THE ELECTRICITY ACT 1989, SECTION 37

PROPOSED BEAULY TO DENNY 400kV STEEL TOWER DOUBLE CIRCUIT OVERHEAD ELECTRICITY TRANSMISSION LINE

SEIRU Ref: IEC/1/36

Precognition of

John Michael Barlow

On behalf of
The Applicants

Needs Case & Government Policy

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1. Personal details

1.1 I am John Michael Barlow (Otherwise known as Mike Barlow), System Manager in SSE Power Distribution, the transmission and distribution business of Scottish and Southern Energy. I have a Bachelors degree in Electrical and Electronic Engineering (B.Sc (Hons)) from the University of Leeds, a Masters degree (M.Sc) in Electrical Power Engineering obtained from Heriot Watt University. I am a Chartered Engineer and a Member of the Institution of Engineering and Technology (C.Eng, MIET).

1.2 I joined the Electricity Industry in 1973 with the North Western Electricity Board, and in 1977 I joined Kennedy & Donkin Consulting Engineers. In 1979, I joined the North of Scotland Hydro Electric Board. I was involved in a variety of engineering based roles including system planning and development for both the transmission and distribution systems, I have over 30 years experience in the electricity supply industry gained in the fields of system planning and capital investment. I have significant experience of managing the Licence obligations of the Company with regard to the development of an efficient, co-ordinated and economical electricity supply system, and of the regulatory interfaces.

1.3 The SSE Power Distribution business is responsible for the delivery of the day to day operation and Licence obligations of the transmission licence holder “Scottish Hydro-Electric Transmission Limited”.

1.4 Most recently I have been involved with the connection offers to renewable generation developers, the introduction of GB wide trading and transmission arrangement in 2005 and the transmission price controls for Scottish Hydro Electric Transmission Limited. This involved, in particular, establishing the needs case for major infrastructure projects such as the proposed Beauly to Denny line.

1.5 I was a member of the DTI/OFGEM Transmission Issues Working Group (TIWG), and I am currently a member of the DTI/OFGEM Transmission Working Group (TWG). Both groups have considered the implications of Government renewable policy on the GB transmission systems and the need for their reinforcement.

2. Introduction

2.1. *Scope of Evidence*

My precognition covers a number of areas in respect of which a number of papers have been presented and lodged as Inquiry documents. These are as follows:

2.1.1 A description of the Government Policy and targets relating to the development of renewable energy and the associated and supporting development of the transmission systems (Doc. No. APL-4/1);

2.1.2 The planning and security standards to which SHETL must adhere, as a condition of its licence, in planning the development of its transmission system (Doc. No. APL-2A/6);

2.1.3 The applications and agreements currently in place with National Grid Electricity Transmission (NGET) and Developers for the connection of renewable generation (Doc. No. APL-4/2);

2.1.4 An assessment of the alternatives to the Beauly-Denny proposal to develop alternative upgrade options on the existing Main Interconnected Transmission System (MITS) (Doc. No. APL-4/5);

2.1.5 The consideration of the requirement to connect generation along the Beauly-Denny route corridor (Doc. No. APL-5/12); and

2.1.6 The consideration of future transmission system development and access arrangements (Doc. No. APL-4/7).

2.1.7 Since initial preparation of these documents, a further paper has been prepared in response to Objectors’ suggestions that an HVDC subsea link may be an alternative. This will be produced as an additional document, entitled ‘The Option of a HVDC Subsea Link’ (Doc.No.APL-5/18) and will be referred to in this Precognition.

2.1.8 Related evidence will be provided by Mr. Brian Punton who will describe the existing SHETL transmission system, address the need to reinforce the transmission system by the proposed Beauly-Denny line in order to accommodate contracted volumes of renewable generation, and describe the key elements of the proposal. Brian is a colleague and a senior member of my System Planning team who has worked with me on this project and related areas for several years.

2.1.9 SKM Consultants have been employed by the Applicants to undertake cost-benefit analysis to validate the proposal and to assess the proposal against several identified alternatives. Further evidence in this respect will be provided by David Bailey, of SKM consultants.

2.1.10 PBPower consultants have been employed by the Applicants to undertake a generic comparison of the use of alternating current (AC) underground cable as an alternative to an overhead line, and with particular reference to its application to the Beauly-Denny line upgrade. Dr Bruce Stedall will provide evidence in respect of the considerations of this alternative.

2.1.11 Finally, PBPower and Andersen PES Consulting have been employed by the Applicants to undertake a generic comparison of the use of high voltage direct current (HVDC) transmission as an alternative to AC transmission, and with particular reference to its application to the

Beauly-Denny line upgrade. Dr Bruce Stedall will provide evidence in respect of the considerations of this alternative.

2.2 *Project*

2.2.1 In response to the SHETL and SPT Statutory and Licence obligations to provide connections for new generators, it is necessary to provide the appropriate reinforcements to the Main Interconnected Transmission System to accommodate the resulting increased power flows on the transmission system.

2.2.2 SHETL has been working closely with SP Transmission (SPT) to develop an efficient, co-ordinated and economic solution to accommodate the renewable generation in the SHETL area, which impacts on the Main Interconnected Grid System in the SHETL & SPT licensed areas. Both Licensees have liaised with National Grid Electricity Transmission to ensure coordination in the development of their transmission systems.

2.3 *Statutory framework*

2.3.1 Scottish Hydro-Electric Transmission Limited (SHETL) and SP Transmission (SPT) are licensed companies in terms of Section 6(1) (b) of the Electricity Act 1989 ("the 1989 Act") as amended by the Utilities Act 2000 and Energy Act 2004.

2.3.2 SHETL and SPT are obliged to develop and maintain an efficient co-ordinated and economic system of electricity transmission and to facilitate competition in the supply and generation of electricity pursuant to Section 9 (2) of the 1989 Act.

2.3.3 SHETL and SPT are responsible for developing the transmission system and connecting new demand and generation to the grid network in accordance with the GB Security and Quality of Supply Standards (CD-L11) and the SO-TO Code (APL - 2A/7).

3. Government Policy & Targets

3.1 I have considered Government policy on renewable generation policy and targets and the implications for the reinforcement of the SHETL transmission system.

3.2 My intention is to provide evidence that the development of the proposed Beauly-Denny line is entirely consistent with the UK Government, DTI & Scottish Executive intentions for the development of renewable generation. It will be for Mr. David Bell to explain the interface between Government energy policy and planning policy.

3.3 Furthermore, I provide evidence to demonstrate that there has been significant discussion with the DTI, the Scottish Executive and the electricity industry regulator, OFGEM, in considering the requirements for necessary GB transmission system reinforcement in order to facilitate that development.

3.4 I make reference to the paper entitled – 'Government Policy & Targets for Renewables' (Doc. No. APL-4/1). Further reference is made within this paper to a number of papers that have been produced by the UK Government or by the Scottish Executive in respect of the need for the development of renewable energy and the associated requirement for the development of the GB transmission system. A number of quotes from these papers are re-stated herein, in order to demonstrate the intention and commitment of the Government bodies. Reference is also made to the liaison that has taken place between the government and regulatory bodies and the three transmission licensees in identifying the potential requirements for transmission system upgrades to accommodate target levels of renewable generation.

3.5 United Kingdom Policy

The UK Government retains control of the overall direction of energy policy. Since devolution in 1999 some energy policy issues have been devolved to Scotland such as energy efficiency and renewable energy. Encouraging more electricity generation from renewable sources is an important element of both the UK and Scottish Climate Change Programmes.

3.6 The Energy White Paper

The 2003 Energy White Paper 'Our Energy Future – creating a low carbon economy' (Doc. No. CD-L/05) outlines the Government target that 10% of electricity supplies within the United Kingdom should be generated from renewable sources by 2010.

3.6.1 The Energy White Paper also outlines the Government's ambition to double the renewable share of electricity from the 2010 target by 2020. These aspirations form an integral part of the Government's long-term aim to reduce carbon emissions by 60% by 2050 to mitigate the impact of climate change.

3.6.2 The White Paper states, *"We need to develop the existing transmission network to exploit our massive onshore and offshore wind resources. Transmission companies must start preparing now to strengthen the network to enable the UK to increase substantially its deployment of renewables"*. It goes on to recognise that natural resources are often greatest in peripheral areas.

3.7 The Energy Review

The DTI's Report in July 2006 'The Energy Challenge – Energy Review Report 2006' (Doc. No. CD-L06) recognises the requirement for renewable generation and the linkage with transmission system development.

3.7.1 Annex E states: "*new, large renewable plants are likely to connect into the transmission network, particularly in Scotland where the 132kV system is categorised as transmission. Because of the geographical concentration of wind resource in Great Britain, there are likely to be complex connection issues accommodating large amounts of wind generation, in particular. Substantial increases in wind generation will therefore require parallel developments in transmission infrastructure.*"

3.7.2 Annex E continues: *"The Government has long recognised these issues. DTI published the RETS study in June 2003 and RETS Revisited in November 2005. Ofgem also published a report between price reviews in December 2004 that approved funding for over £560M capital expenditure, including the upgrading of the Beauly-Denny line."*

3.8 The Scottish Executive

The Scottish Executive has set a target, in its 'Programme for Government 2', that 18% of electricity supplies in Scotland should be generated from renewable resources by 2010. Subsequently, the Scottish Executive has consulted on targets for Scotland by 2020, and reported in 'Securing a Renewable Future: Scotland's Renewable Energy' (Doc. No. CD-L01). The report concluded that Scotland should aspire to generate 40% of its electricity from renewable sources by 2020.

3.8.1 It also reported that '*Government and industry recognise the importance of grid upgrading*', and that '*it is important that the preparatory work required to deliver the necessary upgrades to the grid is allowed to proceed as quickly as possible*'.

3.8.2 In considering the need for the Beauly-Denny project, information provided by the Forum for Renewable Energy Development in Scotland

(FREDS) is relevant. FREDS was set up as one of the objectives of the Scottish Executive report. FREDS has reported on 'Scotland's Renewable Energy Potential: Realising the 2020 target' (Doc. No. CD-L02). The report concluded that a total of 6GW of renewables would be required in Scotland to meet its 2020 targets. Of this, 1.3GW already exists in the form of established hydro-electric schemes, so that the balance of 4.7GW would come from onshore windfarms or other renewable technologies across Scotland.

3.8.3 The FREDS report states: *'the Scottish Executive has confirmed that the target of 40%* (of electricity generation by renewable resources) *should not be regarded as a cap'*. This clearly indicates that, even if the 2010 and 2020 targets relating to the proportion of energy generated by renewable sources are achieved, this should not result in the halting of renewable developments. The policy is a long term one and limits to the levels of development are not set.

