Exhibit 1: AQUIND revenue and social welfare analysis 2020

PRIVATE AND CONFIDENTIAL

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1 Project-specific cost-benefit analysis (CBA)

This section sets out the key inputs into the AQUIND project-specific cost-benefit analysis (CBA). The CBA is the basis for the assessment of country-specific impacts and provides justification for the AQUIND exemption application. In this section, we provide:

- an overview of the benefits of increased interconnection between GB and France;
- a description of the economic dispatch model, used to derive net benefits to producers, consumers, and interconnectors;
- a description of the Project costs;
- an overview of the Project's welfare impacts, including both monetised and additional non-monetised benefits; and
- a cost-benefit analysis summary of the project, including net national impacts.

1.1 Introduction: drivers of increased interconnection

AQUIND Interconnector will significantly increase the cross-border capacity between GB and France delivering an additional 2000MW of capacity to the congested GB-French border. The Project, which will be owned and operated by AQUIND, will be the largest GB interconnector built since IFA in the 1980s.

AQUIND will represent a significant step towards full market integration between GB and mainland Europe and will deliver considerable benefits to GB, France and Europe.

In its 2018 decision on AQUIND's first exemption application, ACER noted that interconnection of up to 8 to 9 GW would be socially beneficial on the GB-France border. GB and France have fundamentally different installed generation mixes, even though both markets are expected to have an increasing proportion of renewable generation in the total installed capacity in the future. Greater interconnection creates significant security of supply benefits and reduces the need for additional investments in firm capacity in both markets. Structural price differences currently exist (and are expected to persist) between the two markets which are driven primarily by differing installed capacity mix, but also by other differences such as the French and GB capacity markets, different approaches to renewable generation support, and different carbon prices.

Cross-border trade is a key pillar of the European Third Package suite of legislation – a key building block of the European Electricity Target Model (ETM). The allocation of capacity via AQUIND will increase opportunities for existing and new market participants to trade across the GB-French border.

The pipeline of planned GB-French interconnector projects has increased since 2013 following the confirmation of the GB Cap and Floor regime. Even with planned investment, GB interconnection is still below other European countries.

Overall, the introduction of AQUIND Interconnector can deliver a range of benefits. The monetised benefits include:

- Increase in European social welfare by approximately €1.3bn in present value terms;
- Increase in French social welfare by approximately €1bn (AQUIND Market Scenario) when the costs and benefits of the AQUIND interconnector are excluded;[1]

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[1] The cost-benefit analysis for France alone should exclude all costs and benefits that relate to other countries and/or to third parties such as AQUIND. This is because under an exemption regarding the Use of Revenues,

- Increase in security and diversity of supply in France; and
- Integration of renewables and achieving national decarbonisation targets in France.

AQUIND Interconnector also brings a number of additional, at this stage non-monetised, benefits:

- Enhanced competition including competition for interconnector capacity;
- Achieving European market integration as a policy objective; and
- Flexibility and provision of system services to the national TSOs.

In this section we first summarize our assumptions and methodology for the CBA (Section 1.2). We then present AQUIND Interconnector project costs and welfare impacts (Section 1.3 and 1.4). Finally, we present the summary of CBA results across Europe and by individual country (Section 1.5).

1.2 Methodology, assumptions and approach

The AQUIND TYNDP modelling approach replicates the ENTSO-E 2018 modelling for the TYNDP. The modelling includes the three main TYNDP scenarios: Sustainable Transition ("ST"), Distributed Generation ("DG") and EUCO covering spot years 2025, 2030 and 2040 (except for EUCO). Only DG scenario is expected to be used by the European Commission for the purposes of the assessment of projects – candidates for the 4th PCI list.

AQUIND replicated TYNDP 2018 analysis as closely as practically possible (modelling methodology is further explained in this exemption application) to obtain the necessary level of details of the outputs of such modelling. The outcome of the AQUIND TYNDP analysis shows that the AQUIND modelling approach is closely aligned with ENTSO-E's approach used for the TYNDP. Our conclusion from the TYNDP modelling exercise is that it validates the modelling approach and framework used in this CBA. To replicate the TYNDP analysis, the project team used the ENTSO-E TYNDP 2018 modelling assumptions. Where specific modelling assumptions were not available, or sufficiently detailed, additional assumptions have been made and recorded.

While AQUIND's modelling of the TYNDP scenarios serves as a validation exercise of the CBA modelling for the exemption application, AQUIND has developed a more detailed set of assumptions which represent a central view of how European power markets are expected to evolve in the future, referred to as the Market Scenario ("AQUIND Market Scenario"). AQUIND has therefore also modelled the socio-economic welfare ("SEW") of the Project under the AQUIND Market Scenario. The AQUIND Market Scenario includes a number of differences and additions to the TYNDP, making it a more comprehensive and robust scenario for this assessment. The AQUIND Market Scenario represents a more up-to-date and comprehensive view of the evolution of European power markets, while maintaining consistency with the base TYNDP assumptions.

Overall, we believe that the AQUIND Market Scenario represents a more plausible scenario of the likely evolution of the electricity markets in GB, France and Europe over the next 25 years. It is based on a more recent data relative to the TYNDP and provides a robust approach to modelling the development of the generation mix across Europe, consistent with the underlying profitability of different plants.. Table 1-1 provides a summary of the key modelling additions, included in the AQUIND Market Scenario (compared to the TYNDP) for the purposes of the AQUIND Interconnector project-specific CBA.

French stakeholders to not bear any costs, nor receive any revenues, related to the interconnector. For the avoidance of doubt, any revenues, above a pre-agreed threshold, that may be shared by AQUIND with French network users, would be included in the CBA.

Table 1-1 AQUIND Market Scenario modifications compared to the TYNDP

Element	Description
Capacity mix	The parameters of the TYNDP 2018 scenarios were established in 2016. The Market Scenario is based on the underlying assumptions behind the TYNDP 2018 (capacity mix in particular) but layers on top a number of additional assumptions to ensure this is a robust and internally consistent scenario over the whole modelling horizon of 25 years from the start of operation. The capacity mix assumptions in the AQUIND Market Scenario are based on contemporary data and real life asset investment decisions (i.e. calculating the profitability of individual generation units across Europe to ensure commercial drivers for operation). This provides valuable insight into plant retirement decisions, adding additional unit-specific detail compared to the TYNDP 2018 assumptions, which are also based on more up-to-date information.
Technology costs	The Market Scenario includes estimates of technology-specific costs to ensure accurate investment and closure decisions and merit order dynamics: ▸ Capital costs; ▸ Annual fixed costs; ▸ Variable costs; and ▸ Financing assumptions (cost of equity, cost of debt, gearing levels, inflation).
Interconnector loss factors	The Market Scenario includes individual interconnector loss factors across Europe and detailed storage parameters for pumped hydro storage and reservoir-based hydro (both missing from the ENTSO-E TYNDP 2018).
Renewable output profiles	Renewable output profiles are based on historical weather conditions (and aligned with demand profiling). For the AQUIND Scenarios, we use historical output from 2012 as the basis for our profiling estimates.
Flexile and inflexible demand and scarcity uplift	The Market Scenario includes a breakdown of flexible versus inflexible demand (to meet an annual demand figure specified by ENTSO-E) and a scarcity uplift (i.e. regression analysis to value scarcity based on the relationship between capacity margins and prices taking into account bidding behaviour above Short-Run Marginal Cost).
Commodity charges	For commodities, we take into account commodity entry charges and gas and coal transportation charges to power stations.
GB balancing charges and losses	For GB, we also model current charges, for example BSUoS and losses, which are included in GB wholesale price projections (known as station gate).

In addition to a central view offered by the AQUIND Market Scenario, AQUIND has developed two alternative scenarios, referred to as the AQUIND High Commodities/Renewables Scenario and the AQUIND Low Commodities Scenario, which show alternative evolutions of future commodity prices and levels of investment in renewable generation. These three scenarios are designed to show a plausible set of future worlds, representing a range in value for AQUIND Interconnector and for society.

Table 1-2 Modelling main scenario descriptions

Scenario	Description
AQUIND Market Scenario	A central view on the evolution of the European power markets. Under this scenario, European Governments continue to pursue a balanced energy policy, attempting to meet the sometimes competing demands of security of supply, competitive market structure, and environmental sustainability.
AQUIND High Commodities/ Renewables Scenario	This represents a scenario where high renewable investment is driven by high commodity prices and economic growth across Europe. This in turns drives price volatility in GB, France and continental Europe leading to increased levels of interconnector investment compared to the AQUIND Market Scenario.
AQUIND Low Commodities Scenario	This represents a scenario with lower economic growth, demand and commodity prices compared to the AQUIND Market Scenario. Low commodity prices, based on observed prices over the last 5 years, result in low renewable investment. Low commodity prices also reduce the running cost of marginal thermal generation with higher capacity margins reducing scarcity, placing downward pressure on wholesale prices across Europe. Low price volatility and cross-border spreads reduce the returns for interconnectors, therefore reducing interconnector investment compared to the AQUIND Market Scenario.

All three AQUIND scenarios set out above use the TYNDP assumptions as an input and build on them to deliver an economically robust and internally consistent set of scenarios, by applying detailed assumptions and contemporary data.

In addition to the TYNDP validation, AQUIND has also completed a project-specific CBA. For the project-specific CBA, a standard CBA methodology is used to calculate the impact of AQUIND Interconnector on society. The CBA considers market price projections “with” and “without” AQUIND Interconnector. The difference between these modelling outcomes reveals the impact that the Project has on wholesale electricity market prices in each country. The distribution of welfare impacts is split between consumers, producers and interconnectors in GB, France and continental Europe. This enables the CBA to be performed for France-only, and in the context of an exempt interconnector (see footnote 1).

The project-specific CBA is based on a detailed set of assumptions about the future development of the GB, French and European wholesale electricity markets. It takes into account recent domestic energy policies, based on the same underlying TSO-led assumptions used as part of the TYNDP. The project-specific CBA also takes in specific unit-level costs to build up a view of the profitability of generators across Europe, which in turn informs the capacity mix development for new and retiring generation.

AQUIND Interconnector project-specific CBA methodology aligns with ENTSO-E CBA guidance.[2]

For the main AQUIND scenarios (the AQUIND Market Scenario, the AQUIND High Commodities/Renewables Scenario, the AQUIND Low Commodities Scenario, outlined in Table 1-2), an economic market dispatch model has been used to project market prices in GB, France and other European countries over the 25-year modelling period (2024 to 2048).

