Natural Hydro Energy

Natural Hydro Energy Ireland

Questionnaire II response (Project Highway)

Interconnection with the UK Market via DC link 1,200MW (this project NHE "Project Highway") to serve Large Scale Hydro Storage (90,000MWhrs) (separate project NHE "Project Store" subject of a separate application)

Please NOTE

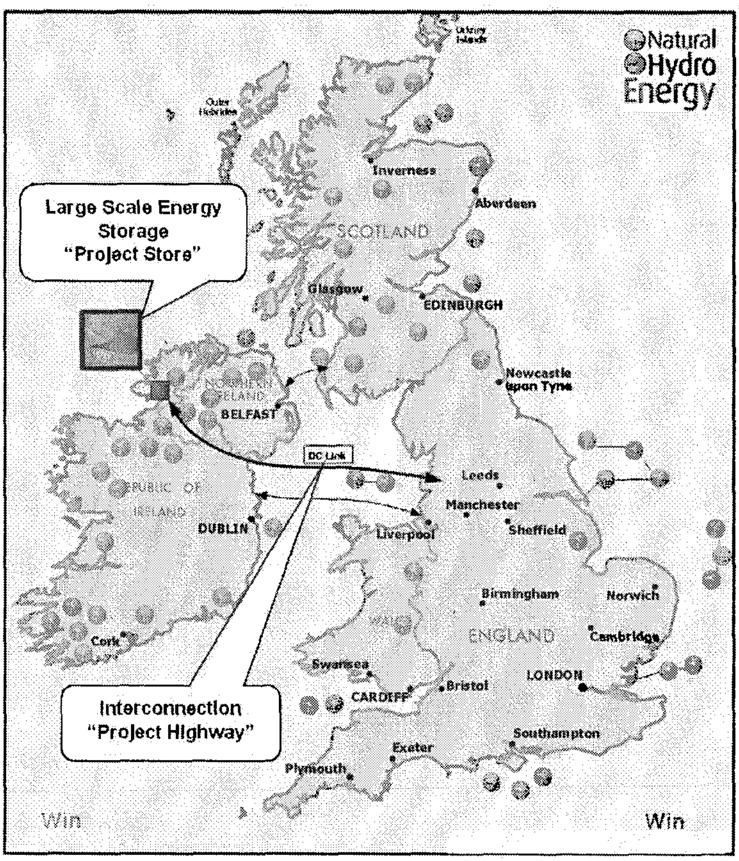
The Natural Hydro Energy overall project consists of two parts:

1. HVDC cable Interconnection between Ireland and the UK, not included in current TYNDPs, is covered by Questionnaire II (NHE Project Highway) and

2. Large scale Hydro Storage facility (NHE Project Store) is covered by Questionnaire III.

This overall project has been in development for three years. It is at an advanced stage of planning.

In this response, for clarity of understanding, Natural Hydro Energy (NHE) gives details of both aspects of this project. NHE responds to the similar questions raised in both questionnaires and the one additional question raised in Questionnaire III as a separate project.



Natural Hydro Energy

Only the DC Transmission link relevant to Questionnaire II need be considered in this response. This is designated NHE "Project Highway"

Ireland's energy resources are large and essential to EU Carbon Free Energy Security.

NOTE EU questions required to be answered in Questionnaires are shown in **BLUE PRINT.**

Responses are in BLACK PRINT

Title of the project: Natural Hydro Energy Project Highway

**** Please send to ENER-B1-PROJECTS@ec.europa.eu and specify the priority corridor in the subject line ****

Introductory information

Contact details of the project promoter(s) (if several, please fill in for each project promoter)

Company: Natural Hydro Energy

☐ TSO ☐ DSO ☒ Other project promoter[1] Other Promoter

Contact person: [redacted]

E-mail address: [redacted]

Telephone number: [redacted]

Type of project

☒ Transmission project not included in TYNDP 2012 – please refer to Questionnaire II

Priority corridor

For the implementation of which energy infrastructure priority corridor is the project necessary? Northern Seas Electricity Corridor

II. Questionnaire for transmission projects not included in TYNDP

1. Reason for non-inclusion of project in TYNDP 2012

☐ No transmission license or no exemption from regulated regime; please explain:

☒ Other, please specify: Change in National Policy and economic imperative to drive energy export from Ireland to other EU countries as a means of meeting EU objectives and driving Ireland's economic recovery

2. General information

a) Name of project

Natural Hydro Energy "Project Highway"

b) Brief description

1,200MW interconnection to UK from Ireland coupling a large hydro energy store to both markets

c) Are any other project promoters involved in the project? (list each)

- Countries: ☒ EU ☐ Non-EU, please specify: United Kingdom
- Name of undertaking: Natural Hydro Energy UK Ireland Strategic Energy Infrastructure
- Contact details: Natural Hydro Energy Ltd.

d) Situation of the project promoter(s):

- What is legal status of the project promoter(s)? Please specify (registered undertaking, group of companies, other).

  Private company with anticipated participation by large EU utilities

- If you are a registered undertaking, please provide the list of all shareholders, information on their main activity and their respective shares in the undertaking.

  This information will be provided in confidence

- What is the share capital of this undertaking?

  €40m with access up to [redacted] construction funding as required

e) Project type

☒ New

☐ Upgrade

☐ Extension

☐ Replacement

f) Key physical characteristics ***[please submit map indicating existing and new lines]***
- Start point (area): North West Ireland
- End point (area): Midlands UK
- Length (km): approximately 450km
- Route type: ☒ Onshore ☒ Offshore

g) Key technical characteristics
- Transmission capacity (MW for DC/ MVA for AC): 1,200MW
- Voltage (kV): 320 - 400kV
- Current: ☒DC ☐AC
- Line type: ☐ OHL ☒ Underground cable

h) Estimated project cost (capital expenditure in million euros) [redacted]

i) Planned date of commissioning (year) 2017

j) Implementation status

☐Pre-feasibility

☐Feasibility/FEED

☒Final Investment Decision (FID)

☒Permitting

☐Construction

k) Obstacles for the implementation of the investment item

☐Permit granting (please explain):

☐Regulatory treatment (please explain):

☐Financing (please explain):

☒Other (please explain): Market integration planning to be completed. This will provide greater commercial certainty

☐None

Please provide:

A list of all studies carried out so far for the project;

List of all studies carried out so far on project

Wind Studies

10 years wind generation data every 15 minutes was analysed initially from the records of Eirgrid the Transmission System Operator for the Republic of Ireland and after the introduction of the Single Electricity Market (SEM) for the combined grids of Northern Ireland and the Republic from the records of the Single Electricity Market Operator (SEMO). The total generation was divided by the installed wind turbine capacity at the appropriate time to give average wind generation per 15 min period per MW of generation over the entire grids.

The resulting data formed the basis of accurate modelling of expected wind generation. Seasonal variations, differences from year to year and in particular values for typical variations of wind generation output over time were all derived from the basic data. These results were used to model wind generation expected to be available for export and also to power pumping for hydro storage reservoirs.

Hourly wind strength records for several years were analysed from the meteorological observatories of the Irish Meteorological Service Met Eireann. Results from these studies were used to determine local wind patterns and variation between regions

Irish Demand Studies

10 years of 15 minute total national grid demand were also analysed initially from Eirgrid and later from SEMO. The demand data was used in conjunction with the wind generation data to determine, when wind generation would have to be curtailed to comply with grid stability constraints. These studies were carried out to model grid operation including potential curtailment, both with and without the National Hydro Energy Hydro Storage project in operation.

System Marginal Price Analysis

10 years of the half hourly System Marginal Price data for every trading period from Eirgrid and SEMO records was also analysed

Operational Modelling

The wind generation, demand and SMP data were three of the principal inputs used in extensive, stochastic, deterministic, modelling of operation of the Natural Hydro Energy project. A full inventory of conventional plant available for generation, the storage capacity of the hydro storage reservoir and the operational characteristics of the NHE plant permitted accurate modelling of how all components would interact together. The output performance in terms of MWh produced from all categories of plant at appropriate prices determined by standard tariff structures permitted projected financial revenues to be calculated under all possible operational scenarios.

Equipment Pricing

Prices for all major electro-mechanical plant components were obtained from an extensive cross section of international suppliers.

Financial Modelling

The outputs from the operational modelling were combined with cost projections for construction of the NHE plant under different equity and loan scenarios to predict financial returns. These have been validated by Morgan Stanley London and Evercore Partners London.

Storage Sites Investigation

The fundamental concept of the Natural Hydro Energy Project sprang from the realisation of the massive, low cost hydro storage potential of particular glacial valleys created on the west coast of Ireland, as a result of the last ice age. Three dimensional cartographic analysis was undertaken initially on 54 valleys to ascertain accurate storage potential. Following detailed geological and hydrological analysis, this was reduced to three. Of these, one is being brought to full project build status.

Dam and Power Station Design

Extensive preliminary civil works and engineering design and costing studies were undertaken for the dam and power station structures by prominent Irish and international consultants Knight Piesold based in Vancouver Canada.

Land Acquisition and Pricing

The necessary land, approximately six square kilometres has been leased for 299 years. Detailed negotiations have been undertaken with both land owners and local communities to ensure agreement from all parties to construction of the project subject to agreed conditions.

Cable Routing

Studies into possible routes for cables linking the NHE Reservoir and power station to the greater Dublin area for interconnection to the Irish national grid and from Ireland to the UK have also been completed and are in detailed discussion with Eirgrid.

Transmission Facilities

Preliminary studies for transmission substations, AC/DC converter stations and cable design and costing have also been completed

Curtailment Studies

The most difficult problem facing Ireland's ability to meet its target of 40% of electricity generation from renewable sources in 2020 is the reduction of satisfactory economic returns to wind farm developers, due to increased curtailment of wind generation to maintain satisfactory grid stability at high levels of wind penetration. This problem has received extensive study, together with the solutions offered by the NHE project

A list of interactions with all concerned transmission system operators (TSO) and/or national regulatory authorities (NRAs): e.g. letter from TSO acknowledging receipt of application for grid connection or landing point, technical and financial proposal from TSO for connection, letter from NRA concerning the applicable legal regime for the project

Discussions and interactions began with Eirgrid Ireland in 2009 and with National Grid UK in 2011. The Storage facilities herein described are of considerable value to both TSOs. The exact nature of its operation acting separately in and between the two systems are a matter of very detailed technical analysis. This is ongoing and can be confirmed by the TSOs.

3. Specific information

a) Which EU Member States are involved or affected by the project with respect to grid transfer capability, at which borders?

Ireland and UK

b) Which non-EU Member States are involved or affected by the project with respect to grid transfer capability, at which borders?

None

c) Does the project cross borders directly or does it have a cross-border impact? Yes

Please specify the impact of the project on the grid transfer capability of each concerned border (in MW) 1,200MW

d) What are the main reasons for you to propose this project for consideration as a PCI?

This project very clearly meets all EU objectives for producing Carbon Free, Price Stable, Secure Power. As such, it is a perfect exemplar of integrated transnational thinking and co-operation.

The particular substantive reasons for proposing the Natural Hydro Energy project from Ireland for consideration as a PCI arise from the following factors:

- Energy sources from the periphery of the EU need to be developed to their full potential. Ireland has 6% of all of the renewable resources of the EU with 1% of the population. Ireland can make a very valuable contribution to EU needs and security.

- The availability of extensive, low cost, high wind strength, onshore wind generation sites in Ireland, far in excess of domestic requirements, to assist satisfying EU renewable generation targets is a low cost, low risk, highly secure strategy.

