North Seas Offshore Energy Clusters Study

Findings

European Commission

Bilbao, 02 April 2019
The North Seas have a vast offshore wind potential – Economically attractive potential depends on competitiveness vs. alternatives

Technical and economically attractive potential

**Technical potential [GW]**
- North Seas: 1,485
- Atlantic: 963
- Baltic Sea: 470

**Economic attractive potential [GW]**
- North Seas: 380
- Atlantic: 172
- Baltic Sea: 78

> Technical potential is the capacity that may be reached considering technical, geographical and space limitations – Without taking into account the grid constraints

> Economic attractive potential is the capacity that can be reached below a reference LCoE of 60 EUR/MWh – Reference is a CCGT power plant in 2030

> Economic attractive potential is dependent on further cost efficiencies along the value chain

Source: WindEurope; Roland Berger
Innovative grid concepts in hybrid projects can help bring costs of offshore wind development down

Hybrid project concepts

CGS IJmuiden Ver – Norfolk

North Sea Wind Power Hub

IJmuiden Ver OWF to UK, COBRA Cable

DE OWF connected to NL

> Hybrid projects are transnational combinations of offshore power generation and transmission assets

> Ownership of such combined assets is typically in the hands of multiple stakeholders, e.g. multiple OWF developers and TSOs

> Analogous, permitting responsibility is typically in the hands of multiple countries' authorities

Source: Roland Berger
Hybrid projects are cost-efficient because they significantly reduce the need for physical infrastructure.

Benefits of hybrid projects (e.g. CGS IJmuiden Ver – Norfolk)

Reference case: Stand-alone OWFs and IC

Hybrid case: Combined grid solution

> Hybrid project eliminates need for infrastructure compared to reference case
  > 130 km of cable not needed
  > 2 onshore converters not needed

> Cost-efficiency of hybrid projects increases compared to reference case

190 km IC cable

4 onshore converter

60 km IC cable

2 onshore converter

- 130 km

- 2 units

Converter station  Transmission cable

Source: 4COffshore; DG Energy Joint Research Center; TenneT B.V.; Vattenfall; Roland Berger
By significantly reducing the need for physical infrastructure, hybrid projects reduce CAPEX and OPEX of offshore power generation.

Significant lifetime benefits of hybrid projects

<table>
<thead>
<tr>
<th>∆Socio-economic welfare (SEW) (hybrid – ref. case) [EUR m p.a.]</th>
<th>∆Lifetime benefit (hybrid – reference case) [EUR m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. -100</td>
<td>Max. 1,500</td>
</tr>
<tr>
<td>Inset: ∆SEW</td>
<td>∆CAPEX</td>
</tr>
<tr>
<td>x 25 years</td>
<td>∆OPEX (cable systems)</td>
</tr>
<tr>
<td>SEW reference project</td>
<td>∆Lifetime benefits</td>
</tr>
</tbody>
</table>

1) 8% discount factor

Source: Joint Research Center; Roland Berger
Additionally, hybrid projects are efficient in terms of maritime space used and thereby reduce the environmental impact.

Reduced environmental impact through hybrid projects

> Reduced space requirements for offshore infrastructure and cable systems

> Efficient use of available resources in heavily used North Seas region (shipping, oil & gas, fishing, etc.)
In summary, hybrid projects are efficient in terms of cost and maritime space used – How did we arrive at these results?

Study approach

1. **Project identification**
   - Study initially considered 18 hybrid project ideas
   - Identification relied on **real assets**, meaning infrastructure either already in place or planned to be built
   - First screening of available assets and sensible concepts
   - Close stakeholder interaction for identifying hybrid project ideas

   Hybrid project ideas are based on real assets

2. **Benefit assessment**
   - Study assessed 10 projects deemed feasible for potential future implementation in detail
   - Benefit assessment for the selected projects evaluated **CAPEX**, **OPEX** and **SEW**
   - Difference compared to a reference case
   - Required project details derived together with stakeholders

   Hybrid projects generate lifetime benefits

3. **Barrier mitigation**
   - Study evaluated barriers and developed mitigations to 5 projects for implementation
   - Focus on projects with a positive benefit assessment
   - Project-specific barrier assessment and derivation of **Action Plan** to overcome barriers in close interaction with stakeholders

   Hybrid project implementation requires to overcome barriers

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1) In cooperation with the Joint Research Center of the European Commission
Source: Roland Berger
By evaluating various hybrid project ideas in the North Seas, we identified five hybrid projects with significant benefits.

Selected hybrid project ideas¹)

¹) Location of offshore wind farms and cable routes indicative

Source: Roland Berger
The five beneficial hybrid projects include two IJmuiden Ver projects, COBRA Cable, DE OWF to NL and NSWPH.

