ECONOMIC APPRAISAL OF POTENTIAL WINDCONNECTOR DEVELOPMENTS

October 2019

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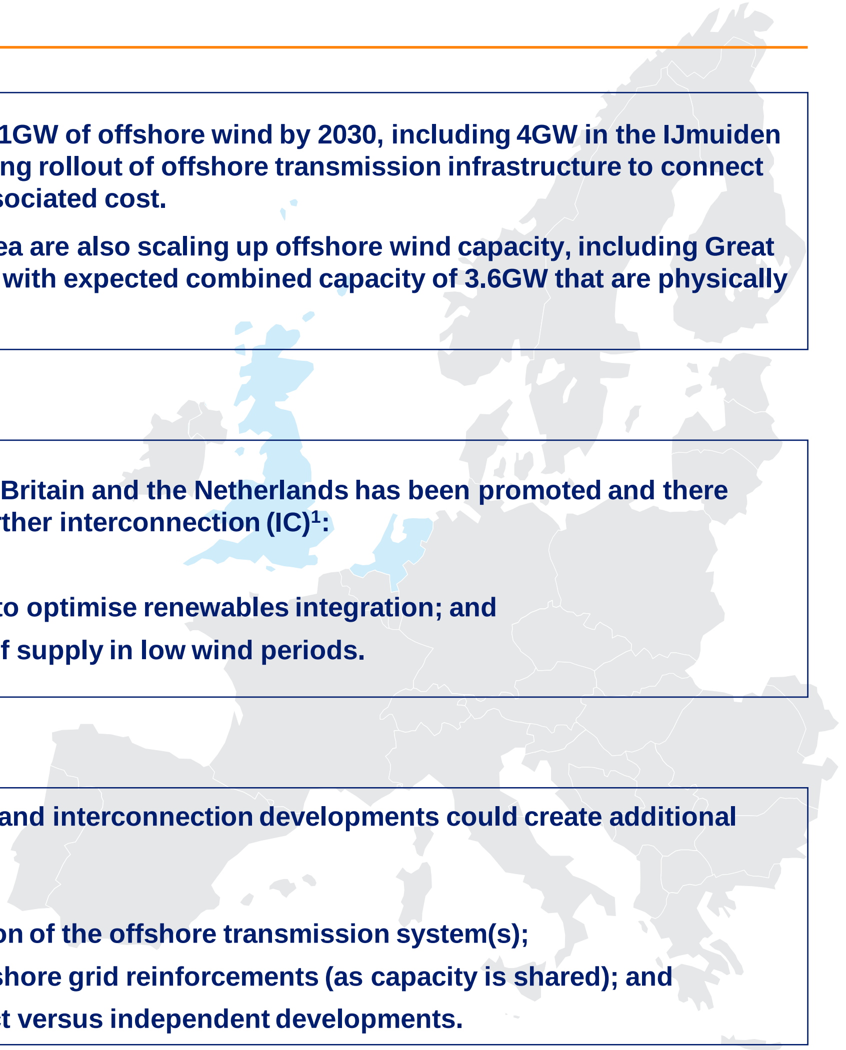
AGENDA

- Introduction
- Key messages on interconnection benefits
- Key messages on WindConnector benefits
- Assessment summary & scorecards

WINDCONNECTOR ECONOMIC APPRAISAL

CONTEXT



Offshore wind developments

- The Netherlands plans to deliver 11GW of offshore wind by 2030, including 4GW in the IJmuiden Ver region. This requires supporting rollout of offshore transmission infrastructure to connect this capacity to the shore, with associated cost.
- Other markets around the North Sea are also scaling up offshore wind capacity, including Great Britain, which has two wind zones with expected combined capacity of 3.6GW that are physically close to the IJmuiden Ver area.

Interconnection development

- Further integration between Great Britain and the Netherlands has been promoted and there appears to be a strong case for further interconnection (IC)[1]:
  - i. due to price differences;
  - ii. due to the need for flexibility to optimise renewables integration; and
  - iii. to support regional security of supply in low wind periods.

Combined development

- Combining offshore transmission and interconnection developments could create additional economic benefits, such as:
  - i. interconnector cost savings;
  - ii. potentially increased utilisation of the offshore transmission system(s);
  - iii. potential for avoidance of onshore grid reinforcements (as capacity is shared); and
  - iv. reduced environmental impact versus independent developments.

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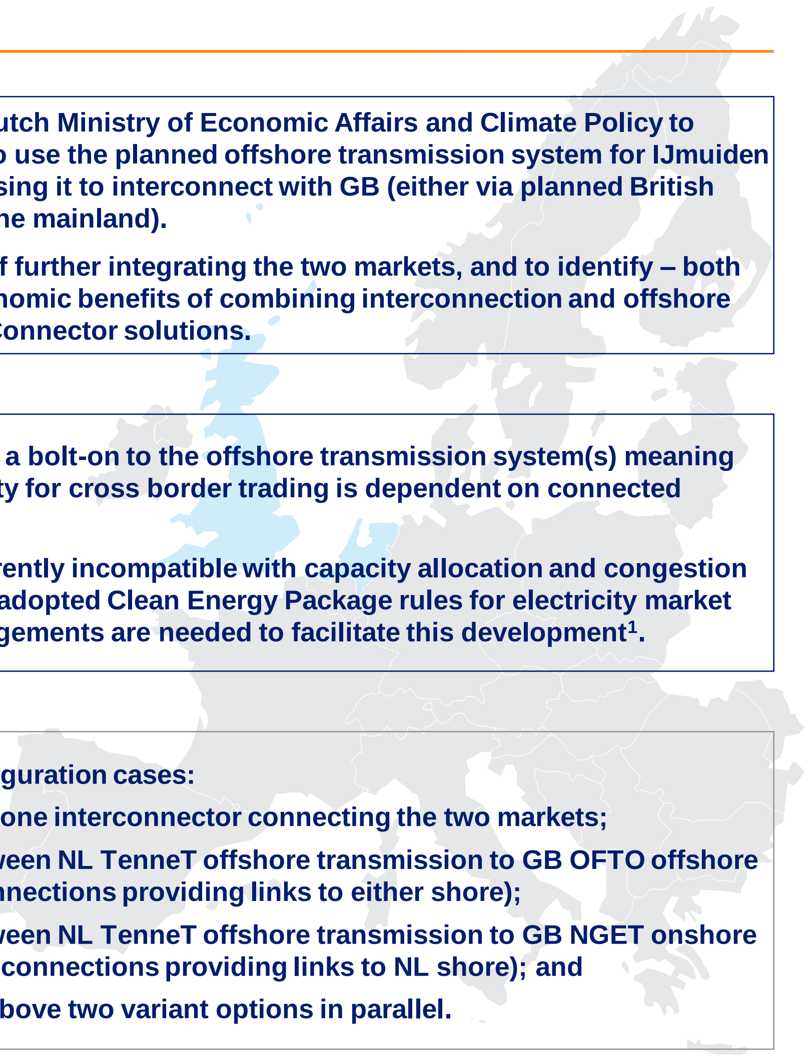
[1] E.g. ENTSO-E Regional Investment Plan 2017 (North Sea), 2018 TYNDP

WINDCONNECTOR ECONOMIC APPRAISAL

OBJECTIVES & APPROACH



Objectives

- TenneT has been requested by the Dutch Ministry of Economic Affairs and Climate Policy to develop a recommendation on how to use the planned offshore transmission system for IJmuiden Ver more efficiently by additionally using it to interconnect with GB (either via planned British offshore transmission or directly to the mainland).
- This study aims to test the benefits of further integrating the two markets, and to identify – both quantitatively and qualitatively – economic benefits of combining interconnection and offshore transmission development via WindConnector solutions.

Underlying principles

- The WindConnector is considered as a bolt-on to the offshore transmission system(s) meaning that available interconnection capacity for cross border trading is dependent on connected offshore wind output.
- It is recognised that this setup is currently incompatible with capacity allocation and congestion management aspects of the recently adopted Clean Energy Package rules for electricity market design, and tailor made market arrangements are needed to facilitate this development[1].

Modelled configurations

- The assessment considers four configuration cases:
  - i. **Market-to-Market (M2M):** standalone interconnector connecting the two markets;
  - ii. **Variant 1A:** WindConnector between NL TenneT offshore transmission to GB OFTO offshore transmission (with windfarm connections providing links to either shore);
  - iii. **Variant 1B:** WindConnector between NL TenneT offshore transmission to GB NGET onshore transmission (with NL windfarm connections providing links to NL shore); and
  - iv. **Variant 2A:** combination of the above two variant options in parallel.

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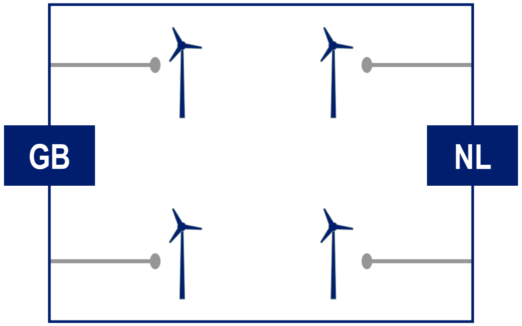
[1] Different market arrangements (e.g. offshore bidding zones) won't lead to a change in the overall socio-economics but could lead to a redistribution of welfare across the stakeholders involved.

