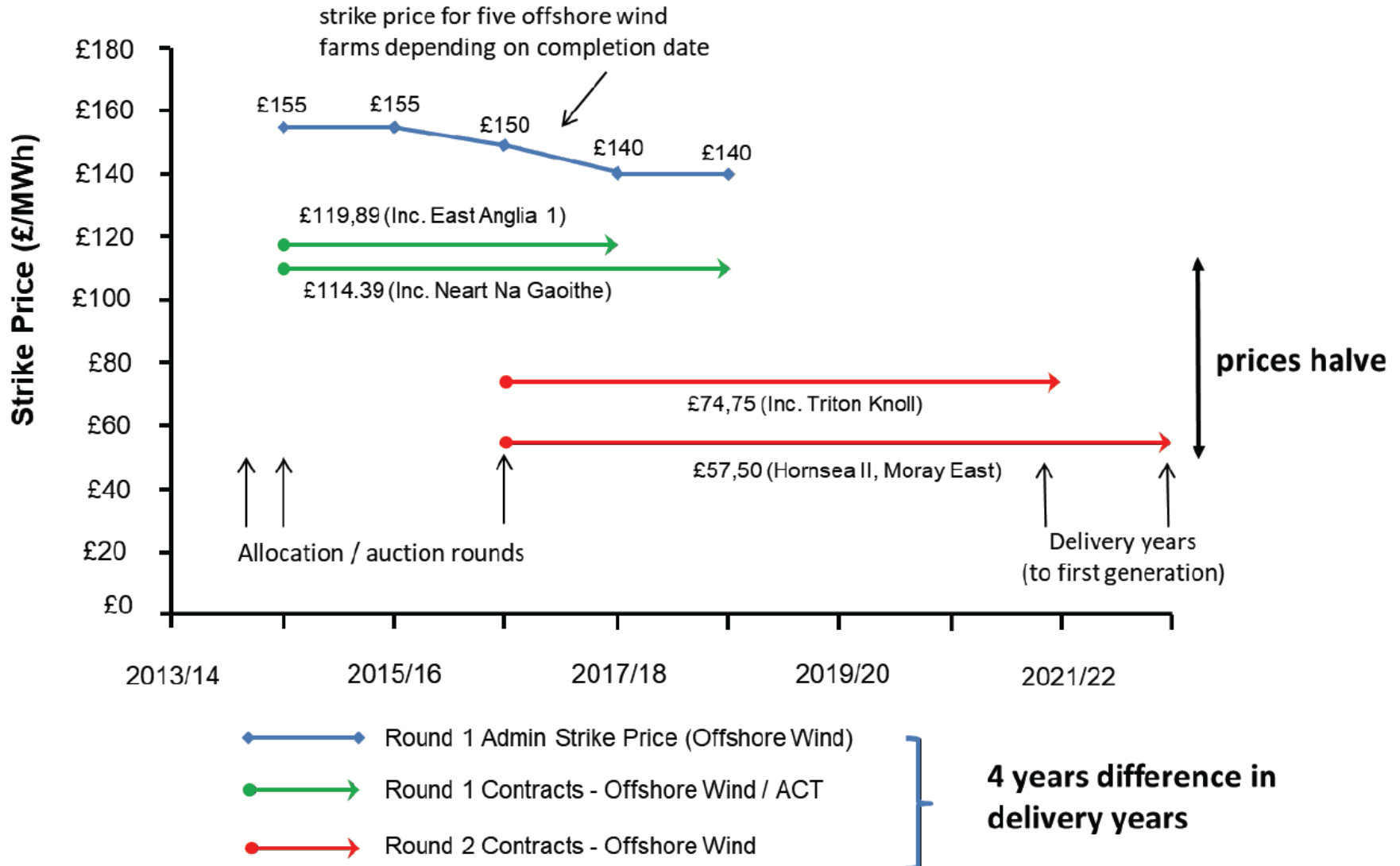
Source: Martin et al., 2018

# UK and Germany dominate but GB closer to BE, DK, NL



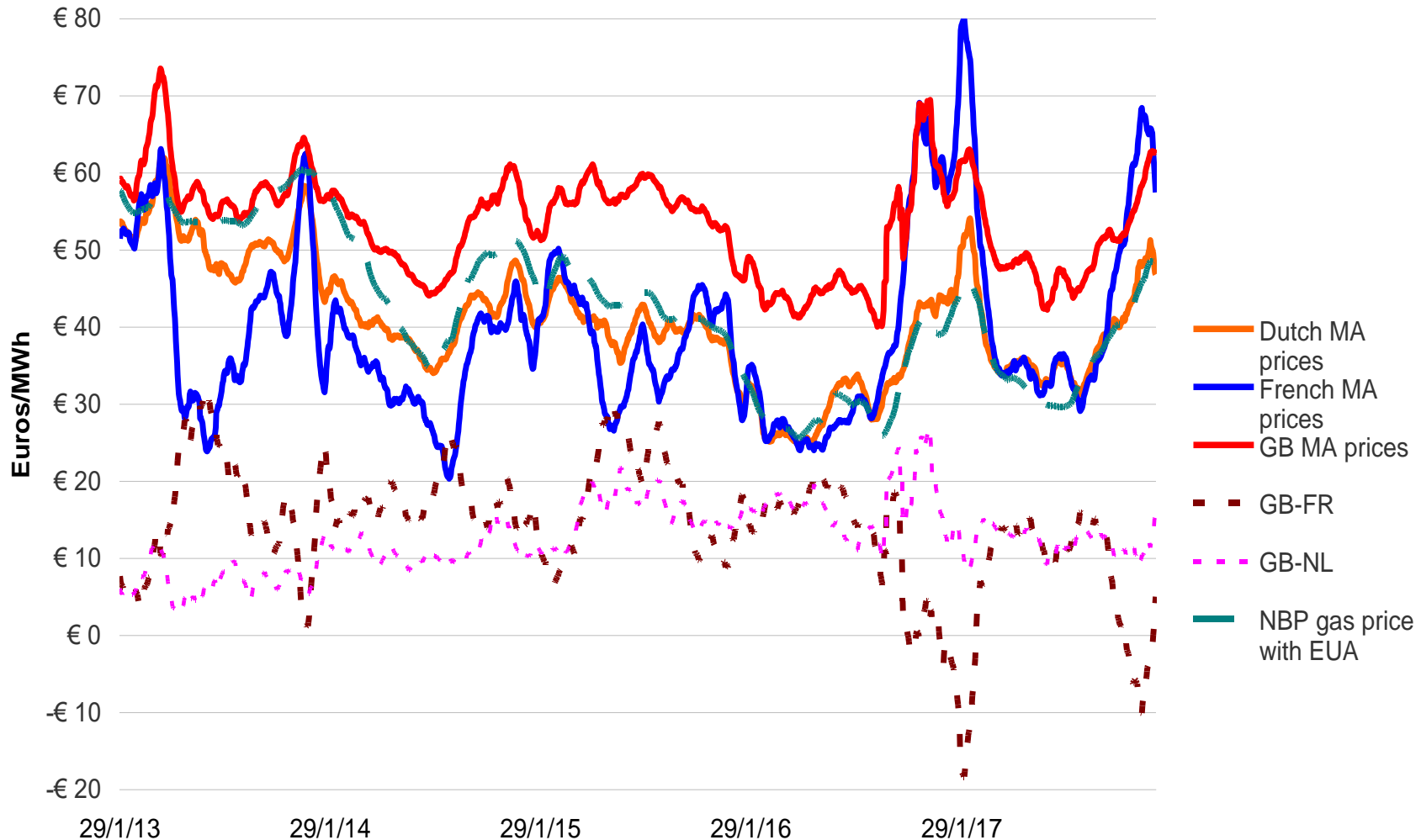
- Off-shore wind farms (OWFs) now cost-effective
  - In GB are **AC** linked
- More **HVDC** Interconnectors (ICs) cost-effective
  - But profits distorted by **asymmetries in carbon prices**
- Connecting OWF to two markets appealing
  - Direct output to more valuable market
  - Use **spare capacity as simple IC**
  - Problems with combining AC & DC elements?
- Meshed off-shore grids (MOGs) **more complex**
  - **Might** evolve but (perhaps?) gains from initial coordination