3.8.4 In respect of the transmission system, the FREDS report recognises: *"Substantial upgrades will be required to Scotland's electricity transmission system depending on the level of renewable generation to be developed"*.

3.8.5 The FREDS report also notes that the grid system upgrades and reinforcements currently approved by the electricity industry regulator, OFGEM will allow the connection of up to 2.3GW of new renewable generation in the North of Scotland. The two projects currently approved in the North of Scotland are the proposed Beauly-Denny overhead line and Inverarnan substation near Sloy.

3.9 The GB Transmission Issues Working Group (TIWG)

The Department of Trade and Industry (DTI) established the GB Transmission Issues Working Group (TIWG) in 2002. The group included representatives from the DTI, the Scottish Executive, OFGEM and the three GB Transmission Licensees (Scottish Hydro-Electric Transmission Ltd, SP Transmission Ltd (SPT) and National Grid Transco (NGT)).

3.9.1 The TIWG reported in June 2003 with 'Transmission Issues Working Group Final Report – June 2003' (Doc. No. CD-L09). TIWG stated, "*Achievement of the renewables target is likely to involve a significant change in the geographical distribution of generating capacity. Appropriate infrastructure must be in place to enable the electricity generated from renewable sources, particularly in remote regions of Great Britain, to be transmitted to centres of demand if lack of transmission capacity is not to act as a barrier to meeting the Government's 10% target*."

3.9.2 The DTI published a further report in November 2005, entitled 'RETS Revisited – Connecting Renewables to the Grid – a Report by the Transmission Working Group of the DTI' (Doc. No. CD-L10). Its intention was to review the progress since the original RETS Report in June 2003.

3.9.3 It noted that "*the level of active consenting work for projects in Scotland have increased substantially and will inevitably lead to increased demands on the transmission network. A lack of planned infrastructure upgrades will have serious implications for Government targets and aspirations out to 2020*."

3.10 In 2004, and subsequent to the transmission licensees report to the TIWG, the industry regulator, OFGEM, consulted on the requirement for transmission upgrades to accommodate the potential growth in renewable generation in Scotland. It concluded its views in its paper ‘Transmission Investment for Renewable Generation – Final Proposals – December 2004’ (Doc. No CD-L15).

3.11 In the north of Scotland, the proposed Beauly-Denny Line and the Inverarnan substation reinforcement in the Argyll & Bute area were both accepted as being cost-effective and categorised as ‘baseline’ expenditure by OFGEM. Funding arrangements were set out in SHETL & SPT Licences which cover the financing costs of these projects.

3.12 In summary, the UK Government and the Scottish Executive have demonstrated a strong commitment to the development of renewable energy as a major contributor to tackling the problem of climate change. Both the UK Government and the Scottish Executive have recognised that there is an associated requirement for the development of the GB transmission system.

3.13 There has been significant discussion with the DTI, the Scottish Executive and the electricity industry regulator, OFGEM, in identifying the requirements for necessary GB transmission system reinforcement in order to facilitate that development.

3.14 The development of the proposed Beauly-Denny line is entirely consistent with the UK Government, DTI & Scottish Executive intentions for the development of renewable generation. Further demonstration of the specific requirement is made in papers entitled ‘The Requirement for System Reinforcement’ (Doc. No. APL-4/4).

4. Planning & Security Standards

4.1 My colleague, David Densley, will have explained in broad terms the Licence requirements with which SHETL is obliged to comply in discharging its duties. Within SHETL, it is for System Planning to design the transmission system in the north of Scotland such that it is consistent with the obligations to develop and maintain an efficient, co-ordinated and economical system for the transmission of electricity, and to facilitate competition in the supply and generation of electricity. Of particular relevance to this project is that it will facilitate competition in generation from renewable sources. In this part of my evidence I discuss in more detail the planning and security standards that are of relevance to the fulfilment of those obligations.

4.2 SHETL and SP Transmission are under licence obligation to develop their transmission systems in accordance with the requirements of specific planning and security standards. The current version of these standards is the GB Security and Quality of Supply Standards (Doc.No.CD-L11) which apply to the three transmission licensees in GB.

4.3 In providing this evidence I make use of the Applicants' paper entitled 'Planning & Security Standards' (Doc. No. APL-2A/6). The paper describes the planning and security standards that SHETL was, via its licence obligations, obliged to comply with in planning its transmission system prior to the introduction of the new British Electricity Trading and Transmission Arrangements ("BETTA") and those standards it is required to comply with, again via its licence obligations, since the introduction of BETTA.

4.3.1 It is in complying with these standards that the requirement is established to reinforce the transmission system. It is then from this requirement to reinforce, and the Licence requirement to develop an efficient and economic system that the Beauly-Denny upgrade is identified and proposed.

4.3.2 Under the terms of a transmission licence granted under section 6(1) (b) of the Electricity Act 1989, (as amended by the Utilities Act 2000 and the Energy Act 2004), Scottish Hydro-Electric Transmission Limited (SHETL) is authorised to participate in the transmission of electricity.

4.3.3 Part 1 of the licence details terms of the licence, Part II standard conditions, Part III amended standard conditions and Part IV special conditions.

4.4 PRE-BETTA

Prior to the introduction of BETTA, and under Special Condition H (Transmission System Security Standard and Quality of Service (Scotland) of its licence SHETL was obliged to:

4.4.1 Plan and develop its transmission system in accordance with the document entitled North of Scotland Hydro-Electric Board (NSHEB) Planning Document TM9001 (Transmission Planning Standard of Security), as appropriate to the purpose under consideration, and the Scottish Grid Code, and

4.4.2 Operate its transmission system in accordance with the document entitled NSHEB System Operation Memorandum No. 3.

4.4.3 The document NSHEB TM 9001 incorporated further standards, including Engineering Recommendation P2/5, NSP 366 “Security of the 400kV and 275kV Systems in Scotland”, and Engineering Recommendation P18, “Complexity of 132kV circuits”.

4.4.4 Engineering Recommendation P2/5 related to security of supply standard for demand connection.

4.4.5 Planning Standard NSP 366 defined the planning criteria necessary for the security of the primary transmission system. It covers key definitions of first circuit outage, second circuit outage and double circuit outage.

4.4.6 Relevant to the proposal, it also covered the number of circuits between supergrid substations. It required that at 100% maximum demand, the system should be capable of withstanding a first circuit outage or a double circuit outage, without overloading the remaining system. At 75% of annual maximum demand, the prevailing system should be capable of withstanding a single circuit fault outage.

4.4.7 Engineering Recommendation P18 set the normal limits of complexity of 132kV circuits by stipulating certain restrictions to be applied to them when they are designed.

4.4.8 Similar planning and operating standards were in place, by licence, for SP Transmission.

4.4.9 This suite of planning and operating standards was used for the assessment of the need for the proposed Beauly-Denny line, based upon the position with respect to contracted generation at April 2004. This position was reported in the Environmental Assessment for the project.

4.5 Development of Planning and Operational Standards for BETTA

In July 2004 as part of Energy Act 2004, OFGEM/DTI published a consultation document on the planning and operating standards to apply under British Electricity Trading and Transmission Arrangements (BETTA). The conclusion of the consultation resulted in a harmonised standard, named the GB Security and Quality of Supply Standard (GB SQSS) version 1.0, September 22, 2004, (Doc. No. CD-L11).

4.5.1 The development of the standards was based on the OFGEM/DTI assumptions, that the standards would not introduce any significant changes in the security and the quality of supply delivered to users, would not require any significant additional new investment in transmission, and would provide clarification of the requirements that would promote a consistent understanding and application of the criteria between the three transmission licensees.

4.5.2 The British Electricity Trading and Transmission Arrangements (BETTA) were implemented on 1st April 2005.

4.5.3 Transmission Licence Standard Conditions D3, which applies to both SHETL and SP Transmission Limited states

'The licensee shall at all times:

Plan, develop and operate the licensee's transmission system, and Co-ordinate and direct the flow of electricity onto and over the GB transmission system,

in accordance with the GB Security and Quality of Supply Standard, together with the STC, the Grid Code or such other standard of planning and operating as the Authority may approve from time to time and with which the licensee may be required to comply (following consultation (where appropriate) with any authorised electricity operator liable to be materially affected thereby)'.

4.6 GB SQSS

The GB SQSS has seven sections.

4.6.1 Section 1: Introduction covering Role and Scope and Document Structure.

4.6.2 Section 2: Design of Generation Connections covers planning standards for connection of generation. Section 2.6.1 states that, following a fault outage of any single transmission circuit, no loss of power infeed shall occur.

4.6.3 Comparison of the pre-BETTA standard NSP 366 and section 2 of the GB SQSS shows that these two standards are similar.

4.6.4 Section 3 deals with the design of demand connections, and a comparison with Engineering Recommendation P2/5 shows that both standards are similar.

4.6.5 Section 4 deals with the design of the Main Interconnected Transmission System (MITS). It details the minimum transmission capacity requirement that, with an intact system, there should be no overloading of the primary transmission equipment.

4.6.6 It further states that under peak demand conditions, in the event of a fault outage, such as a single transmission circuit, or a double circuit overhead line, there shall not be any unacceptable overloading of any primary transmission equipment.

4.6.7 The requirements placed on a Scottish transmission licensee by this section of the GB SQSS are similar to those placed by NSP 366 pre-BETTA.

4.6.8 Section 5 deals with the Operation of the GB Transmission System under prevailing system conditions. These are the conditions on the GB transmission system at any given time, and will therefore normally included times when the system in not completely intact, i.e. when equipment or circuits are out of service on planned or unplanned outages.

4.6.9 This part of the GB SQSS compares with OPMem3 and stipulates (amongst other requirements) that for a fault outage of a single transmission circuit, under prevailing system conditions, there shall not be any unacceptable overloading of any primary transmission equipment.

4.6.10 The GB Security and Quality of Supply Standards apply to the GB system after the implementation of BETTA on 1st April 2005. The standards now apply to the GB transmission systems and have harmonised the Scottish standards with those in use in England and Wales. They do not change the fundamental requirements relative to the earlier standards. The GB SQSS were used to confirm the requirement to upgrade the SHETL transmission system, as proposed by the Beauly-Denny upgrade, in the 2006 studies.

4.6.11 The assessment of the transmission system against these standards, as required by licence, is discussed further in the paper 'The Requirement for System Reinforcement' (Doc. No. APL-4/4), and will be the subject of evidence given by Brian Punton.

5. Renewable Generation Grid Connection

5.1 I seek to provide evidence on the process which renewable developers are required to follow in order to enter into a contract to connect a renewable generation scheme to either the transmission system or distribution system in the north of Scotland. I also provide evidence on the number of renewable generation schemes and their MW capacities that have entered into such contracts, some of which are connected or under construction. These volumes have increased since the submission of the Environmental Statement.