ILLUSTRATION OF PHYSICAL CONFIGURATION CASES

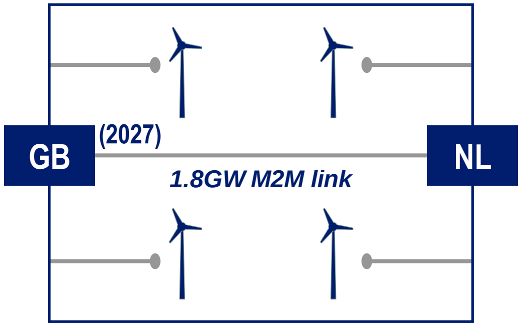
Assessment tests three variants of WindConnector configurations

COUNTERFACTUALS

Reference

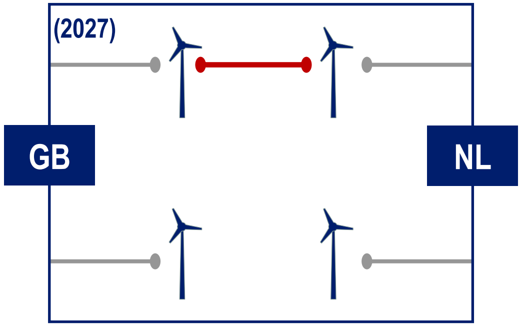


Market-To-Market (M2M)

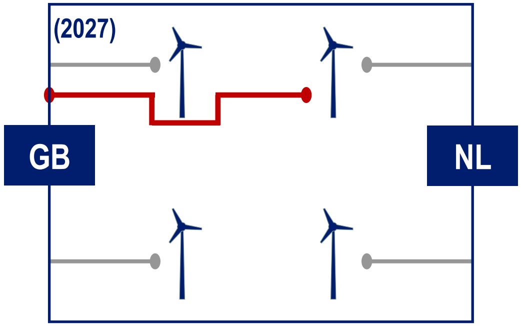


VARIANTS

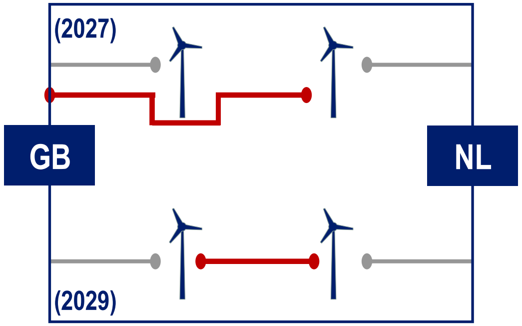
1A: NL TenneT offshore transmission to GB OFTO offshore transmission



1B: NL TenneT offshore transmission to GB NGET onshore transmission



2A: combination of 1A & 1B



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INTERCONNECTION BENEFITS

Market integration between the Netherlands and Great Britain contributes to affordability, sustainability and reliability overall

MESSAGES

A. Affordability

- Interconnection reduces average wholesale price differentials between the two markets, with the majority of flows going from NL to GB.
- Interconnection has a positive socio-economic impact for both markets combined and the wider region.
- Potential for reductions in Dutch renewable support and GB capacity market costs.

B. Sustainability

- Increased renewable generation and reduced thermal generation across markets combined.
- CO_2 emissions reductions overall.

C. Reliability

- Increased access to balancing capacity.
- Interconnection supports Dutch security of supply in low wind periods, reducing the number of high scarcity rent periods in NL.

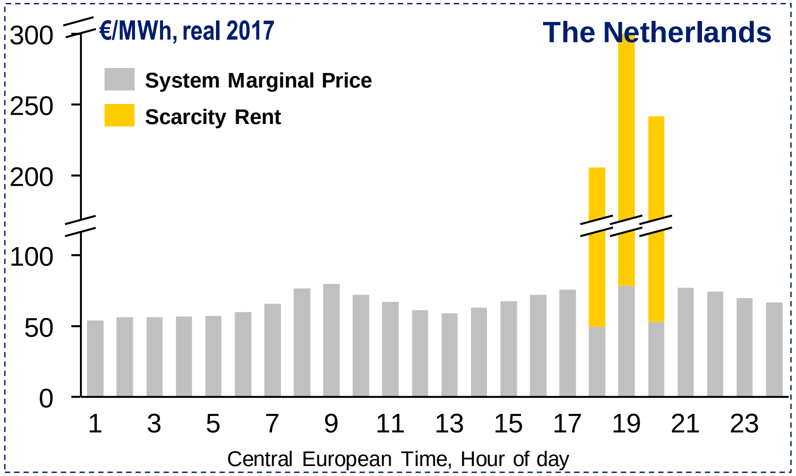
Affordability Sustainability **Reliability**

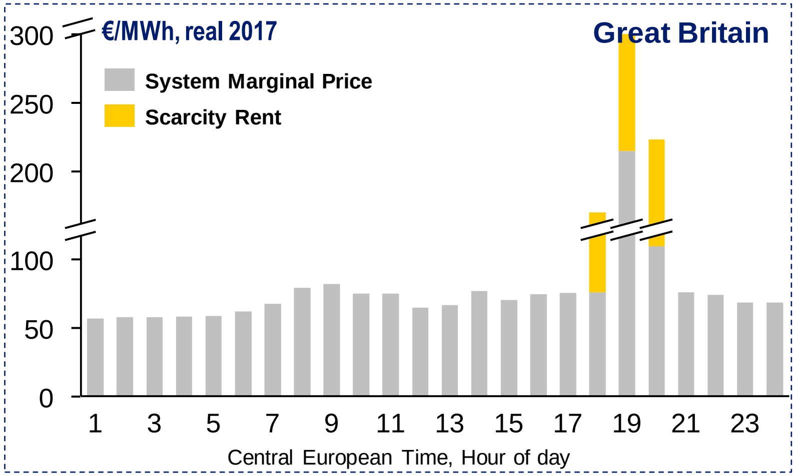
ELECTRICITY PRICES AND DIRECTION OF FLOW

The majority of flows are in the direction from NL to GB; during evening peak hours when Dutch prices spike, the direction of flows reverses

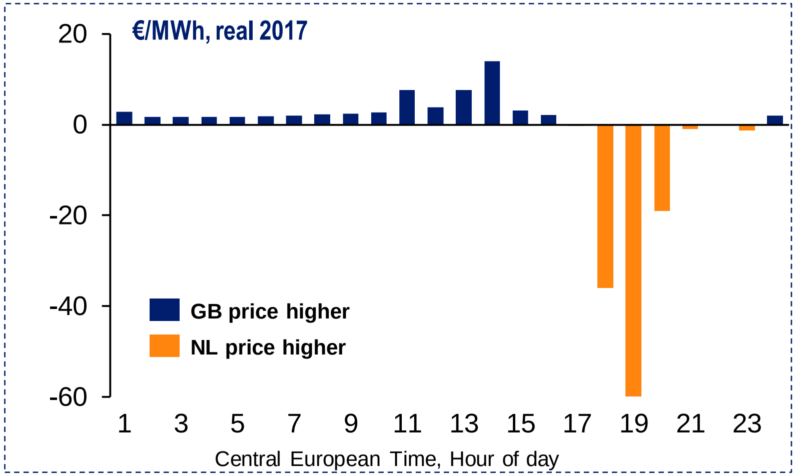
Sample winter day for year 2035, based on the Market-to-Market case