- This project allows for greatly increased penetration of renewable energy in the Irish market above the 40% target level.

- It allows cross border large scale energy trading.

- This, in turn, allows effective competition, with lower projected costs, for increasing renewable generation in all EU Member States, but particularly in the UK and Ireland, to meet 2020 target values.

- There are considerable economic advantages from enhanced energy trading between Ireland, UK and mainland EU.

- NHE provides greatly enhanced security of supply advantages in Ireland and UK arising from large scale hydro storage reservoirs, increased, indigenous, price stable, renewable generation and reduced reliance on imported fossil fuels.

- The project represents considerable technical advances in terms of evolution of a very cost effective design for large scale hydro storage reservoirs.

- Easing integration of intermittent renewable generation by use of large scale hydro storage reservoirs to replace parallel operation of conventional thermal generation to compensate for fluctuation in renewable output.

- Creates <u>essential</u> dispatchability of renewable generation.

- Increasing the arbitrage value of stored, night time, off peak, renewable generation by releasing it during high demand, day time periods.

EU Proposals for Renewable Generation

All EU Member States have agreed target levels of electricity generation from renewable sources by 2020 to reduce emissions of harmful green house gasses and combat climate change. Most member states will need to considerably increase investment in renewable generation, in order to meet these targets. The cost and effectiveness of investments will depend on the category, capacity and strength of the sources of renewable energy available in each Member State.

Trading mechanisms have been evolved to permit States with large amounts of cost effective renewable energy, in excess of their own projected requirements, to export power to countries facing shortages or more costly generation technologies. Hydro electric schemes have traditionally been the largest source of renewable generation worldwide. They currently supply around 19% of electricity generated in the EU. However, throughout Europe, the most economic sites have already been exploited. Limited increases in hydro capacity are planned prior to 2020, but these will fall well short of the overall increase in renewable generation needed to meet the 2020 targets.

Other than hydro, wind generation has become the most successful and cost effective source of renewable generation in recent years. Extensive new large scale wind farms are under construction.

Examination of the TYNDPs for all EU Member States covering the period up to 2020 and beyond, shows that apart from moderate increases in hydro capacity, large amounts of increased wind generation is expected to constitute the main increase in renewable generation.

Economics of Renewable Generation in the EU

Because of the large scale future role envisaged for wind generation, it is important to consider site availability and wind energy levels available across the full range of Member States. Onshore wind is rapidly approaching similar costing per MWh produced to hydroelectric power, on sites with good capacity factors. However, wind generation suffers from an important disadvantage. It, like marine and solar power, is intermittent and can not be dispatched as easily as hydro.

The relative costs of both hydro and wind generation are very dependent on capacity factors. These vary considerably across the EU. Good onshore wind sites have capacity factors in the range 35% - 40%, with exceptional sites producing over 40% of rated capacity per annum. Hydro capacity factors depend strongly on the available head height on the site. High head Alpine and Nordic sites have capacity factors up to 55%. Medium and lower head run of the river sites lie more in the range 20% - 35%.

The working life spans of both hydro and wind generation are also important in determining cost per MWh produced. Realistic lifetimes of 80 to 100+ years are well established for hydroelectric stations, with major refurbishment intervals of around 40 years. Wind turbines have an expected economic life of 20 – 25 years.

Onshore wind and hydroelectricity are currently much less expensive than other competing forms of renewable generation such as offshore wind, marine or solar energy. However examination of the EU TYNDPs up to 2020 indicate that sites for onshore wind are becoming scarcer in many Member States, after available onshore sites have been developed. Towards 2020, it is expected, there will be greater migration to much more expensive, but more readily available offshore sites.

The UK NREAPS show plans for a very large increase in wind power from 5,430MW in 2010 to 22,450MW in 2020. This includes an increase in onshore wind of 10,850MW. However, a large increase of 10,210MW in offshore wind is also included. This will be associated with a significant increase in renewable generation costs.

Capital costs of offshore wind farms are much more expensive (currently in the range 2.5 to 3 times) than the equivalent cost per MW installed capacity of onshore sites. Erection and foundation costs increase rapidly in deeper water. Grid connection costs increase as turbines are located further offshore. Operation and maintenance costs are also much higher for offshore sites, particularly during adverse weather conditions. These increased costs are not offset by slightly higher offshore capacity factors, generally expected to be in the range 40% - 45%, off suitable coasts.

Cost / MWh produced and site availability will largely determine the increased capacity of EU renewable generation. Wind generation is expected to supply the greatest increase. Countries such as Ireland, with extensive availability of low cost, onshore sites, with high capacity factors, significantly above domestic renewable target requirements will have considerable advantages over areas with lower wind strengths and countries, where limited onshore site availability forces migration towards more extensive, but higher cost offshore locations.

Role of Energy Storage in Increasing Penetration of Renewable Generation

One of the major difficulties experienced with integrating sources of renewable generation in large scale electricity grid structures is intermittency. Wind, solar and marine generation are all subject to large scale variation in output over quite short time scales, depending on the intensity of the energy input. These sudden fluctuations can threaten security of supply on grids, unless output from conventional generation can be adjusted sufficiently rapidly, to compensate for the output variation from renewable sources.

In order to safely integrate intermittent, fluctuating, renewable generation, grid operators (Transmission and Distribution System Operators [TSOs & DSOs]) must ensure sufficient reserves of conventional generation are operated in parallel to the renewable sources, so that they can be ramped up or down to compensate, within adequate time response limits, for the worst potential variation in renewable output. Different categories of conventional generation exhibit greater or lesser flexibility in response time to load variation.

Conventional hydro generators and pump/turbines in pumped storage schemes have the fastest response time ranging from less than 1 minute to 2 minutes from no load to full load depending on machine size.

Ramping conventional generation to compensate for parallel variation in renewable output and providing sufficient standby spare conventional capacity introduces significant increased costs. Operating efficiency is lower at part load and fuel consumption is higher per MWh of electricity generated. Ramping plant up and down subjects it to greater wear and tear and maintenance costs increase. Operating plant at part load increases fixed costs such as depreciation over a reduced amount of MWh output. All of these additional charges must all be evaluated in comparing the costs of alternative competing sources of renewable generation

Either conventional hydro generation or pumped storage generation can compensate for intermittent renewable energy very effectively. Both have very rapid response times, which permit them to compensate for sudden changes in renewable output. Efficiency losses under part load operation and increased maintenance charges due to load ramping are less than for thermal plant. Hydro energy stored during high wind conditions can be released, when wind strength is low, so that the combined wind and hydro output is smoothed and in effect provides controlled amounts of dispatchable renewable energy.

Curtailment Constraints on Renewable Penetration

At the early stages of integrating intermittent renewable energy to large scale electricity grids, transmission system operators were concerned with the potential of severe excursions in renewable output to cause instability in grids. If for example, a sudden drop in wind output should occur, before sufficient conventional generation can be brought on line to compensate for the reduction, instability could occur, resulting in load shedding or possible black outs.

To avoid these problems, either sufficient fast acting reserve capacity must be available or renewable generation output may have to be curtailed. Curtailment results in undesirable loss of potential renewable generation. Isolated or lightly interconnected grids are most vulnerable to these conditions. The island grids of Ireland and the UK will be more prone to curtailment than the much more extensive grids in mainland Europe. Stronger interconnection will alleviate this problem, but will not eliminate it.

As the smaller of these two island grids, Ireland offers an interesting insight into the possible effects of curtailment. Renewable energy is allocated priority dispatch status over conventional generation in Ireland to encourage its usage. At the early stages of introducing renewable generation, the Irish TSO was reluctant to permit more than 10% of renewable generation to operate on the grid under any demand conditions.

Increased introduction of fast reacting open cycle gas turbine plant in recent years and greater experience of operating and more accurate forecasting of renewable (primarily wind) generation has permitted this constraint to be extended considerably. Ireland now permits 50% renewable generation on the grid in normal demand conditions, but this has to be reduced to 30%, when demand is lowest.

Ireland has accepted a high target of 40% of electricity generation from renewable sources by 2020. At present, nearly 15% of total generation is supplied by renewable sources. Low levels of curtailment are already necessary on the grid in strong wind conditions, when demand is low, particularly at night time. This is expected to increase considerably as renewable generation approaches the 40% target value. Curtailment will heavily reduce the economic returns from renewable sources, unless a solution to this problem is introduced.

Unique Storage Attributes of Natural Hydro Energy Project Design

The Natural Hydro Energy project will introduce very large capacity, low cost hydro storage reservoirs. These will help eliminate / reduce curtailment constraints on wind generation. The first 1500MW pumped storage station will accommodate 90,000MWh of stored hydro energy in its reservoir. The magnitude of this storage capacity can be appreciated, when compared to schemes in other countries. The UK has 2800MW of pumped storage generation with 14,000MWh storage. France has 7 schemes totalling 184,000MWh. Natural Hydro Energy plans a number of reservoirs in the longer term, any two of which will equal the total French hydro storage capacity.

Most pumped storage schemes have capacity to generate at full load for between 5 to 8 hours. The first NHE project at Kilcar on the North West coast of Co. Donegal, operating under its planned 13 hour daytime generating cycle and 11 hour night pumping regime will be able to generate continuously at full load for 2 weeks, even if there is no wind input. Pumping energy can be supplemented from unused off peak conventional generation in light wind conditions.

Natural Hydro Energy is planning to purchase wind generation daily, from a number of sources for direct export on its HVDC interconnector to the UK and supplement this with hydro generation pumped previously, primarily from off peak wind sources. NHE plans to have 700MW of wind generation contracted from wind farm operators to supply wind generation to NHE for direct export to the UK. This will be in excess of renewable generation planned to meet the Irish 2020 target. NHE will agree to take the total generation from these wind operators without curtailment.

In high wind conditions during daytime export hours, when some wind would normally have to be curtailed to maintain grid stability, NHE will purchase as much of this wind as possible, with the aim of filling the NHE interconnector capacity from Ireland to the UK. This will avoid wind curtailment and wastage of valuable renewable generation.

If insufficient curtailed wind is available together with the directly contracted wind to fill the interconnector, NHE will supplement both these sources by generating from released hydro energy from its large storage reservoir. Wind curtailment is expected to be much higher at night, when system demand is low. NHE plans to purchase large amounts of this wind generation, which would otherwise be curtailed and wasted.

This will improve the economics of off peak wind generation considerably. The increased demand needed for pumping will increase the level at which curtailment would otherwise be required. Large amounts of wind generation, which would otherwise be wasted, will be bought in to supply pumping operations

Interaction of the Interconnection with very large NHE storage capacity will provide a number of important advantages.

- Because much of the hydro generation will be pumped by wind generation, which would otherwise be curtailed, the overall electricity exported to the UK both directly from onshore, high capacity factor wind generation, supplemented by hydro pumped by onshore wind, will contain a very high percentage of renewable energy content. This will involve lower production costs and subsidisation than offshore wind production in the UK.

- The large storage capacity will permit variable wind generation to be supplemented by hydro electricity, ensuring fully controllable / dispatchable power throughout all export periods.

- The value of off peak renewable generation will be increased to high demand day time values

- Much less generation will be wasted due to curtailment

- The interconnector will operate at a high capacity factor and at 100% capacity during export hours

- Much lower interconnector capacity will be needed to export the steady state, average 1500MW of combined wind and hydro generation, than would be needed for the same MWh capacity of volatile wind generation, where interconnector capacity would have to match peak wind generation, while average generation may only be equivalent to 35% of peak.