5.1.1 I seek to demonstrate that there is a large volume of renewable generation seeking access to the transmission and distribution systems such that the need for the proposed upgrade is immediately required. Furthermore, I seek to demonstrate that the need is independent upon the planning consent outcome of any one renewable generation project.

5.1.2 In providing this evidence I make use of the Applicants' paper entitled 'Applications and Agreements for Renewable Generation Grid Connection' (Doc. No. APL-4/2).

5.2 The Renewables Obligation Order (RO) was introduced in April 2002 via secondary legislation using powers introduced in the Utilities Act 2000. In Scotland, the relevant Order is The Renewables Obligation (Scotland) Order for Scotland.

5.2.1 In essence, the Renewables Obligation Order places an obligation on a supplier of electricity to provide a defined proportion of its total energy supplied from eligible renewable sources, or to pay a defined 'buy out' price.

5.2.2 The Renewable Obligation Order has created significant demand for renewable generation. The market in generation has reacted by bringing forward proposals for new renewable generation plant. A large proportion of these proposed new developments is for wind-powered generation in the North of Scotland.

5.3 Generator developers who wish to establish generator schemes, such as windfarms, in the north of Scotland must seek to connect the scheme to the Scottish Hydro-Electric Transmission Ltd (SHETL) transmission system or the Scottish Hydro-Electric Power Distribution (SHEPD) distribution system.

5.3.1 Since 1st April 2005, developers seeking a connection to the transmission system apply to National Grid Electricity Transmission (NGET) as GB System Operator for connection and use of system. NGET in turn request SHETL to assess the connection requirements and the need for transmission system reinforcements, under the requirements of the System Operator/Transmission Owner Code (STC). The requirements for the connection and reinforcement are passed from SHETL, via NGET, to the developer. Similarly, developers seeking a connection to the distribution system apply to SHEPD for connection and use of system.

5.4 The position in respect of generator connection applications at April 2004 formed the basis of the assessment of transmission system reinforcements presented in the Environmental Statement. At that time, developers were in the process of seeking connections for a total of 158 schemes, representing some 5900MW of generation capacity. The amount of generation either built, under construction or contracted to connect onto the existing grid system was 1553MW.

5.4.1 Further offers to developers for generator connection were accepted, awaiting acceptance, or in the process of being made by SHETL/SHEPD amounting to over 4300MW.

5.4.2 The Environmental Statement and the paper 'The Requirement for System Reinforcement' (Doc.No.APL-4/4) demonstrate that, above the level of 1553MW of contracted generation, the transmission system would not be compliant with the relevant planning and security standards.

5.4.3 Following the position at April 2004, there was a significant increase in applications for generation connection in Scotland. At the beginning of 2005, SHETL had received connection applications for over 9GW in the North of Scotland.

5.4.4 The majority of these connection offers made were accepted by the developers, and the current position at 31st October 2006, was that:

627MW of generation capacity was connected

881MW had accepted an agreement for a connection prior to the Beauly-Denny system upgrade or any other system upgrade

892MW had accepted an agreement for connection, but await the Beauly-Denny system upgrade

A further 5,284MW have entered connection agreements, but await the Beauly-Denny and further system upgrades

This represents a total of some 7,684MW of prospective renewable generation.

5.4.5 In addition to the 627MW which is connected at 31st October 2006, the contracts to connect fall into the following categories:

305MW of capacity were under construction.

501MW were consented, awaiting construction.

1494MW had applied for consents.

4758MW had not applied for consents at that time.

Renewable generation developments which are connected, under-construction or consented amount to a total of over 1400MW.

5.4.6 In considering the generation which has an effect on, and an interaction with, the Beauly-Denny line, SHETL has considered generation in the northern part of its network. This geographical area extends to the north and west of a notional line from Kinlochleven on the west coast, eastwards to the north of the Tummel valley, and then north-eastwards to Keith.

5.4.7 The volumes of contracted generation in this region amount to over 4000MW of generation, over 104 sites. Renewable generation development which are connected, under-construction or consented amount to a total of over 900MW.

5.4.8 Grid system reinforcements have been identified which would be necessary to connect up to 5.2GW in the north of Scotland. These grid reinforcement projects have been quoted in the offers made via NGET to the developers, and these are discussed in Applicants' paper 'Future Transmission Development and Access' (Doc. No. APL-4/7).

5.5 Conclusions

5.5.1 There is a significant number of renewable generation schemes, and their associated MW capacities, for which contracts have been entered into for connection from renewable generation developers seeking access to connection to the transmission and distribution system in the North of Scotland – SHETL's licensed area.

5.5.2 Many of the renewable generation projects are below 5MW in capacity, and could be considered as local generation for local community demand. Such schemes are normally offered connections to the local distribution system, and all those in the above figures have entered contracts to that end. Due to the existing generation in the area, the usual direction of flow of energy, after meeting local demand, is in exporting southwards out of the north of Scotland. Regardless of the point of connection to the system, small generators will contribute to this increased flow of energy, and have an impact on the main transmission system.

5.5.3 The case for the proposed Beauly-Denny Line is based on the increase in renewable generation capacity connecting in SHETL's area. This is associated with a specific group of renewable generation projects, and for which the connection contracts specifically require the Beauly-Denny Line to be completed. In the event of any individual project within this group failing to materialise, the enhanced transmission access capacity would be allocated to another renewable project that is currently subject to both the Beauly-Denny upgrade and a named and subsequent transmission upgrade.

5.5.4 As such, the proposed Beauly-Denny upgrade is independent of the gaining of any planning consent of any individual renewable generation project.

5.5.5 Chapter 3 of the Environmental Statement demonstrated that a number of transmission boundaries on the existing system were at their limit for a connected volume of 1550MW of renewable generation in the SHETL licence area. Consequently, in order to utilise this existing transmission capacity, SHETL has entered into connection agreements with some 1500MW of renewable generation schemes, some of which are already connected, and the remainder of which may connect prior to the Beauly-Denny upgrade.

5.5.6 In terms of renewable generation schemes which have gained planning consents, there is a total of over 1400MW, some of which is either connected or under-construction.

5.5.7 Related scope of evidence will be provided by Brian Punton who will describe the existing SHETL transmission system and address the need to reinforce the transmission system, based on these contracted volumes, in order to comply with the licence requirements to meet the GB SQSS. Evidence will be given that the proposed Beauly-Denny line will accommodate increased volumes of contracted renewable generation. References will be made to Applicants' papers APL-4/3 and APL-4/4.

5.5.8 Furthermore, David Bailey, of SKM consultants, will provide evidence on the cost-benefit analysis which he has undertaken to validate the proposal and to demonstrate that the need to reinforce the transmission system is economically justified in accommodating the contracted volumes of generation.

5.5.9 The volume of contracted renewable generation confirms that there is a pressing demand for an adequate transmission system. The number of generator schemes having entered connection agreements remains substantial.

5.5.10 There is a requirement to proceed with the proposed Beauly-Denny upgrade expeditiously, in order to comply with the Licence requirement to facilitate competition in generation. This requirement is reflected in the contractual requirements with NGET, and so through to developers, to provide connection to contracted generation by an agreed connection date, or by a date as soon as possible thereafter, in the event of planning consents being delayed. 892MW of prospective renewable generation schemes await the completion of the proposed upgrade, and will thereupon be able to connect to the system, and generate into the GB market. In turn, this will allow an increased contribution to be made to the renewable energy targets, both in Scotland and the UK.

6. <u>Future Transmission Development and Access</u>

6.1 In Section 5 of my Precognition, I sought to demonstrate that there is a large volume of renewable generation seeking access to the transmission and distribution systems such that the need for the proposed upgrade is immediately required. The purpose of this section is to show the likelihood of 2.5-3GW of renewable generation being developed in the SHETL Licence area, consistent with the Scottish Executive position and The Highland Council Renewable Strategy. This volume of generation is consistent with the need to develop the Beauly-Denny project.

6.2 I provide evidence on the work which has been undertaken to identify possible future development paths for the north of Scotland transmission system that might be required should further renewable generation develop beyond these levels. I provide evidence on the liaison with the government bodies in this respect, and the arrangements that are in place with OFGEM to approve the funding for further upgrade projects dependent upon the status of renewable generation volumes.

6.3 In providing this evidence I make use of the Applicants' paper entitled 'Future Transmission Development and Access' (Doc. No. APL-4/7).

6.4 I have previously stated that at 31st October 2006, the position for 7,684MW of renewable generation development contracted to connect to the transmission and distribution systems in the north of Scotland was:

i) 627MW of generation capacity was connected

ii) 881MW had accepted an agreement for a connection prior to the Beauly-Denny system upgrade or any other system upgrade

iii) 892MW had accepted an agreement for connection, but await the Beauly-Denny system upgrade, and

iv) A further 5,284MW have entered connection agreements, but await the Beauly-Denny and further system upgrades

6.5 Scottish Executive Targets – Forum for Renewable Development in Scotland

6.5.1 The Scottish Executive’s ‘Forum for Renewable Energy Development in Scotland (FREDS)’ reported on ‘Scotland’s Renewable Energy Potential: Realising the 2020 Target’ (Doc. No. CD-L02). The report concluded that a total of 6GW of renewables would be required in Scotland to meet its 2020 targets. Of this, 1.3GW already exists in the form of established hydro-electric schemes, so that the balance of 4.7GW would come from onshore windfarms or other renewable technologies across Scotland.

6.5.2 The FREDS report also notes that the grid system upgrades and reinforcements currently approved by OFGEM will allow the connection of 2.3GW of new renewable generation in the north of Scotland and 4GW in the south of Scotland. These approved projects include the proposed Beauly-Denny line.

6.5.3 This approved grid capacity will allow up to 2.3GW of the required 4.7GW of new renewable generation to be connected in the north of Scotland. This is in proportion to the volume of applications from developers across Scotland.

6.5.4 Based on the current volumes of prospective renewable generation developments across the north of Scotland, approximately 1,600MW of this 2,300MW total might be expected to locate in the northern part of the SHETL Licence area, i.e. in the Beauly-Denny dependent zone.

6.5.5 These volumes of generation are in excess of the current grid capacity in SHETL's Licence area and reinforcement of the transmission system is required.

6.5.6 Further grid upgrades will depend upon renewable generation developers being able to make sufficient commitment for grid connection, such that funding can be approved by the electricity regulator, OFGEM to SHETL to allow construction of these grid upgrades. In order for developers to be able to make such commitments, it is likely that planning consents for their generation developments will need to be in place. The commitment from SHETL, and OFGEM's approvals, to plan and construct further grid upgrade would then follow.