Breakdown of within day shape of wholesale electricity price

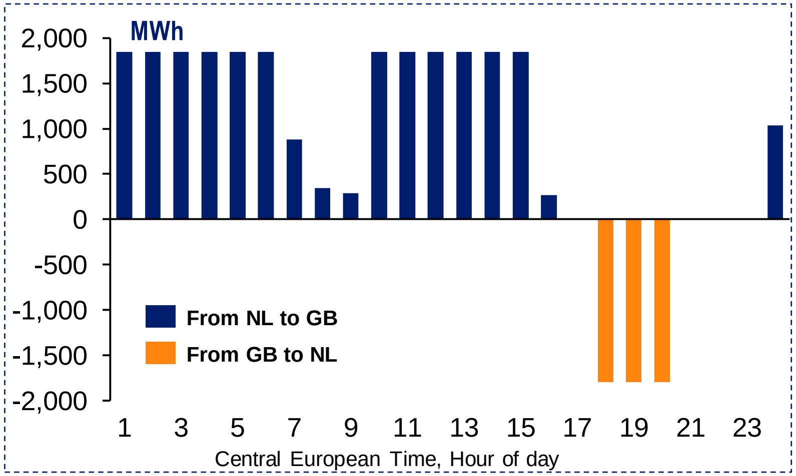




Electricity price difference: GB – NL



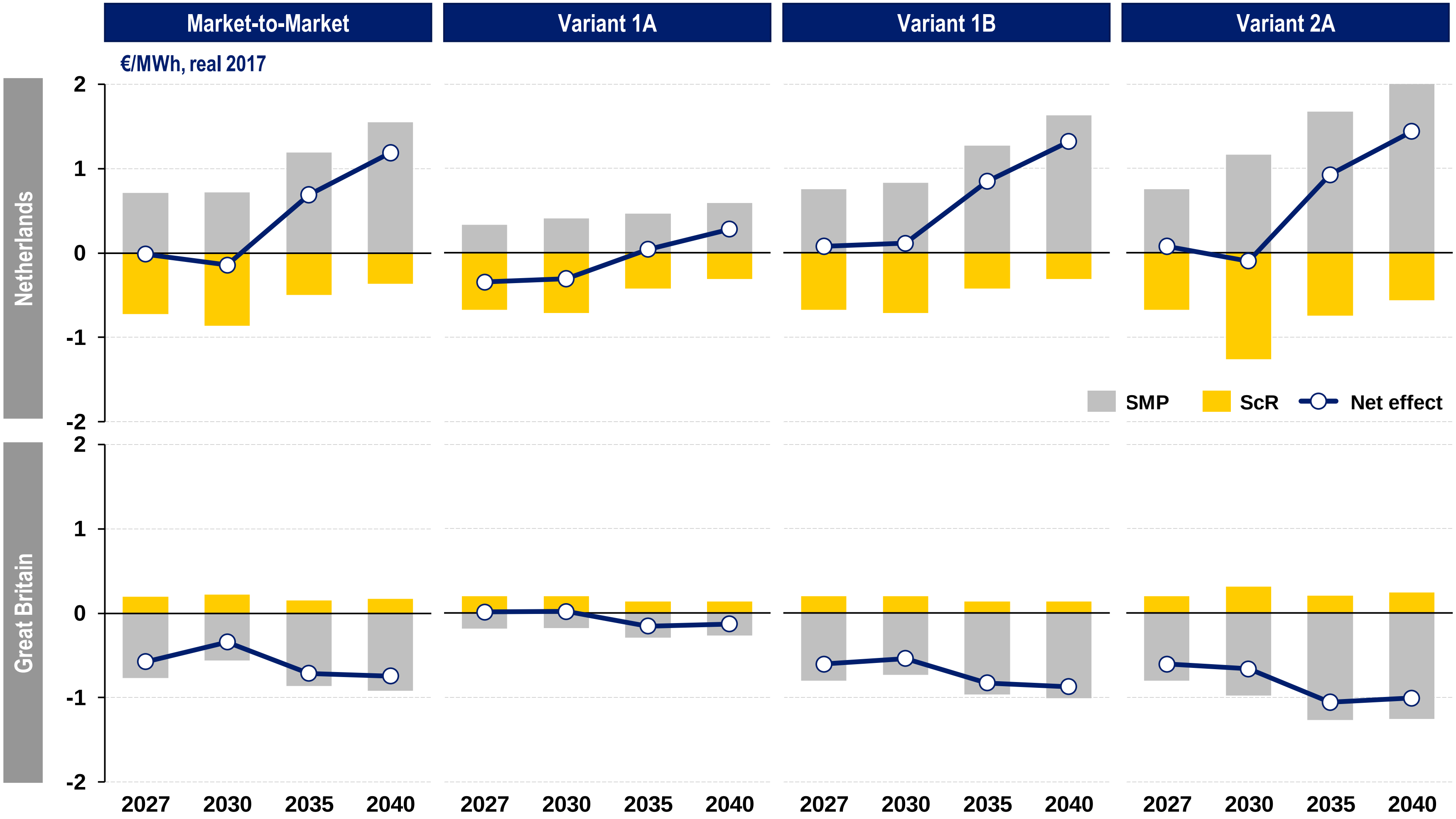
Flow for the 1.8GW M2M cable



Scarcity rent (ScR) represents the ‘mark-up’ (on top of the respective short-run operating costs) participants may include at times when the system is ‘tight’

SUMMARY IMPACT ON PRICE COMPONENTS (VS. REFERENCE)

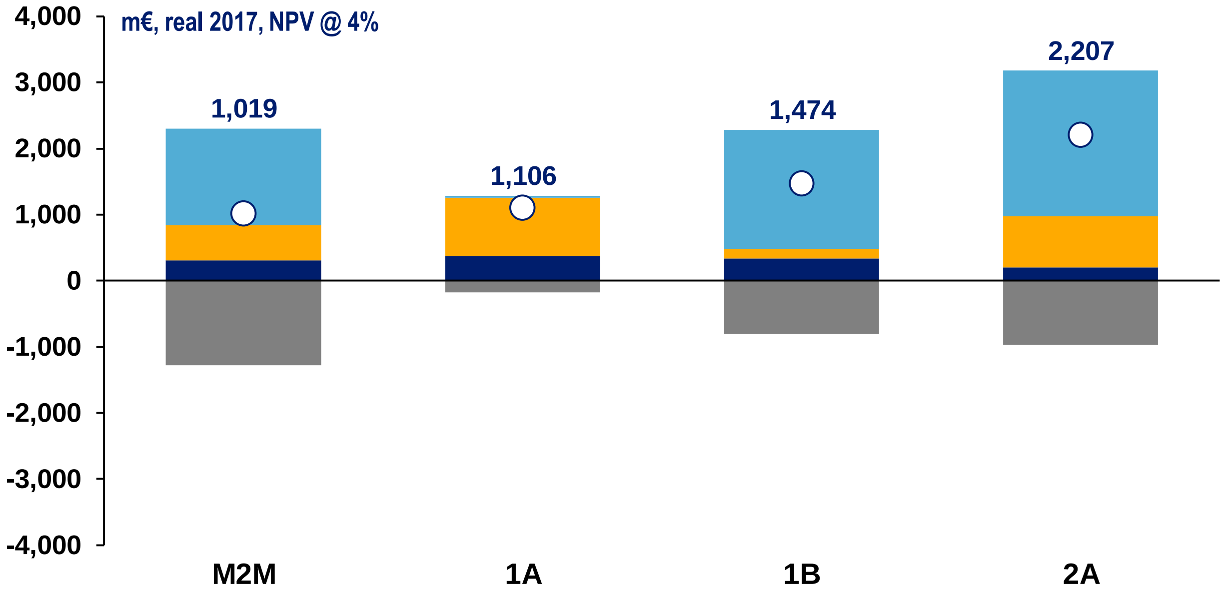
Wholesale electricity prices on an annual average basis converge with increased available interconnection capacity between the two markets



SOCIO-ECONOMIC WELFARE ASSESSMENT (VS. REFERENCE)

Increased interconnection shows a strong socio-economic case across the two markets with stakeholders (consumers, producers & IC owners) overall benefiting

Summary of Socio-Economic Welfare assessment[1] across the two markets combined



🟦 Consumers 🟧 Producers ■ Congestion Rent ▨ Costs ○ Net

Welfare distribution (M2M case)

Dutch stakeholders

- Consumers ⇩
- Producers ⇧
- IC owners ⇧

British stakeholders

- Consumers ⇧
- Producers ⇩
- IC owners *no impact*

Notes

- There is a strong positive effect on overall consumer wholesale electricity cost exposure, with some variations across the cases and between the two markets. Producers and IC owners also benefit overall.
- Interconnection can also provide benefits to the wider region, with consumer wholesale electricity costs in the NW European markets (sharing an IC with either NL or GB) decreasing by c. 4,000m€ (on average across the cases) over the same period.

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[1] Relative to Reference case. Accounting for impact on wholesale electricity market only. Assuming an economic lifetime of 25 years. Values post 2040 are kept flat at 2040 levels.

Affordability Sustainability Reliability

IMPACT ON DUTCH CONSUMERS (VS. REFERENCE)

The negative impact on consumer wholesale electricity costs can be offset by reduced offshore wind support requirements and security of supply benefits

⇩ **Negative impact** ⇧ **Positive impact**

Metric		Impact
01 Wholesale Electricity Costs	▪ Wholesale electricity costs for the Dutch consumer increase driven by the upward impact on Dutch wholesale electricity prices.	⇩
02 Renewable Support Costs	▪ Offshore wind capture revenue from the wholesale market increases (by 1.2€/MWh on average) with additional interconnection capacity potentially leading to lower support requirements (i.e. SDE contribution) for offshore wind developments, as the spread between the capture price and the base amount decreases.	⇧
03 Security of Supply	▪ Interconnection supports Dutch security of supply in low wind periods, reducing the number of high scarcity rent periods in the market. For example, there is on average a 5% reduction in the number of scarcity rent periods (i.e. when system is tight and generators bid above their short-run marginal costs).	⇧

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IMPACT ON BRITISH CONSUMERS (VS. REFERENCE)

