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Off-shore wind and Interconnectors

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Outline

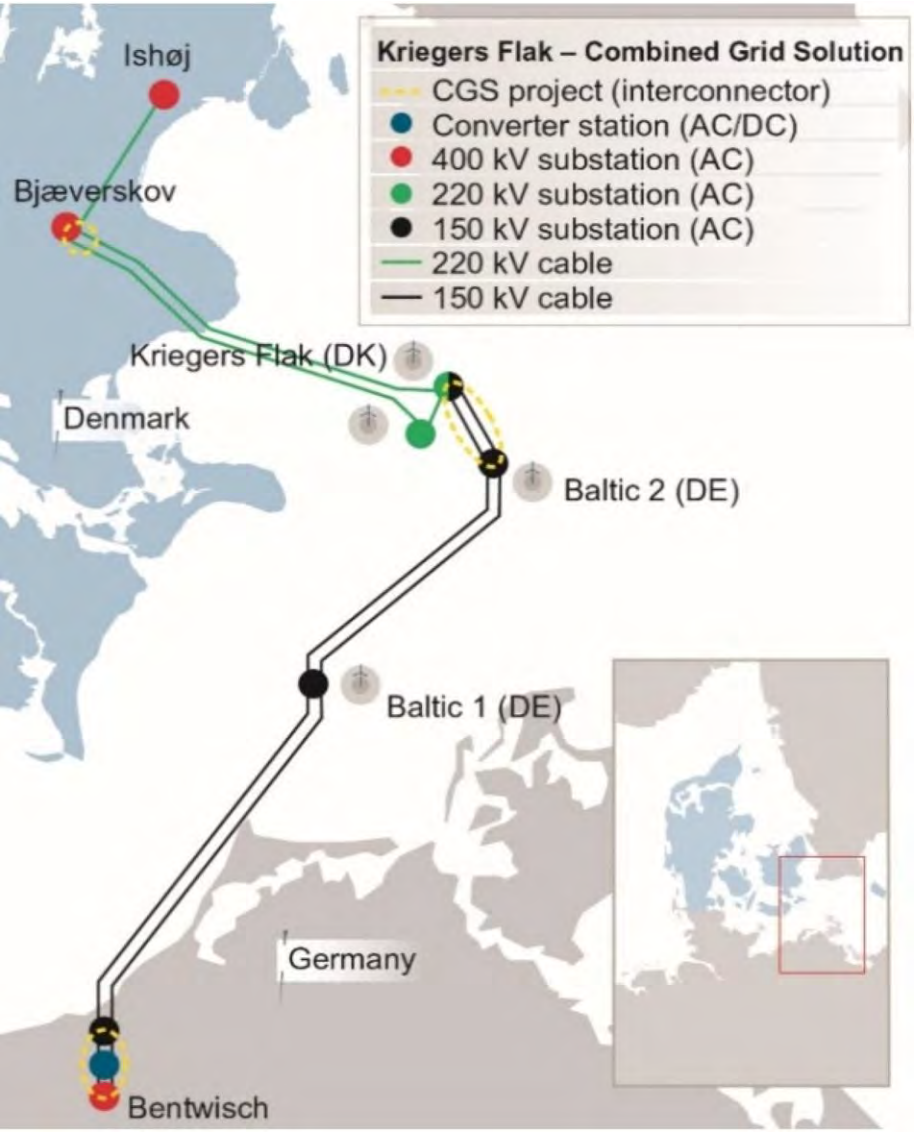
- Case for and problems of combining OWF & ICs
- Example: Kriegers Flak due Q2 2020

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?