6.6 The Highland Council Renewable Energy Strategy

6.6.1 The Highland Council published their 'Highland Renewable Energy Strategy and Planning Guidelines' document in May 2006 (Doc. No.CD-G01). The document details the Council's positive stance in supporting renewable energy development. It recognises that these aspirations must be balanced against the environmental concerns around renewable developments, particularly in relation to onshore wind.

6.6.2 "Preferred" development areas have been identified for large-scale onshore wind, and a larger number of smaller "possible" development areas have also been identified, in which large-scale onshore would be considered. Furthermore, other onshore wind development would be supported for local small-scale projects located near settlements or infrastructure.

6.6.3 The Strategy document comments on the requirement for greater transmission system capability to support the greatly increased renewable energy production contemplated. It generally indicates Council support for upgrades being made to existing grid system corridors rather than the creation of new corridors.

6.6.4 Within the Strategy document, the Council has published three scenarios or "visions" of the renewable energy positions they believe may result from application of their development policies. These visions set out their expectations at 2010, 2020 and 2050 and express these expectations in terms of the regional impact of developments and the mix of generation technologies likely to emerge.

6.6.5 In terms of new renewables capacities developed under the Council Strategy, these are predicted as totalling 1.28GW by 2010; 4.0GW by 2020 and 13.2GW by 2050.

6.6.6 The impact of this renewable development is to be considered on the North West transmission circuits. The relevant generation is that which is to be located to the north and west of a notional line from Kinlochleven on the west coast, eastwards to the north of the Errochty in the Tummel valley, and then north-eastwards to Keith.

6.6.7 The Highland Council view of 1,280MW by 2010 is close to the figure of generation connected, under-construction or consented to connect in this northern zone of around 900MW at October 2006, and supports the requirement for Beauly-Denny Line.

6.6.8 In considering the 2020 figure of 4,000MW, a specific offshore wind component of 1,000MW can be excluded from these grid considerations, as this is likely to connect either at, or to the east of, Keith. This produces a reduced figure of 3,000MW of renewable generation by 2020.

6.6.9 It is possible that the 2020 figure of 3,000MW is likely to see some reduction of expected volumes. At this stage, SHETL has not seen any significant applications for the connection of forestry and marine technologies. A reduced expectation for 2020, perhaps in the range of 1,280MW to 2,500MW, fits reasonably well with a Scottish Executive scenario of 2,300MW in the north of Scotland by this date. This range also fits well with the SHETL proposals for the Beauly-Denny Line.

6.7 The Scottish Executive FREDS report recognises a potential contribution of renewable generation from SHETL's licensed area at 2.3GW by 2020, with around 1.6GW of this that might be expected to locate in the northern part of the SHETL Licence area.

6.7.1 An assessment of The Highland Council's 'Renewable Energy Strategy and Planning Guidelines' document, which indicates 3GW in its area by 2020 (excluding offshore wind), leads to an expectation that generation in the range of 1.3GW to 2.5GW might realistically be expected to materialise.

6.7.2 Both of these positions fit well with a scenario of 2.3GW to 3GW of renewable generation being developed in the SHETL licensed area by 2020. This, in turn, is consistent with SHETL & SPT's proposals to develop the proposed Beauly-Denny Line, which would accommodate generation in the range of 2.5GW to 2.8GW dependent upon the specific locations of schemes.

6.8 Initial Identification of Potential Grid Reinforcements – The RETS Study

6.8.1 This next section discusses the potential for future and further transmission system reinforcements, and the conditions under which such upgrades would be committed.

6.8.2 In 2002, the DTI, under the auspices of the Transmission Issues working Group (TIWG), invited the three transmission licensees (Scottish Hydro-Electric Transmission Ltd, Scottish Power Transmission Ltd and National Grid Transco) to develop transmission options for accommodating significant increases in the level of renewable generation in Scotland.

6.8.3 The ‘Renewable Energy Transmission Study (RETS)’ report which forms an annex to the DTI ‘Transmission Issues Working Group – Final Report – June 2003’ (Doc. No. CD-L09) proposed a strategy for transmission network development capable of accommodating three levels of renewable generation in Scotland: 2,000MW, 4,000MW and 6,000MW. The reinforcements proposed a co-ordinated development plan across the GB networks in three additive stages, designed to facilitate the addition of renewable generation, while avoiding unnecessary investment if growth to the full level of 6,000MW failed to materialise.

6.8.4 The first phase of grid development included for SHETL to strengthen the overhead line between Beauly and the Central Belt of Scotland to 400kV operation. Other work in this phase included upgrades in the Argyll & Bute area, and the possibility of strengthening the 275kV Beauly-Dounreay line by adding a second circuit to the existing towers.

6.8.5 The second phase of grid development in the North of Scotland included for the reinforcement to provide a 400kV circuit between Beauly and Keith to the East.

6.8.6 A final phase of the possible developments included for the completion of a 400kV ring around the north of Scotland by uprating existing tower lines on the east side of the region from 275kV to 400kV operation.

6.9 Transmission Investment for Renewable Generation (TIRG) Projects

6.9.1 In 2004, following the TIWG June 2003 report, and as part of the process of making offers for connection to the GB grid system, SHETL revisited the initial study work and identified the transmission upgrades that would be required to accommodate the renewable generation.

6.9.2 SHETL identified grid projects up to a level of providing capacity for around 5.2GW in the north of Scotland. The other transmission licensees have identified further potential grid upgrades in the south of Scotland and the north of England.

6.9.3 Broadly, the identified grid developments, together with the renewable generation that can be accommodated in the north of Scotland are:

	Up to
Existing System	1.5GW
Beauly-Denny 400/275kV Line	2.5GW
Beauly-Blackhillock 275kV Reconductor	3.0GW
Beauly – Keith 400kV Line	3.8GW
400kV Ring Completion	5.2GW

6.9.4 The purpose of these reinforcements is to provide a 400kV ring in the north of Scotland. The ring would run from the Central Belt at Denny to Beauly, across to Keith, Kintore and Tealing, and back to the Central Belt at Westfield in Fife. This 400kV ring would form an upgraded backbone to the north of Scotland system and provide transmission capacity and security for demand and generation in the area. The backbone would also provide the basic grid framework for the collection and harvesting of renewable generation across the whole of the north of Scotland.

6.9.5 In connecting with the strong 400kV grid system in the centre of Scotland, would be able to transfer renewable energy from the north of Scotland to its own demand centres (Dundee, Aberdeen) and also to the demand centres in the Central Belt. Generation in Scotland in excess of its demand requirement can be exported through the 400kV transmission circuits to the north of England. The north of Scotland system would also continue to provide energy transfers from south of the area to its demand centres in the event of low generation outputs in the north.

6.9.6 The operational capacity of the fully-developed system is significant, being based upon the operational preparation for loss of a single circuit. Under this assessment, all other circuits would remain in service and provide one 400kV route to the Central Belt, in parallel with the four 275kV circuits that form the main elements of the North to South transmission capacity.

6.9.7 Further projects in Caithness & Sutherland to utilise the above grid capacities include the proposed second circuit on the existing Beauly-Dounreay 275kV line.

6.9.8 These potential transmission reinforcement projects have been quoted, in the connection contracts to renewable developers, as ‘contingent reinforcements’ which are required to be complete prior to the connection of associated tranches of renewable generation.

6.10 OFGEM – Transmission Investment for Renewable Generation (TIRG) & Transmission Price Control Review (TPCR)

6.10.1 In 2004, OFGEM consulted on the requirement for transmission upgrades to accommodate the potential growth in renewable generation in Scotland, and concluded its views in its paper 'Transmission Investment for Renewable Generation – Final Proposals – December 2004' (Doc. No. CD-L15). A number of identified transmission upgrades were considered by OFGEM and their consultants in respect of their cost effectiveness.

6.10.2 In the north of Scotland, the proposed Beauly-Denny Line and the Inverarnan substation reinforcement in the Argyll & Bute area were both accepted as being cost-effective and categorised as 'baseline' expenditure by OFGEM. Funding arrangements have been set out in SHETL & SPT Licences which cover the financing costs of pre-construction work, Public Inquiry costs and construction.

6.10.3 In addition to the approval for the proposed Beauly-Denny overhead line, OFGEM approved the upgrading of the Anglo-Scottish transmission circuits. The upgrading of these circuits enhances the transfer capacity to England and allows increased generation volumes to contribute to the full GB electricity market. NGET has been in discussion with OFGEM to gain approval for further reinforcements in north-east England, and is developing operational measures to further increase the transfer capability across the Scotland-England boundary.

6.10.4 These grid system developments will enable additional volumes of generation in Scotland to contribute to the GB market both in Scotland and England, including the additional generation which will connect following the completion of the proposed Beauly-Denny line.

6.10.5 Other projects which were considered in the north of Scotland by OFGEM and their consultants for potential funding at this time included a Beauly-Blackhillock (Keith) upgrade and the connection of the Scottish Islands. OFGEM classified these projects as 'Additional' on the basis that there is significant uncertainty as to whether they would be economically viable, until further renewable generation volumes are sufficiently certain and committed to justify them.

6.10.6 In 2006, SHETL has been engaged with OFGEM on the Transmission Price Control Review for the 2007-2012 period.

6.10.7 As part of these discussions, SHETL put forward a scenario for capital investment based on 3GW of renewable being connected at the end of the five-year period to 2012. This scenario was informed by the current volume of consented renewable projects, the accepted connection agreements with developers and the FREDS report on 2020 targets. OFGEM's consultants considered that a more central case would be for the connection of 1.5GW of renewable generation in the five year period.

6.10.8 As part of the Transmission Price Control Review, OFGEM have been developing proposals on the basis for initiating and funding main system reinforcements. Proposals have suggested that the release by OFGEM of funding for a specific grid upgrade project would depend upon the status of the associated tranche of renewable generation projects requiring the increased transmission capacity. In turn this would require the renewable generation projects to be sufficiently well progressed to be able to sign up to a commitment to connect and to pay Transmission Use of System Charges.

6.10.9 In practice, generation developers will be unlikely to make such commitment until they have some certainty of gaining planning consents for their projects.

6.10.10 This provides an important linkage between the development of the renewables in Scotland and the associated development of the transmission system in order to accommodate them.

6.10.11 No further significant system grid reinforcements have been approved by OFGEM, other than the existing authorisations for Beauly-Denny and Inverarnan Substation which were approved as part of the earlier TIRG discussions, in OFGEM's Final Proposals of December 2004.

6.10.12 OFGEM has indicated that the potential grid upgrade projects can be progressed through the preconstruction stages of design and consenting, but no funding will be released for the commencement of construction until sufficient volumes of generation in a region have made the necessary commitments.

6.10.13 In progressing the options for such upgrades, alternative proposals would be assessed, which would include an assessment of routes, including overhead, subsea and underground options.