AQUIND has also assessed the impact of changing individual market modelling assumptions on the SEW, relative to the AQUIND Market Scenario. We describe these sensitivities below.

[2] 2nd ENTSO-E Guideline For Cost Benefit Analysis of Grid Development Projects (September 2018), referred to as “ENTSO-E CBA guidance”.

Table 1-3 Sensitivities to the AQUIND Market Scenario

Scenario	Description
No scarcity	▸ Bidding behaviour is limited to Short-Run Marginal Cost, without scarcity uplift
Low interconnector investment (GB-FR)	▸ Focusing on the additional benefits delivered by AQUIND Interconnector if other planned GB-France projects do not process as assumed in the Market Scenario
High GB interconnector investment	▸ Assume that AQUIND Interconnector progresses alongside the other known GB-France projects, along with known additional interconnector projects to Norway, Germany and Belgium.
Brexit	▸ Continued reduction in trading efficiency between GB and continental Europe for a prolonged period of time (we assume this continues past 2048) ▸ Modelled by adding a market inefficiency fee – a cross-border charge that reduces the efficiency of cross-border trading between GB and continental Europe
Capex overrun	▸ No adjustments to the market assumptions ▸ Adjustment to the capex contingency

The UK's departure from the EU in January 2020 presents a number of uncertainties for an infrastructure developer. The AQUIND Market Scenario assumes that the short-term impact of Brexit, after the end of the "Transition Period", specifically that GB will no longer participate in single day-ahead European market coupling, will be limited. This assumes that GB and its European neighbours will put in place arrangements to mitigate some of the inefficiency created by Brexit and by the absence of market coupling by the time AQUIND is operational in 2024. We do not define what these arrangements might look like, however we assume that they will allow trade aligned with levels seen today, with market coupling.

There is a risk that the short-term inefficiencies are not replaced and there is therefore a longer-term negative impact of Brexit for cross-border trading between the UK and Europe. This Brexit sensitivity replicates this inefficiency by introducing a market inefficiency fee to all GB cross-border flows for the full modelling horizon. This market inefficiency fee or transaction fee is modelled as additional cost to cross-border trade, similar to a wheeling charge, for all GB interconnectors (including AQUIND).

The market inefficiency fee is applied to all GB interconnectors with Europe, including Norway, and applies to flows in both directions. We assume that there is no market response to these additional charges – i.e. there are no changes to capacity mix or investment decisions. We assume that the Single Electricity Market in Ireland is maintained, and therefore we do not apply the market efficiency fee to flows between the Republic of Ireland and Northern Ireland.

1.2.1 Market modelling approach

The pan-European economic dispatch model used to estimate SEW impacts includes all markets to which GB may be connected, as well as countries connected to these markets. For detailed simulation of the dispatch of power markets at an hourly level AQUIND's advisers (Baringa Partners) used a third party product, PLEXOS® for Power Systems. PLEXOS® is a highly regarded power market simulation software used globally by system operators, utilities and commodity traders and Baringa Partners have used it extensively over the last six years to model in detail European power markets.

At its heart lies a dispatch 'engine' based on a detailed representation of market supply and demand fundamentals at an hourly granularity. The supply mix is represented with the operating parameters of generating plant including costs and operational constraints. For wind, a detailed generation profile based on recent history for wind speeds, and projected future wind capacity has been modelled, such that the results for wind generation vary hour by hour and year by year. The approach has been based on modelling wind generation based on historical outturn data which captures the correlation of wind speeds between different markets.

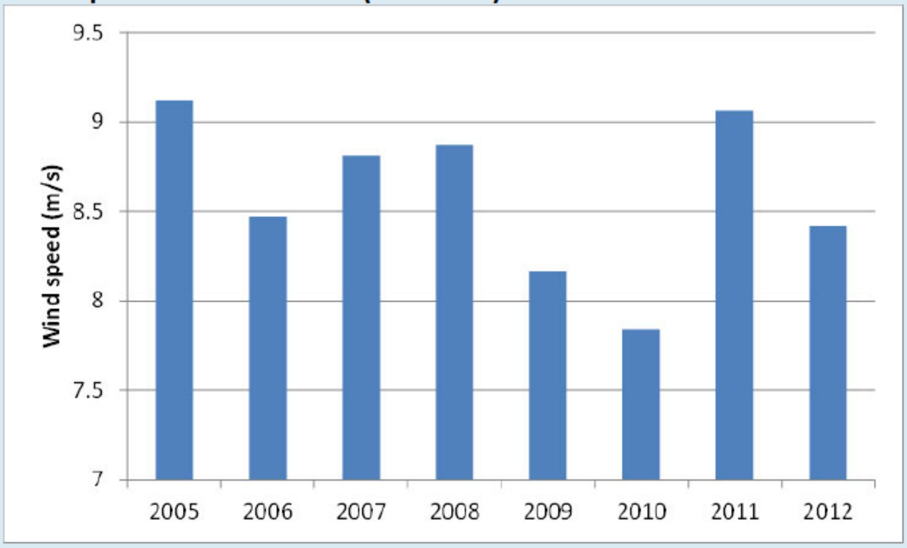
Electricity demand is represented as a projected hourly profile (derived from historic calibration). Market dispatch is then simulated with system-level constraints (e.g. emission limits) optimised to deliver the least cost solution. The marginal cost for each plant is calculated from heat rate curves, fuel costs, transportation costs, non-fuel variable operating costs and carbon costs. Start-up and no-load costs are used in the 'unit commitment' decisions that are taken within PLEXOS®.

Box 1: Reference weather and demand year

In the modelling, Baringa has used the calendar year 2012 as the reference year for weather patterns and electricity demand. Total annual electricity demand and annual peak demand are based on National Grid's Future Energy Scenarios 2018 and RTE Bilan Previsionel 2018 report, and are on a weather corrected basis, but the variation of demand, wind and solar patterns, hour by hour, are based on the actual patterns of a historical year. The year 2012 has been used as it represents a typical year (in aggregate) for weather patterns across Europe.

Figure 1-1 shows average annual wind speeds by region in Great Britain over the timeframe 2005-2012 inclusive. 2012 is very close to the average over this 8-year period. Baringa has performed similar analysis for wind speeds across Western Europe, by region. Across all regions considered in Western Europe, we have found that 2012 has an average rank of 4.8 (where 1 is most windy year and 8 is least windy year). As a middle score would be 4.5, we have concluded that 2012 was indeed a typical 'wind year' and thus is sufficiently representative for the purposes of our modelling.

Figure 1-1 Wind speeds for GB offshore (North Sea) 2005-2012

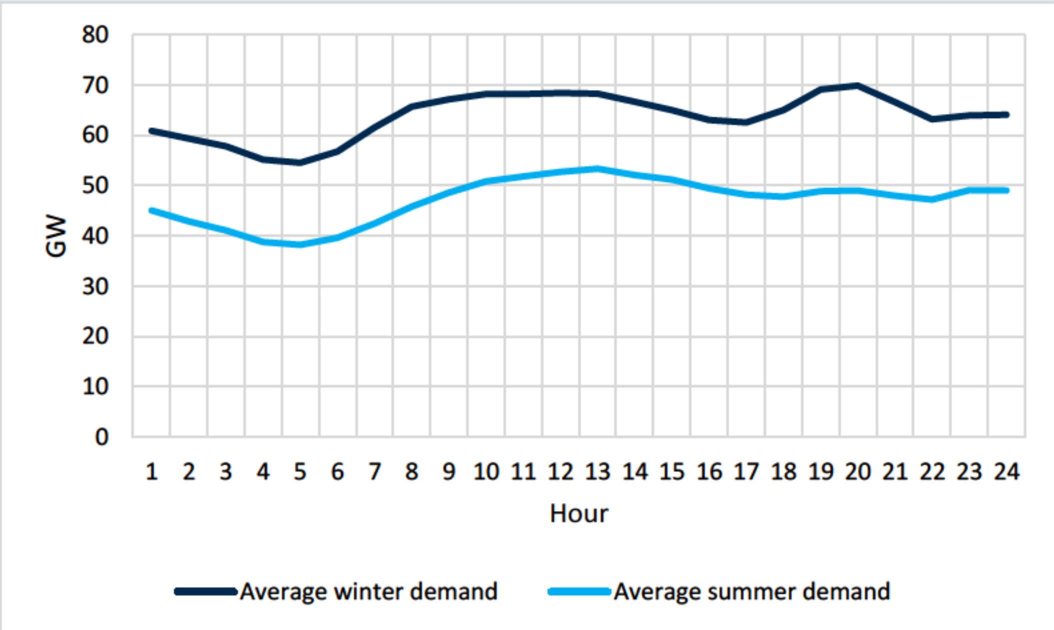


Within 2012, there were some weather features that differentiate 2012 from other years. In particular, February was a particularly cold month (with high demand) in Western Europe. March was however warmer than other years in the study period. Such variation is normal and does not pose any modelling issues as any individual year has some unique features that differentiate that year from any other year. It would be incorrect to average out all outliers because an artificially smoothed year would be unrepresentative of any year and give rise to unrepresentative and potentially biased flows and revenues for interconnectors.

In future, it is uncertain whether weather patterns will follow, on average, historical patterns or not. Although our analysis does not include the last few years, there is no reason to think the recent years are more representative of the likely future weather patterns than the 8-year period that we have analysed in detail, and for which 2012 is the most 'average'.[3] The significance of 2012 in our analysis is only to ensure a consistent set of correlations between the output of intermittent sources of generation and demand. Total capacities of intermittent generation, and total demand levels, are scenario-dependent, with the scenario assumptions outlined in the CBA.

- Figure 1-2 shows the hourly demand in France averaged across the winter and summer. Winter is defined as October to March and summer is defined as April to September.
- Figure 1-3 shows average quarterly hourly demand. Q1 is defined as January to March, etc.