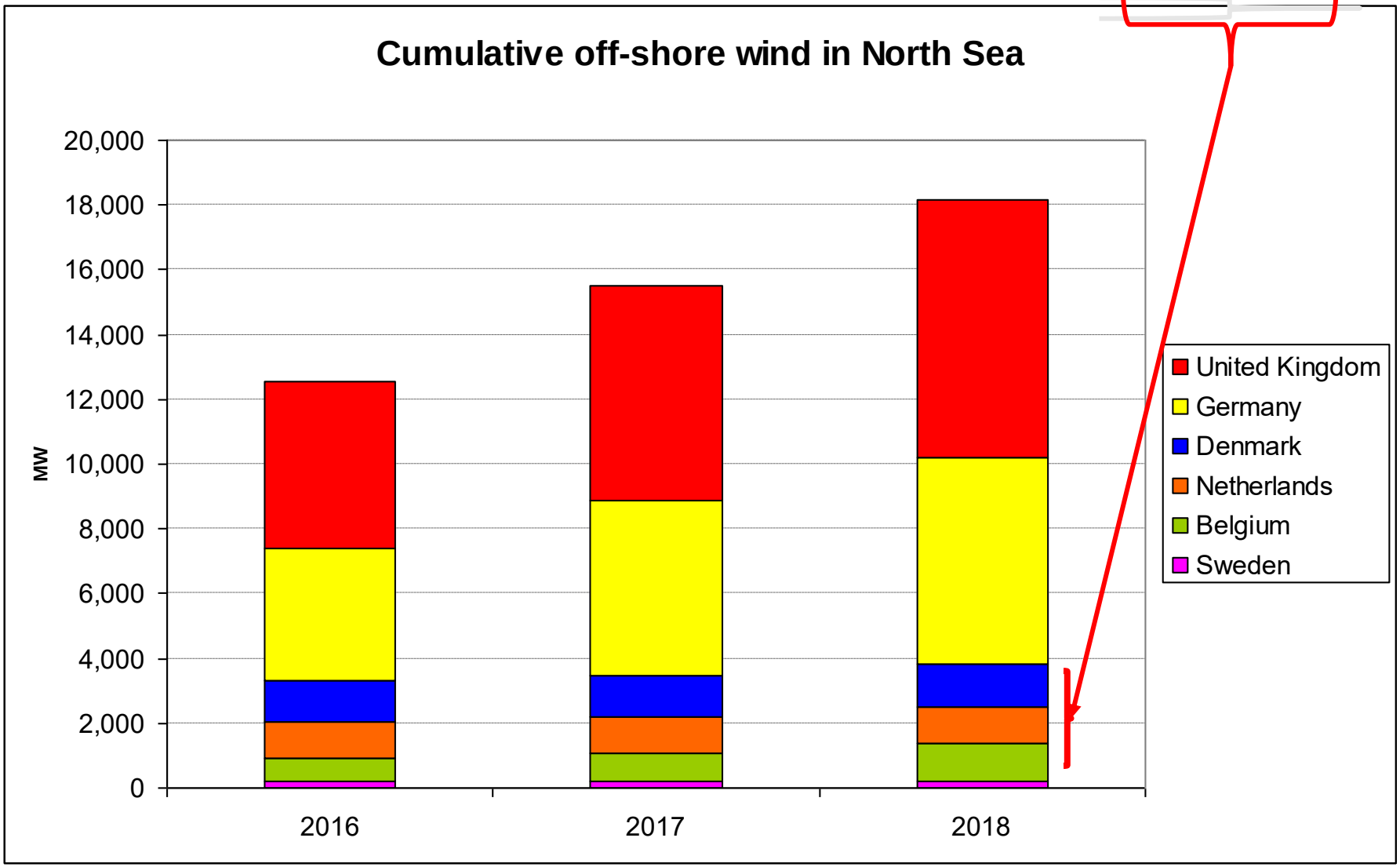
Kriegers Flak
9 years from OWF to IC



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



Combining ICs and OWFs

