Positive Impact on Society of an Open-Door Offshore Wind Farm integrated with Power-to-X

—

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01

Executive summary

Executive summary

Background

The Danish open-door procedure for offshore wind installation is currently subject to debate. The objective of this analysis is to further inform the debate by analysing the impact from a generic project enabled by the open-door procedure. The project consists of 1 GW offshore wind directly connected to a 1 GW PtX plant.

The analysis has been undertaken by KPMG P/S on request from a partnership formed by Ørsted and Copenhagen Infrastructure Partners (CIP).

Approach and methods

Effects on gross value added (GVA), employment and taxes are estimated in an input-output model using tables from the Danish national accounts.

In addition, official assumptions from the Danish Energy Agency are used to estimate the investments associated with the project (i.e. 'Teknologikataloger').

The 'real life' effects will naturally depend on how actual projects are executed, including whether supplies are sourced nationally or from abroad. In general, conservative assumptions have been applied. Thus, it is assumed that offshore wind foundations are solely sourced from abroad and thus do not generate activity in the Danish economy. For other components, the split of domestic vs. foreign production is based on the input-output tables in the Danish national accounts. Likewise, estimated GVA, jobs and taxes do *not* include the effects from increased household consumption. Further, cluster and learning effects are deemed too uncertain to be included in the quantified effects.

Results and considerations

Results are summarised in figure 1 below.

The results on GVA, jobs and taxes include direct effects and indirect effects, i.e. spill-over effects in industries that are sub-suppliers. The effects are not to be considered as structural effects, as the input-output model is based on short-to-medium run effects and does not take crowding-out effects into account.

Rather, the analysis outlines the economic activity that can be attributed to the energy project. Whether this activity is additional to the general economy will depend inter alia on the productive capacity of the economy and the business cycle at the given point in time. It is noted that a modelling in a general equilibrium model can be expected to show significantly lower effects as the activity will likely not be regarded as additional, but rather as replacing other economic activity.

The effects estimated in this report can to a reasonable degree be extrapolated to equivalent projects of smaller or larger size. Uncertainty in the estimate will increase with the degree of extrapolation, e.g. due to limits in the production capacity of the relevant industries.

Figure 1: Estimated effects

Effects from a generic project with 1 GW offshore wind and 1 GW PtX capacity combined.

GROSS-VALUE ADDED (GVA)

Project lifetime

4,100 mEUR

Estimated national economic activity attributed to the project across the phases (2023-2059). Net present value in 2020 prices.

JOBS (FTEs)

Per year in each phase

440 2023-2025 | **3,800** 2026-2028 | **580** 2029-2059

Estimated domestic FTEs that can be attributed to the economic activity from the project. FTEs per year in the different project phases, i.e. development (2023-2025), construction (2026-2028), and operation (2029-2059).

TAXES

Project lifetime

1,500 mEUR

Estimated national tax collection attributed to the project, i.e. income tax and corporate taxation. In 2020 prices. Not-discounted.

OTHER CONTRIBUTIONS

- ✓ **47-80** thousand tons … in **CO_2-emission reduction** per year depending on the fossil fuel that is replaced by hydrogen.
- ✓ Contribution to **security of supply** and eased balancing of the Danish electricity market.
- ✓ Contribution to reach **government target** of 4-6 GW electrolysis capacity in 2030.
- ✓ Contribution of estimated approx. EUR 0.4bn in NPV revenues for future Danish **hydrogen pipeline infrastructure** for entire period.
- ✓ **Increased competitiveness** of Danish PtX industry due to cluster and learning effects.

02

Approach and methods

Background and quantitative results

Background

This analysis has been undertaken by KPMG P/S on request from a partnership formed by Ørsted and Copenhagen Infrastructure Partners (CIP).

The objective of the analysis is to estimate the societal footprint from a generic (fictive) project with 1 GW offshore wind directly connected to a PtX facility with 1 GW capacity. The offshore wind is enabled through the open-door procedure, and the PtX plant is assumed to produce hydrogen only based on an Alkaline electrolyser (AEC). See full list of assumptions in Assumption Book (Appendix B).

The effects estimated in this report can within reasonable limits be extrapolated to equivalent projects of smaller or larger size. Uncertainty in the estimate will naturally increase with the degree of extrapolation. For example, there can be constraints on the production capacities of the relevant Danish industries. As shown in figure 2 the generic project (red mark) will to some extent be constructed in a "low" investment period. However, in 2028 (last year of construction) the construction of the generic project will add to an existing relatively high level of Danish offshore wind projects in construction phase, e.g. Energy Island Bornholm and North Sea offshore wind farms.

Results

The combined project is estimated to generate a gross value added (GVA) in the Danish economy of 4,100 mEUR over the course of the project phases from 2023-2059, including development, construction and operation.

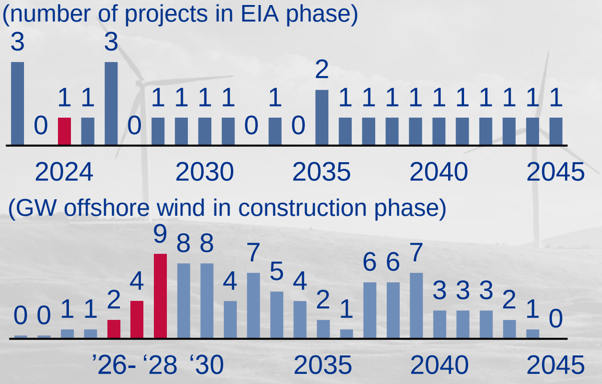
The combined project will create 440 jobs in the development phase (2023-2025), 3,800 jobs in the construction phase (2026-2028) and approx. 580 jobs in the operational phase (2029-2059). Job effects are measured as FTEs per year in each period.

Over the entire project phase, the combined project will generate a total tax contribution of approx. 1,500 mEUR in Denmark. This is a combination of approx. 660 from personal income tax plus approx. 760 mEUR in corporate income tax, and approx. 80 mEUR in electricity tax.