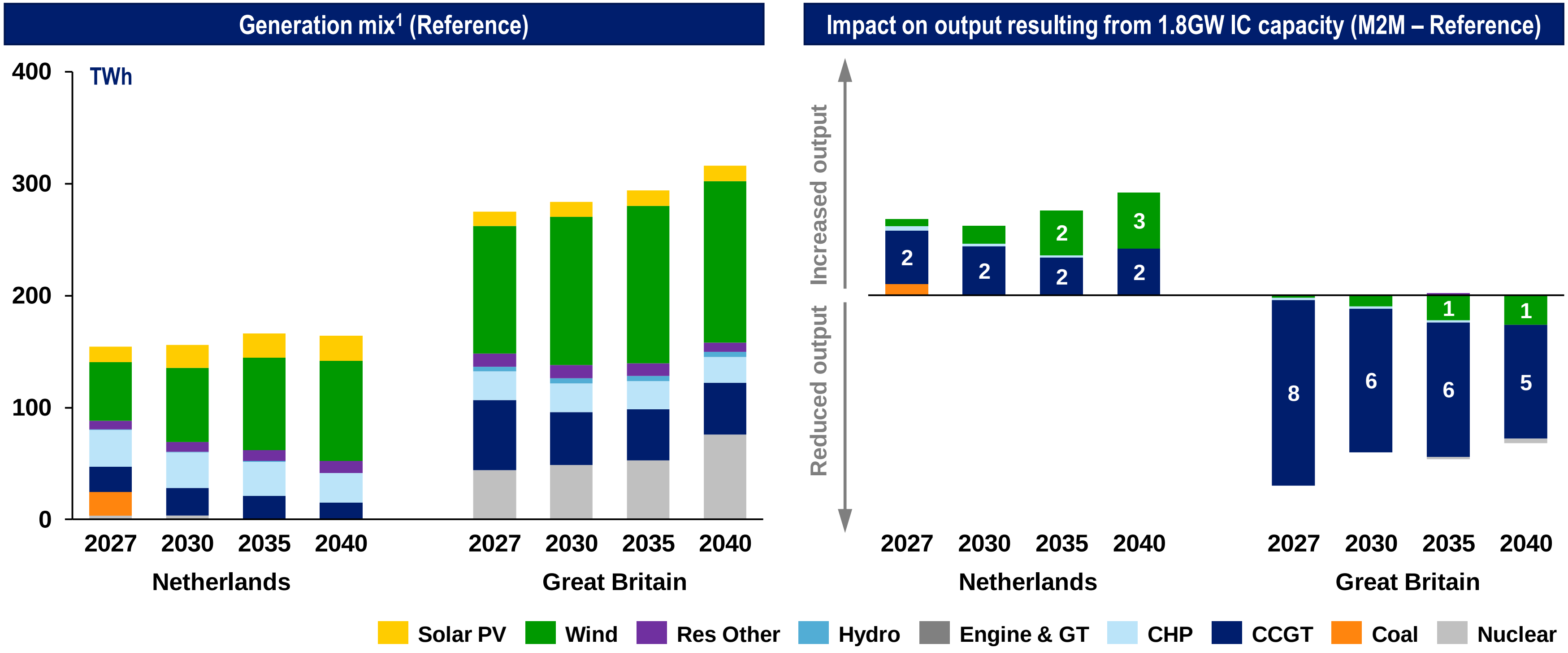
While support requirements for offshore wind can increase, there is a strong positive effect on both wholesale electricity costs and capacity market costs

⇩ **Negative impact** ⇧ **Positive impact**

Metric		Impact
01 **Wholesale Electricity Costs**	Wholesale electricity prices in the GB market decrease with additional interconnection capacity to the Netherlands reducing consumer wholesale electricity costs.	⇧
02 **Renewable Support Costs**	Offshore wind capture revenue from the wholesale market decreases (by 0.5€/MWh on average) with additional interconnection capacity, potentially leading to higher support requirements (i.e. costs of Contracts for Difference) for offshore wind developments.	⇩
03 **Capacity Market Costs**	With additional interconnector capacity, GB (thermal) generators can benefit from increased exports during evening hours increasing their margin from the wholesale market. Capacity market clearing prices, therefore, decrease (by 2.0€/kW on average, driven by this shift of cost recovery from the capacity market into the wholesale market), leading to lower capacity market costs.	⇧

IMPACT ON GENERATION MIX

Interconnection increases renewable generation and reduces thermal generation across the two markets combined



Generation mix[1] (Reference)

Impact on output resulting from 1.8GW IC capacity (M2M – Reference)

Notes

- Interconnection enables more wind and gas generation to be exported from the Dutch system.
- In GB, gas-fired generation is displaced by cheaper imports (from NL). In addition, balancing charges in the GB market (applied to generators but not IC) result in wind generators having a higher variable cost potentially leaving them out of merit compared to the rest of wind generation in the region (mainly during periods when wind generation is highly correlated).

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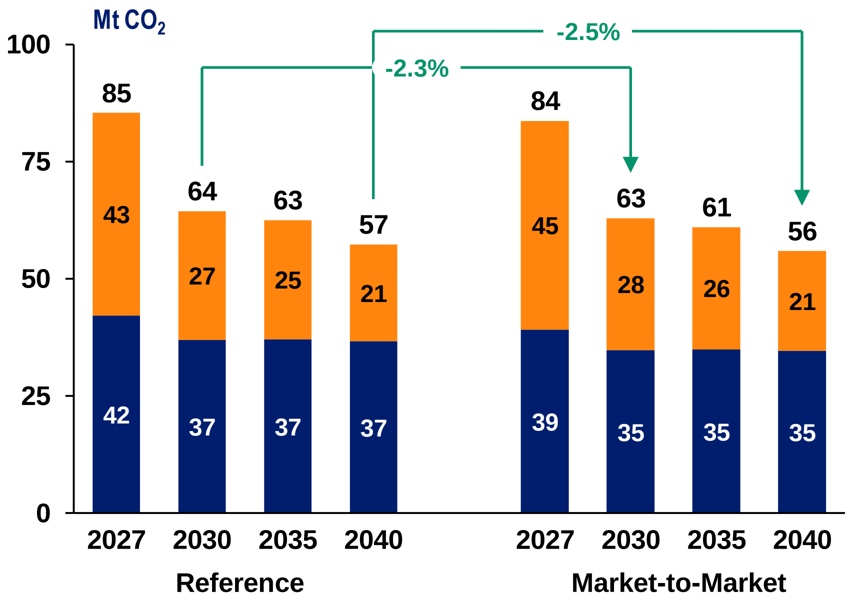
[1] Excluding interconnection flows.

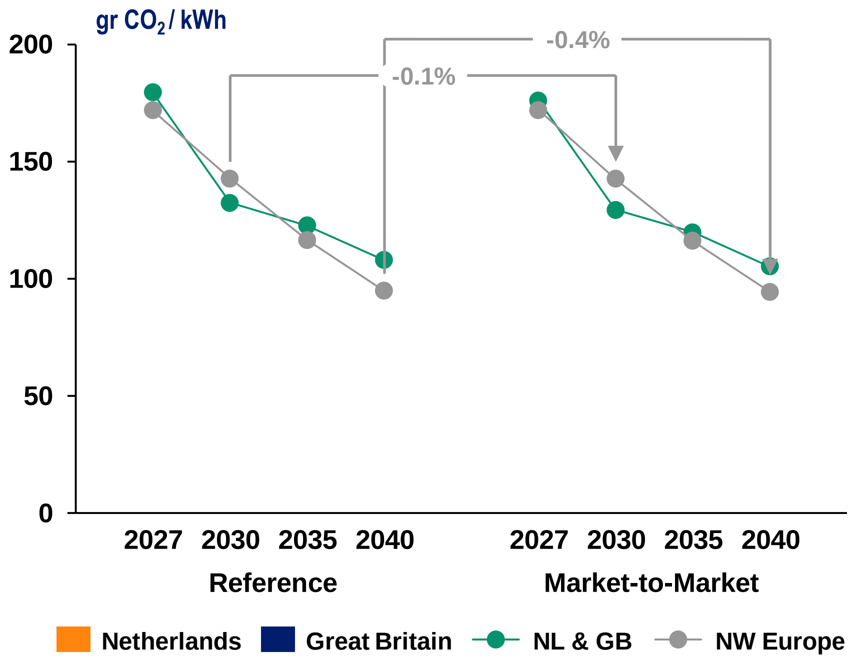
IMPACT ON CARBON EMISSIONS

Interconnection provides CO_2 emissions reductions overall

Carbon emissions in the two markets



Carbon emission intensity across the two markets & NW Europe[1]



Notes

- Interconnection can have a positive impact on emissions, with CO_2 emissions dropping by as much as 2.5% across the Netherlands and GB combined, and by c.0.5% in North West Europe overall (i.e. M2M vs. Reference).
- Carbon emissions (intensity) in the Dutch market increase by c.3.0% driven by increased thermal output outweighing increased wind generation, while in GB emissions drop by c.6.0% due to a reduced output from gas-fired generators.

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[1] Including markets that share interconnection with either NL or GB.