- Large storage capacity will greatly increase security of supply, in ways which will be described later.

- The greater dispatchability and controllability of NHE generation, reduced difficulty and cost of parallel operational costs for conventional compensating generation, increased day time value achieved from the large capacity hydro storage combined with the low cost of high capacity factor onshore wind sites will all contribute to greater penetration of cost effective, reliable, secure, renewable generation.

Advantages of Unique Design Features of NHE Hydro Storage Reservoir

Many of the advantages of the NHE project are due to the low storage cost per MWh associated with the hydro storage reservoir. The low storage cost is a result of a combination of unusual design features, which can be exploited in glacial valley sites on the west coast of Ireland. It is expected that, subject to environmental approval and legal permitting, that the first of these projects will be sited near Kilcar in Co. Donegal in North West Ireland. The main concepts of the design, which contribute to the low cost of these large scale reservoirs are described below.

The project will use sea water as a working medium, instead of fresh water used in nearly all other pumped storage schemes. A sea water based scheme has been operating successfully in Okinawa in Japan for the last 15 years. The ocean will be used as the lower reservoir in the scheme. This greatly reduces construction costs normally associated with artificially created lower reservoirs in conventional pumped storage schemes.

The projects rely on the use of naturally occurring glacial formations created in the last ice age, which in a few rare instances created high valleys suitable for energy storage. Since Ireland has a very low level of seismic activity, a rock fill dam can safely be used to form an upper reservoir for the scheme. This is a less expensive form of construction than traditional concrete dam construction methods.

The dam is expected to be approximately 1.3km in length and will have a possible height of 120m at mid point. It will be constructed at the mouth of a long glacial valley. Having to dam only one end of a long narrow valley provides very large capacity in the upper reservoir in comparison to many conventional pumped storage schemes, where the reservoir is formed by a curtain dam, which completely encircles the reservoir. The geology of the valley floor is made up of primarily impermeable rock.

Water will be carried from the dam in multiple steel penstocks. The distance from the dam to the power house varies from 1 to 3 km on the sites selected by Natural Hydro Energy. The ground slopes gently over the intervening territory and provides heads ranging from 180 to 230m. The penstocks will be laid close to the surface of the ground in shallow covered trenches to minimise environmental impact. Using penstocks greatly reduces excavation and tunnelling costs for machine hall caverns, water head and tail race, access and cable tunnels frequently associated with conventional pumped storage schemes.

The first Natural Hydro Energy power station will be located in the North West of Ireland and will have 10 x 150MW Francis type pump/turbines totalling 1500MW capacity. It will be located approximately 2.5km from the dam. The head between the dam and the powerhouse will be approximately 230m on this site. The storage capacity of the reservoir with approximately 4 square km surface area will be 90,000MWh.

The power station will be connected to the ocean by a short channel. Rock for construction of the dam will come from excavations for the channel and the power station site, which must be located in a cutting to accommodate water transit from the draught tubes of the pump/turbines to the ocean 25m below minimum tide level. This local source of rock minimizes dam construction costs by eliminating the need to transport rock from outside the site.

This unusual design provides exceptionally large storage capacity of 90,000MWhs. Ireland has the potential for up to 300,000 MWhrs. This compares very favourably to the storage capacity of pumped storage schemes in the following countries.

	MWh
Spain	1,530,000
Switzerland	369,000
France	184,000
Austria	125,000
Portugal	107,000
Lithuania	49,000
Germany	39,000
UK	33,000
Greece	21,000
Poland	11,000
Belgum	8,000
Czech Republic	7,000
Luxemborg	6,000
Slovakia	4,000
Ireland	2,000
Bulgaria	1,000

Eurelectric 2020 Report "Hydro in Europe" Powering Renewables"

The Natural Hydro Energy design provides very large, low cost storage capacity to compensate for intermittent wind generation. Two of these Irish schemes would provide equivalent storage to all 7 of the pumped storage schemes in France, which provide important peak capacity in addition to France's 78% nuclear generation capacity.

The Natural Hydro Energy design has a cost per unit power of around €733 per kW installed. This is at the lower end of typical pumped storage scheme costs, which normally range from €700/kW to €2000/kW. The exceptional advantage of the Natural Hydro Energy design arises from its extremely low energy storage cost of €15/kWh, which compares with typical costs ranging from €80/kWh to €200/kWh for conventional energy storage schemes. This is an exceptional and ground breaking result.

This provides the advantage of an exceptional storage cycle length of a minimum of 2 weeks in zero wind conditions, which effectively eliminates intermittency. The Natural Hydro Energy power station can operate indefinitely in only intermittent light to moderate wind conditions. This advantage arises from the unique geographic topography of the long, narrow, sloping, Irish glacial valley sites.

UK Generation Capacity Plans

The UK faces two major challenges to generation capacity up to 2020 and shortly beyond. The existing UK nuclear stations are approaching the end of their economic working life. Most of the first generation Magnox stations have already been closed. All of the remaining 9.3GW Magnox and second generation Avanced Gas Cooled Reactor stations with the exception of Sizewell B are planned to close by 2023.

The remaining 3 oil fired stations and a number of old coal fired stations have chosen to opt out of the requirements for flue gas desulphurization imposed by the EU Large Combustion Plant Directive. A total of 12GW of these stations will have to close by the end of 2015. The continued economic viability of the remaining 20GW of more modern coal fired stations will depend on the costs of new Carbon Capture and Storage technology, which is currently undergoing pilot scheme evaluation.

In addition to the requirements to replace the nuclear and conventional stations facing closure, the UK must greatly increase generation from renewable sources to meet its 2020 target of 30%. This includes NREAP plans to increase onshore wind capacity by 10,850MW and offshore wind by 10,210MW. The migration to more offshore sites as onshore capacity approaches saturation will significantly increase cost of renewable generation.

The closure of the UK nuclear and fossil fuel fired stations together with the large requirement for increased renewable generation will open the UK market to possible imports of cost effective, renewable energy up to 2020. Ireland, with a large surplus of high capacity factor onshore wind farm sites on land with low agricultural and commercial value, well in excess of its own renewable target requirements, will be in a strong position to compete for this potential market.

Ireland has two further important advantages. Its proximity to the UK reduces the length and hence cost of interconnectors. The advantages of the large scale hydro storage reservoirs proposed by the NHE project will also enhance the attraction of dispatchable, cost effective renewable energy imports from Ireland over interconnectors operating at high load factors during high demand day time trading periods.

Renewable Generation from Ireland Aided by Large Scale Storage

Finally, the main reasons, why the NHE project should be proposed for consideration as a PCI are as follows:

- It exploits extensive availability of economic, high strength, onshore wind resources in Ireland with offshore and wave available long term. This will earn valuable revenue for Ireland and greatly assist the UK meet its renewable generation targets benefiting emissions reduction and suppressing climate change in both countries

- Plentiful land with low agricultural or commercial value remains in Ireland, which offers the strongest wind and wave strengths in Europe. These are ideal conditions to expand cost effective sustainability between two cooperating Member States within the EU.

- The Irish home market for power generation is saturated. The only possible utilization of the valuable Irish renewable site potential is for export.

- Limited interconnection capacity is currently available out of Ireland. Much higher capacity would be required to fully exploit Ireland's valuable renewable assets. The NHE project offers a large increase in capacity, which will operate at very high load factors due to the benefits of high capacity storage smoothing peaky export flows from renewable generation.

- Ireland's population density is low on the west coast, which resulted in appropriate grid capacity, when they were constructed. The strong sites for renewable generation are also on the Atlantic coast. Extensive grid reinforcement is needed from wind and wave rich resource western areas to the east coast for export to the UK or Mainland Europe. The NHE project will make major contributions to grid reinforcement at no cost to the state.

- Due to the economic recession, the Irish state would have difficulty in providing funding for this size of project. NHE proposes to arrange funding from private sources, in a manner that will still provide substantial benefits to Ireland.

Natural Hydro Energy

- The proximity of the UK to Ireland will require moderate interconnection costs to exploit Irelands valuable renewable resources combined with large scale, low cost storage.

e) How will the project facilitate market integration, elimination of isolated markets, competition and system flexibility? Please specify in particular the impact on energy system-wide generation and transmission costs.

Market Integration

The NHE project will immediately provide a large increase in interconnection capacity between Ireland and UK. In the longer term, it opens potential for further future interconnection between Ireland, France and mainland Europe via the UK.

The UK is facing difficulties with adequate overall future generation capacity, due to closure of both nuclear and fossil fuel fired plant. In addition, it expects to implement a very large expansion in renewable plant to meet its 2020 target. As the renewable construction programme progresses, the UK plans indicate increased development of around 50% of new wind capacity on expensive offshore sites, after its onshore sites are fully exploited. NHE could assist UK solve some of its generation shortfall and or meet its renewable targets economically.

Ireland has the potential to offer a large export capacity of surplus, dispatchable, low cost, onshore wind generation well in excess of Ireland's own foreseeable home market requirements. Ireland's onshore wind sites have some of the highest wind strength conditions in the World. This advantage coupled with low land values can provide wind generation at very competitive prices.

In addition to high quality onshore sites, the long storage cycle, high capacity, low cost, hydro storage potential will complement strong wind sites. The combined output from both sources will be dispatchable. The value of off peak wind generation will be greatly increased by dispatching it during high cost trading periods, when demand is highest. The large economic storage capacity of the Irish storage reservoirs will ensure that both wind and hydro can complement each other indefinitely, even during protracted periods of low wind strength. Losses due to curtailment will be minimised, which will further improve the economics of NHE generation.

Both Irish onshore wind site and hydro storage capacity is far in excess of Irish home market requirements. The only means by which Irelands valuable assets can be exploited is through export. Many Member States will face more expensive solutions to reach their 2020 targets. There has already been controversy in the UK over the cost of offshore wind sites combined with the additional cost of parallel operation of conventional generation at part load to compensate for wind intermittency. Availability of large amounts of dispatchable, renewable generation from Ireland at attractive prices will further market integration and encourage increased penetration of renewable generation.

Elimination of Isolated Markets

Ireland is no longer strictly speaking an isolated market, since one interconnector to the UK has been in operation for some time and a second is due for commissioning shortly. However, in comparison to the highly interconnected networks of mainland Europe, Ireland's island market is still relatively isolated to a large degree.

The NHE project will greatly reduce this isolation by providing extensive new interconnection capacity. This increased capacity will be essential to exploit Ireland's valuable wind and hydro capacity. By smoothing out peaks and valleys in wind output, the complementary hydro storage will ensure high load factors on interconnectors during export periods. This will minimise interconnection costs.

Competition

One of the primary aims of opening the electricity market is that competition will encourage cost effective prices. The 2020 targets for renewable generation will introduce a new aspect of competition to the open market. Not only will market competition continue between all suppliers, because of the large increases in renewable generation required to meet targets, specialised competition is likely to develop in this sector for the most cost effective renewable sources.

Future increases in fossil fuel prices and renewable technology improvements will continue to improve the competitive position of cost effective, renewable generation, with no fuel costs, in comparison to conventional sources Renewable generation has no fuel costs. Not only are continuously rising fuel prices effecting the electricity market with knock on effects to other industries, concern is increasing in many countries over security of future fuel supplies. This is most acute among countries with limited or no indigenous fossil fuel supplies.

These two important market forces will continue to increase competition between conventional generation and secure, emissions free, price stable renewable energy. Dispatchable, renewable energy will provide an additional bonus. Most Member States will be under pressure to increase renewable generation to meet 2020 targets initially and increasing targets beyond 2020. Competition for cost effective sources is likely to increase. Not only will generation companies seek competitive renewable sources, these will also be attractive to many industries under pressure to reduce emissions.