In general, the project has vastly different contributions over the total project lifetime, with the most significant annual contribution during the construction phase, as this is where most economic activity is generated, also giving rise to the highest employment and tax effects.

As illustration, in figure 3 below, the effects on GVA are shown on an annual basis for all three phases, split between direct and indirect effects.

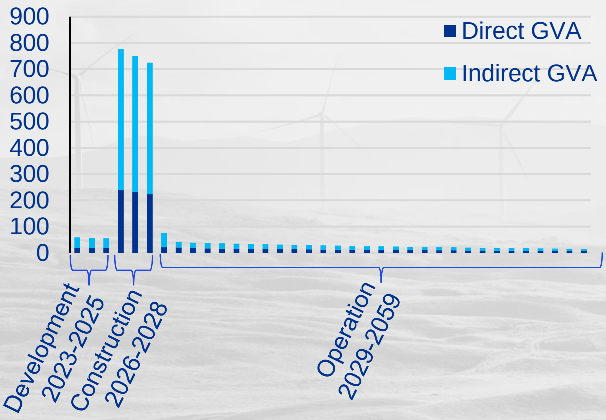
Figure 2: Danish offshore wind projects in EIA (VVM) phase and construction phase



Note: EIA phase is assumed a 1-year period 2 years prior to construction. Construction phase is a 3-year period before commissioning.
Sources: (1) Danish Energy Agency, Analyseforudsætninger til Energinet 2022, published on 9 January 2023 (2) KPMG.

Figure 3: Estimated GVA effects over the course of the entire project phase

(NPV, mEUR, 2020 prices)



Intro to the quantitative methodology

Method

GVA, employment and tax effects are estimated based on an input-output model (IO model) using IO data from Statistics Denmark. Other contributions are analysed based on best available data for the topic, with the assumptions being transparently presented directly on the page where they are presented. An overview of the approach is illustrated in table 1.

In general, the analysis should not be perceived as a socioeconomic analysis as presented in the guidelines for socioeconomic impact calculations by the Ministry of Finance of Denmark. Thus, no alternative scenario is applied, and the objective is not to undertake a cost-benefit or cost-effectiveness analysis.

The analysis uses GVA as the measure of the change in the economic activity from the project. This is the typical approach for specific investment projects related to one or more specific sectors, and not the economy as a whole. GVA is – like GDP – a measure for the value of total national production. The main difference between GVA and GDP is that GVA does not include indirect taxes, where VAT on final sales is the main component.

In addition, it is noted that the estimated effects on GVA, employment and tax collection are not to be considered as structural effects. The IO model is based on actual exchange of goods and services in the economy and does not take crowding-out effects into account. Rather, the analysis outlines the economic activity that can be attributed to the energy project. This is a classic approach to assessing effects from specific investment projects in the short to medium run.

Direct effects cover the direct effects on the economy from the direct investments and operations of projects itself. Indirect effects cover the effects that the project has in other sectors, i.e. sectors delivering intermediate input to the projects, and their subcontractors across the economy. This follows the standard approach in input-output analysis. This is illustrated in table 2.

For further information, see Appendix A 'Methodology'.

Table 1: Approach

1. The starting point is a generic project with 1 GW offshore wind directly connected to a PtX plant with 1 GW capacity.
2. The investment required for the project has been estimated, cf. table below.

Development (DEVEX)	Construction (CAPEX)	Operation (OPEX)
2023-2025	2026-2028	2029-2059
113 mEUR	2,330 mEUR	71m EUR/year

3. The investments are added as a shock to the input-output model to calculate output effect and GVA (see table 2 below).
4. Employment effect and taxation are estimated based on the input-output model's results.
5. Other relevant contributions (CO_2, learning effects, etc.) are analysed based on best available data and transparent assumptions, cf. section '4 Other contributions'.

Table 2: Direct and indirect GVA effects, illustrated by *construction* phase

	Construction of combined project		GVA, mEUR
A	Direct effects	Construction of offshore windfarm and PtX plant	698
B	Indirect effects	Subcontractors to the construction of the windfarm, incl. manufacturers of turbines, cables, electrolyser plus their subcontractors, etc.	1,542
C	Total effects	Sum of direct and indirect effects	2,250

Sources and assumptions

Sources and assumptions

Official and publicly available data sources have been used to the greatest extent possible. See table 3 for an overview of sources used. Thus, effects on GVA, employment and tax collection are estimated based on input-output tables in the Danish national accounts. In addition, official assumptions from the Danish Energy Agency are applied (i.e. ‘AF22’, ‘Teknologikataloger’).

Quantitative effects are reported for the effect in Denmark and scoped for the combined project until the hydrogen leaves the PtX plant. Hence, effects from pipeline transportation of hydrogen etc. are not included, cf. a conservative approach.

Selected assumptions and considerations are highlighted in the following.

- Assumptions for PtX are more uncertain than assumptions for offshore wind given the lesser maturity of the PtX technology.
- Development costs are assumed to be 5% of construction costs for the offshore windfarm. This is a conservative assumption as the Danish Energy Agency assumes approx. 20% of total construction costs. The development costs share for the PtX plant is assumed to equal that of the windfarm.
- PtX costs are estimated based on CAPEX for the AEC electrolyser itself. Construction of the surrounding buildings and acquisition of land are not included in the effects, giving a conservative assumption.
- Tax effects include income taxes, corporate taxes and electricity tax. Income taxes are estimated based on salaries and wages. Corporate tax is estimated based on the return of capital during the same phases. 100% equity financing for the owner of the generic energy project is assumed. Corporate tax rates for an actual project can be lower or higher depending on e.g. legal structure of the company and investors, capital structure, potential joint taxation, etc.
- The generic project will cause activity in the Danish economy but also abroad. This is accounted for through the input-output tables in the national accounts, which specify the level of import for specific industries. In addition, it is conservatively assumed that offshore wind foundations are fully sourced from abroad. At the same time, it is acknowledged that the actual import level will vary between projects depending on their individual sourcing.
- The effects on GVA, tax and employment do not include potential learning effects in the Danish industry. It is acknowledged that energy projects of this type and scale will build valuable expertise and knowhow, but the effects are deemed too uncertain to include in the quantitative assessment of effects.
- All economic effects are measured in 2020 prices. GVA effects follow standards for reporting GVA effects for multiple years. The socioeconomic discount rate is set at 3.5%, following the Danish Ministry of Finance’s discounting rate for socioeconomic analysis.