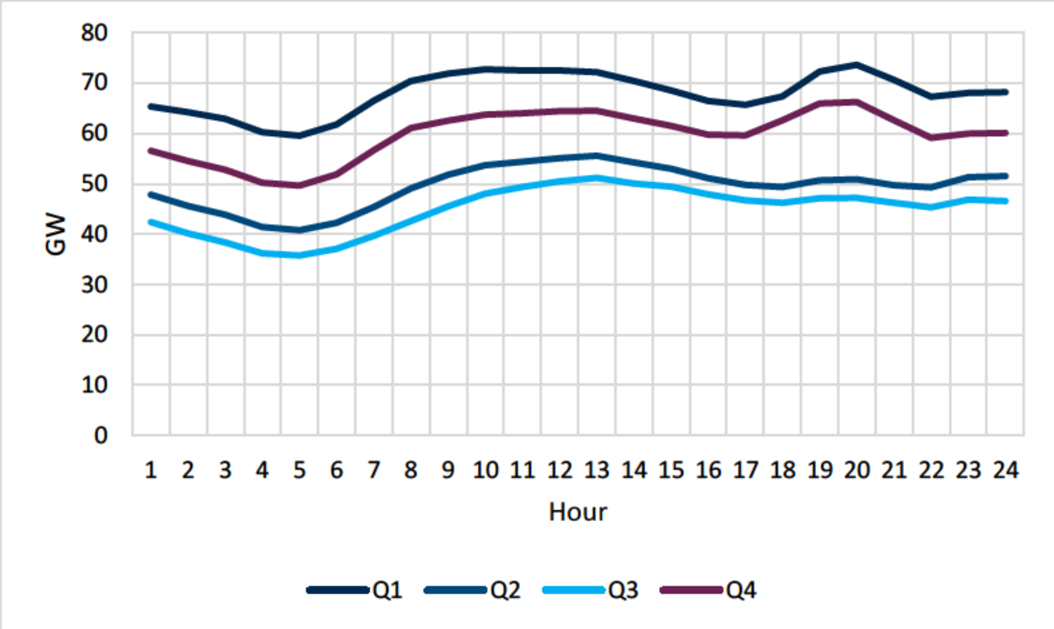
Figure 1-2 2012: Average French summer and winter hourly demand



Source: ENTSO-E data and Baringa analysis

[3] If we were to extend the analysis, it may be as appropriate to consider years preceding 2005 as to consider years since 2012 – there is no reason to believe that the years 2012-2018 are inherently "better" than the years preceding 2002.

Figure 1-3 2012: Average French quarterly hourly demand



Source: ENTSO-E data and Baringa analysis

Whilst we use the 2012 demand profile in our modelling, this is normalised for the relevant year based on the projection of peak demand. For example, if peak demand for the year occurred on a Tuesday in February in 2012, peak demand in 2020 will occur on the same day in February. The level of the peak demand, in GW, will however reflect the modelling year in question and not 2012 peak demand. Therefore, if 2012 saw a particular high demand peak, as experienced in France that year, this level of demand is not used in future years and therefore does not skew the modelling results. Only the demand shape is carried forward with the peak in that year reflecting the TSO view of peak demand.

For France, this approach results in falling annual and peak demand through to 2030, at which point we assume demand remains flat through to 2045. By comparison, French demand increases in the AQUIND High Commodities / Renewables scenario and falls through to 2045 in the AQUIND Low Commodities scenario. These scenarios model a range of demand projections from France, which are internally consistent within each of the three scenarios.

Some of the key outputs (among the various others) from this simulation include:

- System short run marginal cost and price (hourly);
- Hourly generation levels;
- Emissions levels (CO_2 in particular);
- Fuel use; and
- Interconnector flows.

In order to derive wholesale electricity prices from system short run marginal costs ("SRMC") we have developed an 'uplift' function in our modelling. The uplift function recognises that prices do sometimes rise above (and sometimes fall below) SRMC as plant seek to cover their start-up and no-load costs, as well as their annual fixed and investment costs. We model uplift based on the costs incurred in periods of contiguous operation (for start-up and no-load costs) and also as a function of the hourly capacity margin (for annual fixed cost recovery). With respect to the latter, the tighter the capacity margin (during periods of low system availability and / or high demand), the higher the uplift.[4] Conversely, in periods of high system availability (e.g. summer nights) the uplift can be negative as power generation plants effectively compete to remain on the system and avoid having to re-start despite low prices, which may be lower than SRMC. This pricing mechanism reflects the scarcity value of power, positive or negative, on an hourly basis.

The pan-European modelling results with and without AQUIND Interconnector are used to calculate the impact of AQUIND as part of the CBA. The 'without AQUIND' run is therefore the counterfactual, with the difference between the model runs showing the impact of the interconnector on SEW.

The total net SEW impact of AQUIND Interconnector is the sum of the change to consumer welfare, producer welfare and interconnector welfare, which are in turn described in the following sub-sections.

1.2.2 Producer welfare

Net producer welfare is calculated based on the following elements:

- **Wholesale revenue for generators** – Calculated as total generation in a given market in each hour multiplied by the wholesale spot market price in that hour, summed over all hours in a given year. The wholesale generator revenue from the counterfactual in which the interconnector is not built is then subtracted from the corresponding revenue when the interconnector is built.
- **Generation cost** – Calculated as the change in the total annual variable cost incurred by generators in a given market as a result of the interconnector being added. Variable costs include fuel costs, start and shutdown costs, variable operating costs and the cost of emissions. Fixed and capital costs of generation are excluded as the generation mix is fixed in our analysis, and therefore the net change between the main run and the counterfactual is zero.[5]
- **Capacity market revenues** – Calculated as the change in total capacity payments to GB and French generators resulting from the introduction of AQUIND interconnector. The welfare impact for producers will be the equal and opposite of the capacity market revenue attributed to AQUIND in the modelling. This is represented as a transfer of welfare in the

[4] The uplift function is fitted on the basis of historical evidence, comparing model "back-casts" (using observed fuel prices, carbon prices, demand levels and plant availability levels as inputs) with observed market prices (Market Index Prices as reported in the APX Power UK or N2EX power exchange). Scarcity uplift has been close to zero in recent years given the relatively high plant margin in GB. In the future, it may become more significant as the capacity margin tightens, although this will depend on the influence of the Capacity Market.

[5] In our modelling, we assume that power station capacity and other infrastructure are not affected by the introduction of AQUIND Interconnector. The introduction of the interconnector may in fact lead to deferred generation investment, however these impacts are hard to quantify and not accounted for here. We note that Ofgem previously asked Pöyry to assess how capacity reduction, in response to the Window 2 interconnectors, could affect main conclusions of the assessment. Pöyry found that the introduction of new interconnectors could reduce the investment in new CCGTs (by 200MW for Gridlink, the most relevant comparator for AQUIND Interconnector), but this would have limited impact on the interconnector flows. Pöyry concluded that its findings regarding the Initial Project Assessment of all three Window 2 interconnectors remained the same in light of the capacity reduction analysis. Source: Pöyry (2017) Near-Term Interconnector Cost-Benefit Analysis: Independent Report (Cap & Floor Window 2).

CBA assuming the total capacity procured under the CM is the same in the case with and without AQUIND Interconnector.

- **Net producer surplus** – The sum of wholesale revenues, low carbon support costs and capacity market revenue earned by generators, and the (negative) generation costs as defined above.

1.2.3 Consumer welfare

Net consumer welfare is calculated based on the following elements:

- **Wholesale cost of electricity** – Calculated as total demand in a given market in each hour multiplied by the corresponding difference in wholesale spot market prices in that hour comparing the 'with' and 'without' AQUIND Interconnector. Here we implicitly assume that any change in the wholesale price of electricity is passed on to customers in full and that the price elasticity of demand for electricity is zero.
- **DSR curtailment** – Calculated as the change in the cost of demand side response as a result of import/export via AQUIND Interconnector (imports via AQUIND Interconnector in response to a price spike may reduce other demand curtailment actions required to balance the system).
- **Unserved energy** – The impact of the interconnector on expected energy unserved is multiplied by the value of lost load.[6]
- **Net consumer surplus** – This is equal to the sum of the change in wholesale cost of electricity, DSR costs and low carbon support.

1.2.4 Interconnector welfare

Net interconnector welfare is calculated based on the following elements:

- **Interconnector wholesale revenues** – Calculated as the hourly difference in prices between connected markets multiplied by the volume of flows, minus thermal losses for all interconnectors that are assumed to be operational in the model. The increase in cross-border capacity is expected to lead to further price convergence between the GB and France and is likely to result in diminishing marginal returns for other interconnector owners (welfare reducing). The welfare impact of each interconnector that commissions by the time AQUIND Interconnector is operational, is assumed to be split 50/50 between the hosting countries.[7] This item of the CBA also includes the expected revenues for AQUIND which are welfare increasing.[8]

[6] This cost/benefit is zero in our analysis since the GB and French capacity markets are assumed to ensure adequate capacity margins even in the absence of AQUIND Interconnector; therefore all energy is served.

[7] The CBA takes into account the cannibalisation of revenue, as a result of AQUIND, for all planned interconnectors which are expected to commission, based on current estimates, ahead of AQUIND. Interconnectors that may commission after AQUIND are included in the market modelling, however we do not allocate the welfare impact of any revenue cannibalisation for these future projects to AQUIND in the CBA.

[8] A number of new GB interconnectors will be subject to Ofgem's Cap and Floor regime. We have not modelled possible individual project cap and floor levels as part of the calculation of interconnector welfare as the project cost information, and therefore cap and floor levels, are unknown. The impact of AQUIND on interconnectors that plan to commission ahead of AQUIND is taken into account in the CBA.

- **Capacity market revenues** – Calculated as the value of capacity payments to AQUIND Interconnector based on the Baringa CM model results and the assumed AQUIND Interconnector de-rating factor in each scenario.
- **Interconnector cost** – The total cost of building and operating the proposed interconnector (i.e. AQUIND Interconnector costs). For the purposes of the CBA, we assume costs are levelised over the 25-year modelling horizon based on a discount rate of 4%.
- **Net interconnector welfare** – This is given by the sum of the wholesale and capacity market revenues of all interconnectors along with the costs of construction and operation (negative welfare).

For the purposes of the AQUIND Request for Exemption, we have also calculated total welfare excluding the AQUIND costs and revenues. The AQUIND Request for Exemption removes any regulatory underwriting for the proportion of the project in French territorial waters and as such it is not appropriate to allocate any of AQUIND's costs or revenues to France in the CBA. However, the portion of revenues earned by AQUIND Interconnector that exceeds the pre-agreed cap, and is shared with French grid users, would be included as a benefit to France.