6.10.14 Furthermore, a demonstration of economic efficiency and need would be required to be made to OFGEM for the proposed grid reinforcement project.

6.10.15 The development of further grid upgrades, beyond the proposed Beauly-Denny line, will depend upon renewable generation developers being able to make sufficient commitment for grid connection, such that funds can be released by the electricity regulator OFGEM to allow construction of these grid upgrades.

6.10.16 Consequently, there would be a close linkage of generation project consents, developer commitment & required grid capacity. These potential grid upgrade projects would be developed in tandem with the development of the renewable generation volumes that require them. The commitment from SHETL to plan and construct further grid upgrades would follow from OFGEM approvals.

6.11 Conclusion

6.11.1 The completion of the proposed Beauly-Denny Line will provide sufficient grid capacity for the connection of 2.5GW to 2.8GW of renewable generation in the SHETL Licence area. This is broadly consistent with the aspirations of the Scottish Executive to see a contribution from renewable generation in the north of Scotland towards a 2020 target of 6GW. It will also provide the additional capacity to connect volumes indicated by developers and The Highland Council aspirations.

6.11.2 Further identified phases of possible grid development would provide a north of Scotland transmission system capable of accepting up to 5.2GW of renewable generation. In progressing the options for such upgrades, alternative proposals would be assessed.

6.11.3 The initiation of these further grid upgrade projects would depend on the consenting of renewable projects sufficient to justify additional grid capacity, and would be based on a close linkage of generation project consents, developer commitment & required grid capacity.

7. ALTERNATIVES

7.1 *Introduction*

7.1.1 A number of alternatives have been identified and assessed in determining that the proposed Beauly-Denny project meets the licence requirements to develop an efficient, co-ordinated and economical system. These alternatives have included underground cable options, the use of HVDC technology, particularly in regard to subsea options, and the development of other tower line routes in SHETL's licence area.

7.1.2 Evidence on the general use of underground cable technology will be provided by Dr Bruce Stedall of PBPower who has undertaken a generic comparison of the use of high voltage alternating current (HVAC) underground cable as an alternative to overhead line, and specific considerations as an alternative to the proposed HVAC overhead line for the transmission interconnection between Beauly and Denny.

7.1.3 Evidence on the general use of high voltage direct current (HVDC) transmission will also be provided by Bruce Stedall who has undertaken a generic comparison of HVDC transmission with HVAC transmission, and with reference to the proposed Beauly-Denny interconnection.

7.1.4 I will provide evidence on the assessments we have made in considering the option of using a HVDC subsea cable. I will make use of Applicants' paper 'The Option of a HVDC Subsea Link', which considers this option in some detail, to bring together the key findings of our assessments.

7.1.5 I will provide evidence on the assessments we have made of the options of developing other HVAC tower line routes in SHETL's licence area.

7.1.6 In assessing these alternatives, I will also provide evidence on the assessments we have made of the requirement to develop the transmission system along the existing Beauly-Bonnybridge route in the absence of the proposed Beauly-Denny upgrade. Such developments would be required to connect existing and contracted renewable generation which is dependent upon the Beauly-Bonnybridge line route for connection and grid system access.

7.1.7 David Bailey of SKM consulting will provide evidence on the cost-benefit assessments that have been made of several of these alternatives.

8 Assessment of HVAC Transmission Line Alternatives

8.1 The requirement to reinforce the SHETL transmission system in order to accommodate increasing levels of renewable generation has been made in the paper entitled 'The Requirement for System Reinforcement' (Doc. No. APL-4/4), as addressed by Brian Punton. The case has been made for the proposal to upgrade the Beauly-Denny transmission line to increase the north to south transfer capacity of the SHETL network into the SPT Licence area.

8.2 I have assessed a number of alternatives to the selection of the Beauly-Denny circuit as the optimum reinforcement, taking into account the immediate requirement to reinforce the network, and also the possible future development of the network.

8.3 In providing this evidence I make use of the Applicants' paper entitled 'Assessment of Transmission Network Requirements' (Doc. No. APL-4/5). A range of possible overhead line upgrade options for a major transmission reinforcement between Beauly and the ScottishPower system to the south have been identified. A number of alternatives have been considered based on developing the existing circuits and routes that run to the east of Beauly and along the east side of the SHETL's licence area. I seek to provide evidence on the case for selecting the Beauly to Denny route as the optimum network corridor to reinforce, as proposed.

8.4 The assessment is based on maintaining the required security and quality of supply for the transmission network to enable the connection of new renewable generation to the SHETL transmission network.

8.5 The object of the assessment was to investigate the different options for transmission system reinforcement, and to determine which option best meets the required security standards, is most economic and efficient, and is co-ordinated with future transmission system needs within the north of Scotland and across the wider GB network.

8.6 The security of the transmission network is determined by the application of the requirements of the GB Security and Quality of Supply Standard (GB SQSS) (Doc. No. CD-L11). This also determines the transfer capacity that can be achieved across the network. As defined in Section 4 of the GB SQSS, the maximum potential transfer capacity for a transmission network boundary is the thermal limit of the boundary circuits taking into account a range of defined fault and outage events on the network.

8.7 The planning standards require that the most onerous loss of a double circuit overhead line, known as the (N-D) contingency, and the most onerous loss of a single circuit line, known as a (N-1) contingency, should be considered when determining the security of the network. Consequently, the most onerous (N-D) condition usually results in the unavailability of the highest capacity tower line.

8.8 The sharing of power flows across the parallel circuits that make up each boundary, are determined by the respective circuit impedances. However, for the purpose of the investigation, the reasoning behind the reinforcement choices can be explained by using a simple approach based on the algebraic summation of circuit capacities crossing a particular boundary.

8.9 The maximum theoretical transfer capacity across each boundary for the loss of a double circuit, the (N-D) contingency, has been determined by summating the thermal ratings of the remaining circuits left in service. In planning the network to the required security standard, the (N-D) contingency defines the maximum power transfer that the existing network (and any proposed future networks) could achieve. In operational timescales, the GB SQSS requires that in Scotland the prevailing system will be secured throughout the year to a single circuit (N-1) fault contingency. However, under adverse weather conditions such as the presence of lightning, the system will be secured in operational timescales for a double circuit (N-D) fault.

8.10 Methodology

The methodology has been to consider the maximum potential transfer capacity for each of the three relevant transmission boundaries. These are the ‘north-west’, ‘north to south’ and ‘SHETL to SPT’ boundaries. This was initially carried out for each boundary in isolation to determine the range of reinforcement options that exist at each location.

8.11 To analyse each reinforcement option, the individual circuit ratings and the (N-D) and (N-1) boundary transfer capacity that can be achieved by each option are identified. These are summarised in the referenced paper (Doc. No. APL-4/5).

8.12 Subsequent analysis considers combinations of reinforcement options to achieve the required transfer capability across all three transmission boundaries for around 3GW and around 5GW of installed renewable generation in the SHETL licence area.

8.13 The approach taken has been to seek to utilise existing overhead line corridors, and to seek to reinforce those routes, before the consideration of completely new overhead line routes where there have been no overhead lines before.

8.14 The substation at Beauly is an important hub on the SHETL system as it marshals a number of 275kV and 132kV circuits and serves to provide the gathering point for the demand and generation in the area. A large proportion of the new renewable generation output will pass through the Beauly substation. Beauly substation therefore was the necessary starting point for all the transmission reinforcement options considered.

8.15 For each of the boundaries, a number of existing overhead tower lines cross the boundary, and their circuits contribute to the boundary transfer capacity. The (N-D) transfer capacity is defined by taking the loss of the tower line with the highest capacity pair of circuits. Across the north-west boundary this is the loss of the Beauly-Blackhillock 275kV line. The sum of the remaining circuit capacities gives the resultant (N-D) boundary transfer capacity.

8.16 For each boundary, a number of reinforcement options were then considered. In the case of the north-west boundary the options included:

The rebuilding of the 132kV Line on the Moray coast;

The rebuilding of the 132kV Beauly-Boat of Garten Line;

The reconductoring of the Beauly-Blackhillock 275kV Line; and

The rebuilding of the Beauly-Denny 132kV Line to a light 275kV specification.

The existing 132kV tower lines cannot be reinforced to provide any meaningful capacity increase, due to the light physical construction and low height of the towers.

8.17 The best increases in transfer capacity were achieved by upgrading the weakest of the cross-boundary lines. Where the capacity of the upgraded line is greater than that of the existing strongest line, the capacity of the latter is added to the boundary transfer capacity. Where the capacity of the upgraded line is still lower than the existing strongest line, the capacity of the upgrade is added to the boundary transfer capacity.

8.18 Conversely, strengthening the existing strongest line provides no capacity increase to the (N-D) contingency, as this remains the line assumed to be lost under double circuit fault outage.

8.19 On the east side of the network, the option of uprating from 275kV to 400kV operation of the circuits on 400kV construction towers merely reinforced the strongest tower line and did not provide any boundary transfer capacity increase under considerations of the (N-D) outage criteria.

8.20 Summary of First Step Reinforcement Options - Conclusions

The summary section of the paper, at 3.13 to 3.15 (Doc.No.APL-4/5), discusses the most effective reinforcement to progress as a first step upgrade which could then become a building block for other possible staged reinforcements if and when they may be required.

8.21 In considering the reinforcement of the Beauly to Denny Route, it is demonstrated that the existing 132kV line between Beauly and Bonnybridge forms the weakest link across all three transmission boundaries.

8.22 It is also demonstrated that the only reinforcement options which provide an upgrade across all three boundaries are the Proposal, comprising the rebuild of the 132kV Beauly to Denny using a 400kV tower construction, and the option to rebuild on the same route but using a lower capacity, lighter duty 275kV tower construction.

8.23 The Proposal provides a high capacity tower line across all three boundaries. The rebuilding of the existing 132kV tower line between Beauly and Denny results in a substantial increase in transfer capacity across all three boundaries and generally provides the best transfer capacities, under both (N-D) and (N-1) criteria, on all three boundaries.

8.24 This new circuit becomes the strongest link across each transmission boundary and becomes the critical outage in determining (N-D) boundary transfer capacity. The full capacity increase of any subsequent network reinforcements will be fully realised, as the Beauly to Denny line is likely to remain as the critical outage. This forms an excellent basis for further development of the transmission network if and when required.

8.25 A lighter 275kV tower construction for the Beauly to Denny route would provide a third 275kV corridor across the North-South and SHETL/SPT boundaries of similar capacity to other existing tower lines on the east. Although this construction would be slightly lower cost than the Proposal, it results in broadly equalising of the capacities of the three tower lines across the North-South and the SHETL/SPT boundaries. This results in the next transmission reinforcement across these boundaries becoming the strongest link and having to be discounted in determining the boundary transfer capacity. No boundary increase is achieved and there is little benefit from the second upgrade. Consequently, a third reinforcement would be required to further increase the boundary capacity beyond that provided by the light construction 275kV Beauly to Denny option in the first stage.