Table 3: Primary data sources – see full Assumption Book in Appendix B

Data source	Source description	Data use
Statistics Denmark	Input/output tables for Danish Economy (2019, newest available update)	Input/output tables for input/output model, including GVA and employment
Danish Energy Agency	Technology catalogue (Newest updated 2022 version, data interpolation across operation period)	Technology investment and operation costs, efficiency and output
Danish Department of Tax	Tables of applicable average tax rates	Tax rates for income tax, corporate income tax rate, electricity tax and depreciation of investment
KPMG	Assessment of sectors for input to development, construction and operational phase	Assumptions are made, where these are not present in data sources

03

Contribution to gross value added, employment and taxes

Contribution to gross value added

Estimating the gross value added (GVA)

A 1 GW offshore windfarm located in Danish sea territory that is connected to a 1 GW PtX plant (the project) adds value to the community by generating activity in the economy. In determining the gross value added (GVA) the project is divided into the development phase, construction phase and operation phase[1]. The GVA is split into the direct and indirect effects[2]. Monetary effects are discounted to 2023 with a socioeconomic discount rate of 3.5% as recommended by the Danish Ministry of Finance. All figures are rounded off to nearest 100. The results are presented in table 4.

Development phase (2023-2025)*

The GVA from the project is estimated at 60 mEUR over the period from 2023-2025 in direct effects. Further, there is an indirect GVA effect of 130 mEUR in the development phase for the project, totalling a GVA effect of 190 mEUR over the development phase.

Construction phase (2026-2028)*

The construction phase from 2026-2028 is by far the phase that generates the highest activity in the economy on an annual basis. This is due to the high upfront investment costs of both the offshore windfarm and the PtX plant, array cables and connection to the PtX plant. Over the construction period, there is a direct GVA effect of 700 mEUR, and indirect GVA effects of 1,550 mEUR, totalling 2,250 mEUR of GVA in the Danish economy for the construction phase.

For comparison, the annual GVA effects in the construction phase correspond to approx. 5% of the GVA in the entire Danish construction sector as of 2021.

Operational phase*

During the operational phase, the main effect will come from production and sales of green hydrogen as well as the other contributions that are qualified in this analysis.

However, the operation of the project will also create direct and indirect GVA, as a result of operations and O&M.

The direct GVA effects from the operational phase are totalling 1,200 mEUR over the 30 years of operation. Further, the operations and O&M of the project have an indirect GVA effect of 470 mEUR over the 30 years of operation. Hence, the total GVA effects from the operational phase total approx. 1,670 mEUR.

Total GVA effects*

In total, the project will have a GVA effect of 1,960 mEUR in direct effects and 2,150 mEUR in indirect effects, totalling 4,110 mEUR in GVA over the total period from 2023 to 2059, with the highest contribution during the construction phase, when not including the significant other positive effects from the production and value of the produced green hydrogen.

Table 4: The project's gross value added*

NPV, mEUR, 2020 prices	Direct effects	Indirect effects	Total effects
Development (2023-2025)	60	130	190
Construction (2026-2028)	700	1,550	2,250
Operation (2029-2059)	1,200	470	1,670
Total	1,960	2,150	4,110

* Note that all effects are for the period that is noted as referred to in the parenthesis in Table 4, column 1.

[1] The abandonment phase is not included in this analysis.
[2] See methodology.

Contribution to employment

Estimating the employment effect

A 1 GW offshore windfarm located in Danish sea territory that is connected to a 1 GW PtX plant (the project) increases demand for labour in all parts of the project. Both development, construction and operations will require labour, hence increasing employment in the economy. As with GVA, the employment effects can also be split in direct and indirect effects. The results are presented in table 5.

Development phase (2023-2025)

The direct employment effects from the project in the development phase are estimated at 280 FTEs annually in the development phase. Further, employment is estimated at 160 FTEs annually from indirect effects, totalling 440 FTEs per annually in the development phase.

Construction phase (2026-2028)

As with the GVA effects, the construction phase from 2026-2028 are by far the most labour-intensive phase, for the same reasons as with the GVA effects. The direct employment effect is estimated at 2,250 annually over the construction phase. Further, indirect employment effects are estimated at approx. 1,520 FTEs annually over the construction phase. In total, the employment effects are estimated at 3,770 FTEs annually in the construction phase.

Operational phase

In the operational phase, the direct employment effect related to the operational phase is estimated at 390 FTEs per year over the entire operational phase. This covers the direct employment effect of both the 1 GW PtX plant and the 1 GW offshore wind farm. Further, indirect effects are estimated at 190 FTEs per year over the operational phase. The total employment effect in the operational phase is thus estimated at 580 FTEs per year. This is based on the assumptions in the Danish Energy Agency's Technology Catalogue[3].

For employment, as well as for other effects, it should be underlined that the effects are estimated in the short to medium run and hence no crowding-out effects are included.

In general, employment related to the operation phase can be expected to be relatively local compared to the employment effects in the development and construction phases.

Table 5: The project's employment effect

Employment effect (FTEs per year)	Direct effects	Indirect effects	Total effects
Development (2023-2025)	280	160	440
Construction (2026-2028)	2,250	1,520	3,770
Operation, annual (2029-2059)	390	190	580

[3] For comparison, HØST PtX Esbjerg estimates a permanent job creation of 100-150 per year from the PtX plant alone (direct and indirect and including ammonia production). Likewise, QBIS funded by the Danish Maritime Fund (2020) estimated around 50-75 FTEs per year during the operation phase for the Thor offshore wind farm of 1 GW.