Limited availability of high capacity factor, low cost, onshore wind sites in many member states will increase migration of renewable generation towards more expensive offshore sites. This trend will continue to improve the competitive position of onshore sites, with good wind strengths, on land with low agricultural or commercial value.

Ireland has the highest onshore and offshore wind strengths in Europe, plus the strongest wave energy levels. It has abundant sites for high capacity factor, low cost onshore wind generation. There is extensive availability of low value land. The NHE project will avail of all of these competitive advantages to the fullest extent.

The NHE design combined with low seismic activity and unique Irish glacial valley topography, geography and geology offers exceptionally large capacity hydro storage capacity at low cost. NHE hydro storage reservoirs can absorb and store low value, off peak, surplus wind generation to pump hydro into storage and release it later during high demand periods. This is a very important competitive advantage of NHE over conventional onshore generation, without access to storage facilities.

NHE hydro storage will eliminate wastage of curtailed surplus generation in high strength wind conditions above safe grid acceptance levels resulting in further increase in advantages. In low wind conditions, NHE reservoirs can store valuable, high efficiency, low cost, conventional generation, which would otherwise be displaced/unused at night by increased wind penetration.

NHE hydro generation backed up by long term storage will smooth out peaks and valleys in wind generation. This will ensure highly efficient use and low cost design of transmission facilities connecting NHE combined wind and hydro generation to the UK grid. The close proximity of Ireland to the UK market will contribute to low interconnection costs. Low transmission costs will increase NHEs competitive position for exports.

System Flexibility

The NHE project offers a number of important enhancements to flexibility in the Irish grid as well as excellent flexibility in its own internal operations. Conventional hydro turbines and pump/turbines used in hydro storage schemes have the fastest ramping speeds to increase load in emergency situations of any generation category. This makes them ideal for fast reaction to compensate for rapid load changes in intermittent/volatile renewable generation.

The NHE pump/turbines can offer this rapid response flexibility indefinitely, because of the very large capacity of the hydro storage reservoirs and the long pump/generation cycles this storage can support. Most conventional pumped storage schemes have only generation capacity at full load of around 5 to 8 hours. NHE can effectively offer fast response continuously for indefinite periods of time.

In addition to flexible load following services, NHE will offer 1500 MW of the highest reaction speed of spinning reserve to both Irish and UK grids. This is a very valuable asset to both systems to assist recovery from serious fault conditions and protect against catastrophic grid failures and blackouts.

Pumped storage plant has another important inherent spinning reserve advantage over equally fast reacting conventional hydro generators and all other generation categories. It has the ability, under serious grid fault conditions, when operating in pumping mode, to stop pumping and eliminate this demand. It can then change to generation mode and supply the same amount of additional generation. In this way, it effectively doubles the amount of spinning reserve that can be offered to recover from faults.

There is significant concern about inertia on the Irish grid system as penetration of new wind farms increases. Modern direct drive wind turbines are decoupled from the grid through AC/DC converters used for frequency conversion and do not supply any inertia to the grid. As new wind penetration increases, this reduces the effective inertia supplied to the grid by conventional generators, which are displaced by the new wind turbines. Reduction in inertia, decreases the reaction time available for spinning reserve to compensate for serious faults. This increases the risk of load shedding or even catastrophic blackouts.

Finally, the NHE hydro generators will supply large amounts of reactive power to the grids to which it is connected. This is valuable for accurate voltage regulation and improving supply quality.

Impact on energy system-wide generation and transmission costs.

The primary source of energy in the NHE project is onshore wind on high capacity factor sites using low cost land. This combination produces very low cost renewable energy. Clearly, EU renewable generation costs to meet targets will benefit to the maximum extent from this approach.

The impact on overall generation costs will depend on the ratio of renewable and conventional generation adopted by each Member State, to meet 2020 targets, as well as the technologies used. Hydro and onshore wind are the cost leaders in the renewable sector. Combined Cycle Gas Turbine (CCGT) technology leads the fossil fuel sector. Nuclear costs are much more difficult to compare, due to the diverse manner in which decommissioning, waste handling costs and depreciation over various claimed economic lifetimes are charged.

Recent improvements in wind turbine technology, resulting in better performance and reduced cost per MW installed, have contributed to lower costs per MWh produced. Increasing European gas prices, after the severe price drop immediately after the start of the economic recession, have increased CCGT price per MWh produced. These two opposing trends have tended to close the gap between renewable and conventional costs.

Future values will naturally be influenced by fuel prices and availability. Renewable costs have no fuel costs and capital costs are expected to fall slowly due to design improvements and cost reduction due to economies of scale from increased production volumes.

The advantages of the NHE storage facilities in smoothing peaks and valleys in transmission capacities have already been explained. The proximity of Ireland and the UK provide a second saving arising from short cable lengths.

f) How will the project facilitate sustainability, inter alia through the transmission of renewable generation to major consumption centres and storage sites? Please specify in particular, which capacity of renewable generation will be connected directly and indirectly (in GW/1000 km^2). Please specify also the type of renewable generation capacity concerned.

In the longer term, Ireland has both sufficient potential onshore wind site and hydro storage capacity to supply 100% of its foreseeable electricity demand from renewable sources and still have a large surplus for export. More wind and storage capacity is expected be employed in the future to satisfy Irish demands as existing economic conventional generation is retired. The potential surplus of Irish capacity can only be seriously deployed by export via DC undersea cables to the UK and or France and possibly onward to major consumption centres in Europe.

The large hydro storage sites on the west coast of Ireland are adjacent to areas with strongest wind resources. Hence no long transmission links are needed between the contracted NHE wind generation and storage sites. Wind generation on the National Grid that must be curtailed for system security could in theory be absorbed at any connection point between the national grid and the NHE DC link from the hydro storage site to the UK. In practice, the two systems will need to connect at a suitable strong point in the grid, capable of handling the large 1200MW load. This is most likely to be in the greater Dublin area.

All NHE renewable onshore generation will be both directly connected and indirectly connected via the hydro storage reservoirs to the HVDC transmission interconnecting cables linking the natural energy power generation and storage stations to major demand centres in the UK.

The nature of the NHE project makes it more difficult to specify the capacity and type of renewable generation that will be connected. Two sources of primarily onshore wind generation are planned to be used. Purely onshore wind generation totalling 700MW is planned to be contracted exclusively to NHE for export from suppliers.

The second major source of wind is planned to be generation imported from the national grid that would otherwise have to be curtailed. This will be drawn from the full National wind generation pool, which is expected to total around 6400MW for the SEM to meet 2020 targets. This wind will be primarily onshore, but may have some small offshore content. Both wind sources are expected to have 12MW installed capacity per km^2.

The first NHE pumped storage station will be rated at 1500 MW. The associated reservoir is expected to occupy approximately $4km^2$.

These parameters are only for the first NHE project. The application backlog for new wind generation licences in Ireland indicates availability of up to 15,000MW of potential onshore capacity between existing and potential new sites and much more offshore capacity. Five good, viable hydro storage reservoir sites have been identified, totalling around 300GWh storage or around 150% of total French capacity. A primary site has been agreed and initial negotiations with land owners are progressing with the next two sites.

g) How will the project contribute to security of supply and secure and reliable system operation? Please specify the impact of the project on the loss of load expectation for the area of analysis as defined in point 10 of Annex V of the draft Regulation in terms of generation and transmission adequacy for a set of characteristic load periods, taking into account expected changes in climate-related extreme weather events and their impact on infrastructure resilience

Although the primary aim of the project is for energy export, an agreement has been made with the Irish authorities that priority will be assigned to assisting the Irish grid in times of difficulties. The worst failure condition envisaged for the Irish grid is failure of the largest generating set. This is a 450MW CCGT unit. Hence, the NHE 1500MW can supply far more fast reacting spinning reserve than was ever envisaged for the Irish grid. Under normal operation services on the Irish grid, this spinning reserve can be availed of on the UK grid.

In addition to the valuable spinning reserve capability offered by NHE, the pump turbines will supply 1500MW of additional inertia to whichever grid they are connected. This service is of considerable value due to the reduction in inertia arising from increasing penetration of modern direct drive wind turbines, which provide no inertia.

The increase in wind energy provided by the project reduces dependence on imported fossil fuel on which the UK and Ireland are dependent. This in turn increases security of supply.

Increased wind strengths may increase curtailment. This will be countered by using the excessive wind generation to power pumping for hydro storage. This valuable energy, which would otherwise be wasted can be released for use later, when required.

The limit on the project output will be determined by the capacity of the DC transmission cable to the UK. This is designed for continuous operation at 1200MW. Under fault conditions, on one of the two DC cables, standby service can be maintained on the second cable at 600MW. In terms of impact on the UK grid, this is equivalent to the loss of one large generator on the very extensive UK grid.

Ireland has a temperate climate. It is not subject to extreme weather events such as hurricanes, tornadoes or ice storms. It is therefore not anticipated that the NHE project will be subject to extreme weather conditions. The large storage capacity of the hydro storage reservoirs will ensure continuous operation for a minimum period of 2 weeks with no wind generation, under the operational cycle planned for the project. No wind for 2 weeks is an extremely rare occurrence in Ireland.

h) Why is the realisation of this project particularly urgent with regard to the EU energy policy targets of i) market integration and competition, ii) sustainability and iii) security of supply?

i) Market Integration and Competition

The NHE project will provide 1200MW increased interconnection capacity between Ireland and UK. This is more than the combined existing Moyle and the planned EWIC interconnectors. It will react to a window of opportunity to ease potential UK generation shortfalls from the closure of nuclear and older fossil fuelled stations and may assist UK meet its renewable target. Power will be traded over interconnectors operating very efficiently at high load factors during trading periods. This effective use of interconnector capacity by smoothing out fluctuations in wind generation by supplementary hydro will reduce the cost of interconnection capacity and encourage more trading of renewable energy.

The high capacity factors of onshore Irish wind farms, built on low cost land will make the cost of this energy very competitive. This will be further enhanced by the benefits accruing from the hydro storage in curtailment reduction and increased value of wind generation stored in off peak periods and resold during high demand. NHE will also provide the additional advantage of converting intermittent wind power into dispatchable energy.

ii) Sustainability

Sustainability will be enhanced by increased integration of high levels of renewable, emissions free generation. Energy wastage due to curtailment will be reduced. High load factors on interconnectors will reduce associated costs and encourage more renewable trading

iii) Security of Supply

NHE will supply 1500MW of very fast response spinning reserve. This pumped storage, spinning reserve will have twice the reserve effects of conventional generation due to its ability to change from pumping to generating mode. NHE will also supply large inertia and extensive reactive power to assist stability and voltage control.

i) Are there any interdependencies and/or complementarities with other projects? If yes, which?

The existing 500MW Moyle undersea interconnector already links the UK and Irish grids. A new East West 500MW interconnector (EWIC) nearing completion by Eirgrid the Irish TSO between Ireland and the UK is to enter service shortly. These were both planned to provide normal interconnection services between the two national grids prior to plans for the 1200MW NHE interconnector. NHE is specifically planned to provide export of new renewable generation to the UK over the Irish requirement needed to meet its 2020 target. This is not expected to interfere with the services planned for the Moyle and EWIC links. On the contrary, it is hoped that spare capacity on these links may be used to export more NHE hydro generation.

