Decarbonization Wedges Exercise

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OFFSHORE WIND POWER

1. State of the art and current development in different world regions

Technology 1: Land-based offshore wind farms

This type of wind farm involves powerful wind turbines —more powerful than onshore wind turbines— on the seabed. This type of wind turbines are deployed between 10 and 20 meters under water. Land-based offshore wind farms have been developed for the last few years in Northern Europe countries, notably in the U.K., Germany, Belgium and Denmark. China has also been developing land-based offshore wind farms. If the land-based offshore wind farms are located relatively close from the coast, the load factor ranges from 30 to 35%.

Technology 2: Floating offshore wind farms

Floating offshore wind farms are more expensive and involve the use of emerging technologies. This type of wind farms involves operating wind turbines on a floating vessel, which is attached to the seabed. The floating vessel can operate in deeper waters than land-based wind farms —i.e. a few hundred meters. This is why this technology can be used further away from coastal areas, which represents an asset as floating offshore wind farms are less likely to cause social discontent. As floating offshore wind farms are more exposed to wind, the load factor reaches 35 to 40%. This type of wind turbines are assembled in harbors, which makes them easier to build and implement.

European perspectives (2040-2050) show that offshore wind power could account for 25% of all renewable marine energies.

2. Maturity level and technological perspectives

Maturity of offshore wind power

Methodological information:

The maturity level is the TRL, reduced to 5 levels with market deployment enclosed in the higher TRL classes; maturity level scaling: 0 = none; 1 = fundamental research; 2 = R&D; 3 = demonstrator; 4 = low deployment; 5 = large deployment.

	2015	2020	2030	2040	2050
Land-based offshore	3-4	4	5	5	5
Floating offshore	2	3	4	5	5

Potential development of offshore wind power

Methodological information:

Potential development is measured as the percentage of the technology's contribution to environmental protection. This means evaluating, in terms of carbon emissions and of carbon emissions reduction, to what extent this new technology can contribute to limiting temperature increase to 2°C above pre-industrial level according to the time horizon considered in this study. Potential development scaling: 0 = not significant; 1 = significant (i.e. more than 1% of global emissions reduction) in some countries; 2 = significant on the global scale; 3 = very significant on the global scale (i.e. up to 3% of global emissions reduction); 4 = major technology vs. climate change (i.e. more than 3% of global emissions reduction).

		2020	2030	2040	2050
All technologies		1	1	2	2

Costs will decrease rapidly for land-based offshore wind farms, which will lead to the arrival of the technology on markets. As floating offshore wind farms are not mature yet cost analysis is more prospective than for other technologies, but cost reduction concerning floating vessels will probably lead to a strong development. Floating offshore wind farms might even compete with land-based wind farms in the future.

3. Technological, economic and social bottlenecks

<u>Methodological information:</u>

The following table ranks the bottlenecks according to their impact on the development of the technology. A bottleneck ranking at 6 on the scale will hinder or stall the deployment of the technology compared with bottlenecks ranking at 1; conversely, a bottleneck ranking at 1 will hinder the deployment of the technology much less than bottlenecks ranking at 6. Note that the ranking is relative, meaning that a bottleneck ranking at 6 is not necessarily hard to remove; conversely, a bottleneck ranking at 1 is not necessarily easy to remove. Technologies rank according to: research, finance, regulations, resources & environment, security and acceptability. The table also contains keywords associated with each bottleneck.

Technology		**Research & technological bottlenecks**	**Economy and Financial bottlenecks** (investment, risks)	**Regulation & institutional environment**	**Resources & environmental impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and security assets)	**Socio-technical feasibility**
Land-based offshore	Rank	2	6	5	1	3	4
	Key-words	Foundations Connections	Production cost	Legislation Use of maritime space	Foundations Construction Connections Noise	Maintenance Safety of other sea-users	Acceptability Harbor facilities Equitable servitude
Floating offshore	Rank	6	5	4	1	2	3
	Key-words	Floating vessel-wind turbine coupling Anchoring Connections	Production and construction costs Certification	Legislation Use of maritime space	Anchoring Installation Connections Bruit	Maintenance Safety of other sea-users	Acceptability Harbor facilities Equitable servitude

Technology 1: Land-based offshore wind power
Bottlenecks concerning acceptability, resources and security are equally strong.

Social acceptability is likely to vary according to the location and to the degree of implication of populations. Acceptability can be increased by heightening awareness about the benefits of the technology. However acceptability issues linked with local housings and tourists should not be overlooked.

Technology 2: Floating offshore wind power
Bottlenecks linked to research, resources and security are equally strong.

There are still technological bottlenecks to be removed.

Generally, floating offshore wind farms are located further away from coasts than land-based offshore wind farms. This reduces the impact on sea-users. However raising awareness on the benefits of floating offshore wind farms is crucial to increase acceptability, which is low among fishermen and shipping lines.

Is it worth noting that floating offshore wind farms are easier to build as building and assembling is done in harbors and also easier to operate than land-based wind farms. In the future floating offshore technology might compete with the land-based technology, even in shallow waters.

Technologies 1 and 2:
It is also essential to make simpler certification methods based on common standards.

Managing grid connection and distribution are also key factors to the competitiveness of offshore wind power technology.

Last but not least the use of cement, steel and rare metals does not convey an “eco-friendly” image of offshore wind power.

4. Potential radical and incremental innovations

Methodological information:

The following table lists the nature of innovations needed to overcome the bottlenecks mentioned earlier. There are two types of innovations: I stands for 'incremental innovation' (i.e. improving existing products and processes) and R stands for 'radical innovation' (i.e. developing new products and processes).

Technology		**Research & technological innovations**	**Economy and Financial innovations** (investment, risk)	**Regulation & institutional environment**	**Resources & environmental impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and security assets)	**Socio-technical feasibility**
Land-based offshore	I or R	I	I	R+I	R+I	I	I
	Key-words		Regulatory framework line	Support to a technology sector	Materials needed for turbine construction, environmental impact of wind farms	Maritime security	Acceptability
Floating offshore	I or R	R+I	I	R+I	R+I	I	I
	Key-words	New ideas	Regulatory framework line	Support to a technology sector	Materials needed for turbine construction, environmental impact of wind farms	Maritime security	Acceptability

Technology 1: Land-based offshore wind farms

New techniques have to be developed to counterweight the intermittent nature of wind energy —e.g. PHES storage, compressed air, hydrogen technology, super grid, etc. Innovations have to occur in various fields to decrease production and operating costs. Generator designs must especially improve in view of the scarcity of the materials involved in the process. The impact of wind farms on local weather —wind and wave patterns— as well as on ocean floors must not be overlooked either.

Technology 2: Floating offshore wind farms

Floating offshore wind farms need to improve on the same points as those mentioned for land-based wind farms. In addition to those efforts offshore wind technology also needs to reduce dramatically the cost of its floating vessels. Efficient development of offshore wind power depends on three conditions: a stable, long-term regulatory framework; an incentive, long-term buyback policy, which will lead to a rapid development of the offshore wind power market; a reduction of industrial cost.

Launching R&D programs without further delay is the key to success for renewable marine energies and offshore wind farms in particular.