Contribution to tax revenue

Estimating the contribution to tax revenue

A 1 GW offshore windfarm located in Danish sea territory that is connected to a 1 GW PtX plant (the project) increases demand for labour and operating capital, both of which will result in tax revenue.

The employment will generate income taxes, and the operating capital applied will generate corporate taxes.

The effect on tax revenue is split into effects in income tax, corporate tax, and electricity tax (el-afgift). Each include both direct and indirect effects. The results are presented in table 6.

Income tax revenue

Over the project phases, the increased employment and associated increased income from wages and salaries is estimated to generate income tax of 655 mEUR.

Corporate income tax revenue

Further, the increased activity during development and construction will also generate return on operating capital across the economy, leading to corporate income tax revenue of 417 mEUR during development and construction.

In addition, and following the methodology, as described in the respective chapter of this analysis, it is estimated that owner of the energy project itself will pay 339 mEUR in corporate income tax over the project's operational phase from 2029-2059. This estimate of corporate income tax is based on the assumptions given in the methodology description and the assumption that the project is 100% equity financed and does not generate over-normal profits.

Electricity tax

The electricity tax paid for the PtX plant's consumption of electricity is estimated to 77 mEUR over the operational phase from 2029-2059.

Total tax revenue

The total tax revenue over the project's lifetime thereby amounts to 1,488 mEUR in 2020 prices.

Table 6: Tax revenue from the project[1]

mEUR, 2020 prices	Income tax	Corporate tax	Electricity tax	Total effects
Total project lifetime	**655**	**756**	**77**	**1,488**

Note: [1] See methodology and assumption for further description of how income tax and corporate tax are calculated.

04

Other contributions

Greater supply and flow of green hydrogen

Flow of hydrogen supports the financial sustainability of Danish hydrogen infrastructure investments with an estimated EUR 0.4bn in net present value

A political agreement in 2022 sets a target for Denmark to reach an electrolysis capacity of 4-6 GW in 2030. Demand and pipeline infrastructure is an important factor for driving this development. This is clear from the public discussion and also established in a market dialogue performed by KPMG for Energinet and Evida in 2022[4].

One of the main elements in achieving a good economy in an infrastructure project is volume, but the hydrogen production market in Denmark is still immature, which makes infrastructure investment uncertain. It is a well-known *'the chicken or the egg'* dilemma when establishing a market like hydrogen that depends on pipelines for transport. Production needs pipelines to reach end users, and the owner of the pipelines needs certainty for their investment, but there are no certainty because the producers have no contracts with end users due to the lack of ability to deliver large volume through pipes.

A 1 GW PtX project helps to reduce the demand risk for the infrastructure investment by generating revenue to the infrastructure owner. Thus, a 1 GW hydrogen project is estimated to generate a revenue stream of approx. EUR 0.4bn in 2022 prices over a 30-year period[5] discounted to 2023.

This is of course based on the assumption that the PtX facility is connected to hydrogen pipeline infrastructure. Further, the amount of hydrogen produced is estimated based on the Danish Energy Agency's Technology Catalogue, and production is assumed to be transported through pipeline only. An infrastructure tariff is assumed based on preliminary and publicly available estimates from Energinet on average cost of transportation as this is regarded as the best publicly available information[5]. Further, it is mentioned that the actual tariff contribution will naturally depend on a number of factors, including tariff model.

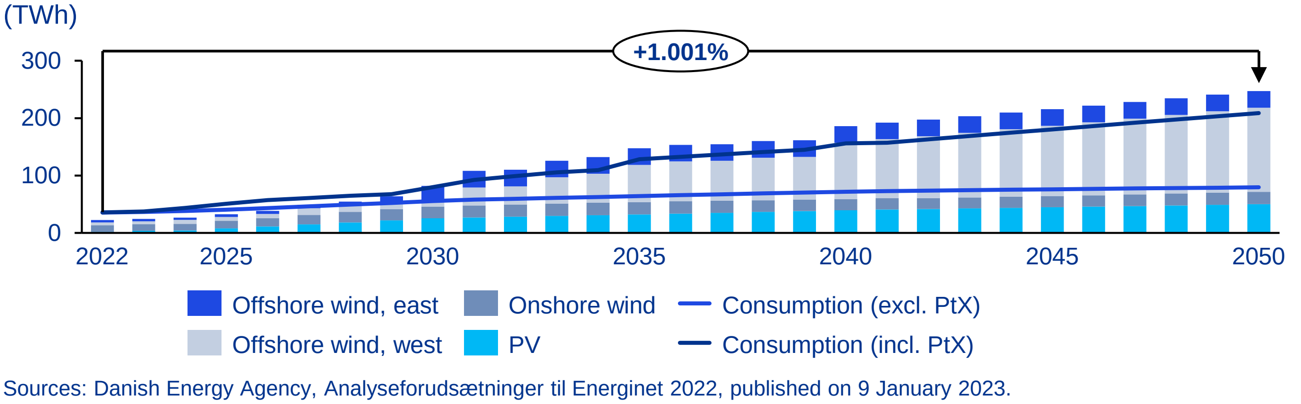
Access to low-cost 100% renewable electricity

Another key factor to ensure development of electrolysis capacity in Denmark is access to low-cost renewable electricity and insurance of 100% renewable electricity. This was established in the market dialogue[4] as well. Reaching the 4-6 GW target of electrolysis capacity will increase electricity demand by 18-27 TWh when assuming 4,500 full load hours (FLH), which is more than half the consumption in Denmark today.

As shown in figure 4, the Danish electricity consumption is expected to be higher than the production of renewable electricity towards 2030. After 2030, production exceeds consumption towards 2050. This forecast is made by the Danish Energy Agency and it shows a gradual increase in offshore wind capacity especially in the North Sea after 2030, and it is assumed to supply a massive expansion of electrolysis capacity.

