Assessing the benefit of restoring the import capacity of the Moyle interconnector

System Operator for Northern Ireland

Executive Summary

This report aims to describe the benefits that could be obtained by restoring the Moyle Interconnector to its original capacity. It does this by calculating the reduction in wholesale electricity prices for the Northern Ireland consumer, and also by analysing consumer surplus.

Background

The Moyle Interconnector connects the transmission systems of Northern Ireland and Scotland. It has suffered a number of outages in recent years and is currently limited to 250 MW flow in both directions. Moyle Interconnector Ltd, a subsidiary of Mutual Energy Ltd, is currently planning remedial works to permanently restore the cable back to its original capacity. This study has been carried out independently by the transmission system operator (SONI) for Mutual Energy Ltd and URegNI. It provides a quantitative assessment of the impact that these works would have on consumers in Northern Ireland, so as to inform the decision making process associated with carrying out the proposed restoration work.

Moyle was originally rated at 500 MW in both directions, however it is normally limited to 450/410 MW import and 295 export due to local transmission restrictions. The export limitation is due to reduce to 80 MW by 2017. This study therefore compares a system where Moyle is rated at 250 MW import and 80 MW export to one where its rating is 450 MW import and 80 MW export.

In general, increasing interconnection capacity between market regions should lead to a more efficient dispatch and to an increased security of supply.

This study is based on a reference year of 2020. It is taken that any benefits identified will be representative of the likely savings over the medium term. Wholesale prices and generator dispatches are determined assuming an all-island single electricity market.

Results

The results show a substantial benefit in terms of reduced production costs and consumer costs. The modelling indicates that the restoration could result in a reduction of approximately 2-3% in wholesale energy prices, with potential savings to the Northern Ireland consumer amounting to around £14 million per annum. A small reduction in System Operation Costs is also seen, along with a small increase in socio-economic welfare.

1 Introduction

The Moyle interconnector is an HVDC link between the transmission network in Northern Ireland and the transmission network in Great Britain (GB), linking Ballycronan More in Northern Ireland to Auchencrosh in Scotland. It is owned and operated by Moyle Interconnector Ltd, a subsidiary of Mutual Energy Ltd. At full operational capacity up until 2012, Moyle could import up to 450 MW into Northern Ireland and export up to 295 MW. While the interconnector itself could carry up to 500 MW in either direction, transmission limitations on the network at either end limit its potential usage.

The Moyle Interconnector suffered an outage to one of its poles in 2012 and has been operating at limited capacity since. It can currently only transport up to 250 MW in each direction. The export capacity is expected to reduce to 80 MW by 2017 due to new projects connecting to the Scottish network, irrespective of restoration work occurring on the interconnector itself. Work is on-going to address this issue.

Mutual Energy Ltd has identified a means through which the interconnector can be reliably restored to its original capacity. The current fault, and previous faults which have been repaired, are caused by damage to the integrated return conductor insulation on the outer layer of the cables. The repair method is to lay replacement low voltage return cables, thus bypassing the integrated return conductors and the failure-prone insulation while continuing to use the robust high voltage core of the existing cables. This document presents the potential benefits of completing this restoration work.

2 Methodology

The methodology adopted here is broadly based on the European Network for Transmission System Operators for Electricity (ENTSO-E) document entitled, "Guideline for Cost Benefit Analysis of Grid Development Projects"[1]. The benefits are examined on a Northern Island basis, from a societal benefit perspective. Benefits to the all-island and Great Britain systems are also considered.

Three areas where benefits may be achieved have been examined. These consist of:

1. A reduction in wholesale energy costs in the single electricity market through lower prices
2. An increase in Socio-economic Welfare through lower electricity production costs
3. A reduction in system operation costs (Dispatch Balancing Costs)

These are estimated using the Plexos dispatch modelling tool. Any monetary benefit in relation to CO_2 emissions and wind curtailment are captured by the production cost savings.