- 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

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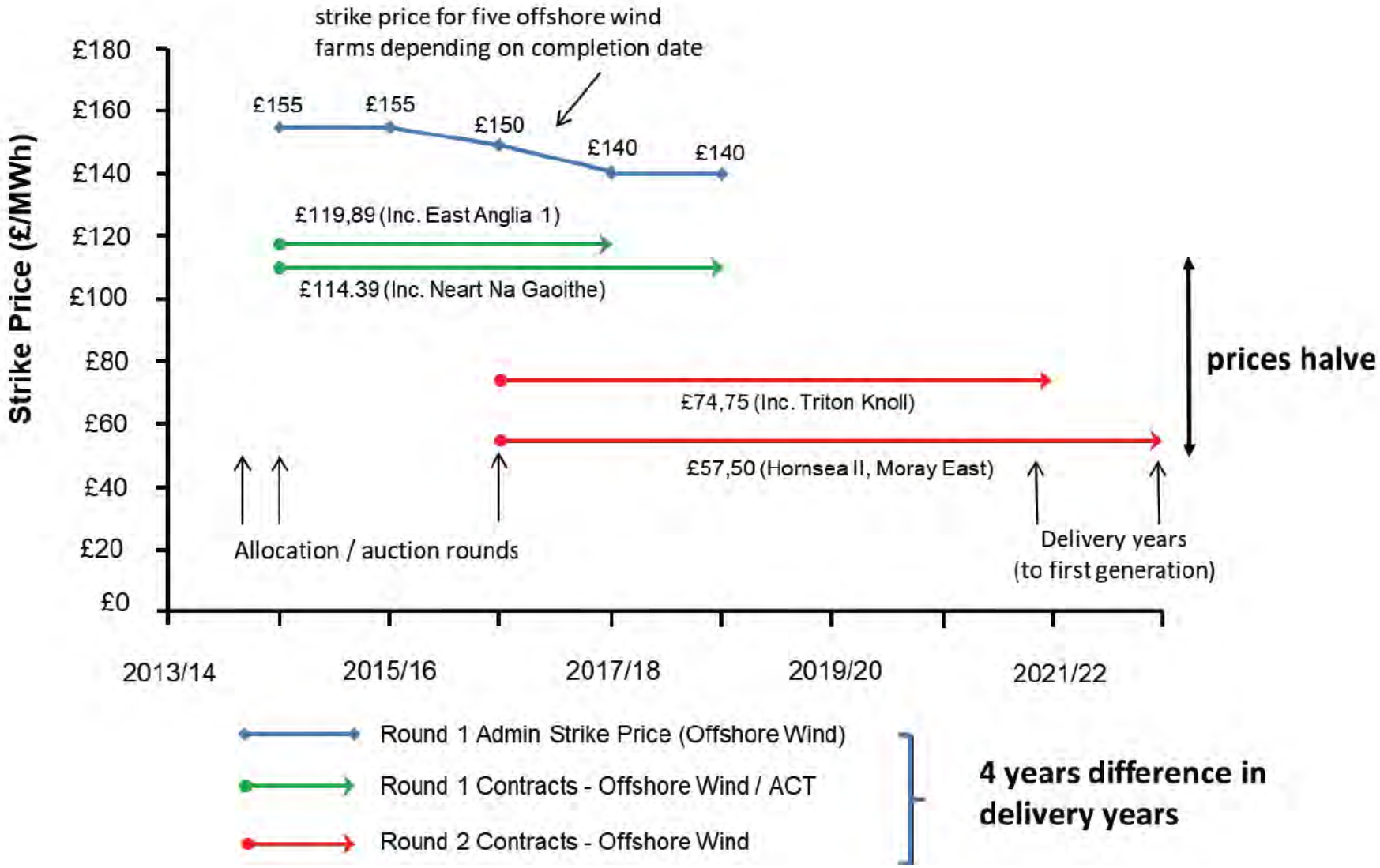
UK Off-shore wind auction prices