8.26 Options which avoid rebuilding on the Beauly-Denny route requiring development of the Moray coast and east coast reinforcement alternatives. Considering the NW boundary, there are two options to the east of Beauly which provide a significant increase in the boundary (N-D) capacity. These involve rebuilding one of the existing transmission lines to the east of Beauly, between Beauly and Keith/Blackhillock, either along the Moray coast, through Elgin and Nairn, or through Boat of Garten. However, these reinforcements provide no increase in the North-South or SHETL/SPT boundaries. Consequently they must be considered in conjunction with other east coast reinforcement options for these boundaries.

8.27 For the North-South boundary the rebuild of the Kintore to Tealing 275kV tower line is the best first step east coast reinforcement alternative. However, this option provides only a modest increase in (N-D) capacity compared to the Proposal. The option of building a completely new tower line between Kintore and Tealing has been discounted due to the availability of existing tower routes which could be utilised to provide the boundary transfer increase.

8.28 For the SHETL boundary, as with the NS boundary, the east coast tower routes provide limited transfer capacity increases as first step reinforcements. The best option is the building of a new tower line between Tealing and Kincardine to increase this boundary capacity as a first step east coast reinforcement, but has the disadvantage of requiring a new and additional transmission route.

8.29 Combining the reinforcement options starting from Beauly and proceeding towards the east coast requires the rebuilding of one of the existing tower routes between Beauly and Keith/Blackhillock (100km). In addition, the rebuild of the Kintore to Tealing tower line (100km) and the build of a new tower line between Tealing and Kincardine (100km) will also be required. The cost of proceeding with reinforcement on this basis is estimated at £520M compared to £350M for the Proposal. It also involves rebuilding around 300km of new tower lines compared to 220km of new build on the Beauly to Denny route.

8.30 In addition the (N-1) boundary capacities provided by an east coast reinforcement route are significantly less than the Proposal and would result in increased operational constraints.

8.31 In considering the optimum reinforcement, it has been concluded that a reinforcement of the Beauly-Denny route incurs least investment, involves tower line builds of lower overall length, and provides the best increase in boundary transfer capacities.

8.32 Combining Reinforcement Options to Optimise Future Transfer Capacity

8.33 In selecting an optimum first stage reinforcement, it is important to consider the possible future development of the transmission system in conjunction with subsequent reinforcements and to ensure that the system can be developed in the most cost-effective, efficient and coordinated way. This is particularly relevant since there are over 7.5GW of contracted renewable generation seeking connection in the SHETL area. Progressing with a first step reinforcement which is then required to be dismantled and rebuilt in the foreseeable future, or which leads to significant stranding of transmission plant is to be avoided.

8.34 I have looked at the possibility of connecting initially around 3GW, and then around 5GW, of renewable generation onto the SHETL network. The transmission network would be required to have boundary capacities capable of accommodating the predicted power transfers. Based on the pattern of renewable generation that has already contracted to connect to the SHETL network, the required boundary transfer capacities have been identified and are summarised in Table 3-9 of the paper (Doc. No. APL-4/5).

8.35 While there are a number of options which can meet the required capacity on the NW boundary, the only reinforcement options on the North-South and SHETL/SPT boundaries which satisfy these transfer capacities involve the rebuild of the weak 132kV Beauly to Denny route or the construction of new east coast 275kV or 400kV overhead lines.

8.36 Comparing the required boundary transfer capacity for 5.4GW installed renewable generation with the boundary transfer capacities provided by each reinforcement shows that, whatever the choice of first step reinforcement, additional reinforcement options are required.

8.37 Taking the Proposal as the first stage, to meet the required boundary transfer for 5.4GW of renewable generation, the option to rebuild one of the existing tower routes between Beauly and Keith/Blackhillock is required. Although the North-South boundary is just satisfied by the Proposal, the SHETL/SPT boundary also requires further reinforcement. In this case, the addition of the reinforcement of the existing line between Kintore, Tealing and Kincardine by re-insulating the line and operating at 400kV provides a significant increase in the North-South and SHETL/SPT boundaries.

8.38 Taking the option to rebuild the Beauly to Denny Line using the lighter 275kV construction as the first stage, indicates that additional east coast reinforcements are required to meet the required boundary transfers for 5.4GW of renewable generation. This is because the introduction of the 275kV L3 option produces three transmission corridors on the North-South and SHETL/SPT boundaries of similar capacity. Consequently, the next reinforcement, in this case the upgrade of the Kintore/Tealing/Kincardine line to 400kV operation, produces no North-South or SHETL/SPT boundary transfer increase. As a result it has been necessary to introduce further reinforcements on the North-South and SHETL/SPT boundaries to achieve the required increase in the boundary capability. Compared to the Proposal there is an additional 100km of new tower line rebuild and a substantial increase in the overall investment.

8.39 Taking the option of avoiding a rebuild on Beauly-Denny route by reinforcing the Beauly to Keith/Blackhillock route as the first stage reinforcement, further reinforcement across the NW is required for the 5.4GW of generation scenario. Some additional benefit can be obtained by reconductoring the existing Beauly to Blackhillock 275kV line. However this is not sufficient to meet the required transfers for the 5.4GW scenario.

8.40 Additional reinforcement could involve another rebuild of one of the remaining routes between Beauly and Blackhillock or indeed the rebuild on the Beauly to Denny route.

8.41 In the absence of a Beauly-Denny upgrade, the North-South boundary requires the rebuild of the Kintore to Tealing line for the 3.2GW generation scenario. However additional reinforcement in the form of upgrading the Kintore, Tealing, Kincardine line to operate at 400kV is required to satisfy the required transfer levels for the 5.4GW generation scenario. On the SHETL/SPT boundary, whilst a new tower route is required between Tealing and Kincardine to provide sufficient capacity for the 3.2GW scenario, the addition of the 400kV upgrade of the Kintore, Tealing, Kincardine line as required for the North-South boundary provides the required capacity required for the 5.4GW scenario.

8.42 Significant harvesting of generation is likely to be required along the Beauly to Denny route requiring reinforcement of this route irrespective of the choice to proceed with east coast reinforcement alternatives. If an east coast reinforcement path was to be selected then the least cost works to harvest the generation along the Beauly to Denny route, estimated at £175M, is likely to be required.

8.43 Compared to the Proposal, this sequence of reinforcements again results in an extra 100km of new line build and substantially more investment.

8.44 The three basic approaches to achieving a system capable of accommodating 5.4GW in the future comprise the following first stages:

The proposal to rebuild Beauly-Denny to 400/275kV operation, at an overall cost of £668M;

The option of building Beauly-Denny to a light 275kV specification at an overall cost of £883M; and

The option of avoiding the Beauly-Denny route by rebuilding along the Moray coast and on the east coast, at an overall cost of at least £963M.

8.45 Conclusions

8.46 In conclusion, we have identified and assessed a range of options for overhead line reinforcement between Beauly and the ScottishPower system. We have compared the reinforcement options as a first step upgrade and then as a combination of reinforcements to meet the network boundary transfers associated with 5.4GW of installed renewable generation.

8.47 In comparing the different reinforcement alternatives, I have identified that the option to rebuild the Beauly to Denny route as a 400kV tower line (the Proposal) has the following key advantages:

It provides the lowest overall investment path, both as a first step reinforcement and as the basis for phased development of the transmission system to accommodate up to 5.4GW of renewable generation.

The option to rebuild the Beauly to Denny route with the lighter 275kV construction ultimately leads to more overhead line construction and substantial additional investment to meet the same required boundary transfer capability.

8.48 There is less new tower line build by starting with the Proposal compared to reinforcing the system on an east coast alternative.

8.49 It allows development of the system without stranding of transmission system assets.

8.50 The Proposal presents the best economic, efficient and coordinated development strategy for the SHETL transmission system.

8.51 On the basis of these assessments, and to meet the transmission licence obligations of SHETL, the alternatives of developing other tower circuits or routes have been discounted in favour of the proposal.

<u>9 Consideration of the Connection of Generation along the Beauly-Denny Corridor</u>

9.1 The existing Beauly-Bonnybridge 132kV tower line forms an integral element of the SHETL Main Interconnected Transmission System, and so plays an important role in enabling the north-south flows of power from the existing generation in the north of Scotland. It also provides system security for the demand centres along the route, including Fort Augustus, Skye & Lochaber, and transmission system access for existing generation in those areas and along the route corridor, including Fasnakyle, Errochty and Braco.

9.2 I provide evidence on the considerations we have made of the transmission system reinforcements that would be required to connect the existing contracted generation along the Beauly-Denny route corridor.

9.3 The proposed Beauly – Denny line reinforcement, in addition to providing an increased north-south transfer capacity between the SHETL and SPT transmission systems, will also improve the system security for the demand centres along the route and transmission system access for existing and future generation along the route corridor and in surrounding areas.

9.4 A significant amount of new renewable generation is seeking to connect in a broad area in the southern and western regions of the Highland Council area, including Lochaber & Skye. Utilising the existing transmission circuits in the region, the generation will require to export its energy onto the proposed Beauly-Denny line at Fort Augustus. Renewable generation connecting further to the south would need to export energy onto the line at Errochty or Braco.

9.5 This generation forms part of the contracted generation which increases the north-south flows on the SHETL system, and contributes to the requirement for its reinforcement. In considering the alternatives to the current 400/275kV overhead line proposals for the Beauly – Denny reinforcement, such as a HVDC reinforcement or an overhead line reinforcement along a different route corridor, there would remain a requirement for SHETL to provide transmission system access to the generation along the Beauly – Denny route corridor would need to be satisfied by complementary reinforcements.

9.6 A number of options have been considered for these possible reinforcements along the Beauly – Denny route corridor and have been outlined, costed and assessed in the SHETL paper ‘Consideration of the Connection of Generation along the Beauly-Denny Route Corridor’ (Doc. No. APL-5/12).

9.7 The costs detailed in the paper for the connection or ‘harvesting’ of generation along the Beauly – Denny corridor have been considered in evaluating the provision of any alternative transmission system reinforcement which does not reinforce the existing Beauly-Bonnybridge line. These alternatives include the reinforcement of the east costs transmission circuits or HVDC links.

9.8 Such alternatives have been considered in more detail in the Applicants’ papers ‘Assessment of Transmission Network Requirements’ (Doc. No. APL-4/5), and ‘Cost-benefit Analysis of the Beauly-Denny Proposal and alternative reinforcements, SKM’ (Doc. No. APL-4/6), and later in my precognition in considering the option of a HVDC subsea link.