The reduction in wholesale electricity costs represents a tangible saving to consumers in Northern Ireland and Ireland. However, it overlaps with the Socio-economic Welfare, and so these two benefits are not additive.

[1] https://www.entsoe.eu/fileadmin/user_upload/_library/events/Workshops/CBA/131114_ENTSO-E_CBA_Methodology.pdf

2.1 Wholesale Electricity Costs

A dispatch modelling software package called Plexos is used to calculate electricity prices. This software models the order in which generators are turned on and off (dispatched) to meet the demand profile, scheduled at hourly intervals. In doing so, it creates an annual chronological generation unit commitment and dispatch schedule. The dispatch is obtained on an economic basis, based on the level of generation required to meet demand levels in each interval and the production costs for each generator. The model assumes that generators bid according to their Short-Run Marginal Costs (SRMC), and the price is set by the marginal unit, similar to the design of the current SEM.

Prices are calculated with and without the Moyle restoration applied, for the year of 2020, for both the all-island and Great Britain power systems. These are then applied to the customer load in Northern Ireland to calculate the wholesale costs of electricity in Northern Ireland.

A new market design (I-SEM) is currently being consulted on by the regulatory authorities. While the latest design of I-SEM may not require SRMC bidding from participants, it is acceptable to assume that an efficient market will converge to a dispatch based on a SRMC merit order with corresponding prices. The same approach has been applied for modelling BETTA, the Great Britain electricity market.

2.2 Socio-economic Welfare

Socio-economic Welfare is captured through measuring the difference in electricity production costs with and without the restoration of Moyle. Production costs include the cost of fuel consumption, of starting up generator units, and of CO_2 emissions, and are calculated using Plexos (see section 2.1). Interconnector flows are optimised based on price differentials between regions. Loss rates on Interconnectors are accounted for.

2.3 System Operation costs

System operation costs, in particular Dispatch Balancing Costs, are the costs imposed on the system in order to maintain a secure electricity supply. They are estimated by comparing the production costs of an unconstrained run, representing a market-based dispatch, with one in which operational constraints are applied. These constraints represent the additional rules required to ensure system security, and the resultant dispatch is more reflective of a 'real' generator dispatch as would be issued by the system operator. This calculation is carried out using the Plexos dispatch modelling software.

3 Assumptions

3.1 Study Year

The study uses 2020 as a representative year for considering costs and benefits. This is an appropriate year to use; it is far enough out that one can assume that many of the challenges affecting efficient system operation will have been overcome, yet close enough to provide a degree of certainty over modelling assumptions. The year 2020 also has binding policy targets that further help to guide modelling assumptions.

3.2 Moyle Capacity

Currently, the Moyle Interconnector can only transport up to 250 MW in each direction. The export capacity is currently expected to reduce to 80 MW by 2017, irrespective of restoration work occurring on the interconnector itself. While work is on-going to address this, this export limitation has been assumed in this study.

This study compares a case where Moyle restoration work has increased the import capacity of Moyle to 450 MW ('Moyle 450 MW Import') to a case where the import capacity remains at 250 MW ('Moyle 250 MW Import').

Scenario	Moyle 250 MW Import	Moyle 450 MW Import
Import capacity	250 MW	450 MW
Export Capacity	80 MW	80 MW

Table 1 Import and export capacities assumed for Moyle in the two study cases. 'Import' refers to flows into Northern Ireland.

3.3 Exchange Rates

The following currency exchange rates are applied to convert the fuel forecast and other non-GBP values that are used in this report.

US$/€	1.28
£/€	0.81
US$/£	1.59

Table 2 Currency exchange rates used in the study

3.4 Fuel & Carbon Price

Fuel prices are taken from the International Energy Association's World Energy Outlook report[2], as is the forecasted European Union Emissions Trading Scheme Carbon price. Carbon prices in Great Britain are set to the Carbon price floor, which is now assumed to be frozen at 2015-16 levels (£18.08/tonne in nominal terms).