The NHE project will have one very important interdependency with all other intermittent renewable generation projects in Ireland. Grid security constraints on the Irish grid have already introduced the need for curtailment of wind generation in strong wind conditions, even though only around 15% of generation is being supplied from renewable sources. Curtailment will have to increase significantly as renewable generation approaches its 40% 2020 target. The reduced income from curtailed wind generation will inevitably reduce the incentives for new wind farm construction. The large hydro storage content of the NHE project will greatly reduce curtailment and support further construction of renewable energy in Ireland.

The questions raised in sections d) to i) of Questionnaire II have been answered above. These are very similar to the questions e) to j) in Questionnaire III listed below, with the exception of g). This is answered separately below.

The additionality of the project is large amounts of internationally traded low cost renewable generation. This is further enhanced by large capacity low cost hydro storage.

Conclusion

Integration of Ireland's extensive energy resources (6% of 27 member states) into the union makes complete economic, technical and political sense. This is s project of considerable importance.

Thank you.

Natural Hydro Energy

Natural Hydro Energy Ireland

Questionnaire III response (Project Store only)

Large Scale Hydro Storage (90,000MWhrs) NHE "Project Store" to be interconnected with the UK Market via DC link 1,200MW (NHE "Project Highway" subject of a separate application)

Please NOTE

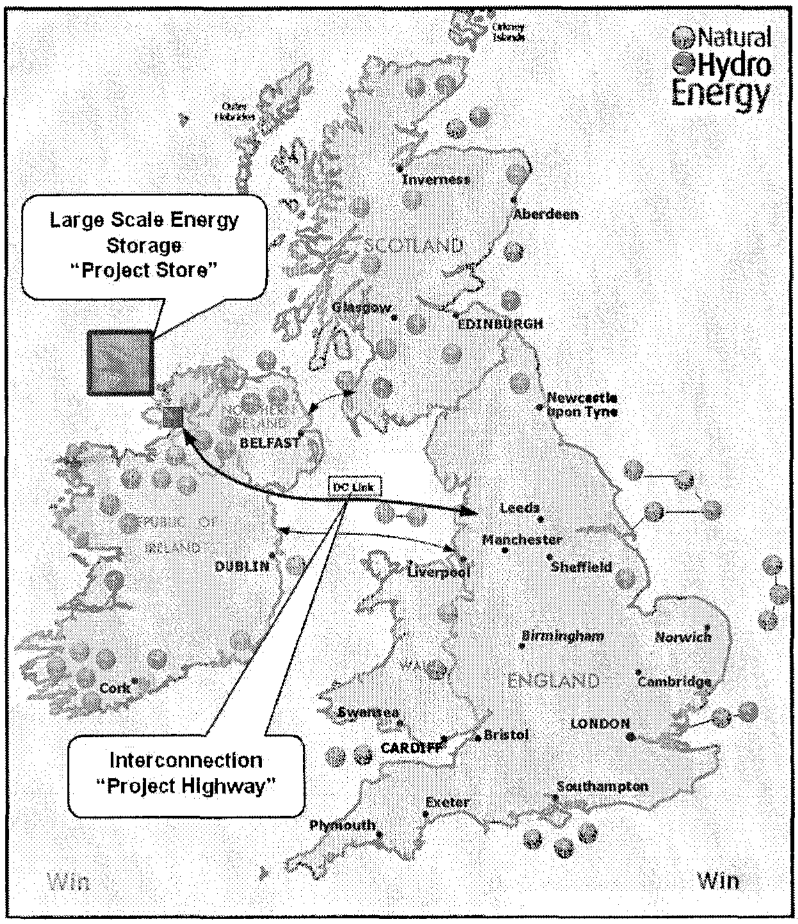
The Natural Hydro Energy overall project consists of two parts:

1. HVDC cable Interconnection between Ireland and the UK, not included in current TYNDPs, is covered by Questionnaire II (NHE "Project Highway") and

2. Large scale Hydro Storage facility (NHE "Project Store") is covered by Questionnaire III.

The overall project has been in development for three years. It is at an advanced stage of planning.

In this response, for clarity of understanding, Natural Hydro Energy (NHE) gives details of both aspects of this project. NHE responds to the similar questions raised in both questionnaires as a separate project.



Natural Hydro Energy

Only the hydro storage reservoir and associated power station relevant to Questionnaire III need be considered in this response. This is designated NHE Project Store. Details of the transmission link are for information purposes only.

Ireland's energy resources are large and essential to EU Carbon Free Energy Security.

NOTE EU questions required to be answered in Questionnaires are shown in **BLUE PRINT.**

Responses are in BLACK PRINT

Title of the project: Natural Hydro Energy Project Store

**** Please send to ENER-B1-PROJECTS@ec.europa.eu and specify the priority corridor in the subject line ****

Introductory information

Contact details of the project promoter(s) (if several, please fill in for each project promoter)

Company: Natural Hydro Energy

☐ TSO ☐ DSO ☒ Other project promoter[1] Other Promoter

Contact person: [redacted]

E-mail address: [redacted]

Telephone number: [redacted]

Type of project

☒ Storage project – please refer to Questionnaire III

Priority corridor

For the implementation of which energy infrastructure priority corridor is the project necessary? Northern Seas Electricity Corridor

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III. Questionnaire for electricity storage projects

1. General information

a) Name of project

Natural Hydro Energy "Project Store"

b) Brief description

90,000MWhrs fast acting Hydro Energy Storage primarily serving the Irish and UK markets

c) Are any other project promoters involved in the project? (list each)

- Countries: ☒ EU ☐ Non-EU, please specify: United Kingdom
- Name of undertaking: Natural Hydro Energy UK Ireland Strategic Energy Infrastructure
- Contact details: Natural Hydro Energy Ltd.

d) Situation of the project promoter(s):

- What is legal status of the project promoter(s)? Please specify (registered undertaking, group of companies, other).

  Private company with anticipated participation by large EU utilities
- If you are a registered undertaking, please provide the list of all shareholders, information on their main activity and their respective shares in the undertaking.

  This information will be provided in confidence
- What is the share capital of this undertaking?

  €40m with access up to [redacted] construction funding as required

e) Project type

☒New

☐Upgrade

☐Extension

☐Replacement

f) Key geographical characteristics ***[please submit map indicating information given below]***

- Location: North West Ireland
- Connection point to transmission network: North West Ireland

g) Key technical characteristics

- Technology (please describe as necessary) Hydro Storage
- Installed generation power (MW) 1,500MW

- Installed generation capacity (GWh) 90 GWhrs.
- (for hydro-pumped storage) Net pumping power (MW) 1500MW
- Response time (seconds) 15 seconds
- Energy rating of storage (minutes) 5,400,000 MW minutes
- Power density of storage (W/kg) Not applicable
- Energy density of storage (Wh/kg) Not applicable
- Round-trip efficiency (charging-discharging) (%) 81%
- Lifetime (years) – for new installations, please specify expected lifetime from start of operation; for upgraded, repowered, retrofitted or extended installations, please specify how this will affect remaining expected lifetime. 40 years before refit in a lifetime of in excess of 80 years.
- Cycles – for battery storage, please specify the expected number of cycles over the lifetime of the battery; for pumped hydro storage, please specify the number of cycles per day (for a given expected lifetime). Normally 1 cycle per day in standard operating mode for in excess of 80 years. Multiple cycles may be used under certain circumstances.
- Voltage at connection point (kV): 320kV DC converted to 400kV AC

h) Estimated project cost (capital expenditure in million euros) [redacted]

i) Planned date of commissioning (year) 2019

j) Implementation status

☐ Pre-feasibility

☐ Feasibility/FEED

☒ Final Investment Decision (FID)

☒ Permitting

☐ Construction

k) Obstacles for the implementation of the investment item

☐ Permit granting (please explain)

☐ Regulatory treatment (please explain):

☐ Financing (please explain):

☒ Other (please explain): Market integration planning to be completed.

This will provide greater commercial certainty

☐ None

2. Specific information

a) Which EU Member States are involved or affected by the project, at which borders?

Ireland and United Kingdom

b) Are any non-EU Member States involved or affected by the project, at which borders?

None

c) Does the project cross borders directly or does it have a cross-border impact? Please specify the installed generation capacity and the average net annual electricity generation capacity over the first 20 years of the project (GWh/year), using appropriate modelling results

13GWh per year Generation capacity over first 20 years 260GWhrs over 20 years

d) What are the main reasons for you to propose this project for consideration as a PCI?

This project very clearly meets all EU objectives for producing Carbon Free, Price Stable, Secure Power. As such, it is a perfect exemplar of integrated transnational thinking and co-operation.

The particular substantive reasons for proposing the Natural Hydro Energy project from Ireland for consideration as a PCI arise from the following factors:

- Energy sources from the periphery of the EU need to be developed to their full potential. Ireland has 6% of all of the renewable resources of the EU with 1% of the population. Ireland can make a very valuable contribution to EU needs and security.

- The availability of extensive, low cost, high wind strength, onshore wind generation sites in Ireland, far in excess of domestic requirements, to assist satisfying EU renewable generation targets is a low cost, low risk, highly secure strategy.

- This project allows for greatly increased penetration of renewable energy in the Irish market above the 40% target level.

- It allows cross border large scale energy trading.

- This, in turn, allows effective competition, with lower projected costs, for increasing renewable generation in all EU Member States, but particularly in the UK and Ireland, to meet 2020 target values.

- There are considerable economic advantages from enhanced energy trading between Ireland, UK and mainland EU.

- NHE provides greatly enhanced security of supply advantages in Ireland and UK arising from large scale hydro storage reservoirs, increased, indigenous, price stable, renewable generation and reduced reliance on imported fossil fuels.

- The project represents considerable technical advances in terms of evolution of a very cost effective design for large scale hydro storage reservoirs.

- Easing integration of intermittent renewable generation by use of large scale hydro storage reservoirs to replace parallel operation of conventional thermal generation to compensate for fluctuation in renewable output.

- Creates essential Dispatchability of renewable generation.

- Increasing the arbitrage value of stored, night time, off peak, renewable generation by releasing it during high demand, day time periods.

EU Proposals for Renewable Generation

All EU Member States have agreed target levels of electricity generation from renewable sources by 2020 to reduce emissions of harmful green house gasses and combat climate change. Most member states will need to considerably increase investment in renewable generation, in order to meet these targets. The cost and effectiveness of investments will depend on the category, capacity and strength of the sources of renewable energy available in each Member State.

Trading mechanisms have been evolved to permit States with large amounts of cost effective renewable energy, in excess of their own projected requirements, to export power to countries facing shortages or more costly generation technologies. Hydro electric schemes have traditionally been the largest source of renewable generation worldwide. They currently supply around 19% of electricity generated in the EU. However, throughout Europe, the most economic sites have already been exploited. Limited increases in hydro capacity are planned prior to 2020, but these will fall well short of the overall increase in renewable generation needed to meet the 2020 targets.

Other than hydro, wind generation has become the most successful and cost effective source of renewable generation in recent years. Extensive new large scale wind farms are under construction.

Examination of the TYNDPs for all EU Member States covering the period up to 2020 and beyond, shows that apart from moderate increases in hydro capacity, large amounts of increased wind generation is expected to constitute the main increase in renewable generation.

Economics of Renewable Generation in the EU

Because of the large scale future role envisaged for wind generation, it is important to consider site availability and wind energy levels available across the full range of Member States. Onshore wind is rapidly approaching similar costing per MWh produced to hydroelectric power, on sites with good capacity factors. However, wind generation suffers from an important disadvantage. It, like marine and solar power, is intermittent and can not be dispatched as easily as hydro.