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WINDCONNECTOR BENEFITS

WindConnectors have an attractive business case and provide potential benefits in terms of offshore transmission utilisation and broader grid development

MESSAGES

A. Project Economics

- The infrastructure cost savings for a WindConnector relative to a standalone interconnector outweigh any reduction in revenues through lower realisable congestion rents, resulting in higher project returns.
- When availability is restricted, this is focused on times of high wind when value of interconnection is lower. Conversely, WindConnector availability is high when interconnection value is high, allowing capture of this value by the WindConnector.

B. Utilisation of Infrastructure

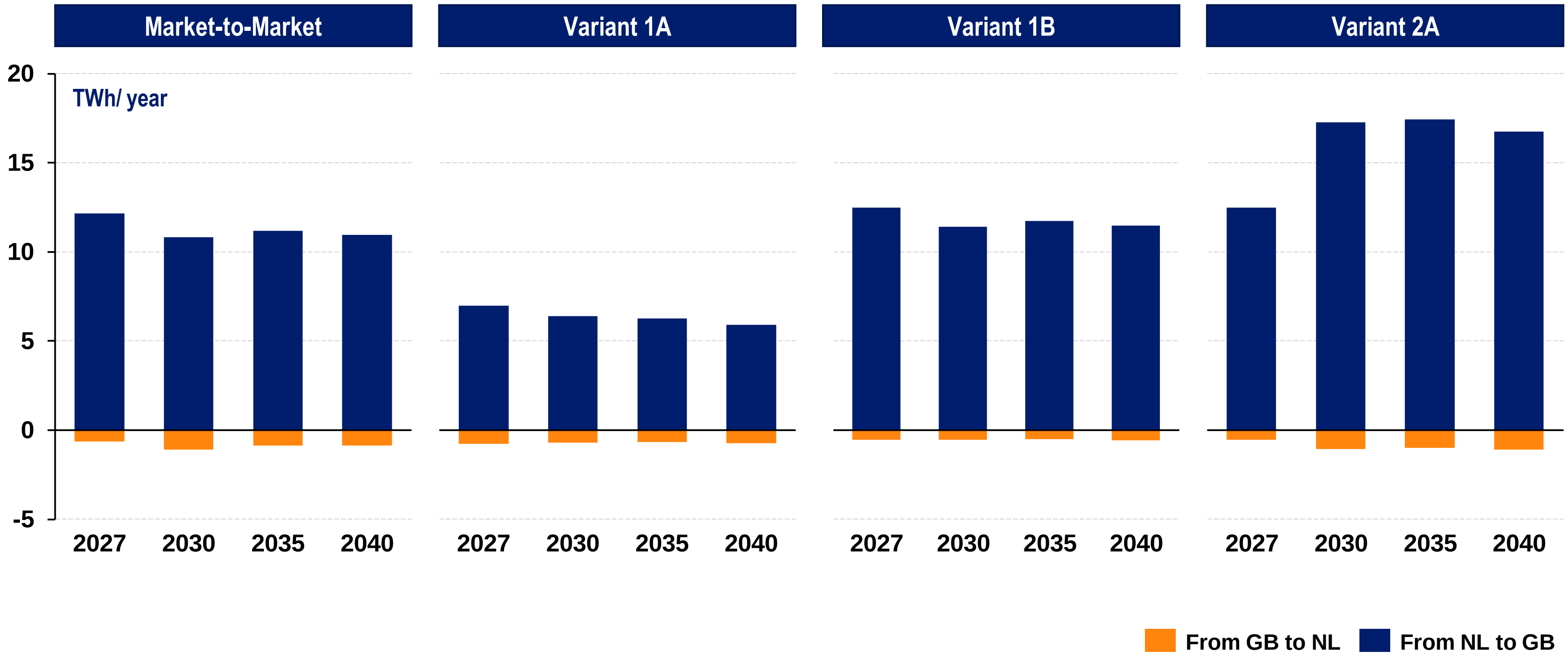
- Depending on the variant, WindConnectors can offer increased utilisation of the shared offshore transmission assets compared to a standalone solution.

C. Grid Integration

- With (near coast) onshore grid capacity in the two markets getting scarcer due to the anticipated quantity of wind infeed coming online, WindConnectors can lead to more efficient integration into the grids, as onshore capacity is shared and potential reinforcement requirements are reduced.
- WindConnectors can reduce the scale of potential onshore and offshore environmental impact, as sharing of assets reduces the scale and duration of development work overall.

WINDCONNECTOR FLOW PATTERNS

Depending on the configuration variant, effective market to market capacity can be restricted leading to overall lower flows

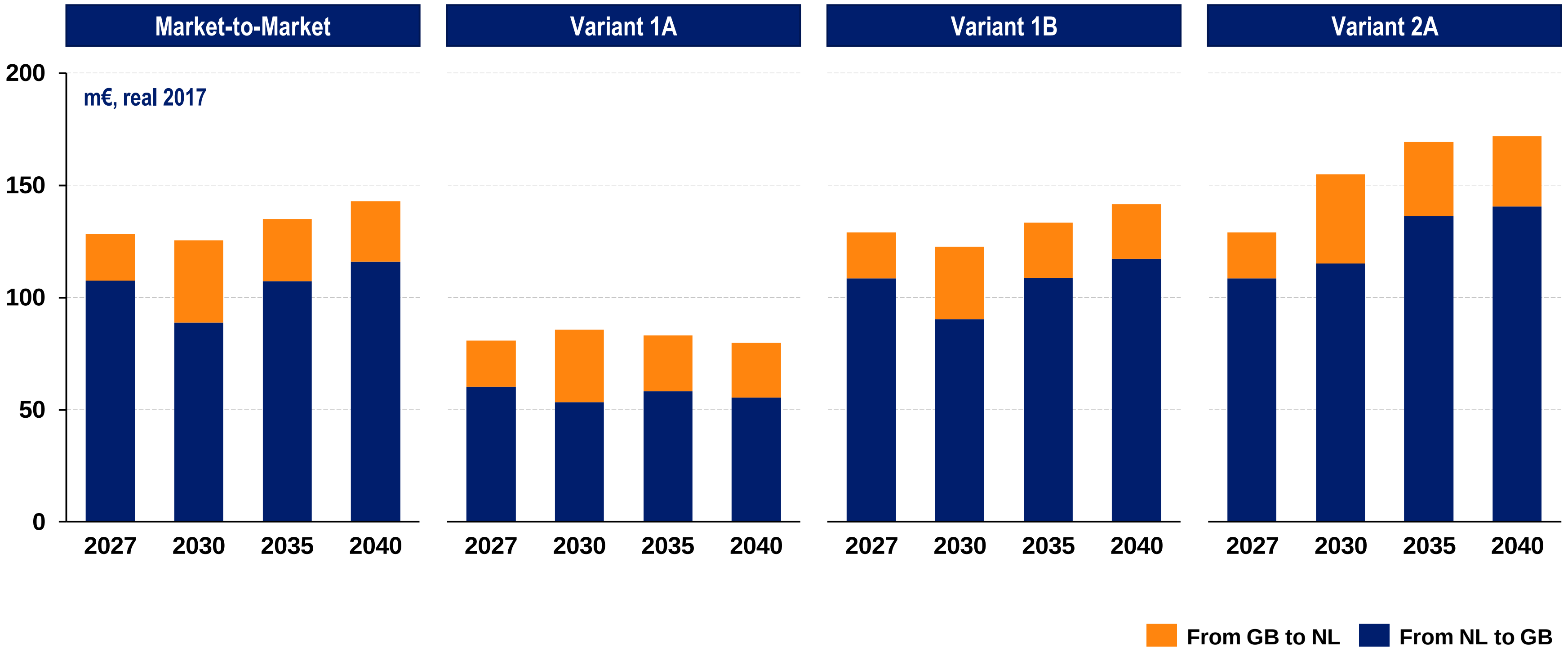


Notes

- While in variant 1A flows from the WindConnector are roughly halved, as the cable can only be utilised when there is free space post wind, variant 1B sees similar flow patterns as the M2M case (as the cable is less restricted).
- Total combined flows increase in variant 2A, driven by the introduction of a second WindConnector in 2029.