	Price	Unit
Natural Gas	7.52	£/MBtu
Coal	66.97	£/tonne
All-island Carbon Price (EU ETS)	15.6	£/tonne

Table 3 Fuel and Carbon Prices (in 2012 Euro per unit)

[2] http://www.worldenergyoutlook.org/publications/weo-2013/ The 2013 report was the most up to date version available at the time that this study was carried out.

3.5 Demand

Demand assumptions are taken from the EirGrid/SONI Generation Capacity Statement 2014-2023**Error! Bookmark not defined.** median forecast. Assumptions on demand for Great Britain are formed using the 'Gone Green' scenario from National Grid's Electricity 10-year statement 2013[3].

	Annual Demand (GWh)	Transmission Peak (MW)
Northern Ireland	9,535	1,775
Ireland	28,945	5,104
Great Britain	285,714	53,685

Table 4 Demand assumptions used in this study

3.6 Renewable Generation

The assumed installed capacity for Renewable Generation matches those outlined in the Generation Capacity Statement 2014-2023, with Northern Ireland meeting the Strategic Energy Framework target of 40% renewables in electricity, and Ireland meeting its European Union 2020 targets of 40% RES-E.

A similar methodology as used in the RA's validated Plexos model[4] is applied to account for generation from intermittent power sources such as wind, hydro and pumped storage. This links future generation patterns to past behaviour. Hourly wind generation profiles are based on real historical profiles[5]. Assumptions on Renewable Generation for Great Britain are formed using the 'Gone Green' scenario from National Grid's Electricity 10-year statement 20133.

Installed capacity (MW)	Northern Ireland	Republic of Ireland	Great Britain
Wind	1,118	3,500	8,988
Wave & Tidal	154	-	20

Table 5 Installed capacity of intermittent RES-E assumed in this study

3.7 Conventional Generation

The generation portfolio is based on the Generation Capacity Statement 2014-2023**Error! Bookmark not defined.**. It matches the base case in that document, which assumes that some older generators will shut down by 2020 due to age or emissions limitations. Units have been assigned typical forced outage and maintenance rates based on historical data. Technical characteristics are based on the Regulators latest validated Plexos model.

For Great Britain, a full representation of the expected generation portfolio is used in the unconstrained production cost model. This portfolio is based on confidential information obtained through ENTSO-E.

[3] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Electricity-ten-year-statement/Current-statement/
[4] See http://www.allislandproject.org/en/market_decision_documents.aspx?article=862948e4-e60f-40e6-b876-d1a34d1c496c for example.
[5] Specifically, the shape of the actual 2009 normalised wind profile is used, as it is considered representative of typical wind conditions.

3.8 Interconnection

The capacity of Moyle will vary depending on the study case, as defined in Section 3.2. EWIC capacity is assumed to be as per present values i.e. 500 MW import into Ireland and 530 MW export from Ireland. Outage rates for both interconnectors are based on best estimates taking into account historical performance.

Interconnector flows are based on price differentials between the two regions, with loss rates taken into account. A loss rate of 2% is assumed for Moyle in both directions, and 6% for EWIC. Countertrading to alleviate wind curtailment is allowed for operational cost modelling.

Interconnection between Great Britain and the European continent is not represented.

3.9 Transmission Network

It is assumed that network developments between now and 2020 will alleviate any potential transmission limitations. In particular, it is assumed that the second North-South interconnector will have been completed by the study period. Therefore, the transmission network is not represented in this study.

3.10 Operational Constraints

Production costs are calculated for both an unconstrained system, representing a market dispatch, and a system constrained by operational rules, representing a more realistic operational dispatch. This constrained model contains the following operational requirements:

- Sufficient operational reserve to cater for the loss of the largest single in-feed
- Minimum amount of inertia to be provided at all times
- A System Non-Synchronous Penetration (SNSP[6]) limit of 75%
- Minimum number of large generator units operating at all times in Northern Ireland and Ireland.