The relative costs of both hydro and wind generation are very dependent on capacity factors. These vary considerably across the EU. Good onshore wind sites have capacity factors in the range 35% - 40%, with exceptional sites producing over 40% of rated capacity per annum. Hydro capacity factors depend strongly on the available head height on the site. High head Alpine and Nordic sites have capacity factors up to 55%. Medium and lower head run of the river sites lie more in the range 20% - 35%.

The working life spans of both hydro and wind generation are also important in determining cost per MWh produced. Realistic lifetimes of 80 to 100+ years are well established for hydroelectric stations, with major refurbishment intervals of around 40 years. Wind turbines have an expected economic life of 20 – 25 years.

Onshore wind and hydroelectricity are currently much less expensive than other competing forms of renewable generation such as offshore wind, marine or solar energy. However examination of the EU TYNDPs up to 2020 indicate that sites for onshore wind are becoming scarcer in many Member States, after available onshore sites have been developed. Towards 2020, it is expected, there will be greater migration to much more expensive, but more readily available offshore sites.

The UK NREAPS show plans for a very large increase in wind power from 5,430MW in 2010 to 22,450MW in 2020. This includes an increase in onshore wind of 10,850MW. However, a large increase of 10,210MW in offshore wind is also included. This will be associated with a significant increase in renewable generation costs.

Capital costs of offshore wind farms are much more expensive (currently in the range 2.5 to 3 times) than the equivalent cost per MW installed capacity of onshore sites. Erection and foundation costs increase rapidly in deeper water. Grid connection costs increase as turbines are located further offshore. Operation and maintenance costs are also much higher for offshore sites, particularly during adverse weather conditions. These increased costs are not offset by slightly higher offshore capacity factors, generally expected to be in the range 40% - 45%, off suitable coasts.

Cost / MWh produced and site availability will largely determine the increased capacity of EU renewable generation. Wind generation is expected to supply the greatest increase. Countries such as Ireland, with extensive availability of low cost, onshore sites, with high capacity factors, significantly above domestic renewable target requirements will have considerable advantages over areas with lower wind strengths and countries, where limited onshore site availability forces migration towards more extensive, but higher cost offshore locations.

Role of Energy Storage in Increasing Penetration of Renewable Generation

One of the major difficulties experienced with integrating sources of renewable generation in large scale electricity grid structures is intermittency. Wind, solar and marine generation are all subject to large scale variation in output over quite short time scales, depending on the intensity of the energy input. These sudden fluctuations can threaten security of supply on grids, unless output from conventional generation can be adjusted sufficiently rapidly, to compensate for the output variation from renewable sources.

In order to safely integrate intermittent, fluctuating, renewable generation, grid operators (Transmission and Distribution System Operators [TSOs & DSOs]) must ensure sufficient reserves of conventional generation are operated in parallel to the renewable sources, so that they can be ramped up or down to compensate, within adequate time response limits, for the worst potential variation in renewable output. Different categories of conventional generation exhibit greater or lesser flexibility in response time to load variation. Conventional hydro generators and pump/turbines in pumped storage schemes have the fastest response time ranging from less than 1 minute to 2 minutes from no load to full load depending on machine size.

Ramping conventional generation to compensate for parallel variation in renewable output and providing sufficient standby spare conventional capacity introduces significant increased costs. Operating efficiency is lower at part load and fuel consumption is higher per MWh of electricity generated. Ramping plant up and down subjects it to greater wear and tear and maintenance costs increase. Operating plant at part load increases fixed costs such as depreciation over a reduced amount of MWh output. All of these additional charges must all be evaluated in comparing the costs of alternative competing sources of renewable generation

Either conventional hydro generation or pumped storage generation can compensate for intermittent renewable energy very effectively. Both have very rapid response times, which permit them to compensate for sudden changes in renewable output. Efficiency losses under part load operation and increased maintenance charges due to load ramping are less than for thermal plant. Hydro energy stored during high wind conditions can be released, when wind strength is low, so that the combined wind and hydro output is smoothed and in effect provides controlled amounts of dispatchable renewable energy.

Curtailment Constraints on Renewable Penetration

At the early stages of integrating intermittent renewable energy to large scale electricity grids, transmission system operators were concerned with the potential of severe excursions in renewable output to cause instability in grids. If for example, a sudden drop in wind output should occur, before sufficient conventional generation can be brought on line to compensate for the reduction, instability could occur, resulting in load shedding or possible black outs.

To avoid these problems, either sufficient fast acting reserve capacity must be available or renewable generation output may have to be curtailed. Curtailment results in undesirable loss of potential renewable generation. Isolated or lightly interconnected grids are most vulnerable to these conditions. The island grids of Ireland and the UK will be more prone to curtailment than the much more extensive grids in mainland Europe. Stronger interconnection will alleviate this problem, but will not eliminate it.

As the smaller of these two island grids, Ireland offers an interesting insight into the possible effects of curtailment. Renewable energy is allocated priority dispatch status over conventional generation in Ireland to encourage its usage. At the early stages of introducing renewable generation, the Irish TSO was reluctant to permit more than 10% of renewable generation to operate on the grid under any demand conditions.

Increased introduction of fast reacting open cycle gas turbine plant in recent years and greater experience of operating and more accurate forecasting of renewable (primarily wind) generation has permitted this constraint to be extended considerably. Ireland now permits 50% renewable generation on the grid in normal demand conditions, but this has to be reduced to 30%, when demand is lowest.

Ireland has accepted a high target of 40% of electricity generation from renewable sources by 2020. At present, nearly 15% of total generation is supplied by renewable sources. Low levels of curtailment are already necessary on the grid in strong wind conditions, when demand is low, particularly at night time. This is expected to increase considerably as renewable generation approaches the 40% target value. Curtailment will heavily reduce the economic returns from renewable sources, unless a solution to this problem is introduced.

Unique Storage Attributes of Natural Hydro Energy Project Design

The Natural Hydro Energy project will introduce very large capacity, low cost hydro storage reservoirs. These will help eliminate / reduce curtailment constraints on wind generation. The first 1500MW pumped storage station will accommodate 90,000MWh of stored hydro energy in its reservoir. The magnitude of this storage capacity can be appreciated, when compared to schemes in other countries. The UK has 2800MW of pumped storage generation with 14,000MWh storage. France has 7 schemes totalling 184,000MWh. Natural Hydro Energy plans a number of reservoirs in the longer term, any two of which will equal the total French hydro storage capacity.

Most pumped storage schemes have capacity to generate at full load for between 5 to 8 hours. The first NHE project at Kilcar on the North West coast of Co. Donegal, operating under its planned 13 hour daytime generating cycle and 11 hour night pumping regime will be able to generate continuously at full load for 2 weeks, even if there is no wind input. Pumping energy can be supplemented from unused off peak conventional generation in light wind conditions.

Natural Hydro Energy is planning to purchase wind generation daily, from a number of sources for direct export on its HVDC interconnector to the UK and supplement this with hydro generation pumped previously, primarily from off peak wind sources. NHE plans to have 700MW of wind generation contracted from wind farm operators to supply wind generation to NHE for direct export to the UK. This will be in excess of renewable generation planned to meet the Irish 2020 target. NHE will agree to take the total generation from these wind operators without curtailment.

In high wind conditions during daytime export hours, when some wind would normally have to be curtailed to maintain grid stability, NHE will purchase as much of this wind as possible, with the aim of filling the NHE interconnector capacity from Ireland to the UK. This will avoid wind curtailment and wastage of valuable renewable generation.

If insufficient curtailed wind is available together with the directly contracted wind to fill the interconnector, NHE will supplement both these sources by generating from released hydro energy from its large storage reservoir. Wind curtailment is expected to be much higher at night, when system demand is low. NHE plans to purchase large amounts of this wind generation, which would otherwise be curtailed and wasted.

This will improve the economics of off peak wind generation considerably. The increased demand needed for pumping will increase the level at which curtailment would otherwise be required. Large amounts of wind generation, which would otherwise be wasted, will be bought in to supply pumping operations

Interaction of the Interconnection with very large NHE storage capacity will provide a number of important advantages.

- Because much of the hydro generation will be pumped by wind generation, which would otherwise be curtailed, the overall electricity exported to the UK both directly from onshore, high capacity factor wind generation, supplemented by hydro pumped by onshore wind, will contain a very high percentage of renewable energy content. This will involve lower production costs and subsidisation than offshore wind production in the UK.

- The large storage capacity will permit variable wind generation to be supplemented by hydro electricity, ensuring fully controllable / dispatchable power throughout all export periods.

- The value of off peak renewable generation will be increased to high demand day time values

- Much less generation will be wasted due to curtailment

- The interconnector will operate at a high capacity factor and at 100% capacity during export hours

- Much lower interconnector capacity will be needed to export the steady state, average 1500MW of combined wind and hydro generation, than would be needed for the same MWh capacity of volatile wind generation, where interconnector capacity would have to match peak wind generation, while average generation may only be equivalent to 35% of peak.

- Large storage capacity will greatly increase security of supply, in ways which will be described later.

- The greater Dispatchability and controllability of NHE generation, reduced difficulty and cost of parallel operational costs for conventional compensating generation, increased day time value achieved from the large capacity hydro storage combined with the low cost of high capacity factor onshore wind sites will all contribute to greater penetration of cost effective, reliable, secure, renewable generation.

Advantages of Unique Design Features of NHE Hydro Storage Reservoir

Many of the advantages of the NHE project are due to the low storage cost per MWh associated with the hydro storage reservoir. The low storage cost is a result of a combination of unusual design features, which can be exploited in glacial valley sites on the west coast of Ireland. It is expected that, subject to environmental approval and legal permitting, that the first of these projects will be sited near Kilcar in Co. Donegal in North West Ireland. The main concepts of the design, which contribute to the low cost of these large scale reservoirs are described below.

The project will use sea water as a working medium, instead of fresh water used in nearly all other pumped storage schemes. A sea water based scheme has been operating successfully in Okinawa in Japan for the last 15 years. The ocean will be used as the lower reservoir in the scheme. This greatly reduces construction costs normally associated with artificially created lower reservoirs in conventional pumped storage schemes.

The projects rely on the use of naturally occurring glacial formations created in the last ice age, which in a few rare instances created high valleys suitable for energy storage. Since Ireland has a very low level of seismic activity, a rock fill dam can safely be used to form an upper reservoir for the scheme. This is a less expensive form of construction than traditional concrete dam construction methods.

The dam is expected to be approximately 1.3km in length and will have a possible height of 120m at mid point. It will be constructed at the mouth of a long glacial valley. Having to dam only one end of a long narrow valley provides very large capacity in the upper reservoir in comparison to many conventional pumped storage schemes, where the reservoir is formed by a curtain dam, which completely encircles the reservoir. The geology of the valley floor is made up of primarily impermeable rock.

Water will be carried from the dam in multiple steel penstocks. The distance from the dam to the power house varies from 1 to 3 km on the sites selected by Natural Hydro Energy. The ground slopes gently over the intervening territory and provides heads ranging from 180 to 230m. The penstocks will be laid close to the surface of the ground in shallow covered trenches to minimise environmental impact. Using penstocks greatly reduces excavation and tunnelling costs for machine hall caverns, water head and tail race, access and cable tunnels frequently associated with conventional pumped storage schemes.

The first Natural Hydro Energy power station will be located in the North West of Ireland and will have 10 x 150MW Francis type pump/turbines totalling 1500MW capacity. It will be located approximately 2.5km from the dam. The head between the dam and the powerhouse will be approximately 230m on this site. The storage capacity of the reservoir with approximately 4 square km surface area will be 90,000MWh.