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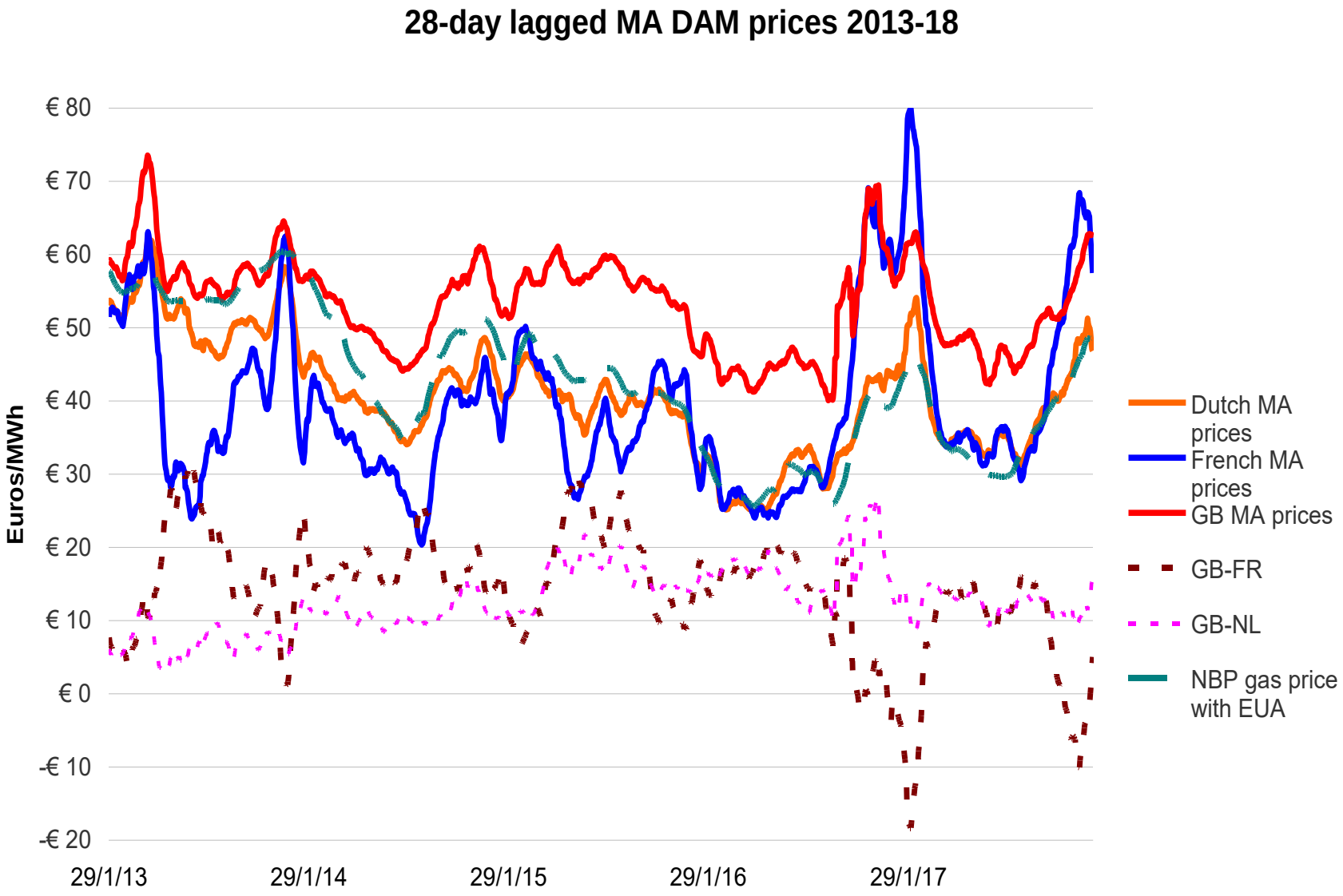
GB normally higher price than FR, NL => import!