4 Results

4.1 Wholesale Electricity Costs

Increasing the import capacity of Moyle should cause a reduction in wholesale electricity prices. Increased imports reduce the need to run expensive generators on the island. In this study, the Plexos production cost model showed a decrease in load-weighted prices of **2.3%** when the import capacity of Moyle is increased from 250 MW to 450 MW. Calculating the wholesale cost of Northern Ireland load using these prices gives a saving of **£14 million over the 12 months period modelled**. These results are shown in Table 6.

[6] Certain types of generation, primarily wind, are not synchronised with the system frequency. The percentage of the total generation on the system at any instant that is non-synchronous is termed the SNSP. There is a technical limit as to the level of SNSP that can be accommodated on the power system at an instantaneous point in time.

	Northern Ireland	
	Load-weighted price (£/MWh)	Wholesale Cost (£million)
Moyle 250 MW import	62.88	607
Moyle 450 MW import	61.42	593
Saving	**2.3%**	**14**

Table 6 Comparison of prices and wholesale electricity costs for Northern Ireland with and without the increased import capacity of Moyle.

When the calculation is applied on an all-island basis, the savings increase in proportion with the four-fold increase in load. The all-island wholesale cost reduces by **£55 million** per annum.

	All-island	
	Load-weighted price (£/MWh)	Wholesale Cost (£million)
Moyle 250 MW import	62.59	2,418
Moyle 450 MW import	61.18	2,363
Saving	**2.3%**	**55**

Table 7 Comparison of prices and wholesale electricity costs for the all-island system with and without the increased import capacity of Moyle.

For Great Britain, the results show a small reduction of 0.8% in the wholesale price due to the increased Moyle capacity, which is within the margin of error.

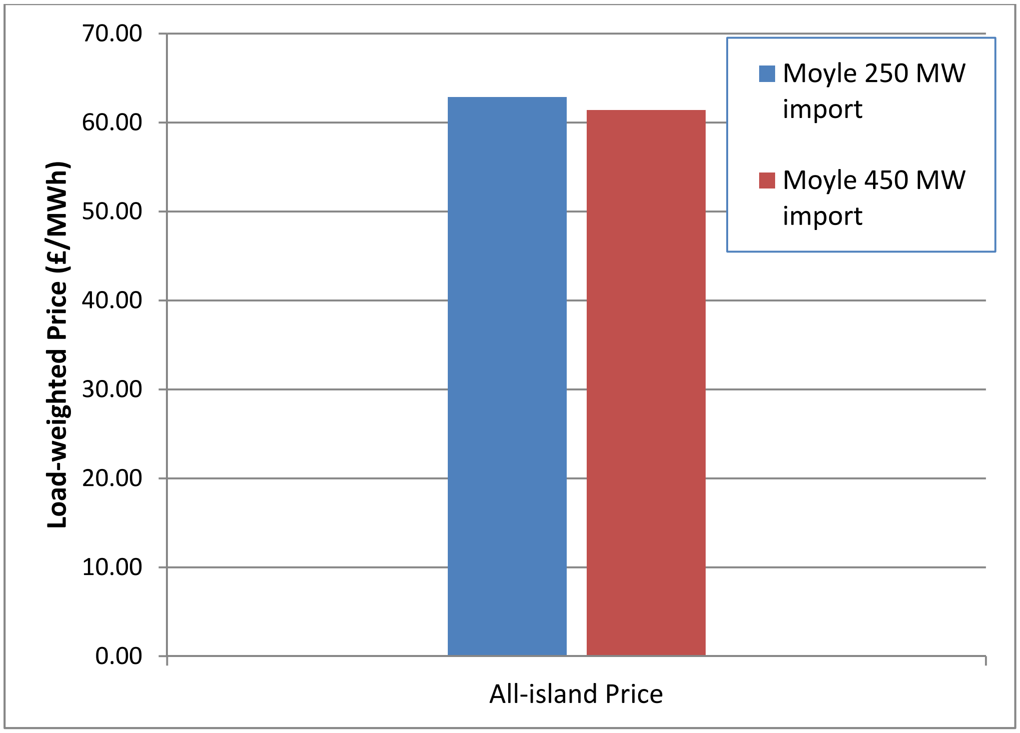

Figure 1 Load-weighted prices for each of the study cases

While considering these results, it should be noted that there is a margin of error in calculating system prices typically in the order of 1 or 2%. The aim of the Plexos model is to minimise production costs as opposed to prices. While there is some correlation between these two objectives, they are not equivalent, as two dispatches with the same production costs could lead to a different marginal price.