9.9 The paper ‘Consideration of the Connection of Generation along the Beauly-Denny Route Corridor’ (Doc. No. APL-5/12) considers the limitations of the existing SHETL/SPT transmission system along the Beauly – Denny route corridor, the key features of the proposed Beauly-Denny line, the existing and contracted generation along the corridor, the key requirements for the connection of that generation and the options for the connection of that generation in the absence of the proposed line.

9.10 A summary of the levels of existing and contracted renewable generation in the region is given in Table 4.1.1 of the paper.

9.11 Some 438MW of generation already exists in the area and a further 970MW is contracted to connect. This totals 1408MW of renewable generation. This excludes the potential for small scale schemes which may be developed as community projects along the coastal settlements of Lochaber and Skye.

9.12 Highland and Perth & Kinross Council Regions

The Highland Council has recently published ‘Highland Renewable Energy Strategy and Planning Guidelines, May 2006’ (Doc. No. CD-G01) which includes details of zones of preferred and possible development for both major onshore wind farms and for local scale onshore wind farms.

9.13 The proportion of the identified zones which are considered to be dependent on the transmission circuits on the Beauly – Denny route corridor for access to the SHETL, and wider GB transmission system, are indicated in Figures 4.2.1.1 and 4.2.1.2 of the referenced paper (Doc.No. APL-5/12), which are based on the Figures 6.2.4 and 6.2.7 of the Highland Council report.

9.14 It is evident from the figures that both major and local scale onshore wind farm development within the western and southern regions of Highland Council's area would be dependent on the Beauly – Denny transmission circuits for grid access.

9.15 The Highland Council report recognises the importance, and supports development, of the existing Beauly – Denny route corridor, with any such developments taking consideration of routing and construction method improvements to reduce the potentially negative impacts of such a development. The generation connection options considered in the paper APL-5/12 minimise the extent of any new overhead line routes that would be required by the rebuilding of existing circuits and/or the use of underground cable for any additional/new circuits.

9.16 Furthermore, it is evident that the areas of search within the western and southern regions of Perth and Kinross Council's area would be dependent on the Beauly – Denny transmission circuits for grid access.

9.17 Capabilities of Existing 132kV Circuits

The construction of the existing 132kV Beauly-Bonnybridge circuits limits the circuits to a rating of 132MVA with no options to upgrade this rating via the use of larger conductors and/or re-insulation of the line to a higher voltage level.

9.18 Both the levels of existing and contracted generation along the route of the Beauly – Denny (Bonnybridge) and the current and predicted levels of North – South power transfer from Beauly are in excess of the capabilities of the existing 132kV circuits.

9.19 As a short term solution to the overloading of the Beauly – Denny (Bonnybridge) circuits, Phase Shifting Transformers (PST) have recently been installed at Errochty on the Fort Augustus – Errochty circuits to limit the North – South flows on the circuits and prevent overloading of the Braco – Bonnybridge (Denny) section of the circuit.

9.20 However, recent operational experience indicates that these Phase Shifting Transformers will soon reach their operational limitations due to the increasing volume of generation being connected both on the route and to the north of Beauly.

9.21 The long term solution to overcome the limitations imposed by the capacity restrictions of the existing 132kV circuits from Beauly is to provide additional capacity in the form of circuit reinforcement along the Beauly – Denny route corridor since this would enable the generation on route to connect.

9.22 The proposed Beauly – Denny overhead line proposal provides reinforcement of the route corridor such that it enables both the connection of the increased levels of that generation along the route and provides increased North – South transfer capacity between SHETL and SPT.

9.23 The key features of the Beauly – Denny proposal in relation to connection of the generation and demand on its route corridor are relevant.

- Demand centres at Fort Augustus and Braco are secured against both single and double circuit outage conditions with the capability to be supplied from the north and the south.

- Generation connections along the Beauly–Denny route corridor would have full network access under both single and double circuit outage conditions without system overloads arising.

- Nominal flow to the south of generation on the route avoids the need for additional transfer capacity from Beauly.

9.24 Eleven options for reinforcement of the Beauly – Denny route corridor were identified and considered on the general basis of:

- Rebuilding the existing 132kV overhead line circuits with increased capacity 132kV or 275kV overhead line circuits; or
- Retaining the existing 132kV overhead line circuits and installing additional 132kV underground cables in parallel; or
- Retaining the existing 132kV overhead line circuits and installing parallel connected HVDC underground circuits.

9.25 A summary of the reinforcement options considered against the key requirements, together with their capital cost estimates, was given in Table 2 of the report, and is shown below:

Option	Cost (£M)	Demand Secure	Circuit Overloads Under Outage	Normal Beauly - Fort Augustus Generation Flow	Increased SHETL-SPT North - South Transfer Capability
1 New 275kV Overhead Line Along Full Route	£ 300	YES	NO	South Towards SPT	Significant
2 New 132kV Overhead Line Along Partial Route	£ 130	YES	YES	North Towards Beauly	No
3 New 132kV Overhead Line Along Full Route	£ 175	YES	NO	South Towards SPT	Limited
4 New 275/132kV Overhead Line Along Full Route (S)	£ 220	YES	NO	South Towards SPT	Limited
5 New 275/132kV Overhead Line Along Full Route (N/S)	£ 295	YES	NO	South Towards SPT	Limited
6 New 275kV/132kV Overhead Line Along Partial Route	£ 170	YES	YES	North Towards Beauly	No
7 New 132kV Overhead Line Along Partial Route (Beauly - Fort Augustus - Foyers Ring)	£ 175	YES	NO	North Towards Beauly	No
8 New 132kV Cables Along Partial Route	£ 260	YES	NO	North Towards Beauly	No
9 New 132kV Cables Along Partial Route (Beauly - Fort Augustus - Foyers Ring)	£ 270	YES	NO	North Towards Beauly	No
10 HVDC (Single) at Fort Augustus and Errochty	£ 320	YES	YES	North Towards Beauly	No
11 HVDC (Dual) at Fort Augustus and Errochty	£ 390	YES	NO	North Towards Beauly	No

Table 2: Comparison of Options Against Key Requirements

9.26 Conclusions

A number of conclusions were drawn from the consideration of transmission system reinforcements that would be required to connect the existing and contracted generation levels along the Beauly – Denny route corridor in the absence of the proposed Beauly-Denny line.

9.27 The transmission circuits along the Beauly – Denny route corridor would provide grid access for both major and small scale renewable generation in the Southern and Western areas of both Highland Council and Perth & Kinross Council regions, and would be consistent with preferred and possible areas of development.

9.28 The existing 132kV rated circuits on the Beauly – Denny route corridor do not have sufficient capacity to accommodate the contracted volume of generation.

9.29 A number of overhead, underground and HVDC reinforcement options were considered to meet the key requirements of meeting demand security, ensuring no circuit overloads under outage conditions, providing nominal flow of generation to the South and, if possible, increasing the SHETL/SPT North – South transfer capacity.

9.30 Several options would be feasible, but a number would result in the northwards flow of generation towards Beauly which would reduce the transfer capacity available for generation to the north of Beauly. For others the increased north-south transfer capacity would be limited due to the limitations in their circuit capacities.

9.31 Of the viable options identified, the option which would represent the most economic and efficient scheme for the connection and transfer south of the existing and contracted generation on the Beauly – Denny route corridor would be the rebuilding of the complete existing 132kV route from Beauly to Denny (Bonnybridge) with 132kV L7 towers at a estimated cost of £175M.

9.32 If the volume of generation seeking to connect along the Beauly – Denny route corridor was to increase above the current contracted levels then reinforcement options based on the use of 275kV L3 towers along the partial or complete route would need to be considered. The estimated costs would range from £220M to £290M dependent on the extent of 275kV reinforcements required.

9.32 The considerations for increased transmission capacity along the Beauly-Denny corridor recognise that the SHETL transmission system is predominantly based on the east side of the licence area. The proposed Beauly-Denny line upgrade provides increased north to south transfer capacity for the whole system. However, it also provides an efficient means for facilitating the connection of renewable generation, and the gathering of the output of that generation across a wide region on the west side of the SHETL licence area.

9.33 The costs detailed in the paper for the connection or ‘harvesting’ of generation along the Beauly – Denny corridor have been considered in evaluating the provision of any alternative transmission system reinforcement which does not reinforce the existing Beauly-Bonnybridge line. These alternatives include the reinforcement of the east coast transmission circuits or HVDC links.

10. The Option of a HVDC Subsea Link

10.1.1 We have considered the option of an HVDC subsea cable as an alternative to the proposed Beauly-Denny scheme. This is one of a number of alternatives that have been considered, including those of upgrading on the AC tower line circuits on the east of the SHETL Licence area.

10.1.2 Evidence on the general use of high voltage direct current (HVDC) transmission will be provided by Bruce Stedall who has undertaken a generic comparison of HVD C transmission with HVAC transmission system, including the use of HVDC subsea cables. Applicants' paper Doc.no.APL-5/15 is relevant to this evidence.

10.1.3 We have compared the reinforcement options in terms of power system benefit across the Northwest transmission boundary. We have considered the option of a HVDC subsea cable by defining and comparing three options for reinforcing the circuit capacity across the Northwest transmission boundary that cuts across the existing circuits emanating from Beauly to the south:

a) The Beauly-Denny reinforcement as proposed;

b) A lower rated (lighter construction) overhead line reinforcement on the same route; and

c) A subsea 1.2GW HVDC cable reinforcement.

10.1.4 For the subsea HVDC reinforcement option we have identified four variations running to Hunterston, Cockenzie, Teesside and Deeside. The options have been assessed with reference to defined objectives for the reinforcement.

10.1.5 System benefit is calculated in terms of improvements to transfer capacity across that boundary for the three reinforcement options. It is shown that the Beauly-Denny reinforcement as proposed provides an increase in operational boundary capacity of over four times that provided by a single 1.2GW HVDC submarine cable link. Moreover the cost of the Beauly-Denny reinforcement is around 20% lower than the lowest-cost option of the HVDC link alternatives (that is, to Hunterston).

10.1.6 It is also noted that additional mainland ac reinforcement costs are attributable to the subsea HVDC options because HVDC subsea schemes are unable to connect generation along the Beauly-Denny route.

10.1.7 Sinclair Knight Merz (SKM) valued the costs of transmission reinforcement against the energy constraint costs before and after those reinforcements, in order to identify the optimum reinforcement option. It is demonstrated in Applicants' paper 'Cost-benefit analysis of the Beauly-Denny proposal and alternative reinforcements' (Doc.No.APL-4/6) that the option of providing a single HVDC link from Beauly to the south, in order to reinforce the northwest transmission boundary, results in a Net Present Value (NPV) of some 70% more expensive than the proposal. David Bailey of SKM consulting will provide evidence on the cost-benefit assessments that have been made of HVDC subsea alternatives.