# UK Off-shore wind auction prices

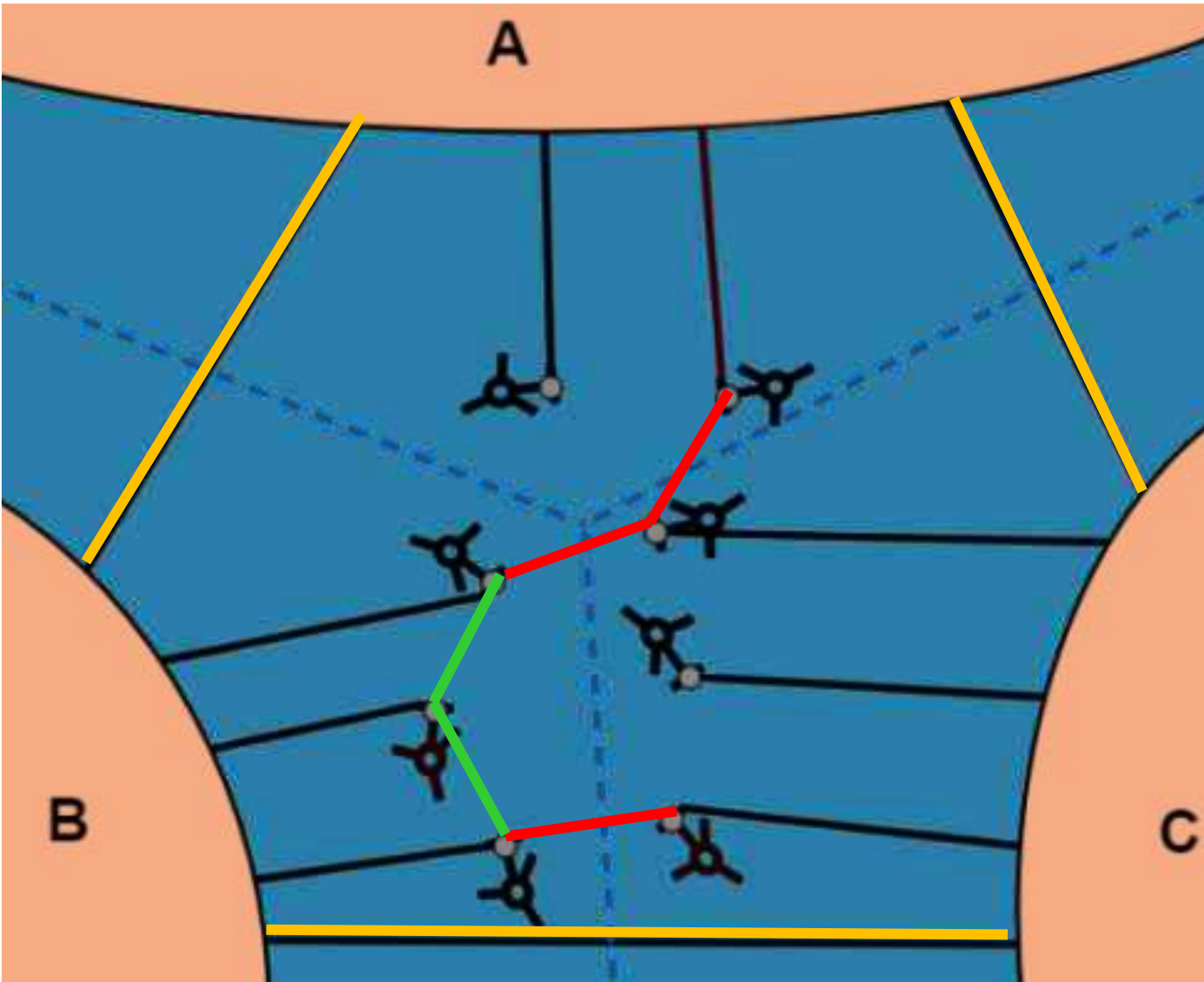


# GB normally higher price than FR, NL => import!

28-day lagged MA DAM prices 2013-18



# From BAU to national distributed hubs

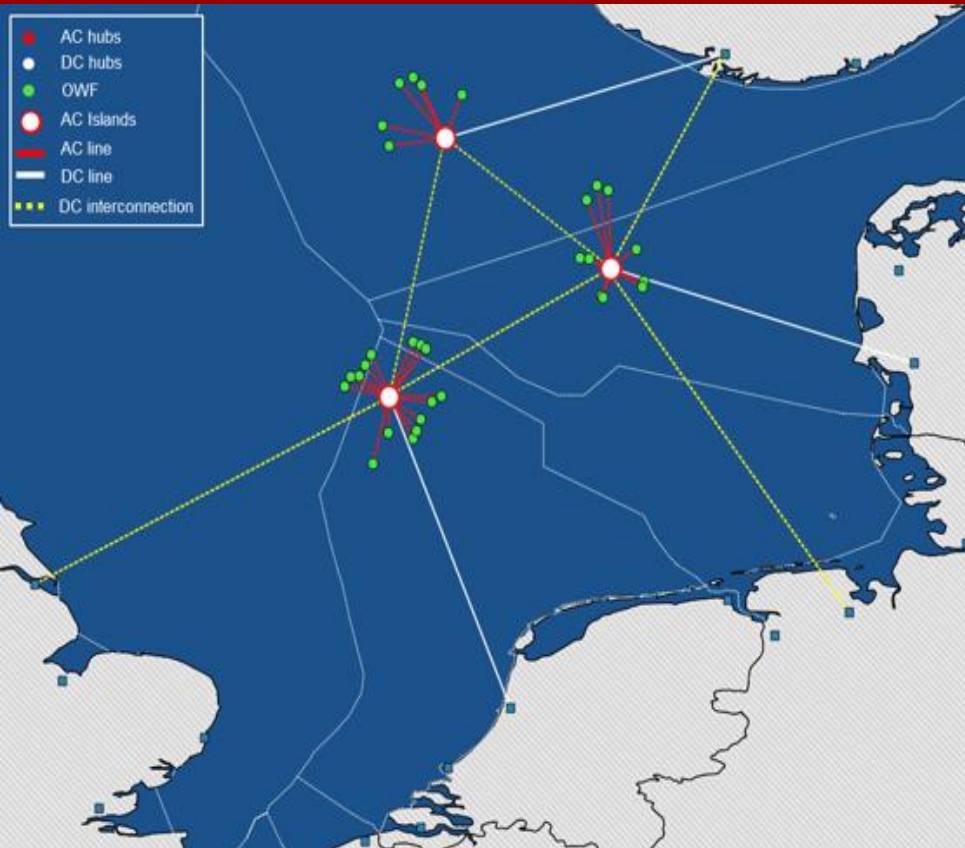


- Existing ICs
- New IC links
- MOGs

Source:  
PROMOTioN



# MOG: Meshed Off-shore grid



Centralised wind power hubs concept  
 – Regular AC hubs

European distributed hubs concept

Source: PROMOTioN

- HVDC **radial** links
  - offshore converter controls the DC current ensuring full evacuation of wind; onshore converter controls voltage
- **Multi-terminal** HVDC links
  - Radial converter disposition no longer works
    - => more than one properly controlled DC voltage regulator critical for stability (could also help on-shore congestion)
  - But **hard to test stability** of real large-scale systems
    - C.f. recent black-out and role of **Hornsea 1 on 9/10/19**
- Lack of generally accepted **offshore grid codes**
- Not fully defined in EU or international **law**
- Lack of regulatory/legal certainty **hampers investment**
- Devising suitable **cost/benefit sharing rules tricky**

## Q1 Incentive changes helpful to coordinate?

- Identify **best synergistic** OWF and IC projects
  - Ideally **separately economic with OWF among best**
  - assuming coordination net benefit  $> 0$ , agree standards of interoperability before defining sites for OWF
  - If coordination net benefit  $\gg 0$ , negotiate cost/benefit sharing solution with other country and coordinate before construction
- Otherwise design incentive to facilitate later connection
  - E.g. OWFs (notionally) finance IC and receive congestion rents or IC offers payment for use of OWF links – issues of **who owns what**

## Q2 How introduce without disruption?

- For GB AC-linked OWF to a EU OWF AC-linked – **hybrid**: decide **where BtB** converter located
- DC-linked OWF: critical to ensure **inter-operability**
  - If need common standards press ENTSO-E
  - If interoperable, simpler to extend to other OWFs/ICs?
- Set out model contracts?
- Then each country goes ahead with its OWF
  - IC could be done at same time or later

- Identify **objectives**:
  - RES share? C reduction? Security of supply? Reduced wind curtailment?
- Minimise WACC via suitable financing (e.g. RAB, LT contracts, ...)
- Align **incentives**:
  - **Auction** with sensible RES support, set C price, suitable SoS/ancillary service payments
- Re-engage with ENTSO-E, DG ENER, ACER, TSOs to **harmonise grid codes, dispatch etc.**