The results are all estimated in €2018m.

1.3 Project Costs

This section presents a bottom-up cost breakdown as well as a summary of the cost benchmarking assessment performed to validate the efficiency of the expected costs.

1.3.1 AQUIND project costs overview

AQUIND is currently engaging with potential suppliers through an active tender process. Therefore, the cost breakdown that can be provided at this stage is subject to further refinements.

The following section provides detailed assumptions on the DEVEX, CAPEX, OPEX and explain our approach to the replacement and decommissioning costs. We also discuss the key areas of uncertainty regarding our cost assumptions and provide evidence on the efficiency of these costs.

1.3.2 Detailed DEVEX and CAPEX costs

Table 1-4 provides detail on the development and consenting costs ("DEVEX"), which include cost of obtaining permits, conducting feasibility studies, obtaining property rights, ground and preparatory work, design, environmental impact assessment, onshore and offshore surveys, tendering and procurement, cost of raising funding, legal fees, and other professional fees relating to the project.

Table 1-4 Historical and expected DEVEX costs

Costs before commissioning (€m, real 2018 prices)	2015-2019	2020	2021
DEVEX	[redacted]	[redacted]	[redacted]

Table 1-5 provides more detail on the construction costs ("CAPEX"). The total CAPEX (excluding development costs) is estimated to be €1,426m in 2018 real terms (undiscounted) for costs incurred between 2020 and 2024. This includes:

- Contractor costs for cable, connection and converter stations (such as contractors' project management, design and engineering, procurement of materials and equipment for HVDC marine and onshore cables, HVAC cables and accessories, fibre optic cables and accessories, converter stations, installation and commissioning, and the related environmental costs); and

- AQUIND's costs (such as AQUIND's project management, engineering and supervision costs and Contractor's All Risk insurance).

CAPEX presented in Table 1-5 does not include replacement and decommissioning costs.

Table 1-5 Expected CAPEX

Capex	Assumptions	Cost (Real €m 2018)					
		2015-19	2020	2021	2022	2023	2024
Cables	Cost for equipment and installation. *Excludes type tests/prequalification tests, tax, customs charges.*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	...of which [redacted]% Marine (DC): 4 cables with total length of 728km.						
	...of which [redacted]% Underground (DC, AC): 4 HVDC cables with total length of 230km. HVAC cables with total length of 6km. (GB only – French AC cable costs included in "French Connection Works".)						
	...of which: [redacted]% Fibre optic cables and other costs						
France connection works	Cost for RTE construction works and studies required to connect asset at Barnabos. Excludes VAT.	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
GB connection works	Construction works, including AC cables (included in AC cables and Converter station costs).	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Converter stations	2 x VSC HVDC converter stations for each monopole (4 in total).	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Owner's costs	Owner's project management, engineering and supervision costs	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	CAR insurance	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total CAPEX (2021-2024)		[redacted]					
Total DEVEX (2015-2021)		[redacted]					
Total CAPEX and DEVEX costs (used in the CBA), 2015-2024		**1,426**					

Notes:

(1) Contingency for CAPEX has been included in the estimates above (not as a separate line item).

(2) No explicit financing costs have been included at this stage. We note that the cost of financing will depend on the outcome of the regulatory discussions currently ongoing and on the final form of the regime that will apply to AQUIND.

<u>**Replacement costs**</u>

In addition to the upfront CAPEX set out above, we anticipate that AQUIND will incur replacement costs ('REPEX') during the first 25 years of operation. This is estimated to be around €[redacted]m/year (in real terms) on average. These costs include:

- A replacement of the control system between years 15 and 20 (one system for each pole, of which AQUIND has two);
- A replacement of the communications system; and
- Regular replacements of HMI (every 7 years).

The REPEX costs have not been included in the Project-specific Cost-Benefit Analysis.

Decommissioning costs

The regulatory regime for AQUIND is requested for 25 years, but the design life of HVDC cables, all equipment, buildings and infrastructure would be 40 years.

At a time when the Project becomes obsolete, the equipment will be decommissioned in an appropriate manner, agreed with relevant stakeholders and materials reused and recycled where possible. Because the decommissioning is well beyond the time horizon of the regulatory regime, the Project-specific CBA does not include either the terminal value of the Project at the end of the regulatory regime nor the decommissioning costs. Also, we note that the ACER indicates in its recommendation on the Cross-Border Cost Allocation mechanism[9] that that the terminal value of such projects at the end of 25-year regulatory regime should be set to zero for the purposes the CBCA evaluation, which accordingly does not take fully into account the social economic welfare benefits or the revenues of the Project. For consistency, we therefore take this approach for the purposes of the CBA for the AQUIND exemption application. Accounting for the decommissioning costs and not accounting for the value of the Project after year 25 and up to the end of its useful life would skew the CBA and business analysis. However, for reference, we have estimated the present value of decommissioning to be around €[redacted]m as at the end of 2019. This is based on the assumption that the decommissioning costs will be comparable with IFA2 at around €[redacted]m in 2063,[10] which is slightly less than €10m when discounted to present value at the end of 2019.

1.3.3 Detailed Operations and Maintenance cost

AQUIND's operating cost projections are based on project operating and maintenance costs only. The costs reflected in the Project-specific CBA do not include business interruption insurance, corporation tax, property taxes, or business rates, as these items are not counted according to the Recommendation.

The total costs included in the CBA are estimated to be €14m/year and are highlighted in Table 1-6 below. However, additional costs expected to be incurred by AQUIND and are included in the table below for reference.

Table 1-6 AQUIND operating costs

Operating & Maintenance costs	Cost per annum (real €m 2018)
Converter stations – maintenance and repairs contract	[redacted]
Converter stations – spares replenishment	[redacted]

[9] ACER Recommendation 05/2015 available here.

[10] IFA's decommissioning costs have been estimated at €14m for a cable of half the capacity of AQUIND. These costs also only correspond to the GB portion of the interconnector. The AQUIND's decommissioning costs can therefore be estimated as [redacted] = €[redacted]m (source: Ofgem Final Project Assessment of the IFA2 interconnector to France, July 2018, p.5).

Cable inspection, spares storage & biennial marine survey	[redacted]
General overhead, personnel, leases & administration	[redacted]
Trading & Commercial Operations costs	[redacted]
Insurance costs (Operations)	[redacted]
SUBTOTAL OPEX (exclusive of taxes) – used in CBA	**14.2**
Local property taxes and business rates	[redacted]
Insurance costs (Loss of revenues)	[redacted]
TOTAL OPEX (inclusive of taxes and insurance costs) – not used in the CBA, included for reference	**27.3**

1.3.4 Project cost uncertainty and benchmarking

The main source of cost uncertainty at this stage relates to the outcome of the EPCI tender process and therefore the upfront CAPEX costs. AQUIND has sought to reduce the uncertainty regarding the CAPEX costs using two approaches: by eliciting preliminary quotes from prospective suppliers and by benchmarking the CAPEX costs against relevant benchmarks. The outcomes of these assessments are described below in turn.

1.3.4.1 Prospective suppliers

AQUIND has engaged with several prospective bidders and obtained a range of quotes that were used to estimate the CAPEX used in this exemption application. The focus of these requests for quotes was on the two major components of CAPEX: cables and converter stations.

- In 2016, AQUIND engaged with prospective bidders, in support of its exemption application; and
- In February 2019, AQUIND re-engaged with prospective bidders, to validate and refine the previous quotes.

The quotes received in 2016 and in 2019 were not materially different from each other, which gives confidence that the underlying costs are not in themselves subject to significant uncertainty. The cost of the cables estimated in 2016 was close to the refined estimates from 2019. The cost of converters was estimated to be slightly lower in 2019 compared to 2016.

The quotes that AQUIND received for cables did not specify a cost range. Of the four quotes received in February 2019, AQUIND has conservatively relied on cost forecasts in-between the first and second highest cost estimates.

One quote that AQUIND received for converter stations specified a range of +/-20%, whilst another quote for converter stations specified a range of less than +/-5%. Of the three quotes received in February 2019, AQUIND has conservatively relied on cost forecasts in-between the first and second highest cost estimates.

Where the prospective suppliers quoted a range of prices, they often referred to specific underlying uncertainties or assumptions underpinning their quotes, such as the prevailing cost of metals (copper and lead in particular), union labour rates and the exchange rates, which are outside of the supplier's and AQUIND's control.

1.3.4.2 *Benchmarking of costs*

The CAPEX costs have also been benchmarked on a top-down against similar undersea HVDC interconnector projects in North-West Europe. On this basis, AQUIND's costs are comparable to similar projects being developed between GB and France. In particular, the costs are very similar to those of IFA2, which have been assessed by Ofgem as part of the Final Project Assessment and found to be efficient.

Table 1-7 Benchmarking of AQUIND Interconnector capex

Project	Total costs (€m)	Average costs (€m/ GW)	Distance (km)	Comments / observations	*Source*
AQUIND	1,426	713	240		*Own estimate*
IFA2	762[11]	762	240	Comparable (but higher) cost to AQUIND.	*Ofgem FPA and CRE Deliberation*
BritNed	600	600	260	Comparable cost to AQUIND.	*BritNed website*
FAB Link	850 – 1,200	607 – 857	216	AQUIND is within the range of costs reported for FAB Link.	*4cOffshore and TYNDP*
Gridlink	~900	647	160	Gridlink appears to be cheaper, but cable is also shorter than AQUIND.	*Gridlink leaflet*
Celtic	930	1,329	1,150	Celtic is a much longer cable relative to AQUIND and therefore expected to be more expensive	*Investment Request*
VikingLink	1,970	~1,400	760	Considerably longer cable due to connecting to Denmark, so costs are expected to be higher on a per MW basis.	*PCI presentation, developer website*
Greenlink	~400	792	400	Greenlink is a longer cable with one quarter of AQUIND's capacity and therefore not directly comparable.	*TYNDP*
NeuConnect	1,500	1,071	720	Considerably longer cable due to connecting to Germany, so costs are expected to be higher on a per MW basis.	*TYNDP and developer website*

We expect that the tender process itself will provide additional certainty on the CAPEX for the Project.