By 2020, a new market design will be in place. The current Bidding Code of Practice requiring generators to bid in their Short-Run Marginal Costs (SRMC) may no longer apply, and generators may have a freer rein to determine their own bids. The manner in which the marginal price is calculated is also expected to change. However, in a competitive market, one can assume that generator bids will converge to their SRMC as the level of competition increases, and that the price calculated from a SRMC production cost model will represent the marginal price.

Prices including an uplift component to account for generator start-up costs were also examined and showed no real change in the comparative results.

4.2 Socio-economic Welfare

Comparing production cost figures between the two cases shows how increasing the capacity of Moyle reduces the cost of generating electricity. The production cost attributable to interconnector flows is represented by the price at the region of origin of the flows. For the single electricity market, this would be the BETTA price for imports (which are added to the production cost) and the all-island price for exports (which are subtracted from the all-island production cost).

Due to the nature of dispatch optimisation, production costs are calculated on an all-island basis. To determine the Northern Ireland component, costs are split according to the ratio of customer load, of which Northern Ireland comprises 25%. Production costs presented here are unconstrained, reflecting a market dispatch.

The studies show a reduction in electricity production costs of **£10 million** on an all-island basis. Taking the Northern Ireland component gives a saving of **£2 million.** The effect on production costs in Great Britain is negligible – a slight increase is observed, though this is within the margin of error for that region.

Production Cost Saving (£million)	
All-island	**10**
Northern Ireland	**2**
Great Britain	**-1**

Table 8 Saving in Production costs due to the increase to Moyle's import capacity.

4.3 System Operation Costs

Dispatch balancing costs (DBC) are the costs imposed on the system in order to maintain a secure electricity supply. With the market rules for a balancing market in the I-SEM still being developed, it is not possible to know exactly the allocation of balancing costs between generators, suppliers, and TSOs. For this study, operational reserve, inertia, and an SNSP requirement have been modelled, as well as a minimum requirement for large units in both Ireland and Northern Ireland (see section 3.10 for more details).

Increasing the import capacity of Moyle to 450 MW will have some obvious impacts on system operation. At this capacity, the interconnector can provide 50 MW of operational reserve at all times, which it is unable to do currently. However, this benefit is somewhat countered by the fact that a 450 MW infeed may form the largest generation contingency on occasion. Also, increased import capacity on Moyle will compete with large conventional generators that may be required to run for system security reasons.

The flexibility with which TSOs can utilise interconnector flows plays a key role on the impact interconnection has on DBC. In the current SEM design, interconnector flows are initially set based on an unconstrained market schedule. The TSO can alter these flows in order to benefit the consumer through a process known as countertrading. In this study, countertrading to reduce the curtailment of priority dispatch generation has been allowed. It is uncertain whether countertrading on an economic basis to reduce the largest single infeed (LSI), which occurs at present, will be possible under I-SEM. This could have a large impact on reducing operational costs.

The results show that increasing the import capacity of Moyle reduces DBC by £8 million[7]. These figures are on an all-island basis. Converting to Northern Ireland gives a saving of **£2 million**.

Operational Costs		
	All-island	Northern Ireland
Savings (£million)	8	2

Table 9 Savings in DBC caused by increasing the import capacity of Moyle.

4.4 Interconnector Flows

As one might expect, increasing the import capacity of Moyle leads to an increase in the volume of imports on that interconnector. Imports on EWIC drop slightly, as the increased capacity on Moyle will be used before EWIC due to its lower loss rating (2% vs. 6%).