WINDCONNECTOR CONGESTION RENT

When availability is restricted this is focused on times of high wind when value of interconnection is lower and vice versa



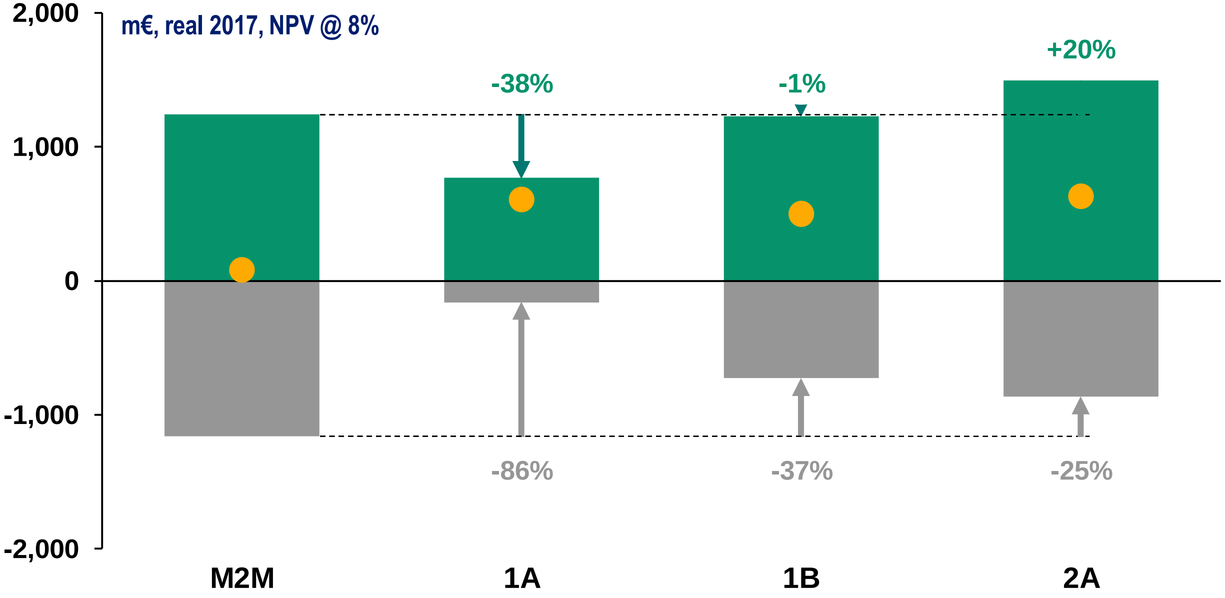
Notes

- Differences in flows across the various cases also show up in congestion rent analysis, however, the impact is of lower magnitude. E.g. while flows in variant 1A are roughly halved, the WindConnector is generating c. 40% lower revenue, meaning that value of flow is higher on a €/MWh basis.

COMMERCIAL ASSESSMENT

The infrastructure cost savings for a WindConnector outweigh any reduction in revenues resulting in higher project returns

Summary of commercial case presented as Net Present Value[1] and differences against the M2M



Main indicators

NPV [million Euros, real 2017]

- ❑ M2M: 82
- ❑ 1A: 607
- ❑ 1B: 500
- ❑ 2A: 630

Internal Rate of Return

- ❑ M2M: 9%
- ❑ 1A: 41%
- ❑ 1B: 15%
- ❑ 2A: 16%

🟩 Revenues ▨ Costs ● Net

Notes

- The above estimates do not include any access fee or charge for use of the transmission lines. Revenues only account for the realisable wholesale market congestion rents and do not include other potential revenues such as payments from the GB capacity market or potential payments for the provision of ancillary services.

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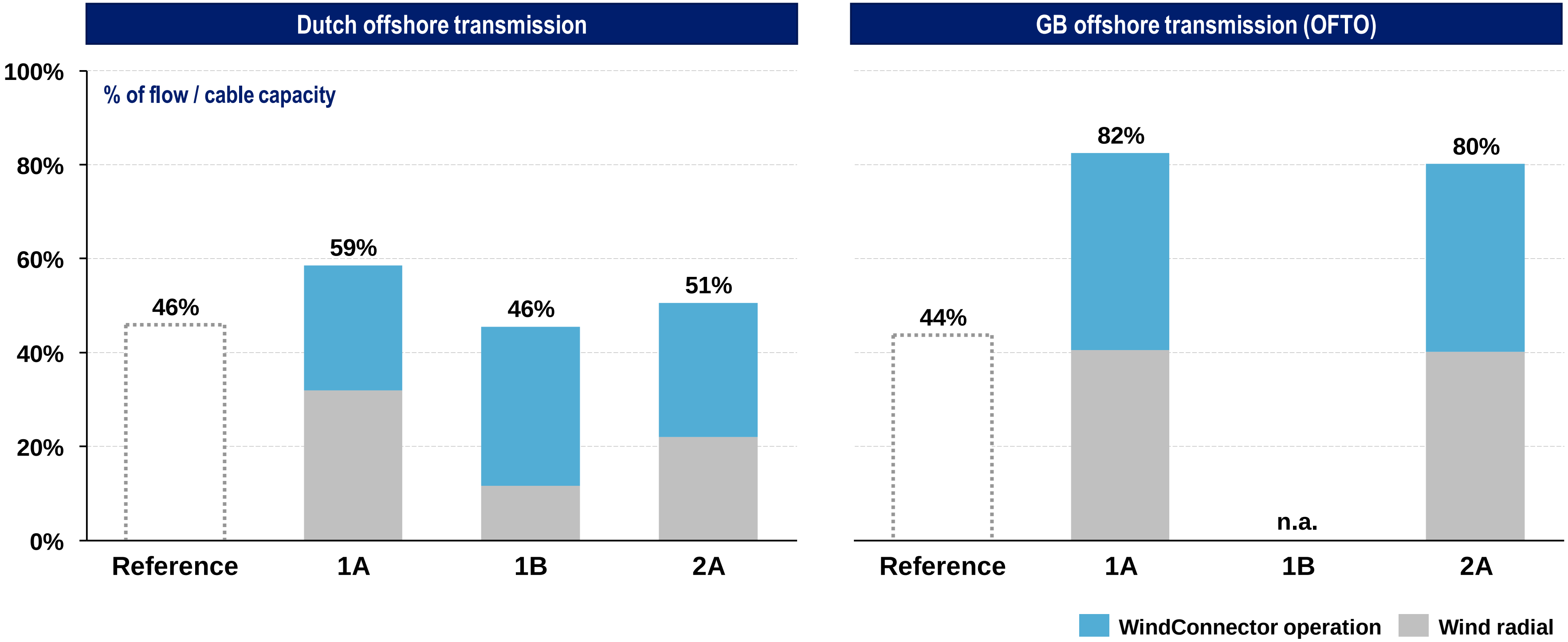
[1] Assuming an economic lifetime of 25 years. Values post 2040 are kept flat at 2040 levels.

USAGE OF SHARED OFFSHORE TRANSMISSION ASSETS

Shared asset use can improve the rate of utilisation of the transmission assets to shore, but this depends on the WindConnector configuration

Based on year 2030



Notes

- Utilisation rates for the offshore transmission assets connecting the wind farms to their respective onshore transmission systems – differentiating between a. ‘Wind radial’ (transmitting wind to own market) and b. ‘WindConnector operation’.
- When integrated network solutions allow for shared asset use involving both windfarm output transmission and market-to-market flow potential, the rate of utilisation for the shared assets can improve.

For the Dutch market, variants 1A and 1B include Ijmuiden Ver A&B. Variant 2A includes Ijmuiden Ver A-D.
For GB, variant 1A includes Boreas A; while variant 2A incudes Boreas B. In variant 1B, WindConnector does not share infrastructure with any of the GB offshore windfarms.

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ASSESSMENT SUMMARY

No benefit → ○

Higher benefit value → ●

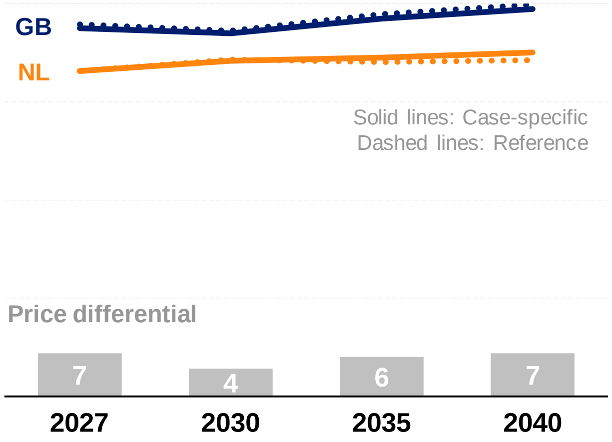
			Market-To-Market	Variant 1A	Variant 1B	Variant 2A
Interconnection benefits	**Affordability** socio-economic case		◕	◕	◕	●
	Sustainability CO$_2$ emissions reductions		◑	◔	◑	◕
	Reliability reduction in scarcity rent periods		◑	◔	◔	◕
WindConnector benefits	**Project Economics**	IRR	◔	●	◕	◕
		NPV	◔	●	◕	●
		Asset utilisation rates	●	◑	●	◕
	Utilisation of Infrastructure shared offshore transmission assets		○	◕	○	◑
	Grid Integration reinforcements & environmental impact		○	◕	◑	●

Quantitative assessment

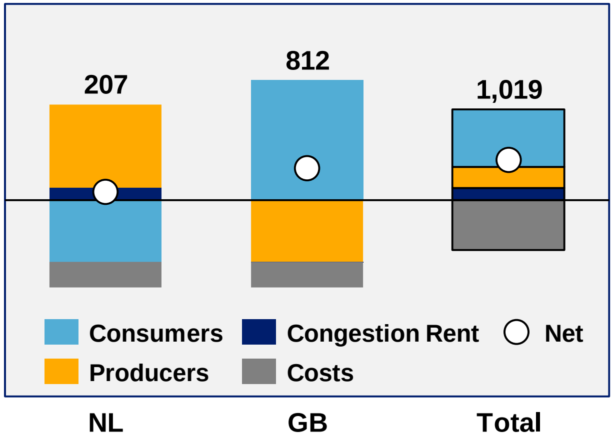
Qualitative assessment

MARKET-TO-MARKET

Average electricity price (vs. Reference, €/MWh)