The 1 GW offshore windfarm project will accelerate the expansion of offshore wind capacity, which is necessary for achieving a quick start of the hydrogen industry, and perhaps necessary for gaining a market position in Central Europe before another market player wins it.

Figure 4: Electricity consumption and production of renewable electricity (RES-e)



Sources: Danish Energy Agency, Analyseforudsætninger til Energinet 2022, published on 9 January 2023.

[4] Markedsdialog om brintinfrastruktur, KPMG, 2022
[5] Estimated based on Energinet, Feasibility study user group meeting no. 2 28 Nov. 2022. Energinet's preliminary estimate indicates an average cost of transportation of 9 EUR/MWh from 2029-39, 8 EUR/MWh 2040-50 – and 6 EUR/MWh is assumed subsequently. DEA's Technology Catalogue assumes hydrogen output pct. of 68, which implies an annual hydrogen production of 3 TWh when assuming 4,500 FLH. discount rate 3.5.

Security of supply and eased balancing

Increased security of supply when the hydrogen production is local

After the invasion of Ukraine in 2022, Europe's gas supply from Russia has been reduced significantly and is converting towards zero. But the IEA expects that there will be a shortage in 2023 of 27 bcm of natural gas[6] if no additional actions are taken and highlights the importance of starting up new supply chains from other sources than import from Russia.

Hydrogen could to some extent substitute natural gas within a decade or two and increase the security of supply if the production is placed in the EU and Denmark. As illustrated earlier, this will require a rapid expansion of offshore wind and infrastructure if Denmark is to take part in this development. The 1 GW hydrogen plant will support this development.

Co-locating offshore wind farms with PtX has a high value for the power grid

The increasing share of intermittent renewable energy in the power system increases the need for ancillary services for balancing supply and demand. As shown in figure 5 the Danish TSO, Energinet, has increased expenditures on ancillary services over the past few years and expects expenditures to increase even further towards 2025. The development in ancillary services underlines the need for users that can change how much energy they use as well as power production capacity that can produce more energy during times when renewable energy production is low.

The 1 GW hydrogen project connected directly to a 1 GW offshore windfarm needs to be connected to the main grid for technical reasons. But the connection also adds value to the main grid by adding extra electricity capacity to the grid when prices are high. In this case, hydrogen production is turned to a minimum and power from the offshore windfarm can be injected to the grid if needed.

In figure 6, the production duration curve illustrates how many hours per year a 1 GW offshore wind farm operates at full capacity. The graph also displays the distribution of the 10% highest electricity prices. For example 22.3% of the highest-priced hours fall within the interval of 7009-7884 hours, during which the wind farm would produce an average of 12%.

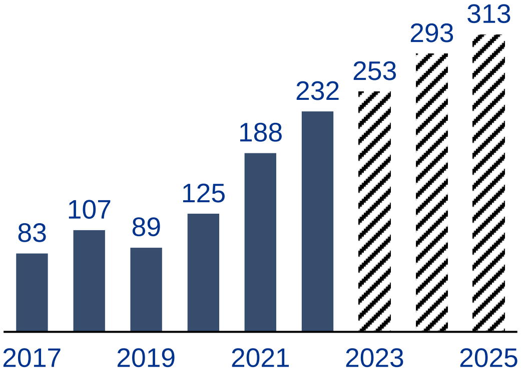
The hours with high prices are correlated with hours of low wind, but there is still a significant production that can benefit the grid and the consumers. Especially when offshore wind capacity is expanding, and more offshore windfarms can contribute to the electricity supply in the hours with high prices and when the system is under stress, this will keep electricity prices more stable in the price zone.

In situations with low prices and low wind production from the offshore wind farm, for example at hours of very high solar PV production, the PtX plant can consume electricity.

The duration curve and the electricity prices used in figure 6 are simulated and provided by Ørsted. The figure shows a specific year but represents a tendency of offshore wind production contributing to the electricity supply in the hours with high demand and low production.

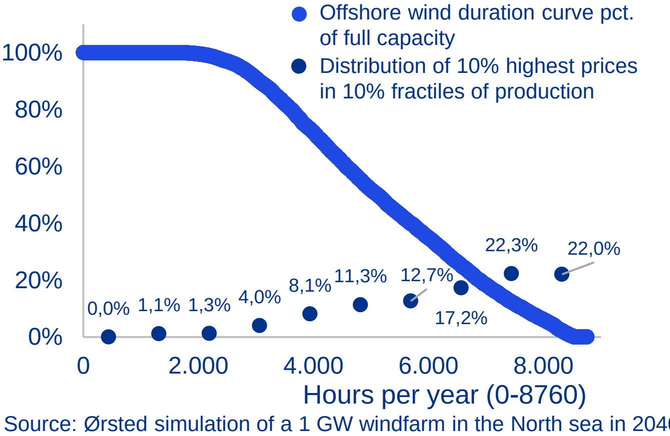
Figure 5: Energinet's expenditures on ancillary services

(mEUR, current prices)



Source: Energinet.

Figure 6: Production duration curve – 1 GW in The North Sea



Source: Ørsted simulation of a 1 GW windfarm in the North sea in 2040

[6] IEA, World Energy Outlook, 2022

Emission effects

Emission effects can arise from hydrogen replacing consumption of fossil fuel in the industry or in the transport sector

The emission effects of a PtX project of 1 GW and 1 GW offshore windfarm arise from the end-use of carbon-free hydrogen. Hydrogen has the potential of replacing fossil fuel in transport and in the industry.

Thus, an assumption in the analysis of emission effects is that the offshore windfarm does not have an independent effect on CO_2 abatement because the abatement occurs when hydrogen substitutes an existing fossil fuel consumption.