	Moyle 250 MW import		Moyle 450 MW import	
	Imports (GWh)	Exports (GWh)	Imports (GWh)	Exports (GWh)
Moyle flows	-1,687	96	-2,881	80
EWIC flows	-2,500	303	-2,351	286
Moyle + EWIC	-4,188	399	-5,232	366

Table 10 Imports and exports on EWIC and Moyle with and without the Moyle restoration.

The volume of countertrading in the constrained models is shown in Table 11. Increasing Moyle's import capacity does not have any significant impact on countertrading volumes.

	Moyle 250 MW import	Moyle 450 MW import	Difference
Volume of Countertrades (GWh)	70	68	-2

Table 11 Countertrading volumes with and without the Moyle restoration.

4.5 Renewable Generation & Carbon Emissions

In general, interconnectors facilitate intermittent renewable generation, such as wind, through the ability to export that generation when it would otherwise be unusable. The Moyle restoration on its own will not provide an increase to the interconnector's export capacity, unless the limitation due to congestion on the Scottish side is addressed. The results from this study reflect this, with no real change to the curtailment level of RES-E generation when the Moyle import capacity is increased.

[7] Note that the margin of error on these figures is at least +/- £2 million for the all-island figures.

	Moyle 250 MW import	Moyle 450 MW import	Difference
RES-E Curtailment	1.6%	1.7%	**0.1%**

Table 12 Curtailment of renewable generation with and without the Moyle restoration.

The impact on CO_2 emissions depends strongly on the merit order in each region. While increased interconnection capacity should lead to a more efficient dispatch, this does not necessarily mean a 'cleaner' one. For example, a coal unit will be cheaper to run than a gas unit in the model used here, as the assumed carbon price is not enough to close the gap in forecasted fuel prices.

In calculating CO_2 emissions, it is best to look at the sum of emissions from all study regions i.e. combined for Ireland, Northern Ireland, and Great Britain, so that the possibility of emissions transferral is not ignored. Where individual regions are reported, emissions due to interconnector flows are calculated using the average carbon intensity (kg/MWh) in the source region.

The results show a slight increase in the volume of CO_2 emissions from electricity generation when the import capacity of Moyle is increased. The increased import capacity on the interconnector means that occasionally generation in the single electricity market will be replaced by generation from Great Britain, where the average carbon intensity is slightly higher. Note that these results are taken from the unconstrained market model, as the constrained model used for calculating Balancing Costs only contains a representative model of Great Britain.

	CO2 Emissions (MTonne)		
	Moyle 250 MW import	**Moyle 450 MW import**	**Difference**
All-island only	14.6	14.9	**0.3**
GB only	85.5	85.5	**0.0**
Combined Regions	100.1	100.4	**0.3**

Table 13 All-island and GB CO2 emissions, under each of the study cases. Results are taken from the unconstrained market model.

4.6 Summary

The benefits to Northern Ireland presented in this report are summarised in Figure 2. The largest benefit comes from the reduction in wholesale electricity costs to consumers. Savings are also seen in socio-economic welfare and system operation costs. Note that while the savings in wholesale electricity costs and system operation costs can be considered additive, the socio-economic welfare savings overlap with the wholesale electricity costs.

Summing the benefits due wholesale electricity costs and system operation costs gives a total of £16 million on a Northern Ireland basis, or £62 million on an all-island basis.