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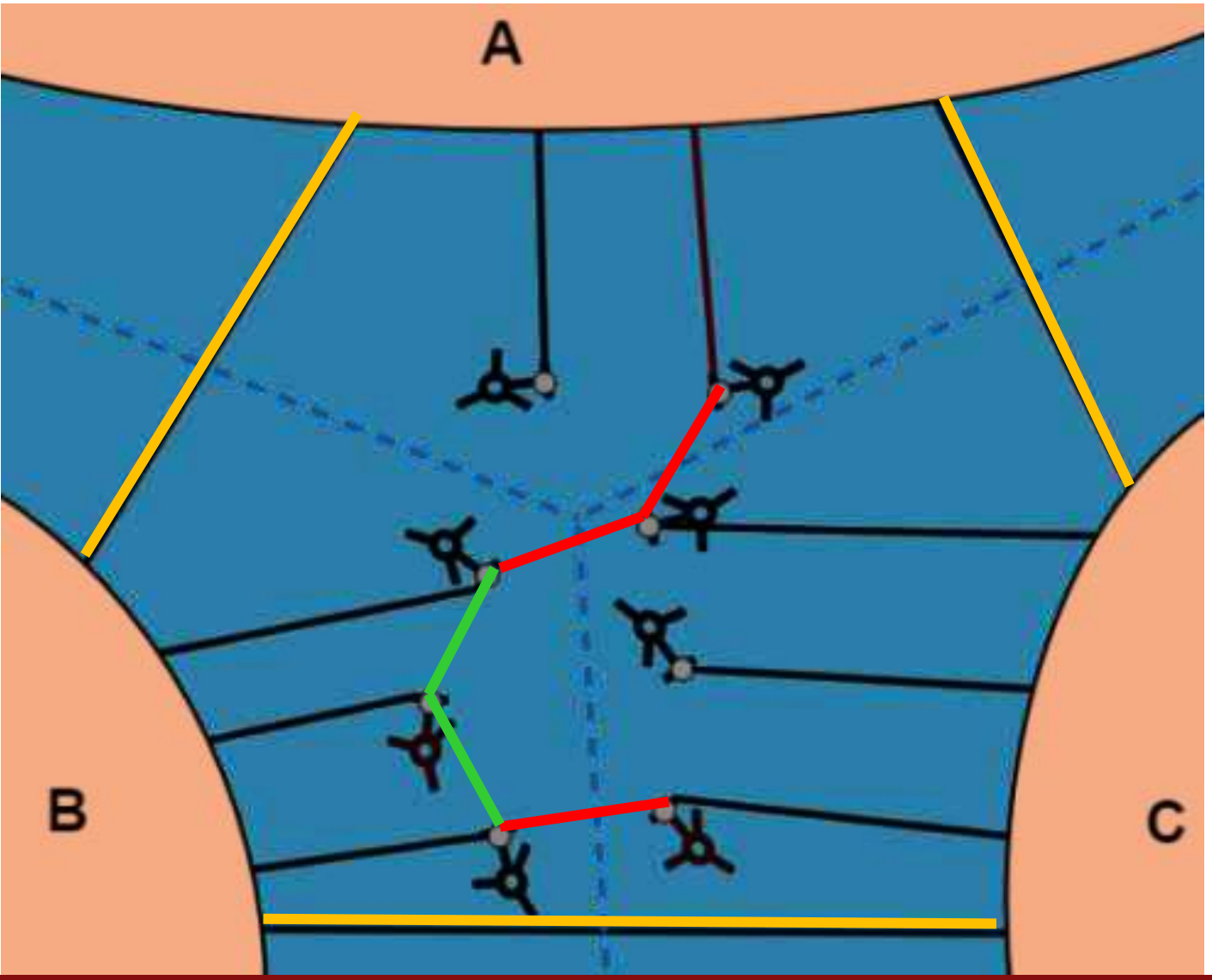
From BAU to national distributed hubs