Assessment of selected hybrid project ideas:

<table>
<thead>
<tr>
<th>Project Description</th>
<th>$\Delta$CAPEX$^1$</th>
<th>$\Delta$OPEX$^1$</th>
<th>$\Delta$SEW$^1$</th>
<th>$\Delta$Lifetime benefits$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 IJmuiden Ver OWF to UK</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td>2 CGS IJmuiden Ver – Norfolk</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td>3 Nautilus</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
<tr>
<td>4 UK OWF connected to BE</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
<tr>
<td>5 COBRA Cable</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td>6 DE OWF connected to NL</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
<tr>
<td>7 NeuConnect</td>
<td>$\uparrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
<tr>
<td>8 CGS DE OWF – NL OWF</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
<tr>
<td>9 North Seas Wind Power Hub</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
</tr>
<tr>
<td>10 &quot;Project Irish Sea&quot;</td>
<td>$\Downarrow$</td>
<td>$\uparrow$</td>
<td>$\Downarrow$</td>
<td>$\Downarrow$</td>
</tr>
</tbody>
</table>

1) $\uparrow$ if >5%, $\uparrow$ if between 5% and 0%, $\downarrow$ if 0%, $\downarrow$ if between 0% and -5%, $\downarrow$ if <-5% benefits relative to total (cost)

Source: Joint Research Center; Roland Berger
We propose four concrete actions to overcome barriers to hybrid project development

Barriers and proposed actions

<table>
<thead>
<tr>
<th>Barriers to implementation</th>
<th>Recommended actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>National focus of energy policy (legal and regulatory framework)</td>
<td>Implement project-specific, enforceable legal agreement to provide security for developers</td>
</tr>
<tr>
<td>Lack of proper de-risking instruments for developers</td>
<td>Provide public financial support to de-risk cross-border projects with pilot character</td>
</tr>
<tr>
<td>Misalignment of costs and benefits among stakeholders</td>
<td>Establish principles for allocation of costs and benefits among countries and stakeholders</td>
</tr>
<tr>
<td>Technical risks and onshore grid congestion</td>
<td>Widen the hybrid approach towards an integrated regional energy system approach (sector coupling)</td>
</tr>
</tbody>
</table>

Source: Roland Berger
National focus of energy policy hinders hybrid project development – HANSAs provide project-specific, enforceable legal framework

National focus of energy policy

Barrier description

> Despite a planned internal energy market in the EU, most countries still implement their own energy policies and rules
  – Uncertainty about jurisdiction over assets in hybrid projects and thus project development responsibility
  – Uncertainty about hybrid cable system classification
  – Uncertainty about tender processes for offshore wind farms involved in hybrid projects
  – Uncertainty about market arrangements

> National focus of energy policies and rules hinders development of hybrid projects

Recommendation

Hybrid Asset Network Support Agreements (HANSAs)

> Provide security for developers through project-specific, enforceable legal agreements between countries

Short-term certainty and long-term effects

> Ensure that specific mitigation measures designed to overcome relevant barriers are developed and implemented
> Offer both short-term certainty and the possibility of informing future legal frameworks – e.g. the European Commission considers how to tackle hybrid cable system classification
Lack of de-risking instruments for developers of hybrid projects – Instruments like Connecting Europe Facility provide starting point

Lack of proper de-risking instruments for developers

Barrier description

> Hybrid projects are riskier than conventional offshore developments
  > Largely untested
  > Require collaboration between multiple parties
  > Must integrate several projects into one
> Developers need incentives to switch from a conventional offshore project to a hybrid project concept during early project stages
> Lack of public funding to de-risk hybrid concepts hinders hybrid project development

Recommendation

Public financial support
> Helps developers and investors to de-risk pilot hybrid projects
> Allows for early-stage alignment across assets and countries

EU’s Connecting Europe Facility (CEF)
> Example of public funding programme to support, among others, the development of hybrid projects which have a PCI status
> Additionally, CEF Energy for "Renewable cross-border cooperation" will provide co-financing for early-stage ideas which are not eligible based on a PCI status, such as DE OWF to NL

Source: Roland Berger
Transnational character of hybrid projects results in misalignment of costs and benefits among stakeholders – Clear principles needed

Misalignment of costs and benefits among stakeholders

Barrier description

> Knowledge on costs and benefits of a hybrid project are key for stakeholders
> Without cost and benefit transparency there is no commitment to hybrid project development
> Each hybrid project generates a unique set of costs and benefits, which can be unfairly distributed
  – Country A may carry the burden of grid connection costs
  – Country B may benefit from cheaper electricity
> Lack of clear principles governing the fair allocation of costs and benefits hinders hybrid project development

Recommendation

Principles for fair allocation of costs and benefits

> Allow to redistribute costs and benefits fairly across involved project developers and other stakeholders – e.g. also an agreement on revisiting a fair cost and benefit allocation after the commissioning of a hybrid project can make sense
> Act as a starting point for the development of project-specific solutions in the context of hybrid projects

Source: Roland Berger
Technical risks of high capacity offshore generation, onshore grid connection and onshore grid congestion – Sector coupling needed

Technical risks and onshore grid congestion

Barrier description

> Hybrid approach allows to significantly increase utilisation of available offshore wind potential
> Increases in offshore generation capacity increases reliance on individual generation assets and transmission infrastructure
> Developers need flexibility to combine all available technologies in order to maximise benefits
> Mandated, disintegrated energy systems hinder hybrid project development

Recommendation

Sector coupling
> Allows to widen the hybrid approach towards an integrated energy system
> Reduces strain on transmission systems
> Allows to store energy during times of oversupply

Power-to-gas technology
> Represents a type of power conversion technology, which converts electricity into gas
> Proposed hybrid projects such as the North Sea Wind Power Hub provide can provide a testing ground for this energy system approach

Source: Roland Berger