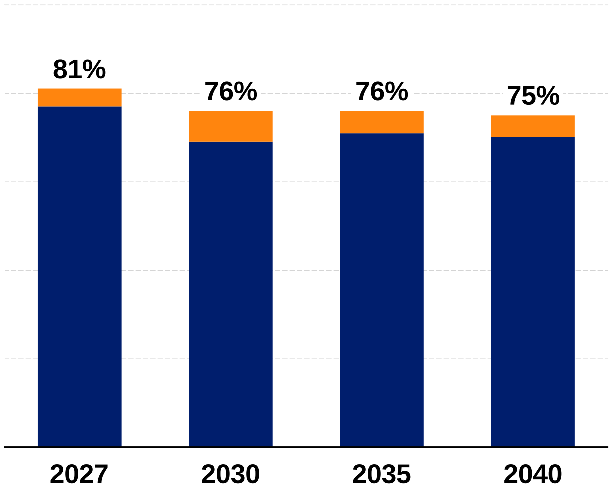


Socio Economic Welfare assessment (m€, real 2017, NPV @ 4%) – relative to Reference case

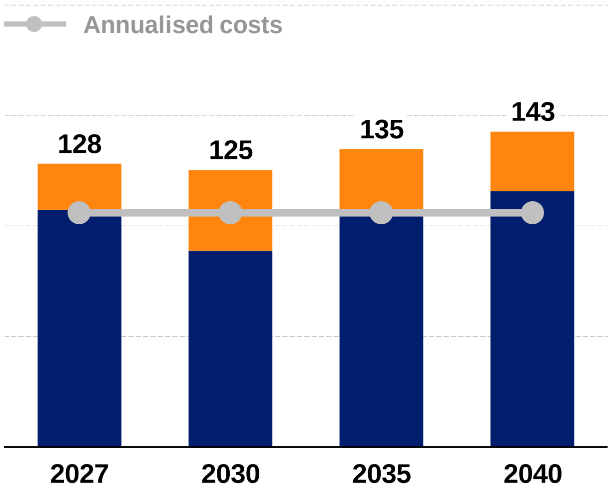


	NL	GB	Total
Cons.	-1,581	3,039	1,458
Prod.	2,111	-1,578	533
C. Rent	318	-8	310
Costs	-641	-641	-1,283
Net	207	812	1,019

Utilisation rates (annual flows / capacity)



Commercial case (m€, real 2017)



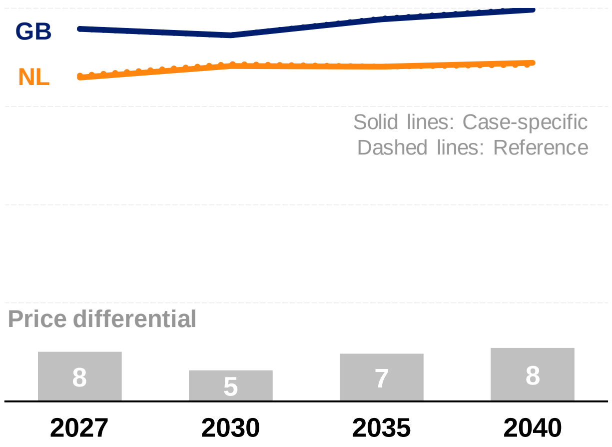
Project summary

- NPV
  m€, real 2017, @8% assuming a 25-year economic lifetime
  - Revenues: 1,242
  - Costs: - 1,160
  - Net: 82
- IRR 9%

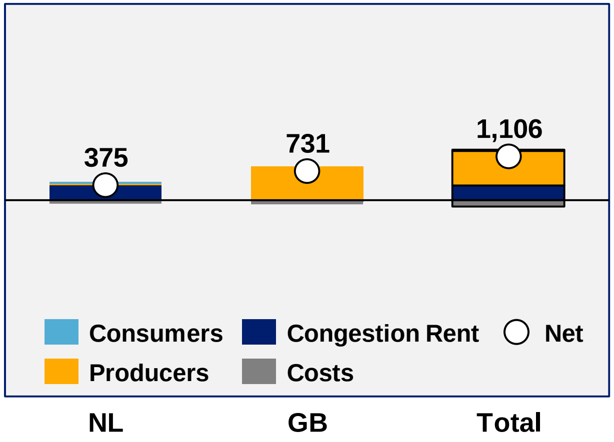
🟧 From GB to NL 🟦 From NL to GB

VARIANT 1A

Average electricity price (vs. Reference, €/MWh)

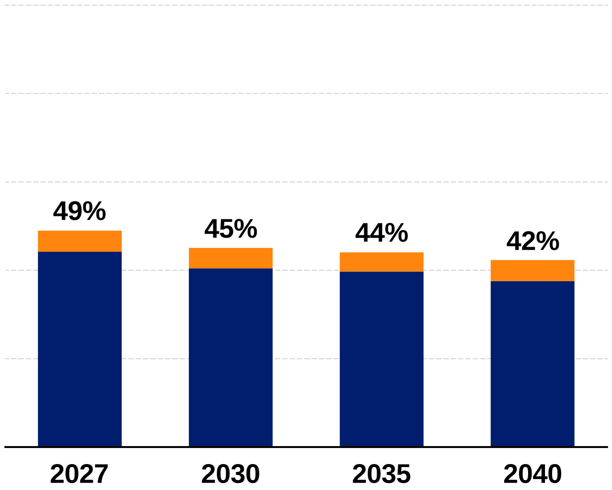


Socio Economic Welfare assessment (m€, real 2017, NPV @ 4%) – relative to Reference case

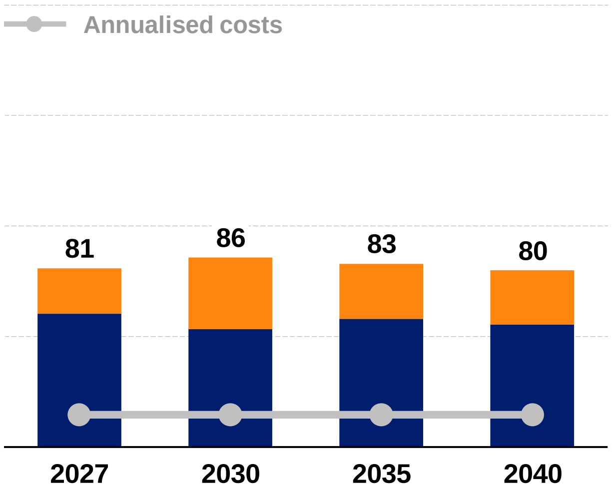


	NL	GB	Total
Cons.	59	-27	32
Prod.	33	845	880
C. Rent	371	-	371
Costs	-88	-88	-177
Net	375	731	1,106

Utilisation rates (annual flows / capacity)



Commercial case (m€, real 2017)



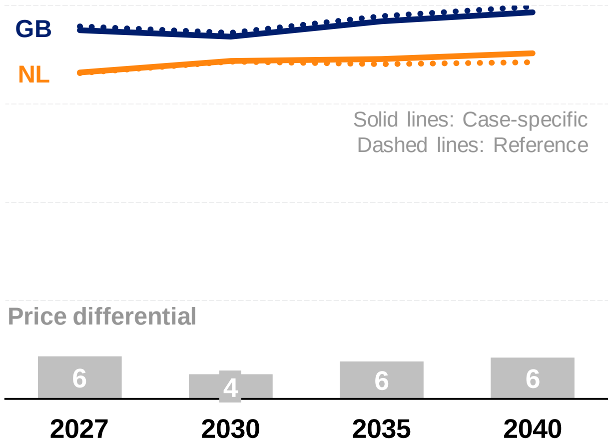
Project summary

- NPV
  m€, real 2017, @8% assuming a 25-year economic lifetime
  - Revenues: 767
  - Costs: - 160
  - Net: 607
- IRR 41%

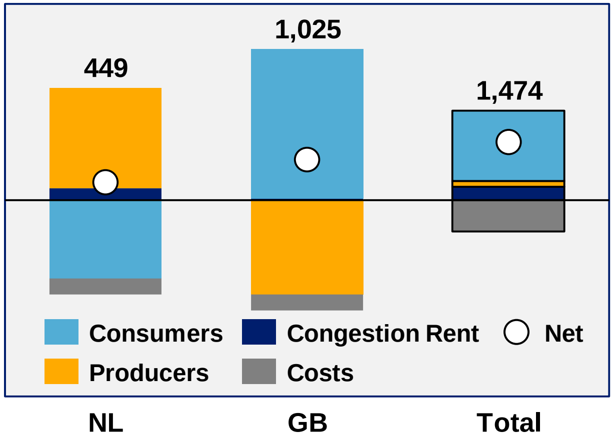
🟧 From GB to NL 🟦 From NL to GB

VARIANT 1B

Average electricity price (vs. Reference, €/MWh)