The OPEX costs are currently estimated to be around €14m/year, or **1% of CAPEX.** This is comparable to FABLink and lower than IFA and IFA2:

[11] CAPEX and DEVEX for the GB half of the interconnector is reported as £347m (or €392m). CAPEX for the French side of the interconnector is reported as €370m.

- RTE has previously estimated the O&M costs for IFA2 as €9.6m/year (1.3% of CAPEX), which was subsequently revised to €4.5m/year (0.6% of CAPEX). CRE was, as of 2016, minded to use an estimate of €8.5m/year, which is **1.15% of CAPEX** (estimated at €740m).[12]
- Ofgem approved a placeholder[13] for IFA2's annual OPEX costs of £10.95m (real 2016/17 prices)[14] which is **3.2% of CAPEX** (estimated at £347m).[15]
- Based on IFA's annual accounts, we estimate that its annual OPEX is €39.6m (for the entire link), which is **5% of CAPEX** (assumed at €798m).
- FAB Link has estimated its annual OPEX to be between €7.6m and €12m[16], which corresponds to **0.6 to 1.4% of CAPEX** (estimated at €850-€1,200m).

1.4 Project welfare impact

This section sets out the welfare impacts of AQUIND Interconnector. Section 1.4.1 provides an overview and a summary of the main benefits. Section 1.4.2 describes how AQUIND Interconnector is expected to operate in terms of its utilisation and revenues. In Sections 1.4.3 to 1.4.4 we set out the detailed monetised and non-monetised benefits. Finally, Section 1.4.5 describes other cross-border monetary flows (including commentary on the impact on the Inter TSO Compensation (ITC) mechanism) resulting from the operation of AQUIND Interconnector.

1.4.1 Overview of key welfare impacts

The ENTSO-E CBA guidance outlines the multi-criteria assessment framework used to evaluate project benefits. These include the impact of a project on:

- The integration of the internal energy market;
- The development of a single European grid to permit the achievement of EU climate policy and sustainability objectives;
- Security of supply; and
- System stability.

There are a number of benefit indicators used by ENTSO-E to evaluate the project benefits above. These include a combination of monetised/quantified benefits and unquantified indicators. Below we list the impact of the Project using the relevant indicators, where monetary values are discounted at 4%. The estimates of variation in grid losses below do not include losses on AQUIND Interconnector, as these are already monetised through the SEW estimates. The variation in grid losses also do not include estimates of monetised losses on other GB interconnectors produced by Tractebel, as these are also included within the SEW estimates.

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[12] CRE (2016) Consultation by CRE (French Energy Regulatory Commission) regarding the interconnector 'IFA2' between France and Great Britain, p.5 and CRE (2017) Deliberation of the French Energy Regulatory Commission of 2 February 2017 forming a decision regarding the interconnector "IFA2" project, page 4

[13] We note that in the FPA, Ofgem described the OPEX allowance for IFA2 as a 'placeholder', as those costs will be assessed at the Post-Construction Review stage.

[14] Cap and Floor financial model, IFA2, FPA, tab 'Input', row 33.

[15] Ofgem (2018) IFA2 FPA. Both OPEX and CAPEX figures are only for the GB side of the interconnector.

[16] TYNDP website (accessed here) and FABLink presentation

Table 1-8 Main European welfare impact results, AQUIND Market Scenario (€m NPV)[17]

Indicators	Units	AQUIND Market Scenario				
		Net producer welfare	Net consumer welfare	Net interconnector welfare (excl.AQUIND)	AQUIND's revenues	AQUIND's Costs
Socio-Economic Welfare (SEW)	€m NPV	€ 4,788	-€ 858	-€ 3,543	[redacted]	-€ 1,305
National constraints (SEW local study)	€m NPV	N/A	N/A	N/A	N/A	N/A N/A
Variation in grid losses	TWh	19.0				
	€m NPV	-€ 188				
Security of supply (EENS)	€m NPV	€ 222				
Total monetised welfare impact (including AQUIND)	€m NPV	[redacted]				
Other non-monetised impacts						
RES integration (variation in generation curtailment)	TWh	6.18				
CO2 emissions reduction	MTonnes	2.78				
Other	-	In addition to RES integration and the reduction of carbon emissions, the Project delivers other non-monetised benefits, which are described further in Section 1.4.4.				

The welfare impact estimate of AQUIND Interconnector indicates a significant net positive benefit across the EU. This includes both monetised impacts, quantified as changes in socio-economic welfare across producers, consumers and interconnectors, as well as the contribution of AQUIND to the maintenance of generation adequacy through security of supply. The total monetised welfare impact of the Project is approx. €1.3bn on an NPV basis including the grid losses and security of supply benefits. In addition, other quantified benefits include a significant integration of renewable generation (reduction in curtailment), and the reduction of CO_2 emissions, only part of which are captured through SEW. Other benefits of the Project include its contribution to enhanced generation competition, achieving European market integration and decarbonisation targets.

1.4.2 Interconnector revenues and utilisation

AQUIND is expected to earn revenues from several sources:

[17] The SEW impacts include AQUIND's estimates of payments to and from network users in GB and France. Further information can be found in Section 4.

- Congestion rents – revenues earned through arbitraging the price differentials between GB and France;
- Capacity market payments – revenues earned through payments from the GB capacity market; and
- Ancillary services – revenues earned through providing voltage control, frequency control, reactive power and black start services in both GB and France.

For the exemption application, AQUIND has estimated the revenues earned through congestion rents through the market model, based on the hourly wholesale price differentials between GB and France over the 25-year regime duration. We have included a projection of the flows across the link as well as the congestion rents by direction below.

Figure 1-4 Annual flows across AQUIND, AQUIND Market Scenario

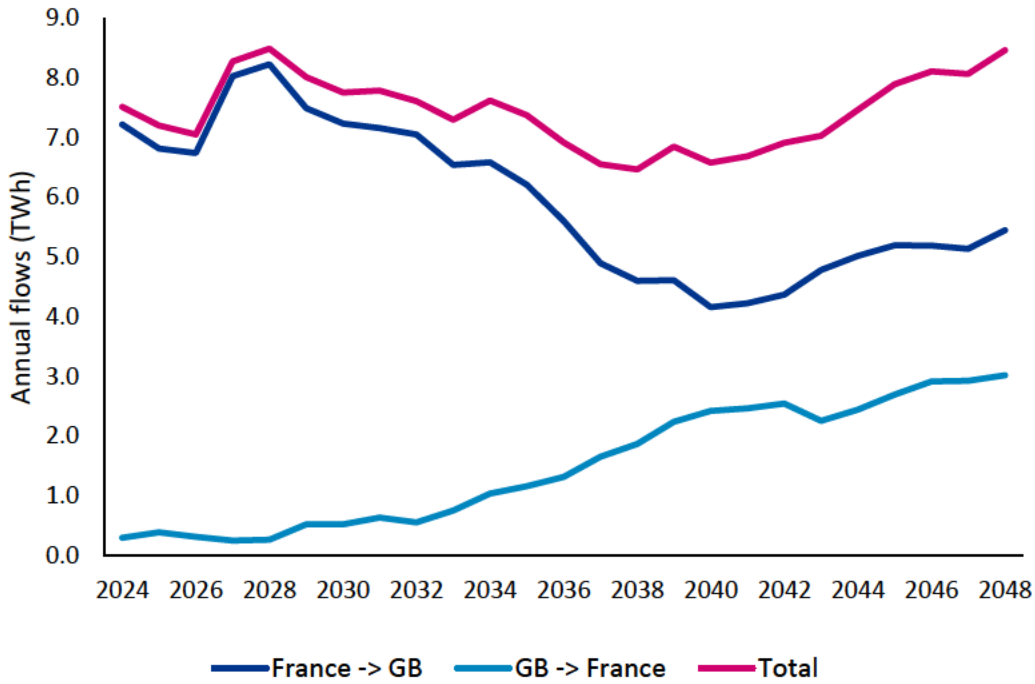
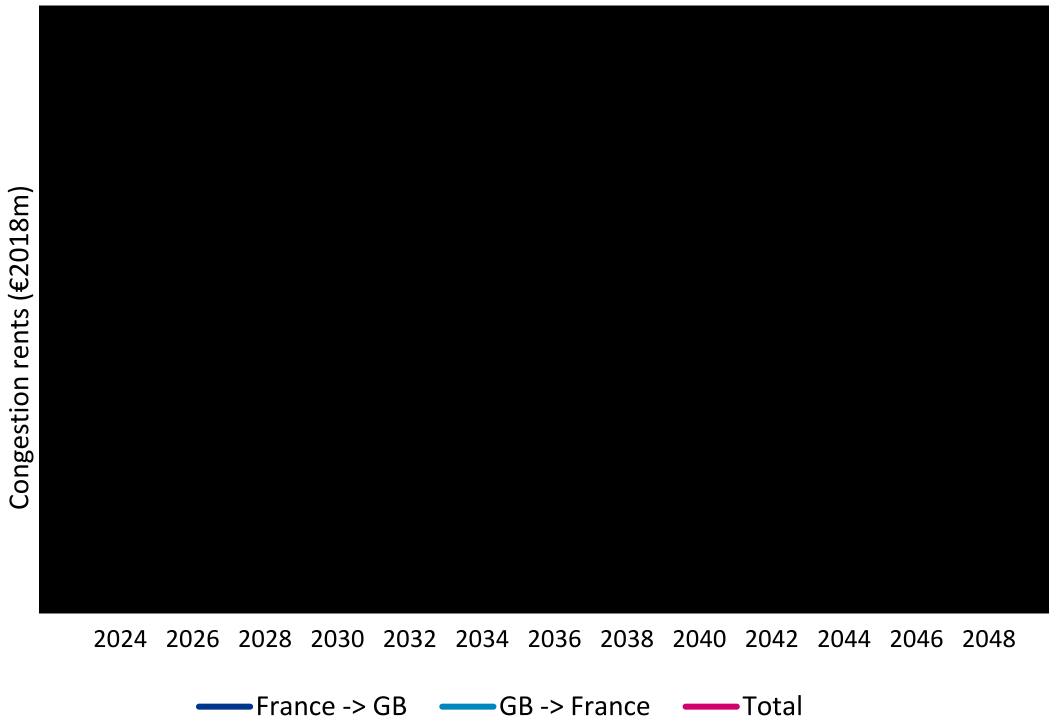


Figure 1-5 Annual congestion rents for AQUIND, AQUIND Market Scenario



We also model additional revenues earned through the GB capacity market.[18] AQUIND's revenues from the GB capacity market are modelled based on a stack of all the CM offer prices, where the stack volume in GW is the de-rated capacity of the generators participating in the mechanism, summed in ascending price order. Offer prices in the GB CM are a function of annual fixed costs, capital costs for new build, the profits (infra-marginal rents) that generators earn in the wholesale market, and risk premia (determined by the likelihood of penalty payments for unavailability at times of system stress). In our modelling, we find the point in the stack at which the de-rated capacity meets the security standard. The offer price of this marginal generator then sets the capacity price for that year.