The CO_2 abatement will depend on which type of fossil fuel hydrogen substitutes

In the outlined project, the hydrogen is distributed through a pipeline and sold to the highest bidder, and therefore the end user is not known in advance. Thus, the emission impact is shown as a range of potential buyers representing different CO_2 abatements depending on the buyer's current consumption of fossil fuel that the hydrogen will substitute. Based on these assumptions, the CO_2 abatement is expected to be in the range of 47-80 kton CO_2 per year[7], when assuming a production of 3 TWh of hydrogen. Table 7 below gives an overview of the CO_2 abatement when hydrogen substitutes different types of fossil fuel.

The upper range of the estimate is based on hydrogen replacing coal used in industry without carbon capture, as this consumption has the highest CO_2 emission. The lower range of the estimate is based on hydrogen substituting natural gas in either transport or industry.

When hydrogen is used as input to the production of e-fuels it shall be underlined that there is a difference in global CO_2 emissions, depending on whether the e-fuel is produced using a biogenic or fossil carbon source.

When using a biogenic carbon source, the global emission reduction from using e-fuels is equal to the previous emissions from using fossil fuels. In table 7, this is shown for flights and shipping. When using a fossil carbon source, the e-fuel will emit fossil carbon. However, the carbon released from the use of the e-fuel has in this case been captured from a fossil source that would otherwise have emitted the same amount of CO_2 to the atmosphere. Following current rules for accreditation of carbon capture, the emission reductions will be 100% allocated to the power plant, industrial plant, etc. where the fossil CO_2 is captured. However, the effect from this carbon capture and use in e-fuel could just as well be accredited to the end user of the e-fuel, leaving the power plant, industrial plant, etc. with unchanged emissions. Thus, the results in table 7 illustrate the effects on global carbon emissions, not depending on whom the carbon capture is accredited to, given that the fossil CO_2 in a BAU scenario would otherwise have been emitted to the atmosphere from i.e. the fossil power plant.

Table 7: CO_2 abatement potential for the generic project (3 TWh of hydrogen)

(kton CO_2)

Direct use in transport, as substitute for:		Direct use in industry, as substitute for:		Input in E-fuel that substitute:	
Petrol	62	Coal	80	Fuel - Flight	61
Diesel	63	Diesel	63	Fuel - shipping	67
Natural gas	47	Natural gas	47		
Fuel - shipping	67				
Fuel - flight	61				

Source: Danish Energy Agency, data for CO_2 emissions for different fuels and KPMG calculations

[7]This only relates to the operation phase. Emissions related to construction and abandonment are not included.

Cluster and learning effects as well as effects on the supplier market

Public and private collaboration drives new market and generates new export potentials

Hydrogen is a new market with the potential of being a new great export opportunity for Denmark due to the massive expansion of offshore wind creating a lot of hours with surplus wind production and low energy prices. If this is exploited, it will have spill-over effects on a lot of different supplier markets in Denmark and generate export for billions of euros as showcased by the offshore wind industry since the early 2000.

The journey of wind and especially offshore wind started in 1993. Denmark was the first country in the world to prove that it was possible for turbines to exist in the harsher environment at sea, and that their power yield gradually would become commercially viable[8].

Later in 1997, the Danish government together with the energy industry made an action plan outlining the conditions for large-scale expansion of offshore wind power. This led to the development and construction of two large-scale offshore windfarms in Denmark in 2002 and 2003, and these have further driven the offshore wind business in Denmark.

In 2019 and 2020, the wind business generated about EUR 15bn of revenue and nearly half of this was exported as shown in table 8. The business accounts for around 50% of total export of energy technologies and services and employs approx. 33,000 employees in Denmark. The employment effect is primarily concentrated in Jutland, and especially the centre of Jutland, where the wind business employed 3.5% of private employees in 2020[9].

Experience is crucial for the industry's competitiveness

New technologies as hydrogen production are expensive at first, but cost decreases in line with the expansion of capacity. This effect is called learning effect. Studies show that the learning effect on CAPEX for electrolysers is expected to be 9-13% from 2020-2030 depending on the electrolysis technology[10]. Approximately the same learning rate was observed for offshore wind in the period from 2011 to 2021 as shown in figure 7.

A 1 GW PtX plant will increase Denmark's likelihood of obtaining the necessary knowhow related to the PtX industry. Getting this expertise in Denmark can be central for realising first-mover advantages, unlocking the potential of cost reduction and gaining competitive advantages.

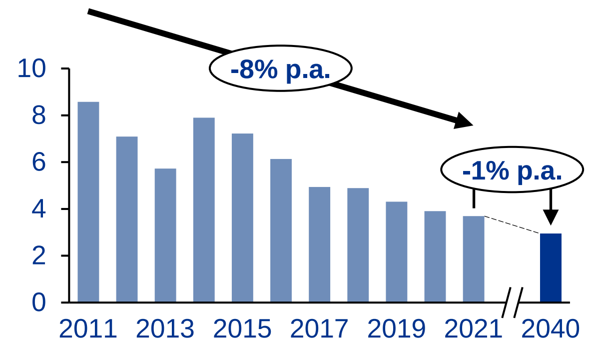
Table 8: Key figures of Danish wind power industry

	2019	2020
Revenue, EUR bn	15	15
Export, EUR bn	7	6
Export, share of total export of energy technology and services[1]	54%	47%
Employment	33,159	32,721

Sources: Energistyrelsen, Green Power Denmark, DI Energi, Dansk Fjernvarme, Eksport af energiteknologi og -service 2020, 2021. DAMVAD Analytics & Wind Denmark, Branchestatistik 2021

Figure 7: Levelized cost of energy for offshore wind

(EUR/kWh, 2021 prices)



Sources: IRENA, Renewable Power Generation Costs in 2021, Danish Energy Agency, Technology Catalogue

[8] Energistyrelsen, Danish Experiences from Offshore Wind Development, 2017
[9] DAMVAD Analytics & Wind Denmark, Branchestatistik 2021
[10] Hydrogen Council, Path to hydrogen competitiveness, A cost perspective, 2020

Appendix A

Methodology

Methodology

The quantitative effects are calculated in an input-output model developed by KPMG for the specific project and based on input/output tables from Statistics Denmark. An input/output model is a standard economic framework to estimate short- to medium-term effects on the economy driven by changed activity or structure in one or more sectors, e.g. from new investments, changes in production structure, substitution from imports to domestic production, etc.