The power station will be connected to the ocean by a short channel. Rock for construction of the dam will come from excavations for the channel and the power station site, which must be located in a cutting to accommodate water transit from the draught tubes of the pump/turbines to the ocean 25m below minimum tide level. This local source of rock minimizes dam construction costs by eliminating the need to transport rock from outside the site.

This unusual design provides exceptionally large storage capacity of 90,000MWhs. Ireland has the potential for up to 300,000 MWhrs. This compares very favourably to the storage capacity of pumped storage schemes in the following countries.

	MWh
Spain	1,530,000
Switzerland	369,000
France	184,000
Austria	125,000
Portugal	107,000
Lithuania	49,000
Germany	39,000
UK	33,000
Greece	21,000
Poland	11,000
Belgum	8,000
Czech Republic	7,000
Luxemborg	6,000
Slovakia	4,000
Ireland	2,000
Bulgaria	1,000

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The Natural Hydro Energy design provides very large, low cost storage capacity to compensate for intermittent wind generation. Two of these Irish schemes would provide equivalent storage to all 7 of the pumped storage schemes in France, which provide important peak capacity in addition to France's 78% nuclear generation capacity.

[redacted]

This provides the advantage of an exceptional storage cycle length of a minimum of 2 weeks in zero wind conditions, which effectively eliminates intermittency. The Natural Hydro Energy power station can operate indefinitely in only intermittent light to moderate wind conditions. This advantage arises from the unique geographic topography of the long, narrow, sloping, Irish glacial valley sites.

UK Generation Capacity Plans

The UK faces two major challenges to generation capacity up to 2020 and shortly beyond. The existing UK nuclear stations are approaching the end of their economic working life. Most of the first generation Magnox stations have already been closed. All of the remaining 9.3GW

Magnox and second generation Advanced Gas Cooled Reactor stations with the exception of Sizewell B are planned to close by 2023.

The remaining 3 oil fired stations and a number of old coal fired stations have chosen to opt out of the requirements for flue gas desulphurization imposed by the EU Large Combustion Plant Directive. A total of 12GW of these stations will have to close by the end of 2015. The continued economic viability of the remaining 20GW of more modern coal fired stations will depend on the costs of new Carbon Capture and Storage technology, which is currently undergoing pilot scheme evaluation.

In addition to the requirements to replace the nuclear and conventional stations facing closure, the UK must greatly increase generation from renewable sources to meet its 2020 target of 30%. This includes NREAP plans to increase onshore wind capacity by 10,850MW and offshore wind by 10,210MW. The migration to more offshore sites as onshore capacity approaches saturation will significantly increase cost of renewable generation.

The closure of the UK nuclear and fossil fuel fired stations together with the large requirement for increased renewable generation will open the UK market to possible imports of cost effective, renewable energy up to 2020. Ireland, with a large surplus of high capacity factor onshore wind farm sites on land with low agricultural and commercial value, well in excess of its own renewable target requirements, will be in a strong position to compete for this potential market.

Ireland has two further important advantages. Its proximity to the UK reduces the length and hence cost of interconnectors. The advantages of the large scale hydro storage reservoirs proposed by the NHE project will also enhance the attraction of dispatchable, cost effective renewable energy imports from Ireland over interconnectors operating at high load factors during high demand day time trading periods.

Renewable Generation from Ireland Aided by Large Scale Storage

Finally, the main reasons, why the NHE project should be proposed for consideration as a PCI are as follows:

- It exploits extensive availability of economic, high strength, onshore wind resources in Ireland with offshore and wave available long term. This will earn valuable revenue for Ireland and greatly assist the UK meet its renewable generation targets benefiting emissions reduction and suppressing climate change in both countries

- Plentiful land with low agricultural or commercial value remains in Ireland, which offers the strongest wind and wave strengths in Europe. These are ideal conditions to expand cost effective sustainability between two cooperating Member States within the EU.

- The Irish home market for power generation is saturated. The only possible utilization of the valuable Irish renewable site potential is for export.

- Limited interconnection capacity is currently available out of Ireland. Much higher capacity would be required to fully exploit Ireland's valuable renewable assets. The NHE project offers a large increase in capacity, which will operate at very high load factors due to the benefits of high capacity storage smoothing peaky export flows from renewable generation.

- Ireland's population density is low on the west coast, which resulted in appropriate grid capacity, when they were constructed. The strong sites for renewable generation are also on the Atlantic coast. Extensive grid reinforcement is needed from wind and wave rich resource western areas to the east coast for export to the UK or Mainland Europe. The NHE project will *make major contributions to grid reinforcement at no cost to the state.*

- Due to the economic recession, the Irish state would have difficulty in providing funding for this size of project. NHE proposes to arrange funding from private sources, in a manner that will still provide substantial benefits to Ireland.

- The proximity of the UK to Ireland will require moderate interconnection costs to exploit Irelands valuable renewable resources combined with large scale, low cost storage.

e) How does the project contribute to the integration of the internal energy market, competition and / or eliminate isolated markets?

Market Integration

The NHE project will immediately provide a large increase in interconnection capacity between Ireland and UK. In the longer term, it opens potential for further future interconnection between Ireland, France and mainland Europe via the UK.

The UK is facing difficulties with adequate overall future generation capacity, due to closure of both nuclear and fossil fuel fired plant. In addition, it expects to implement a very large expansion in renewable plant to meet its 2020 target. As the renewable construction programme progresses, the UK plans indicate increased development of around 50% of new wind capacity on expensive offshore sites, after its onshore sites are fully exploited. NHE could assist UK solve some of its generation shortfall and or meet its renewable targets economically.

Ireland has the potential to offer a large export capacity of surplus, dispatchable, low cost, onshore wind generation well in excess of Ireland's own foreseeable home market requirements. Ireland's onshore wind sites have some of the highest wind strength conditions in the World. This advantage coupled with low land values can provide wind generation at very competitive prices.

In addition to high quality onshore sites, the long storage cycle, high capacity, low cost, hydro storage potential will complement strong wind sites. The combined output from both sources will be dispatchable. The value of off peak wind generation will be greatly increased by dispatching it during high cost trading periods, when demand is highest. The large economic storage capacity of the Irish storage reservoirs will ensure that both wind and hydro can complement each other indefinitely, even during protracted periods of low wind strength. Losses due to curtailment will be minimised, which will further improve the economics of NHE generation.

Both Irish onshore wind site and hydro storage capacity is far in excess of Irish home market requirements. The only means by which Irelands valuable assets can be exploited is through export. Many Member States will face more expensive solutions to reach their 2020 targets. There has already been controversy in the UK over the cost of offshore wind sites combined with the additional cost of parallel operation of conventional generation at part load to compensate for wind intermittency. Availability of large amounts of dispatchable, renewable generation from Ireland at attractive prices will further market integration and encourage increased penetration of renewable generation.

Competition

One of the primary aims of opening the electricity market is that competition will encourage cost effective prices. The 2020 targets for renewable generation will introduce a new aspect of competition to the open market. Not only will market competition continue between all suppliers, because of the large increases in renewable generation required to meet targets, specialised competition is likely to develop in this sector for the most cost effective renewable sources.

Future increases in fossil fuel prices and renewable technology improvements will continue to improve the competitive position of cost effective, renewable generation, with no fuel costs, in comparison to conventional sources Renewable generation has no fuel costs. Not only are continuously rising fuel prices effecting the electricity market with knock on effects to other industries, concern is increasing in many countries over security of future fuel supplies. This is most acute among countries with limited or no indigenous fossil fuel supplies.

These two important market forces will continue to increase competition between conventional generation and secure, emissions free, price stable renewable energy. Dispatchable, renewable energy will provide an additional bonus. Most Member States will be under pressure to increase renewable generation to meet 2020 targets initially and increasing targets beyond 2020. Competition for cost effective sources is likely to increase. Not only will generation companies seek competitive renewable sources, these will also be attractive to many industries under pressure to reduce emissions.

Limited availability of high capacity factor, low cost, onshore wind sites in many member states will increase migration of renewable generation towards more expensive offshore sites. This trend will continue to improve the competitive position of onshore sites, with good wind strengths, on land with low agricultural or commercial value.

Ireland has the highest onshore and offshore wind strengths in Europe, plus the strongest wave energy levels. It has abundant sites for high capacity factor, low cost onshore wind generation. There is extensive availability of low value land. The NHE project will avail of all of these competitive advantages to the fullest extent.

The NHE design combined with low seismic activity and unique Irish glacial valley topography, geography and geology offers exceptionally large capacity hydro storage capacity at low cost. NHE hydro storage reservoirs can absorb and store low value, off peak, surplus wind generation to pump hydro into storage and release it later during high demand periods. This is a very important competitive advantage of NHE over conventional onshore generation, without access to storage facilities.

NHE hydro storage will eliminate wastage of curtailed surplus generation in high strength wind conditions above safe grid acceptance levels resulting in further increase in advantages. In low wind conditions, NHE reservoirs can store valuable, high efficiency, low cost, conventional generation, which would otherwise be displaced/unused at night by increased wind penetration.

NHE hydro generation backed up by long term storage will smooth out peaks and valleys in wind generation. This will ensure highly efficient use and low cost design of transmission facilities connecting NHE combined wind and hydro generation to the UK grid. The close proximity of Ireland to the UK market will contribute to low interconnection costs. Low transmission costs will increase NHEs competitive position for exports.

Elimination of Isolated Markets

Ireland is no longer strictly speaking an isolated market, since one interconnector to the UK has been in operation for some time and a second is due for commissioning shortly. However, in comparison to the highly interconnected networks of mainland Europe, Ireland's island market is still relatively isolated to a large degree.

The NHE project will greatly reduce this isolation by providing extensive new interconnection capacity. This increased capacity will be essential to exploit Ireland's valuable wind and hydro capacity. By smoothing out peaks and valleys in wind output, the complementary hydro storage will ensure high load factors on interconnectors during export periods. This will minimise interconnection costs.

f) How does the project facilitate integration of renewable generation? Please describe, using appropriate modelling results.

In the longer term, Ireland has both sufficient potential onshore wind site and hydro storage capacity to supply 100% of its foreseeable electricity demand from renewable sources and still have a large surplus for export. More wind and storage capacity is expected be employed in the future to satisfy Irish demands as existing economic conventional generation is retired. Despite this increased future usage, the potential surplus of Irish capacity can only be seriously deployed by export via DC undersea cables to the UK and or France and possibly onward to major consumption centres in Europe.

The renewable generation that can be exported from Ireland can be produced economically primarily from highly cost effective onshore wind farms constructed on land with low agricultural or commercial value, which is subject to exceptionally strong wind conditions. This large surplus of cost effective renewable generation can be of considerable assistance, initially to the UK in meeting its 2020 and possible future increased renewable generation targets at lower cost than UK offshore wind projects. It will also be available to assist the UK address generation capacity needs to replace closures of existing nuclear and fossil fuel fired stations.

In addition to having a large surplus of cost effective onshore wind capacity available for export, a large hydro storage scheme is planned to alleviate/eliminate the intermittency effects of wind generation. By merging intermittent, real time wind generation with supplementary dispatchable hydroelectricity, NHE can ensure export of steady state dispatchable generation on its 1200MW DC transmission link in its associated "Highway" project. Planning application procedures are expected to commence shortly on the first site subject to completion of finance availability, which is currently in progress. The site is planned to have power station with 1500MW generation/pumping capacity with 90,000MWh storage capacity.