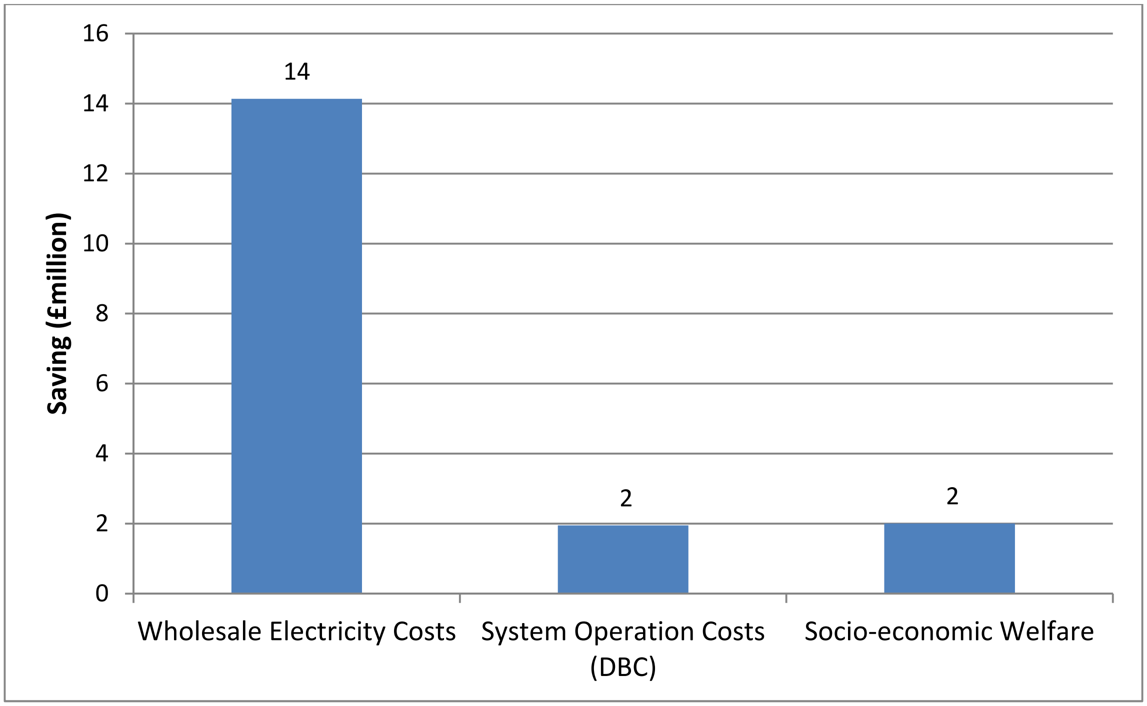

Figure 2 Benefits to Northern Ireland due to increasing Moyle's import capacity to 450 MW.

4.6.1 Additional Benefits

It should be noted that there are benefits in addition to those presented here that would be expected from increasing the capacity of Moyle. For example, increasing the import capacity of Moyle should lead to an improvement of security supply form a generation adequacy perspective. This benefit has not been quantified here.

Another benefit of this project that is not explicitly valued here is the increased reliability of the Moyle interconnector. At present, Moyle has one fully operational cable and has developed an alternative running mode[8] that would allow it to continue operating at 250 MW if the Integrated Return Conductor insulation on that cable was to fail. This mode of running cannot be utilised long term due to potential magnetic field issues so, in the absence of this cable replacement project, a cable repair would need to be executed to secure Moyle's ability to operate at 250 MW. Such a scenario would not arise after the replacement low voltage return cables are laid, as the IRC insulation will be bypassed. These avoided costs are not reflected in the analyses and if included would further increase the benefits obtained by refurbishing the interconnector.

Increasing the import capacity of Moyle would lead to a larger volume available for the Moyle capacity auctions. This benefit has not been quantified here.

[8] This involves using the intact high voltage elements of both existing cables

5 Conclusion

The study clearly shows a substantial benefit to restoring Moyle's import capacity to 450 MW. Increasing the import capacity leads to a reduction in wholesale electricity costs to consumers in the all-island single electricity market. Savings are also seen in socio-economic welfare and system operation costs. Combined benefits of £16 million per annum can be delivered to the Northern Ireland consumer, and this rises to £62 million when considering savings on an all-island basis. Other benefits, such as capacity benefit, increased reliability of the interconnector, and increased volumes available for capacity auction, have not been quantified here.