A key feature of an input/output model is that it can estimate both the direct and indirect effects. Direct effects relate to changes in the activity or structure of a given sector. Indirect effects cover how this affects all other sectors, through changes in the activity from sectors that deliver input to the given sector. The direct effects can be seen as the first order effects to the change in the activity in the given sector. The indirect effects are then second order effects, driven by changes in other sectors that deliver input to the sector affected by the first order effects. Following this logic, there will also be an effect in the sectors delivering input to the sectors affected by the second order effects and so forth.

This is a well-recognised effect in the economy, closely related to the “money multiplier”. To exemplify this, we can look at a case where a customer spend EUR 10 in a bakery. The bakery pays some of the EUR 10 in wages and cost of capital, but also buys intermediate inputs such as flour, yeast, electricity. etc. If EUR 6 is spent on these intermediate inputs, then these EUR 6 generate activity in the sectors delivering intermediate input. Subsequently, these sectors will also pay wages and cost of capital, as well as using intermediate inputs, increasing activity in the sectors delivering their respective intermediate inputs.

An input/output model is a mathematical tool that sums all these cascading effects in the domestic economy and can hence estimate the direct effects from (in the example) a purchase of EUR 10 in a bakery (the direct effects) and the subsequent effects all the way back through the value chain (indirect effects). The input/output model can calculate both the direct and indirect effects on both output (activity), gross value added (GVA), employment, and wages and salaries.

By enhancing the input/output model with the tax rate on wages and salaries as well as the tax rate for corporate income tax, the tax effects can additionally be calculated on the output from the input/output model for both direct and indirect effects.

A keynote here is that the input-output tables only provide data for gross operating surplus and wages and salaries in each sector. From this the GVA can be calculated for each sector by adding wages and salaries to the gross operating surplus. However, depreciations and financial costs are not specified. Due to this fact, some assumptions are needed to calculate the corporate income tax. The first assumption is that existing sectors do not have any depreciations left to deduct from corporate income tax. The other assumption is that all sectors are either 100% financed by equity and/or that the tax rate paid on marginal income on financial institutions (interest on loans) is the same as the corporate income tax. These assumptions are necessary given the available data in an input/output model, but gives a reasonable estimate for the corporate income tax paid by all subsectors. To calculate the corporate income tax from the combined generic project, we have used a more precise method for calculating the corporate income tax, as we know the invested capital and the period for depreciation. Given the invested capital in the combined project, the operating costs and depreciations (assuming 15% depreciation per year for all assets) and KPMG’s conservative estimate of a 5% ROE, we have calculated the return on equity as basis for the corporate income tax. For this estimation, a 100% equity financed project is assumed.

The methodology for other contributions (qualified effects) is described alongside the description and qualification of the effects.

Table with overview of methodology for quantified and qualified effects

Quantified effects	Direct effects	Indirect effects	Method
Gross value added (GVA)	Increased domestic production from direct suppliers for development, construction and operation of combined project	Increased domestic production from subcontractors for development, construction and operation of combined project	The GVA and employment effects are effects calculated by using an input/output model as described in more detail on the previous slide. Tax effects are subsequently calculated on the basis of the results from the input/output model.
Tax revenue	Income tax from suppliers for development, construction and operation of combined project Corporation tax from suppliers for development, construction and operation of combined project Electricity tax from PtX plant	Income tax from subcontractors for development, construction and operation of combined project Corporation tax from subcontractors for development, construction and operation of combined project	
Employment	Employed by developer and direct suppliers of combined project	Employed by subcontractors for development, construction and operation of combined project	

Qualified effects	Effect	Method
Emission effects	CO_2 abatement when substituting existing fossil fuel consumption with green hydrogen	Emission effects are based on a range of likely end uses that can be substituted by hydrogen. Emissions effects are calculated by multiplying the CO_2 content of fossil fuel consumption substituted by hydrogen with the amount of hydrogen produced.
Greater supply and flow of green hydrogen	Consumption of hydrogen infrastructure, incl. tariff payments	The project contribution to the hydrogen network operator is transportation cost times hydrogen production.
Security of supply	See description under relevant slide for qualified effect	
Cluster and learning effects as well as effects on the supplier market	See description under relevant slide for qualified effect	
Not included	*Producer and consumer surplus* *Derivative effects on concession payments* *Effect on investment needs in the electricity grid*	

Appendix B

Assumptions

Basic assumptions for quantitative analysis

All assumptions are made by KPMG based on the argumentation as stated in the table below. The assumptions have been made without input from Ørsted and CIP. However, all assumptions have been discussed with Ørsted and CIP in order to clarify the need for further argumentation of specific assumptions. In those cases the argumentation below includes the outcome of these discussions.

Assumption element	KPMG assumption for analysis	KPMG argumentation
Methodology	Job effects, GVA and tax payments calculated through input-output model (IO)	Standard methodology for assessing those effects for stand-alone projects
Crowding out, etc.	The IO model is based on short-to-medium run effects and does not take crowding-out effects into account. Crowding-out effects, etc. accrue in the long run and are modelled through CGE models, which are not standard for analysis of stand-alone projects and partial analysis like the current model	Standard methodology for assessing those effects for stand-alone projects in the short-to-medium run
Data source for input-output data	Statistics Denmark	Assessed to be best source for Danish input-output data
Model set-up	KPMG developed input-output model Excel-based	KPMG has chosen to use the KPMG developed input-output model instead of Statistic Denmark's multipliers to increase transparency of data and methodology and to allow for higher degree of customisation of calculation of multipliers and addition of new industries, etc.
Note on costs	The analysis includes CAPEX and OPEX costs, but not ABEX	The analysis is focused on development, construction and operations and is hence scoped before eventual decommissioning and related to this. Furthermore, both the windfarm and PtX plant can potentially run longer than the stated technical lifetime, and as such it is not clear when ABEX would incur

Assumptions for development phase, 2023-2025

All assumptions are made by KPMG based on the argumentation as stated in the table below. The assumptions have been made without input from Ørsted and CIP. However, all assumptions have been discussed with Ørsted and CIP in order to clarify whether they have up-front knowledge that is not in line with the used assumptions. This has not been the case, leading to the below assumptions that alone represent KPMG assumptions for a generic 1 GW combined project in the generic 1 GW combined offshore windfarm and PtX plant (AEC Electrolyse) in the operational phase.