The clearing price for the GB CM auction could be set by either older existing plant, or potential new build – in either case determined on the basis of the 'missing money' required by the participant to cover fixed and/or capital costs. We assume payments to AQUIND from the CM auction are subject to a de-rating factor. For existing GB interconnectors, BEIS (formerly DECC) and National Grid have calculated and published de-rating factors as part of their publications ahead of each relevant capacity market auction. As there is currently no published de-rating factor for AQUIND, we have estimated a de-rating factor based on the average of the French interconnector de-rating factors for IFA, IFA2 and ElecLink in the AQUIND Market Scenario.[19] In the absence of a de-rating factor specific to AQUIND Interconnector, we consider this approach provides a reasonable assumption for the rate that will apply. We have also applied the relevant de-rating factors for generators, based on National Grid's published assumptions.

[18] We model Capacity Market in both GB and France aligned with current policy, assuming that the GB CM will be re-introduced in time for AQUIND's commissioning in 2023. We assume that the value to AQUIND from the GB CM is based on the de-rating factors applied to other GB-France interconnectors. We do not currently assume any value to AQUIND from participation in the French CM because the route for interconnectors to earn revenue through this mechanism is currently uncertain.

[19] For the GB CM, this is assumed to be 72% from 2025 to 2030, falling to 52% in 2050.

Figure 1-6 GB Capacity Market revenues, AQUIND Market Scenario

GB capacity market revenue (€2018m)

[redacted]

2024 2026 2028 2030 2032 2034 2036 2038 2040 2042 2044 2046 2048

1.4.3 Monetized welfare benefits

1.4.3.1 Socio-economic welfare (“SEW”) – EU-wide market study

The results of the market modelling have been used as inputs to the CBA to show the welfare impact of AQUIND Interconnector. The CBA also takes into account non-wholesale market effects, such as Capacity Mechanisms.[20] The benefits for France, GB and Europe are presented in Table 1-9.

The CBA is based on modelling three spot years – 2025, 2030 and 2040 – which aligns with the TYNDP 2018 spot year estimates. For the TYNDP scenarios, we understand that the CBA calculation for all three TYNDP (DG/ST/EUCO) scenarios includes the common estimates from the 2025 Best Estimate Scenario, along with the relevant 2030 and 2040 estimates for the DG/ST/EUCO scenarios. For the AQUIND Market Scenario, AQUIND Low Commodities Scenario, and AQUIND High Commodities/Renewables Scenarios, we also use the spot year estimates for 2025, 2030 and 2040.

The NPV is calculated based on these spot year estimates. For years prior to 2025, we extend the 2025 estimates backwards to 2024. For impacts after 2040, we extend the 2040 impacts forward. For years between 2025 and 2030 and between 2030 and 2040, we use a linear interpolation of benefits between the two values. The sum of these annual estimates is used to estimate the NPV impact in each scenario, using a 4.0% discount rate and assuming no residual value as required in the Recommendation (Annex I). This approach also aligns with ENTSO-E CBA guidance. Table 1-9 presents that high-level CBA results for AQUIND Interconnector under the main AQUIND Market Scenario.

[20] We model Capacity Market in GB aligned with current policy. We assume that the value to AQUIND from the GB CM is based on the de-rating factors applied to other GB-France interconnectors. We do not currently assume any value to AQUIND from participation in the French CM as the route for interconnection to earn revenue through this mechanism is currently uncertain.

Table 1-9: Expected welfare impact (present value), AQUIND Market Scenario[21]

	Net present value of benefits [Meuro], France			Net present value of benefits [Meuro], GB		
Benefit component	**Producer surplus**	**Consumer surplus**	**IC surplus**	**Producer surplus**	**Consumer surplus**	**IC surplus**
SEW (EU-wide market study)[22]	€ 4,418	-€ 2,092	-€ 1,392	-€ 2,136	€ 2,275	-€ 1,088
National constraints (SEW local study)	N/A			N/A		
Variation of generation curtailments	Included in SEW			Included in SEW		
Variation in losses	- €23			-€ 165		
Security of supply (load)	€ 222 in total					
Other monetised benefits						
Total	€ 1,314[23]					

The key monetised benefit of AQUIND Interconnector is the socio-economic welfare impact on European countries. However, ENTSO-E CBA methodology introduces a number of additional indicators, to consider in addition to the SEW (ENTSO-E CBA indicator B1). In the following subsections we set out:

- Variation in Grid Losses (ENTSO-E CBA indicator B5); and
- Security of Supply (ENTSO-E CBA indicator B6, B7 and B8).

Additional non-monetised benefits of AQUIND Interconnector are set out in Section 1.4.4.

1.4.3.2 Variation in losses

The ENTSO-E CBA guidance requires the impact of a project on the reduction in thermal losses on the grid to be considered. AQUIND notes that ENTSO-E has indicated potential adjustments to the future methodology applied to the calculation of grid losses.[24] For this exemption application, we rely on

[21] The SEW impacts include AQUIND's estimates of payments to and from network users in GB and France. Further information can be found in Section 4..

[22] In the AQUIND Market Scenario, the impact of RES integration and CO2 emissions are monetised as part of SEW.

[23] The total welfare impact includes producer, consumer and interconnector SEW estimates for other countries in addition to GB and France.

[24] For example, ENTSO-E notes: "In the TYNDP 2018, ENTSO-E used a new approach to monetize losses associated with each project described in a new Cost Benefit Analysis methodology, discussed with stakeholders and approved by the European Commission. The methodology was followed rigorously and correctly. However, it appeared that the final results were unexpectedly highly impacted for some projects by the difference in granularity of input variables or by projects different sensitivity to climate conditions (same conditions have been applied to all projects). The steps necessary to amend the approach, including amending the methodology, discussing it with stakeholders and implementing it was impossible in the time-frame of the TYNDP 2018 development. This has led to what may be considered as too high monetized losses values that would not occur in reality. ENTSO-E acknowledges these facts and recommends to use the results of losses computation with cautiousness when conducting any sort of financial analysis to estimate the project profitability and feasibility."

losses calculated externally through a technical consultancy, Tractebel. The methodology for the calculation of variation in grid losses is consistent with the approach suggested in TYNDP 2018. The estimate is developed using a regional transmission grid model, calculating the hourly flows with and without the Project. This is then monetised based on the marginal costs as given by the market simulations. Further detail about the methodology for the quantification of variation in grid losses can be found in Exhibit 14.

Alongside the initial work undertaken by Tractebel, we have undertaken additional analysis to better align the modelling undertaken by Baringa and Tractebel. In particular, this post-processing exercise uses the flows across AQUIND Interconnector as a proxy for the total system losses generated by AQUIND in GB, France and across Europe. Whilst we recognise that this is a simplification of the losses analysis, which is a very complex piece of modelling, we consider it an appropriate step to better align the Tractebel and Baringa analysis. We expect that this step to better align the analysis improved the consistency of the SEW and losses analysis giving a more accurate CBA result.

The post-processing started by comparing the 2030 flows across the GB-France border, with AQUIND, in both the Baringa and Tractebel analysis. Our analysis showed that Baringa projected 64% of the annual flows of Tractebel. All else being equal, lower flows across the border would result in lower system losses (in the case of France) and a lower reduction in system losses (in the case of GB). Applying the same methodology to the AQUIND Low Commodities and High Commodities/Renewables scenarios gave results of 68% and 49% respectively.

Applying these scalars to the NPV of total losses used in the CBA gives a more consistent view of the losses from the AQUIND scenarios.

Table 1-10 Monetised value of the variation in grid losses resulting from AQUIND

€m NPV @ 4.0%, real 2018	AQUIND Market Scenario	AQUIND Low Commodities	AQUIND High Commodities / Renewables
Original analysis (as presented in the Investment and CBCA Request equation 3.0)			
Variation in losses, France	-€ 36	-€ 60	-€ 76
Variation in losses, GB	€ 258	-€ 221	-€ 232
Total losses	**-€ 294**	**-€ 280**	**-€ 308**
SCALED analysis			
Variation in losses, France	-€ 23	-€ 29	-€ 52
Variation in losses, GB	-€ 165	-€ 108	-€ 158
Total losses	**-€ 188**	**-€ 137**	**-€ 210**

As AQUIND's SEW estimates include the impact of losses on the Project itself, and other GB/EU interconnectors[25], the estimates below exclude the estimates of losses on the Project and other GB links, to avoid double counting.

The monetised grid losses in the table above are negative when the impact of AQUIND on variation in grid losses represents a net cost, and are positive when the impact represents a net benefit. The monetised impact of the variation in grid losses in GB is a net positive value, due to the impact of the Project on marginal cost more than offsetting an increase in net losses. These estimates do not include

[25] Technical line losses are an input to the modelling in Plexos.

the impact of grid losses on AQUIND Interconnector or other GB/EU interconnectors, which are monetised as a cost through AQUIND's approach to SEW estimates.

1.4.3.3 Security of supply (load)

AQUIND will provide a reliable alternative source of electricity for GB and French consumers and network users over its operational life. The nature of interconnection technology is such that AQUIND is projected to achieve over 98% technical availability over its operational period, significantly higher than most conventional thermal assets.

The ENTSO-E CBA guidance indicates that additional transmission capacity may provide benefits through improved security of supply, which includes three subcategories:

- Adequacy to meet demand (ENTSO-E CBA Indicator B6) – transmission capacity allowing demand in one area to be met through generation in another area;
- System flexibility (ENTSO-E CBA Indicator B7) – capability of an electric system to accommodate fast and deep changes in demand, allowing system balancing over a wider area in a future with greater intermittent renewable generation; and
- System stability (ENTSO-E CBA Indicator B8) – capability of a system to regain equilibrium after a physical disturbance.