NHE hopes to construct several of these hydro storage facilities in the future. A large number of 57 sites were examined at the beginning of the project. Five of these are most suitable for development. They would total 300,000MWh of storage capacity. Agreement has been reached with landowners on one site and is progressing on two others. The unique features of the design of the hydro storage projects have already been described. The resulting low cost of €15/MWh of hydro energy stored and the very long cycle time of a minimum of 2 weeks are the key features in overcoming the intermittency problem of renewable generation and facilitating greater integration of cost effective onshore wind generation.

NHE plans to utilise wind generation from two sources. It is planned to agree contracts with producers to supply 700MW of contracted onshore wind generation capacity to NHE on a continuous basis. NHE will guarantee to purchase these supplies in full, with no curtailment. As a second source, NHE plans to import wind generation from Eirgrid, which would otherwise have to be curtailed to maintain grid stability. Both these sources are planned to supply real time wind generation for export to the UK on the NHE 1200MW DC "Highway" interconnector during daytime trading periods. If these two sources have insufficient available output to fill the cable capacity, NHE will release sufficient stored hydro to generate the balance needed to fill the cable.

Export is planned for 13 day time hours each day. During the remaining primarily night time period, NHE will use both contracted wind generation and imported wind generation from Eirgrid, which would otherwise be curtailed, to supply power for pumping water into the storage reservoir. In the event of shortage of wind energy, NHE can use imported conventional power for pumping. This can be sourced either from unused, efficient Irish CCGT or coal fired base load plant or from UK imports on the NHE interconnector.

The Republic of Ireland currently has around 3800MW of efficient, economic CCGT and coal fired plant. Total night demand ranges from minimum night time values of 1800MW in Summer to around 2300MW in Winter. Hence, there will always be significant unused conventional capacity available at night. In addition, significant amounts of this capacity will be displaced by wind generation, which is allocated priority status. The amount of conventional plant dispatched at night will depend on wind strength, but considerable unused capacity will available even under low wind conditions. This can compete with night time prices for imports from the UK of conventional generation or possibly curtailed UK wind if some is available.

The effective reduction in curtailed renewable generation that the large NHE storage capacity will provide will reduce the cost of wind generation. This will encourage greater expansion. It will also substitute for and reduce the cost of parallel operation of conventional generation to compensate for renewable intermittency. This will further contribute to reducing renewable generation costs as well as contributing to increased system security.

Hydro generators have the fastest reaction speed of all categories of generators. They can ramp from zero to full load In as little as 15 seconds, which takes the next fastest open cycle gas turbine plants 15 minutes. This can supply large amounts of the highest quality spinning reserve capacity to whichever grid it is connected, which is very valuable in assisting fault recovery. The 1500MW NHE potential reserve will make an important contribution to system security.

The fast response time of hydro plant is also very useful in rapid load following to compensate for short term minute to minute changes in renewable output. This is becoming more important as volatile renewable capacity increases. Fast load following ability is being awarded premium prices in many utilities experiencing increasing difficulties with effective short term load following ability.

Increased penetration of the latest direct drive wind turbines is causing concern on the Irish grid over reduction in inertia on the grid. The direct drive machines are decoupled from the grid by AC/DC converters used for frequency conversion between the slow rotor/generator rotational speed and the 50HZ electrical output from turbine/generators to the grid. Because no inertia is supplied by these turbines, their increased deployment instead of conventional generation is reducing the overall level of inertia on the grid.

Inertia slows the reduction in generator speed after a fault on the grid causes generation to fall below demand. Balance between generation and demand on a grid maintains stable frequency. Inertia slows down generator speed reduction and fall in frequency under fault conditions and permits more time for spinning reserve to come into operation to relieve the problem. The NHE hydro generators will provide large inertia to help overcome this problem.

In addition to the advantages described above, the NHE project will provide one further important boost to renewable generation. Renewable generation must follow the available wind conditions throughout the full 24 hour daily cycle. Demand for electricity is much lower at night than during the day. Power prices fall heavily at night, when there is plenty of the most efficient, lowest cost plant available to compete for the low demand. The UK Renewable Operation Certificates offer a fixed subsidy per MWh to wind generation on top of the basic system marginal price. Hence, night time wind is less valuable than day time wind.

This is currently under review. However, regardless of the commercial outcome of the review, night wind is inherently less valuable than day wind, particularly during peak demand. Because demand is lower at night, curtailment is more likely to arise for intermittent renewable energy. NHE offers a major advantage of absorbing potentially curtailed wind at night for pumping operations. This pumped hydro capacity can be "time shifted"/"arbitraged" and released during the day to provide generation at much higher day time prices. This will greatly increase the value of wind generation and make renewable generation more attractive as well as much easier to integrate.

The large hydro storage sites on the west coast of Ireland are adjacent to areas with strongest wind resources. Hence no long transmission links are needed between the contracted NHE wind generation and storage sites. Grid imports that would otherwise be curtailed for system security could in theory be absorbed at any connection point between the national grid and the NHE DC link from the hydro storage site to the UK. In practice, the two systems will need to connect at a suitable strong point in the Irish grid, capable of handling the large 1200MW load. This is most likely to be in the greater Dublin area.

The hydro generation from NHE storage reservoirs can be used to ensure high load factors on both the NHE cables from the storage reservoir site to Dublin and on the onward link to the UK. By eliminating the peaks and valleys normally associated with transmission of volatile renewable generation, NHE will ensure operation of its transmission cables at high load factors close to 100% during trading hours in comparison t around 35%, when carrying volatile, intermittent wind generation alone. This is the final benefit NHE can provide to encourage greater penetration of the most economic form of renewable generation.

The advantages described above are only for the first NHE project. The application backlog for new wind generation licences in Ireland indicates availability of up to 15,000MW of potential onshore capacity between existing and potential new sites and much more offshore capacity. Five good, viable hydro storage reservoir sites have been identified, totalling around 300GWh storage or around 150% of total French capacity. A primary site has been agreed and initial negotiations with land owners are progressing with the next two sites.

g) What is the additionality of the project? Please list the installed capacity of each existing storage installation using a technology similar to the one of the project in a radius of 200 km from the project.

[please submit map showing location and size of each existing storage installation

The additionality of the project is primarily as follows:

- It will capitalise on the large surpluses of internationally tradable, low cost, dispatchable, renewable generation that can be made available for export from Ireland by exploitation of the extensive inventory of suitable sites.

- The increase in wind energy provided by the project reduces dependence on imported fossil fuel on which the UK and Ireland are dependent. This in turn increases security of supply.

- The potential wind capacity is further enhanced by 1500MW of hydro generation/pumping with a storage capacity of 90,000MWh and minimum load cycle of 2 weeks and an exceptionally low storage cost of €15/MWh.

- The large, low cost storage capacity will greatly alleviate the difficulties and integration costs of increased wind penetration by providing a dispatchable output of combined real time wind and supplementary hydro generation.

- Hydro storage can time shift low value night time wind generation to meet high value day time demand.

- Increased wind strengths may increase curtailment. This will be countered by using the excessive wind generation to power pumping for hydro storage. This valuable energy, which would otherwise be wasted can be released for use later, when required.

There is no storage installation within 200km of the NHE site. The nearest is the 292MW Turlough Hill scheme which is over 250km distant.

h) How does the project ensure security of supply and a secure and reliable system operation? Please describe, using appropriate modelling results.

Although the primary aim of the project is for energy export, an agreement has been made with the Irish authorities that priority will be assigned to assisting the Irish grid in times of difficulty. The worst failure condition envisaged for the Irish grid is failure of the largest generating set. This is a 450MW CCGT unit. Hence, the NHE 1500MW can supply far more fast reacting spinning reserve than was ever envisaged for the Irish grid. Under normal operation services on the Irish grid, this spinning reserve can be availed of on the UK grid.

Pumped storage plant has another important inherent spinning reserve advantage over equally fast reacting conventional hydro generators and all other generation categories. It has the ability, under serious grid fault conditions, when operating in pumping mode, to stop pumping and eliminate this demand. It can then change to generation mode and supply the same amount of additional generation. In this way, it effectively doubles the amount of spinning reserve that can be offered to recover from faults.

In addition to the valuable spinning reserve capability offered by NHE, the pump turbines will supply 1500MW of additional inertia to whichever grid they are connected. This service is of considerable value due to the reduction in inertia arising from increasing penetration of modern direct drive wind turbines, which provide no inertia.

The hydro generators will supply large amounts of reactive power, which has an important role in ensuring voltage stability on the grid.

i) Why is the realisation of this project particularly urgent with regard to the EU energy policy targets of i) market integration and competition, ii) sustainability and iii) security of supply?

i) Market Integration and Competition

The NHE project will provide 1200MW increased interconnection capacity between Ireland and UK. This is more than the combined existing Moyle and the planned EWIC interconnectors. It will react to a window of opportunity to ease potential UK generation shortfalls from the closure of nuclear and older fossil fuelled stations and may assist UK meet its renewable target. Power will be traded over interconnectors operating very efficiently at high load factors during trading periods. This effective use of interconnector capacity by smoothing out fluctuations in wind generation by supplementary hydro will reduce the cost of interconnection capacity and encourage more trading of renewable energy.

The high capacity factors of onshore Irish wind farms, built on low cost land will make the cost of this energy very competitive. This will be further enhanced by the benefits accruing from the hydro storage in curtailment reduction and increased value of wind generation stored in off peak periods and resold during high demand. NHE will also provide the additional advantage of converting intermittent wind power into dispatchable energy.

The principal urgency of expediting the NHE project is to alleviate serious potential curtailment of renewable generation on the Irish grid, to avoid stability problems as wind penetration approached closer to the 2020 target

ii) Sustainability

Sustainability will be enhanced by increased integration of high levels of renewable, emissions free generation. Energy wastage due to curtailment will be reduced. High load factors on interconnectors will reduce associated costs and encourage more renewable trading

iii) Security of Supply

NHE will supply 1500MW of very fast response spinning reserve. This pumped storage, spinning reserve will have twice the reserve effects of conventional generation due to its ability to change from pumping to generating mode. NHE will also supply large inertia and extensive reactive power to assist stability and voltage control.

j) Are there any interdependencies and/or complementarities with other projects? If yes, which?

The existing 500MW Moyle undersea interconnector already links the UK and Irish grids. A new East West 500MW interconnector (EWIC) nearing completion by Eirgrid the Irish TSO between Ireland and the UK is to enter service shortly. These were both planned to provide normal interconnection services between the two national grids prior to plans for the 1200MW NHE interconnector. NHE is specifically planned to provide export of new renewable generation to the UK over the Irish requirement needed to meet its 2020 target. This is not expected to interfere with the services planned for the Moyle and EWIC links. On the contrary, it is hoped that spare capacity on these links may be used to export more NHE hydro generation.

The NHE project will have one very important interdependency with all other intermittent renewable generation projects in Ireland. Grid security constraints on the Irish grid have already introduced the need for curtailment of wind generation in strong wind conditions, even though only around 15% of generation is being supplied from renewable sources. Curtailment will have to increase significantly as renewable generation approaches its 40% 2020 target. The reduced income from curtailed wind generation will inevitably reduce the incentives for new wind farm construction. The large hydro storage content of the NHE project will greatly reduce curtailment and support further construction of renewable energy in Ireland.

Conclusion

Integration of Ireland's extensive energy resources (6% of 27 member states) into the union makes complete economic, technical and political sense. This is a project of considerable importance.

Thank you.