Offshore windfarm	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for development start year[1]	n.a.	n.a.
Development, share of total construction costs	No established data or data sources for development cost shares for 1 GW PtX plants. KPMG will assume 5% equal to the share of offshore windfarm[3]	IO tables split of domestic vs. foreign production[2]	740000 Other technical business services[4]
Development costs	20m EUR/GW[5]	IO tables split of domestic vs. foreign production[2]	740000 Other technical business services[4]

Sources: [1] *Danish Energy Agency, Technology Catalogue,* [2] *Statistics Denmark,* [3] *KPMG Assessment* [4] *KPMG Assessment,* [5] *Danish Energy Agency and KPMG Assessment*

AEC Electrolyser	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for operations start year	n.a.	n.a.
Development, share of CAPEX costs	5%[1]	IO tables split of domestic vs. foreign production[2]	740000 Other technical business services[3]
Development costs	0.05m EUR/MW[1]	IO tables split of domestic vs. foreign production[2]	740000 Other technical business services[1]

Sources: [1] *KPMG Assessment and assumptions* [2] *Statistics Denmark,* [3] *Industry code for Copenhagen Offshore Partner and KPMG Assessment*

Assumptions for construction phase, offshore windfarm 2026-2028

All assumptions are made by KPMG based on the argumentation as stated in the table below. The assumptions have been made without input from Ørsted and CIP. However, all assumptions have been discussed with Ørsted and CIP in order to clarify whether they have up-front knowledge that is not in line with the used assumptions. This has not been the case, leading to the below assumptions which alone represent KPMG assumptions for a generic 1 GW project in the construction phase for the offshore windfarm.

Assumption element	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for operations start year	n.a.	n.a.
Construction costs per MW	1.88m EUR/MW[1]	n.a.	n.a.
Split of construction cost shares			
Turbines	43.9%[1]	IO tables split of domestic vs. foreign production[2]	280010 Manufacture of engines, windmills and pumps
Foundation	13.4%[1]	Offshore concrete foundations are primarily imported from Poland and non-domestic countries. Hence KPMG assumed foreign production[3]	Not relevant, as import does not give significant Danish footprint
Array cables	1.3%[1]	IO tables split of domestic vs. foreign production[2]	270020 Manufacture of wires and cables
Grid connection	15.3%[1]	IO tables split of domestic vs. foreign production[2]	270020 Manufacture of wires and cables
Installation	25.5%[1]	IO tables split of domestic vs. foreign production[2]	330000 Repair and installation of machinery and equipment

Sources: [1] *Danish Energy Agency, Technology Catalogue,* [2] *Statistics Denmark,* [3] *KPMG Assessment*

Assumptions for construction phase, AEC Electrolyser 2026-2028

All assumptions are made by KPMG based on the argumentation as stated in the table below. The assumptions have been made without input from Ørsted and CIP. However, all assumptions have been discussed with Ørsted and CIP in order to clarify whether they have up-front knowledge that is not in line with the used assumptions. This has not been the case, leading to the below assumptions that alone represent KPMG assumptions for a generic 1 GW project in the construction phase for the AEC Electrolyser.

Assumption element	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for construction start year[1]	n.a.	n.a.
Construction costs per GW	450m EUR/GW input[1]	n.a.	n.a.
Split of construction cost shares			
Equipment	90%[1]	IO tables split of domestic vs. foreign production[2]	260020 Manufacture of other electronic products[3]
Installation	10%[1]	IO tables split of domestic vs. foreign production[2]	330000 Repair and installation of machinery and equipment[3]

Sources: [1] *Danish Energy Agency, Technology Catalogue,* [2] *Statistics Denmark,* [3] *Statistics Denmark industry description and KPMG Assessment*

Assumptions for operations phase, combined project 2029-2059

All assumptions are made by KPMG based on the argumentation as stated in the table below. The assumptions have been made without input from Ørsted and CIP. However, all assumptions have been discussed with Ørsted and CIP in order to clarify whether they have up-front knowledge that is not in line with the used assumptions. This has not been the case, leading to the below assumptions that alone represent KPMG assumptions for a generic 1 GW combined offshore windfarm and PtX-plant (AEC Electrolyser) in the operational phase.

Offshore windfarm	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for operations start year	n.a.	n.a.
Technical lifetime	30 years[1]	n.a.	n.a.
Full load hours	4,775[1]	n.a.	n.a.
Variable O&M	4.17 EUR/MWh[1]	IO tables split of domestic vs. foreign production[2]	330000 Repair and installation of machinery and equipment[3]
Fixed O&M	42,000 EUR/MW[1]	IO tables split of domestic vs. foreign production[2]	330000 Repair and installation of machinery and equipment[3]

Sources: *[1] Danish Energy Agency, Technology Catalogue, [2] Statistics Denmark, [3] KPMG Assessment*

AEC Electrolyser	KPMG assumption for analysis	Assumed domestic vs. foreign delivery	Sector used in input/output analysis
Year for financial and technical data	Interpolation from 2020 to 2030, updated to relevant year for operations start year[1]	n.a.	n.a.
Fixed O&M	2% of specific investment/ year[1]	IO tables split of domestic vs. foreign production[2]	330000 Repair and installation of machinery and equipment[3]

Sources: *[1] Danish Energy Agency, Technology Catalogue, [2] Statistics Denmark, [3] Statistics Denmark industry description and KPMG Assessment* kpmg.com/socialmedia

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