The B6 and B7 indicators are quantified estimates, while the B8 indicator is a qualitative assessment.

The benefits of system adequacy are quantified through the Project's estimated impact on Expected Energy Not Served (EENS).

The EENS benefit is quantified through a Monte Carlo simulation of generation and transmission systems, simulated across several climatic years. The full methodology for both the quantification of B6 and B7 benefits is detailed in Exhibit 14. The value of the EENS benefit is quantified below in Table 1-11 for the AQUIND Market Scenario. We have followed the same scaling methodology for the EENS methodology, as applied for grid losses, explained in 1.4.3.2 above.

Table 1-11 Security of supply (EENS), AQUIND Market Scenario

€m NPV @ 4.0%, real 2018	AQUIND Market Scenario
Security of supply (EENS)	**€ 222**

AQUIND Interconnector will contribute to system stability (ENTSO-E CBA Indicator B8) through the improved transient stability, voltage stability, and frequency stability of the power system in GB and France.

1.4.4 Additional benefits (non-monetised)

In addition to the Project's impact on socio-economic welfare, grid losses, security of supply and RES integration, the Project is expected to deliver a wide range of other benefits across Europe. In this section, we discuss the additional benefits that AQUIND Interconnector delivers in terms of:

- Integration of renewables and achieving national decarbonisation targets;
- Enhanced competition;
- Security and diversity of supply (in addition to the monetised impacts set out in the previous section);

- Achieving European market integration as a policy objective; and
- System flexibility.

1.4.4.1 Achieving national decarbonisation targets

The costs and benefits of the integration of renewable energy sources ("RES") are valued as part of the total SEW in the AQUIND Market Scenario. The ENTSO-E CBA guidance indicates that this should be quantified through the reduced curtailment of RES due to greater interconnection, as well as the lower short-run variable generation costs of RES. The overall impact of AQUIND Interconnector on increased RES integration is included within the SEW but is also estimated in terms of TWh of renewable generation output.

The TYNDP modelling approach isolates the impact of each project on RES integration. For the Market Scenario, AQUIND Interconnector is projected to increase renewable generation across Europe by 6.18 TWh over the CBA period. Table 1-12 presents the RES integration results for the main scenarios.

Table 1-12 RES integration – main scenarios (over the assessment period)

RES integration		Total
AQUIND Market Scenario	*TWh*	6.18
AQUIND Low Commodities Scenario	*TWh*	6.39
AQUIND High Commodities/Renewables Scenario	*TWh*	21.22

Similar to the benefits of RES integration, AQUIND Interconnector is expected to contribute to CO_2 emissions reductions. These benefits are included within the SEW estimate and are monetised through a reduction in emissions costs (i.e. less carbon intensive generation will result in a reduction in the cost of carbon). The impact of AQUIND on reduced CO_2 emissions are also quantified in terms of Mtonnes of CO_2.

For the Market Scenario, AQUIND Interconnector is projected to reduce CO_2 emissions by 2.78 Mtonnes. Table 1-13 presents the RES integration results for the main scenarios.

Table 1-13 Reduction in CO2 emissions – main scenarios (over the assessment period)

CO2 emissions		Total
AQUIND Market Scenario	MtCO2	2.78
AQUIND Low Commodities Scenario	MtCO2	25.32
AQUIND High Commodities/Renewables Scenario	MtCO2	35.55

The more efficient dispatch of generation across GB and France from improved market access and in particular the opportunity for a more efficient dispatch of renewables is expected to reduce overall carbon emissions. In 2019, the UK Committee on Climate Change (CCC) recommended new UK greenhouse gas targets of net zero by 2050.[26] Several studies have pointed to the role of increased GB-EU interconnection as the least cost means of achieving such decarbonisation targets.[27]

[26] Committee on Climate Change, "Net Zero – The UK's contribution to stopping global warming", published 2 May 2019.

[27] E3G, "UK-EU Electricity Interconnection: The UK's low carbon future and regional cooperation after Brexit", Briefing paper published January 2019.

Similarly, France adopted a Climate Plan in 2017 that seeks to achieve "carbon neutrality" by 2050. Its energy policy framework, governed by the Law on Energy Transition for Green Growth (LTECV) includes ambitious decarbonisation targets, including a 40% reduction in GHG emissions (compared to 1990) by 2030, and 75% reduction in GHG emissions by 2050. In this context, the Multi-Annual Energy Plan (Les programmations pluriannuelles de l'énergie, or "PPE") notes that interconnectors (and other sources of flexibility) are key to support growing penetration of renewables.[28] In this sense, interconnectors can be seen as one of the enablers of long-term decarbonisation in France.

We assess some of the benefits of AQUIND Interconnector in terms of reduced CO_2 emissions and increased RES integration through our SEW estimate, but a range of benefits in relation to AQUIND Interconnector's role in achieving these decarbonisation targets are not quantified in our approach or in the ENTSO-E methodology. We refer to these benefits in Section 1.4.2. AQUIND Interconnector will also make a significant contribution to the implementation of the new energy policies in France that are currently being discussed.

1.4.4.2 Enhanced competition

Interconnection enables cross-border electricity flows, providing market participants access to connecting markets and increasing the size of the energy markets. This allows participation from a larger number of market participants and can allow new entrants to put competitive pressure on incumbents. Interconnection increases competitive pressure in two ways: through both the dispatch of lower cost generation, but also by reducing the mark-up, or scarcity uplift, above marginal cost that generators are able to bid into the market. The CBA methodology applied in this exemption application accounts for the socio-economic welfare benefits of the first impact that interconnection has on competition, but not the second impact. This second impact would likely result in an increase in consumer welfare in the CBA, as lower uplift transfers welfare from producers to consumers.

AQUIND Interconnector will provide an additional 2000MW of tradeable capacity across the congested GB-France border. The capacity will be made available to all market participants through regulated market mechanisms (implicit and/or explicit auctions).

At the macro level, AQUIND Interconnector will increase competition in Europe by creating new opportunities for cross-border trade. This will increase liquidity and, the opportunity to trade across a larger market, should displace more expensive generation in the importing market leading to price convergence. Increased market liquidity is generally associated with lower bid-ask spreads, which reduces the cost of wholesale market participation for both generation and demand.

Competition in capacity auctions

The inclusion of interconnection in the GB and (future) French Capacity Market ("CM") auctions provides a possible additional competitive benefit for consumers. AQUIND, as a price-taker in the GB CM auction, will displace more expensive thermal generation setting the marginal price for capacity in the auction. This competitive pressure introduced by the Project should reduce the cost of capacity contracts to the benefit of GB consumers (representing a further welfare transfer from producers to consumers in the CBA). Assuming the contribution of interconnection to the CM in France is aligned with this approach, the same benefit will apply to French consumers.

[28] French Strategy for Energy and Climate, Multi-Annual Energy Plan (PPE), Draft for Comments (2020), Section 5.3.3.

1.4.4.3 *Security and diversity of supply*

AQUIND Interconnector will provide a reliable alternative source of electricity for GB and French consumers and network users over its operational life. The nature of interconnection technology is such that AQUIND is projected to achieve over 98% technical availability over the Project lifetime, significantly higher than most conventional thermal assets.

The security of supply benefit provided by AQUIND Interconnector will be partially captured through participation in the GB and French capacity markets, and result in possible deferred/avoided generation investment. Moreover, AQUIND Interconnector is estimated to contribute to a decrease in the probability of unserved energy. The differences in the GB and French generation mix will ensure that AQUIND provides a degree of diversification for both GB and France.

The Project will deliver additional security of supply benefits through improved system flexibility. The benefits of this are incorporated into the estimate of additional net transfer capacity AQUIND Interconnector delivers in relation to existing cross-border capacity. The welfare effects of this are therefore quantified through the socio-economic welfare estimate.

AQUIND Interconnector also delivers additional security of supply benefits through improved system stability. However, these benefits are not quantified as part of the CBA.

AQUIND Interconnector will contribute to system stability (ENTSO-E CBA Indicator B8) through the improved transient stability, voltage stability, and frequency stability of the power system in GB and France.

1.4.4.4 *European market integration*

Cross-border trade of electricity is a key pillar of the European Third Package suite of legislation, and a key building block of the European Electricity Target Model for cross-border trade. Well interconnected trans-European electricity grids are "*indispensable for making the energy transition a success*"[29] and the development of European electricity interconnectors is "*an important obligation for the European Union together with its Member States set out in the European Treaties to strengthen economic, social and territorial cohesion*".[30]

To promote the proper functioning of the internal energy market, the European Council has set targets to achieve 10% electricity interconnection by 2020 and 15% by 2030.[31] The Commission Expert Group on electricity interconnection also suggested that options for further interconnectors should be urgently investigated in countries where nominal transmission capacity of interconnectors is below 30% of peak load or below 30% of installed renewable generation capacity.[32]

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[29] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, dated 23 November 2017: https://ec.europa.eu/energy/sites/ener/files/documents/communication_on_infrastructure_17.pdf

[30] Towards a sustainable and integrated Europe Report of the Commission Expert Group on electricity interconnection targets, November 2017, page 14 (the "Expert Group Report"): https://ec.europa.eu/energy/sites/ener/files/documents/report_of_the_commission_expert_group_on_electricity_interconnection_targets.pdf

[31] (i) Outcome of the October 2014 European Council: https://ec.europa.eu/clima/sites/clima/files/strategies/2030/docs/2030_euco_conclusions_en.pdf; and (ii) COM(2014) 330, Communication from the Commission to the European Parliament and the Council, dated 28.5.2014: https://www.eesc.europa.eu/resources/docs/european-energy-security-strategy.pdf

[32] Expert Group Report, page 7

AQUIND Interconnector will double the current GB-FR capacity and provide a >30% increase in capacity when the links under construction are taken into account. The French electricity market is already well connected to other central European Member States. The large structural difference in the electricity prices in GB and France provides a clear signal for further interconnection to facilitate efficient cross-border trade and GB-French, as well as wider European, price convergence. AQUIND Interconnector will also greatly contribute to GB meeting the EU interconnection target of 15% of installed capacity by 2030 as proposed in 2014.

The Project will provide an opportunity for the efficient dispatch of renewables in GB, France and across connected markets. As renewable investment increases in GB and France, the probability of curtailment of intermittent generation also increases. The additional cross-border capacity provided by AQUIND Interconnector offers the opportunity to export this additional power during periods of high renewable generation.