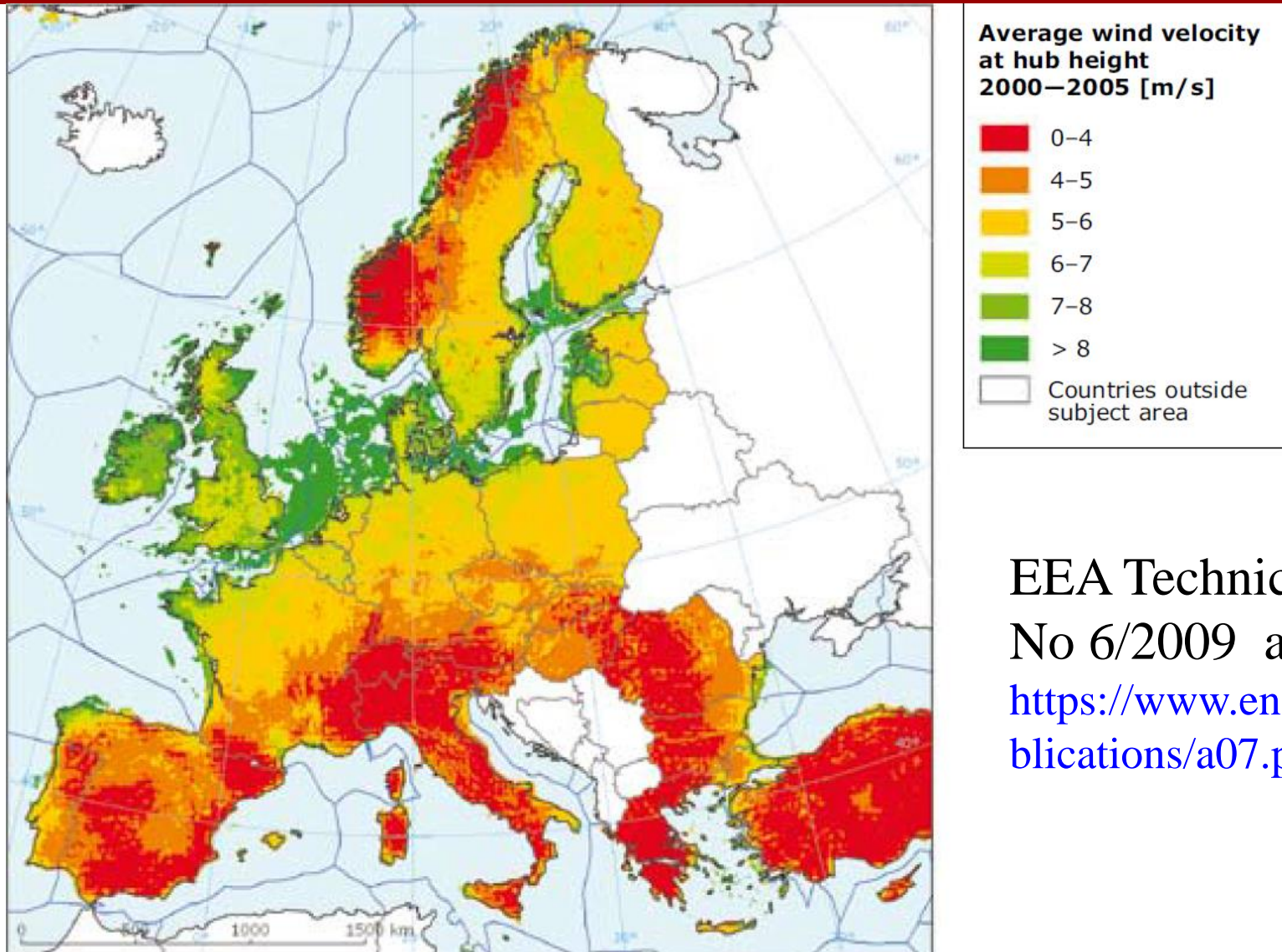
- **Kriegers Flak** provides **proof of concept**
  - of **AC-OWFs** so simpler **but still took time**
  - OWFs built 2011, interconnected in 2020, Sweden dropped out
- Next decade likely to see ICs linking some OWFs
  - Might some planned ICs be close enough to future OWFs?
  - If so **are coordination benefits sufficient to justify effort?**
- AC-OWFs – can they bridge the N Sea sensibly?
  - If so follow Kriegers Flak model?
- **DC linking harder** unless preferred links to OWFs
- Aligning standards, grid codes, aiming at interoperability, legal definitions etc. will take time **so start now**
  - Design model cost & benefit sharing contracts
  - Design efficient support mechanisms and ancillary services
  - Brexit does not help

- PROMOTioN project at <https://www.promotion-offshore.net/results/deliverables/>
- Marten, A-K., Akmatov V., Sørensen, T., Stornowski, R., Westermann, D., Brosinsky, C., 2018. Kriegers flak-combined grid solution: coordinated cross-border control of a meshed HVAC/HVDC offshore wind power grid, *IET Renewable Power Generation Special Issue: Coordinated Control and Protection of Offshore Wind Power and Combined AC/DC Grid*, doi: 10.1049/iet-rpg.2017.0792
- Ofgem NIC National HVDC Centre's work on multi-terminal HVDC Grids at [https://www.promotion-offshore.net/fileadmin/PDFs/D9\\_3\\_Press\\_Release\\_forIssue.pdf](https://www.promotion-offshore.net/fileadmin/PDFs/D9_3_Press_Release_forIssue.pdf)



# Wind resource up to 50m depth, hub ht 80m onshore, 120m offshore

Green is good, red poor



EEA Technical report  
No 6/2009 at  
<https://www.energy.eu/publications/a07.pdf>





# European centralised hubs