Existing ICs

New IC links

MOGs

Source: PROMOTioN

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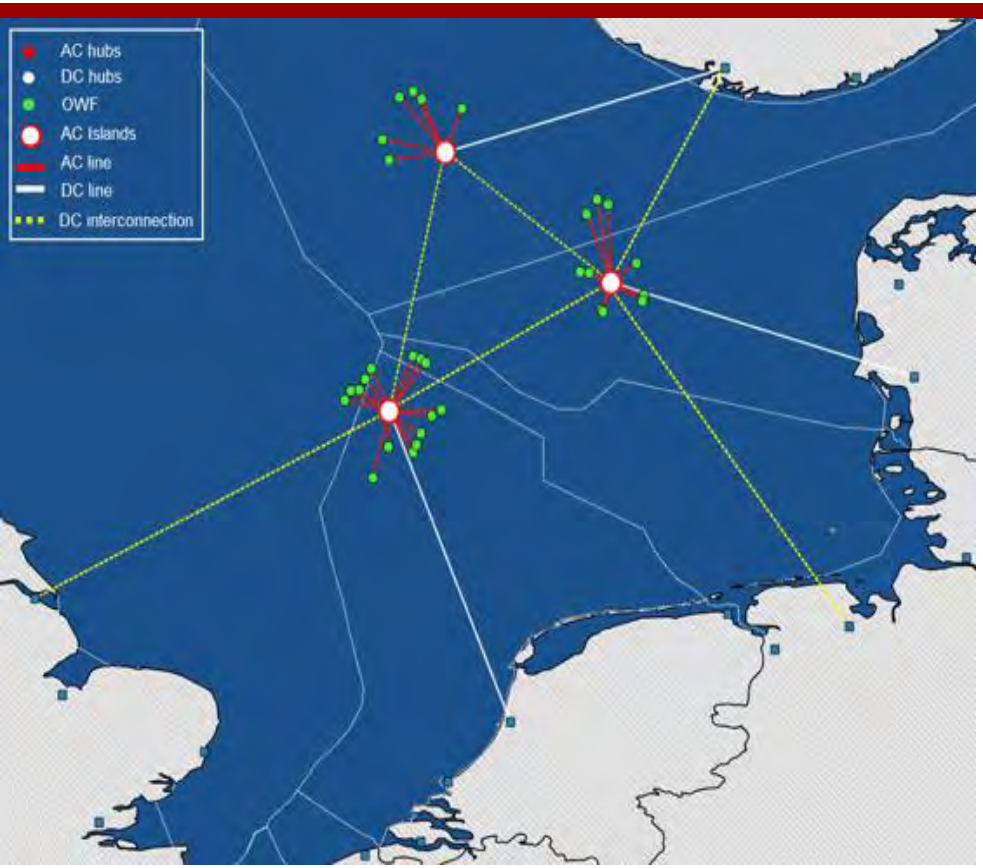
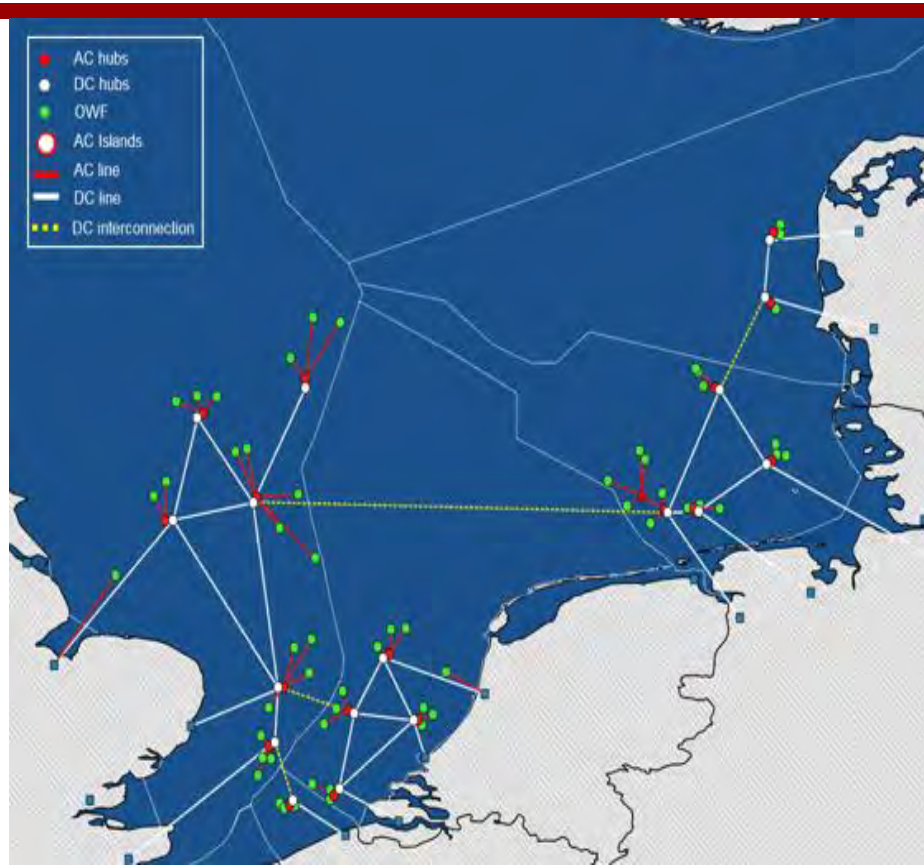
MOG: Meshed Off-shore grid



Centralised wind power hubs concept – Regular AC hubs



European distributed hubs concept

Source: PROMOTioN

MOG problems

- 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 >> 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

Q3 stakeholder engagement

- 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.