1.4.4.5 Flexibility and system services

AQUIND Interconnector will use VSC technology and therefore be in a position to provide a range of services to the national TSOs, National Grid and RTE, to improve flexibility in real time trading timeframes. This may include the provision of mandatory and commercial ancillary services (for example voltage control, reactive compensation, frequency control and black start capability services) and for emergency assistance and cross-border balancing. Some of these ancillary services will be provided voluntarily based on publicly tendered commercial agreements with National Grid, further enhancing the competition in this market for the benefit of network users. Similarly, in France, AQUIND Interconnector may provide frequency and voltage ancillary services to RTE.

The Project will also be able to provide emergency assistance to both National Grid and RTE.

1.4.5 Other cross-border monetary flows

As a non-incumbent TSO interconnector developer, AQUIND does not have access to the relevant information to calculate its impact on the ITC mechanism. AQUIND has therefore sought guidance from relevant TSOs to assess this impact. As the TSOs were not able to quantify the impact AQUIND may have on the ITC mechanism, we estimate the impact to be zero for the purposes of the CBA.

Table 1-14: Other cross-border monetary flows (revenues, ITC, other charges, grants)

ITC (electricity) Country	Net present ITC impact [Meuro present value]
ITC (France)	Data provided by indicated a benefit from AQUIND of €3.85m in the Market Scenarios, €0.68m benefit in the High Commodities scenario and a benefit of €1.32m in the Low Commodities scenario.
ITC (GB)	No data provided by NG ESO
Other charges	Nil
Grants	Nil

1.5 Cost-benefit analysis summary and discussion

This section brings together the analysis of AQUIND project costs (Section 1.3) and the welfare impact analysis (Section 1.4). In the first subsection we consider the overall impact of AQUIND Interconnector on France, GB and other European countries, while in the second subsection we consider the impact on individual countries in more detail.

1.5.1 European CBA

This section summarises the European CBA by combining the project costs – capex and opex – as well as the producer, consumer and interconnector welfare impacts. Opex is included in the CBA as an annual cost. The total project capex is annuitized, using the 4% discount rate, and applied in equal increments through each of the 25 years of the CBA.

We account for technical losses in the market modelling, based on the technical characteristics of AQUIND interconnector as described in Section 4. In the CBA, the interconnector losses are split between GB and France on a 50/50 basis. The interconnector mid-point capacity is set at 2000MW, which effectively assumed that AQUIND takes 2037.5MW (i.e. half of the 3.6% losses) from the exporting market and delivers 1962.5MW to the importing market. The cost of these losses is therefore internalised in the Socio-economic Welfare calculation in all scenarios.

The results also include other monetised indicators, Variation in Grid Losses and Security of Supply – Expected Energy Not Served.

The full CBA results are summarised in Table 1-15 below. In the hosting countries, the CBA results indicate that AQUIND delivers high overall social welfare in France at €934m, net cost in social welfare in GB at -€949m. The distribution of benefits across GB and France point broadly to flows from France to GB, leading to a net positive welfare for GB consumers and French producers. In other European Member States/countries, the total net social welfare is positive and estimated at €403m.

Table 1-15 Full CBA results

€m NPV @ 4.0%, real 2018		AQUIND Market Scenario	AQUIND Low Commodities Scenario	AQUIND High Commodities/ Renewables Scenario
GB welfare	Net producer welfare	-€ 2,136	-€ 3,842	-€ 3,068
	Net consumer welfare	€ 2,275	€ 4,032	€ 3,826
	Net interconnector welfare	-€ 1,088	-€ 770	-€ 1,265
	Net social welfare	**-€ 949**	**-€ 580**	**-€ 507**
French welfare	Net producer welfare	€ 4,418	€ 8,220	€ 2,023
	Net consumer welfare	-€ 2,092	-€ 5,735	-€ 598
	Net interconnector welfare	-€ 1,392	-€ 1,453	-€ 1,353
	Net social welfare	**€ 934**	**€ 1,032**	**€ 72**
Impact on other European Countries	Net producer welfare	€ 2,506	€ 5,070	-€ 3,040
	Net consumer welfare	-€ 1,040	-€ 4,627	€ 4,858
	Net interconnector welfare	-€ 1,064	-€ 1,078	-€ 878
	Net social welfare	**€ 403**	**-€ 635**	**€ 941**
AQUIND	Revenues	[redacted]	[redacted]	[redacted]
	Costs	-€ 1,305	-€ 1,305	-€ 1,305
	Net AQUIND welfare	[redacted]	[redacted]	[redacted]
Variation in Grid losses	FR losses	-€ 23	-€ 52	-€ 29
	GB losses	-€ 165	-€ 158	-€ 108

	Total losses	**-€ 188**	**-€ 210**	**-€ 137**
Security of Supply (EENS)	**Total**	€ 222	€ 543	€ 99
Total European Welfare	**Including AQUIND**	[redacted]	[redacted]	[redacted]
Total European Welfare	**Excluding AQUIND**	**€ 421**	**€ 151**	**€ 468**

Table 1-16 presents the results for France, excluding the costs and revenues attributed to AQUIND (EENS is split 70/30 between GB and France).

Table 1-16 Full CBA results for France excluding AQUIND revenues and costs

€m NPV @ 4.0%, real 2018		AQUIND Market Scenario	AQUIND Low Commodities Scenario	AQUIND High Comm/Ren' Scenario
French welfare	Net producer	€ 4,418	€ 8,220	€ 2,023
	Net consumer	-€ 2,092	-€ 5,735	-€ 598
	Net interconnector	-€ 1,392	-€ 1,453	-€ 1,353
	Net social	**€ 934**	**€ 1,032**	**€ 72**
Variation in Grid losses (France)	France	-€ 23	-€ 52	-€ 29
Security of Supply (EENS) (France)[33]	France	€ 67	€ 163	€ 30
Total French welfare	France	**€ 977**	**€ 1,143**	**€ 73**

In addition to the CBA based on the main scenarios above, we also have assessed the socio-economic welfare impact based on the sensitivities in Table 1-17 below. The estimates of the variation in grid losses and security of supply benefits are based on the estimates for the AQUIND Market Scenario.

Table 1-17 CBA results for Europe, sensitivities

€m NPV @ 4.0%, real 2018	No scarcity	Low IC investment	High IC investment	Brexit	Capex overrun
Net social welfare (GB)	-€ 194	-€ 778	-€ 1,038	-€ 945	-€ 949
Net social welfare (FR)	€ 716	€ 1,213	€ 776	€ 776	€ 934
Net social welfare (Other)	€ 685	€ 184	€ 420	€ 430	€ 403
AQUIND welfare	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Variation in Grid losses	-€ 188	-€ 188	-€ 188	-€ 188	-€ 188
Security of Supply (EENS)	€ 222	€ 222	€ 222	€ 222	€ 222
Total European welfare	**€ 1,462**	**€ 1,758**	**€ 559**	**€ 1,200**	**€ 1,203**

Across all five sensitivities set out above, AQUIND Interconnector delivers a total net positive welfare impact for Europe as well as a total net positive welfare impact for France on its own.

In addition, we have calculated the sensitivity results for France excluding the AQUIND revenues and costs to reflect the proposed regulatory and commercial arrangements in France under the AQUIND Request for Exemption.

Table 1-18 CBA results for France excluding AQUIND costs and revenues, sensitivities

€m NPV @ 4.0%, real 2018	No scarcity	Low IC investment	High IC investment	Brexit	Capex overrun
Net social welfare (France)	€ 716	€ 1,213	€ 776	€ 776	€ 934
Variation in Grid losses (FR)	-€ 23	-€ 23	-€ 23	-€ 23	-€ 23

[33] Assuming that 30% of these benefits are attributed to France.

€m NPV @ 4.0%, real 2018	No scarcity	Low IC investment	High IC investment	Brexit	Capex overrun
Security of Supply (EENS)	€ 67	€ 67	€ 67	€ 67	€ 67
Total French welfare	**€ 760**	**€ 1,257**	**€ 820**	**€ 819**	**€ 977**

Appendix A Optimal interconnector capacity

AQUIND's CBA considers the optimal capacity on the GB-French border by calculating the total project benefits under a range of interconnector investment assumptions.

- The Market Scenario assumes a total GB-French cross-border capacity of 5.4 GW, with AQUIND taking the total capacity to 7.4GW from 2024.
- The Low Commodities Scenario assumes a total GB-French cross-border capacity of 4GW, with AQUIND taking the total capacity to 6GW from 2024.
- The High Commodities/Renewables scenario assumes a total GB-French cross-border capacity of 5.4GW with AQUIND taking the total capacity to 8.8GW from 2024, with a subsequent 1 GW of capacity built in 2030 taking the total to 8.8 GW.
- The High Interconnector sensitivity starts with the Market Scenario but adds an additional 1 GW of GB-French capacity in 2030 (in addition to AQUIND).

Table 19 shows the CBA results for AQUIND across each of these three scenarios and additional sensitivity.

Table 19 AQUIDN CBA with a range of GB-French capacity assumptions[34]

Scenario/Sensitivity	GB-French capacity (GW)	CBA –Total welfare (€m, NPV)	CBA – France (€m, NPV)
Market Scenario	7.4	421	934
Low Commodities	6	151	1,032
High Commodities	8.8	468	72
High Interconnection (Market Scenario plus 1GW)	8.4	192	776

We conclude from this simple comparison that AQUIND's CBA is robust to range of interconnector capacity additions up to 8.8GW on the GB-French border. This leads us to a conclusion that there is demand for interconnection on the GB-France border in excess of 8 GW suggesting that based on this analysis, the optimal capacity on the GB-French border is in excess of 8 GW.

This conclusions is consistent with ACER's 2018 decision as part of AQUIND's first exemption application. Here, ACER noted that interconnection of up to 8 to 9 GW would be socially beneficial on the GB-France border. Their rational was that GB and France have fundamentally different installed generation mixes, even though both markets are expected to have an increasing proportion of renewable generation in the total installed capacity in the future.

[34] Comparing scenarios, as shown in Table 19, we note that the different scenarios include a range of other assumptions changes, not just differences in GB-French interconnector capacity. The High Interconnector sensitivity provides a direct reference point to the Market Scenario, with the only change being the additional of interconnector capacity on the GB-France border.