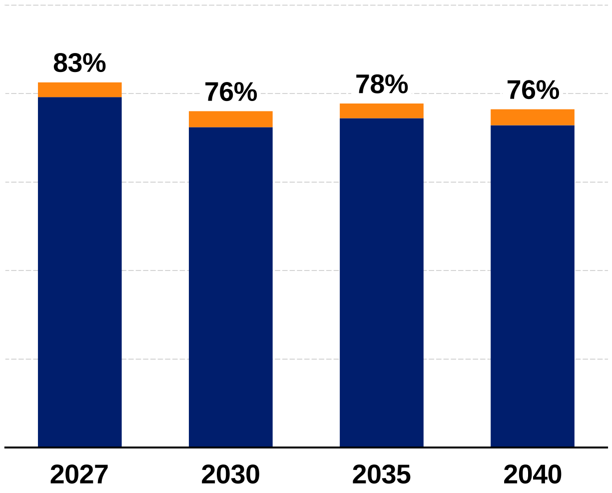


Socio Economic Welfare assessment (m€, real 2017, NPV @ 4%) – relative to Reference case



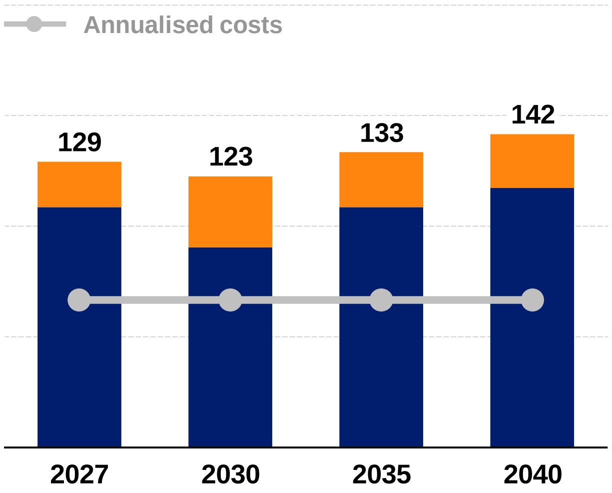
	NL	GB	Total
Cons.	-2,004	3,803	1,798
Prod.	2,559	-2,412	147
C. Rent	297	38	335
Costs	-403	-403	-805
Net	449	1,025	1,474

Utilisation rates (annual flows / capacity)



🟧 From GB to NL 🟦 From NL to GB

Commercial case (m€, real 2017)

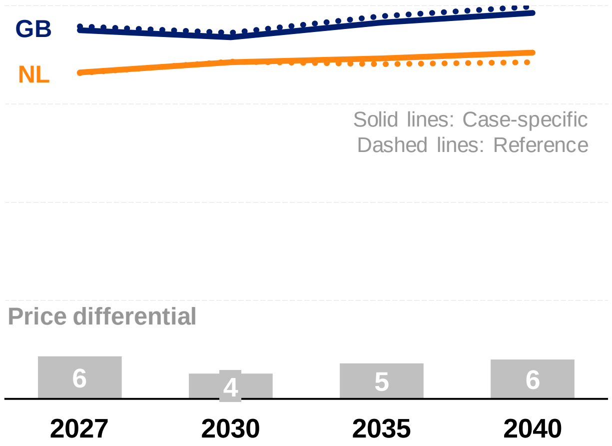


Project summary

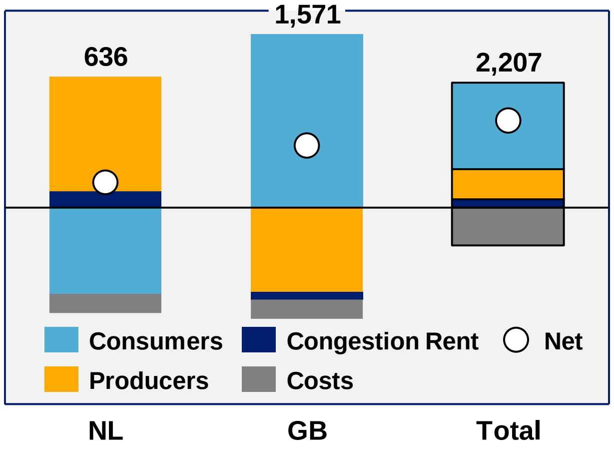
- NPV
  m€, real 2017, @8% assuming a 25-year economic lifetime
  - Revenues: 1,228
  - Costs: - 728
  - Net: 500
- IRR 15%

VARIANT 2A

Average electricity price (vs. Reference, €/MWh)

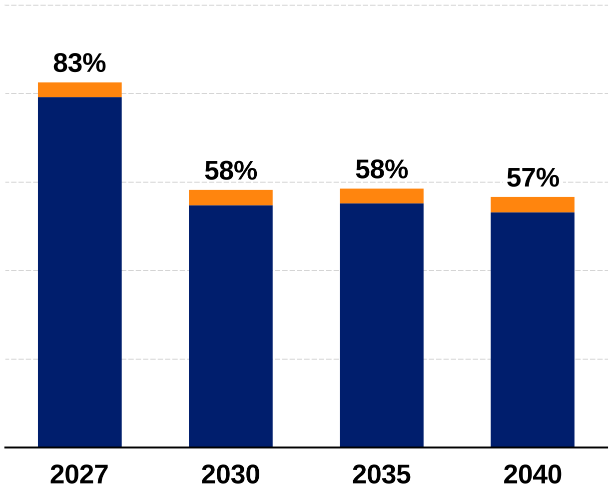


Socio Economic Welfare assessment (m€, real 2017, NPV @ 4%) – relative to Reference case

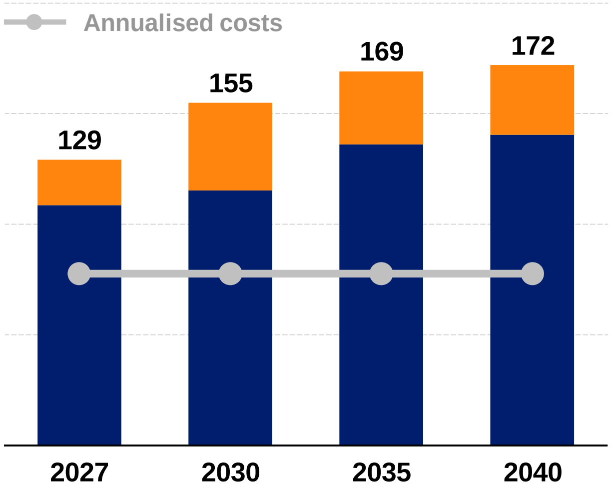


	NL	GB	Total
Cons.	-2,197	4,397	2,201
Prod.	2,913	-2,144	769
C. Rent	405	-198	206
Costs	-484	-484	-969
Net	636	1,571	2,207

Utilisation rates (annual flows / capacity)



Commercial case (m€, real 2017)



Project summary

- NPV
  m€, real 2017, @8% assuming a 25-year economic lifetime
  - Revenues: 1,496
  - Costs: - 865
  - Net: 631
- IRR 16%

🟧 From GB to NL 🟦 From NL to GB

Annex: Supporting Information

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BACKGROUND TO THE MODELLING

MARKET SCENARIO & ASSUMPTIONS

- **The assessment takes Pöyry's Q1 2019 'Central – Coal Prohibition' scenario as its basis in terms of the market and policy backdrop. Some of the key characteristics are as follows:**
  - **Demand projections, fuel and carbon price assumptions from Pöyry's Q1 2019 Central scenario.**
  - **Capacity mix based on Pöyry's Q1 2019 Central – Coal Prohibition scenario in line with the government's Coal Prohibition Bill[1] outlining plans to move to a coal free electricity system by 2030 in the Netherlands. The following pre-agreed adjustments were implemented:**
    - **i. Offshore wind and solar PV capacity assumptions in the Netherlands adjusted to reflect Klimaatakkoord target;**
    - **ii. Offshore wind capacity in the GB market adjusted to reflect National Grid's Steady Progression scenario for 2030;**
    - **iii. No additional interconnection capacity between Great Britain and the Netherlands assumed to be commissioned before 2040; and**
    - **iv. Thermal capacities are adjusted to ensure internal consistency and security standards are met for both markets.**
- **The assessment assumes that the offshore wind farms involved in this study bid in their 'home market' and no changes have been made in relation to revised or potentially additional bidding (or pricing) zones. Different market arrangements (e.g. offshore bidding zones) could lead to a redistribution of welfare across the stakeholders involved, however, we do not expect them to lead to a change in the overall socio-economics.**

CONVENTIONS

- **All monetary values quoted in this report are in Euros in real 2017 prices**
- **Annual data relates to calendar years running from 1 January to 31 December**
- **Unless otherwise specified, results are presented as an average of five historical weather-years, i.e. 2010-2014**
- **Unless otherwise attributed the source for all tables, figures and charts is Pöyry Management Consulting**

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[1] The Netherlands' Wet verbod op kolen bij elektriciteitsproductie ("Prohibition on usage of coal for electricity production bill")

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