Conclusions

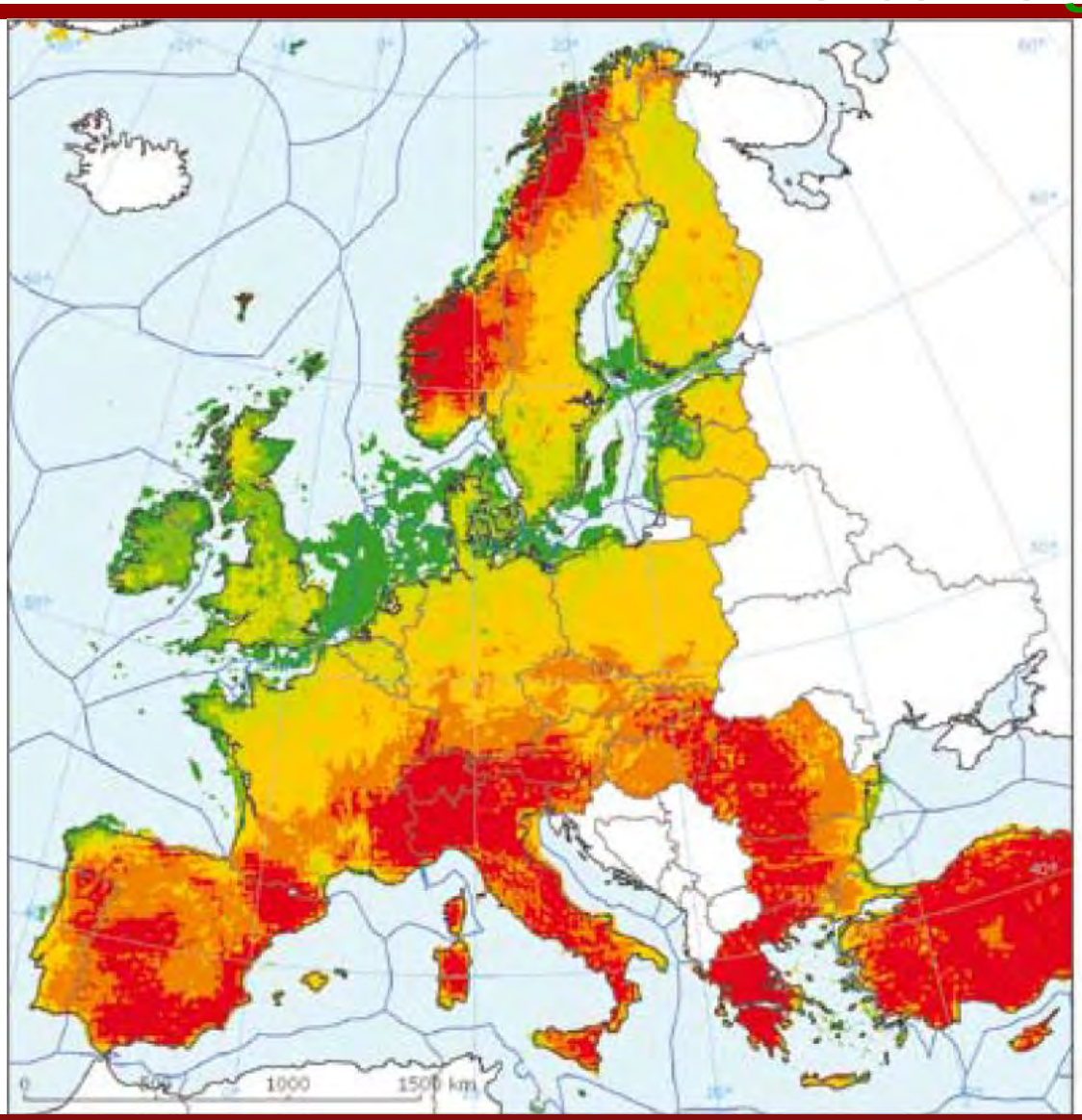
- Kriegers Flak provides proof of concept
  - of AC-OWFs so simpler but still took time
  - OWFs built 2011, interconnected in 2020, Sweden dropped out
- Next decade likely to see ICs linking some OWFs
  - Might some planned ICs be close enough to future OWFs?
  - If so are coordination benefits sufficient 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

References

- 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

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