10.1.8 I will make use of the Applicants' paper entitled 'The Option of a HVDC Subsea Link' (Doc.No.APL-5/18), which considers this option in some detail, to bring together the key findings of these assessments.

10.1.9 It is will be shown that the Beauly-Denny reinforcement as proposed provides the largest amount of system benefit for the lowest investment and capitalised constraint costs.

10.1.10 A number of objectives of a transmission system reinforcement are met by the proposed rebuilding and upgrading of the Beauly-Denny line. They include:

a) Developing a mainland transmission system which is capable of matching the geographically dispersed locations of renewables – the harvesting of onshore renewables;

b) Increasing the transmission strength of existing ac (alternating current) system, particularly across the North-West boundary, and North to South generally;

c) Transferring renewable generation to Central Belt of Scotland to meet Scottish Executive targets for 40% of Scotland's energy to be sourced from renewable energy;

d) Meeting contractual agreements with developers to connect renewable generation, and so meet the associated Transmission Licence obligations of Scottish Hydro-Electric Transmission Limited (SHETL);

e) Developing the transmission system incrementally in order to match the development of renewable generation capacity, so avoiding the risk of stranding assets;

f) Looking to the potential future development of the grid system

10.2 The Use of HVDC Systems

10.2.1 The PBPower Report on 'A Generic Comparison of High Voltage Direct Current (HVDC) transmission with AC transmission, with reference to the Proposed Beauly-Denny Interconnection' (Doc.No.

APL-5/15) considers the alternatives of HVDC systems including HVDC overhead lines, land cables and subsea cables.

10.2.2 In consideration of where AC overhead lines are utilised, it states that *'The transmission of electrical energy worldwide is primarily based on AC overhead line technology. Some 97% of the onshore extra high voltage electricity transmission network in Europe is of AC overhead line construction, with 3% being underground cable. AC overhead line transmission prevails, primarily because it represents the best value approach to establishing and maintaining an electrical power grid. The use of AC provides for future flexibility, as it allows for easy transformation between voltage levels, as used for different transmission and distribution duties'.*

10.2.3 The SHETL 132kV & 275kV transmission system is predominantly an AC overhead network, with cable section representing only 1% of the network length.

10.2.4 In respect of where and when HVDC systems might be deployed, the PBPower report states that *'HVDC is a proven technology and provides an important solution to some transmission problems. However, at an installed worldwide capacity of about 70GW, and with just 70 projects in service to date, it is a tiny fraction of the overall power transmission capacity. Nevertheless, HVDC can provide the most economic solution when electrical energy has to be transported between two points which are electrically far from each other'.*

10.2.5 Subsea HVDC cable circuits are generally used to cross sea where transmission links across land is not possible and where the combination of the power to be transmitted and the distance is too great for HVAC subsea cables.

10.3 Costs of HVDC Subsea Links

10.3.1 The PB Power Report (Doc.No. APL-5/15) derives an illustrative capital cost for a 220km 1.2GW HVDC subsea link of around £300M and compares it to an illustrative cost of around £125m for an overhead line of similar capacity. The difference is due to the cost of AC/DC convertor equipment required at each end of a DC link, and the costs of manufacturing and installing the subsea cable as described in that report.

10.3.2 In respect of a subsea link alternative to the proposed Beauly-Denny 400kV AC overhead line, there are several route options that can be considered to transfer power from the north of Scotland to locations further south. As the main requirement for the reinforcement is to provide transmission capacity to relieve the North-West boundary on SHETL's transmission system, the northerly location would be at Beauly Grid substation. Options for the south location include Cockenzie and Hunterston, and Teesside or Deeside for locations in the north of England.

10.3.3 Cockenzie and Hunterston options provide links from Beauly to the Central Belt of Scotland integrating with the strong 400kV & 275kV transmission system there, and forms a direct alternative to the proposal for connecting into the Central Belt system at Denny. Teesside or Deeside options further increase the distances, but connect into strong parts of the transmission system in the north of England.

10.3.4 Estimated distances and costs for a 1.2GW HVDC link for these options are:

Option	Subsea Distance (km)	Land Distance (km)	Estimated Cost (£M)
Beauly-Hunterston	163	100	425
Beauly-Cockenzie	380	15	465
Beauly-Teesside	480	15	555
Beauly-Deeside	430	90	645

10.3.5 The cost of the Beauly-Denny reinforcement is around 20% lower than the lowest-cost option of the HVDC link alternatives (that is, to Hunterston).

10.4 The Requirement to Harvest Generation on the Beauly-Denny Route

10.4.1 One of the fundamental objectives of reinforcing the north of Scotland transmission system is to develop a mainland system which is capable of matching the geographically dispersed locations of renewables.

10.4.2 HVDC technology is fundamentally a point to point transmission option, where there is no requirement to collect generation at intermediate points along the route length.

10.4.3 The Applicants' paper entitled 'Consideration of the Connection of Generation Along the Beauly – Denny Route Corridor' (Doc.No. APL-5/12) considers the requirement for the reinforcement of the existing Beauly-Bonnybridge 132kV overhead line to accommodate the contracted generation in the area of collection and along the route. As this is the only transmission link in the area, it collects generation from Kinlochleven eastwards to the Tummel valley, and northwards to Fort Augustus and Fasnakyle to the south of Beauly, and includes the areas of Lochaber and Skye.

10.4.4 The alternative of a subsea link fails in itself to harvest this contracted generation, and would require the additional reinforcement of the existing Beauly-Bonnybridge overhead line to accommodate the generation. The paper identifies the reinforcement costs associated with this required upgrade, and this cost needs to be taken into account in assessing the comparative costs of the subsea link option.

10.5 Providing Capacity and Constraint Relief

10.5.1 Basic Costs of Providing Circuit Capacity

10.5.1.1 In terms of providing basic circuit capacity, AC overhead lines are significantly lower cost than cabled alternatives. Overhead lines would expect to be used when practical and acceptable, and in preference to other alternatives such as land or subsea cable links or HVDC schemes.

a) The two circuits of the proposed Beauly-Denny line over a route length of 220km provide a combined rating of 4740MVA for £350M, representing a unit £335/MW.km.

b) A Beauly-Denny 275kV line of lower capacity (lighter construction) provides 1620MVA of rating for £290M representing a unit cost of £810/MW.km.

c) A 395km 1.2 GW HVDC subsea link provides 1.2GW of rating for £465M (excluding harvesting costs and the cost of dynamic reactive compensation at Beauly) representing a unit cost of £980/MW.km.

10.5.1.2 The higher capacity AC overhead line provides far better value in the establishment of additional circuit rating south of Beauly, and in unit terms is at least around three times cheaper than the HVDC link, even before taking into account the additional harvesting and compensation costs.

10.5.1.3 The PB Power report describes how HVDC technology comes into its own in certain applications where it represents the best and cheapest solution and also derives unit costs from a range of optimal applications for AC and HVDC technologies that demonstrate a cost ratio of at least 4 to 1 for generic HVDC submarine cable technology compared to generic onshore AC overhead line.

10.5.2 Planning Capacity - Relief of NW Boundary.

10.5.2.1 The main requirement for system reinforcement is to provide increased transmission system capacity across the North-West boundary, to the south and east of Beauly.

10.5.2.2 We have considered in the paper, for capacity planning purposes, the additional capacity which can be accommodated as a result of a system reinforcement. The additional capacity that is created across the system boundary is dependent on the total capacity of all circuits crossing it, reduced to allow for the most critical outage under winter conditions. For overhead lines, this is normally the loss of the largest capacity double circuit line. Where a cable link forms part of the parallel paths across the boundary, this critical outage can be that of the largest single cable circuit.

10.5.2.3 The three basic options have been considered again:

a) The proposed Beauly-Denny double-circuit 400/275kV line (4740MVA);

b) A double circuit 275kV line of lower capacity (1620MVA);

c) A single 1.2GW HVDC circuit cable from Beauly (1200MW)

10.5.2.4 For the North-West boundary, the addition of any of these options provides the largest circuit or circuit pair across the boundary, and increases the remaining boundary transfer capacity by around 1GW. The benefit of all the options is that the capacity of the circuit which was previously the critical outage, that of the 1050MW Beauly-Blackhillock 275kV double-circuit line, is now available to be added to the total boundary transfer capacity.

10.5.2.5 For the option of the single circuit cable from Beauly, and in respect of the North-West boundary, it is immaterial where the southern landing point is located, provided it is south of the SHETL boundary.

10.5.2.6 The transfer capacity for the overhead line upgrades increases to 1446MVA. For a 1.2GW cable link the capacity increases slightly further to 1710MVA, as a result of being able to use the 264MVA capacity of the existing Beauly-South line.

10.5.2.7 The benefit of providing the additional capacity of the Beauly-Denny proposal, and in the additional cost above the lower capacity overhead line, is seen as further upgrades to the boundary become necessary. The full capacity of these further upgrades adds directly to the boundary transfer capacity.

10.5.3 Operational Capacity – Relief of Constraints

10.5.3.1 For operational purposes, an assessment is made of the system capacity which can be used on a daily basis. This operational capacity across the system boundary is dependent on the total capacity of all circuits crossing it, reduced to allow for the contingency of losing the most critical single outage. Single circuit outages are used for both overhead lines and for cabled circuits, under normal weather conditions.

10.5.3.2 The increase in capacity provides relief of the number of occasions, and the extent to which, generators may be required to be constrained off by NGET, as the GB System Operator, in order to maintain a safe operation of the system. A greater increase in boundary transfer capacity will reduce the level of energy constrained off the system for a given level of connected generation.

10.5.3.3 Considering the three basic options to increase the existing operational boundary transfer capacity of 1185MVA;

a) The proposed Beauly-Denny double-circuit 400/275kV line of 4740MVA capacity, produces a new equivalent capacity summation of 3376MVA,

b) A double circuit line with a lower capacity of 1620MVA, produces an equivalent capacity summation of 2256MVA, whilst

c) A single circuit cable of 1.2GW capacity produces an equivalent capacity summation of 1710MVA.

10.5.3.4 For the HVDC link, the operational capacity is only increased by one of the single circuits on the Beauly-Blackhillock 275kV line, at 525MVA. The system must be operated such that it can withstand the loss of the cable link, such that energy flows on the remaining circuits do not cause dangerous overloads, or subsequent loss of further circuits. This increase in capacity is not significantly greater than the existing system, and can be expected to provide little constraint relief for the renewable energy, compared to the other options.

10.5.3.5 The lower capacity Beauly-Denny 275kV overhead line provides a greater capacity increase, at 1071MVA, than the HVDC subsea link, because in addition to the availability of the Beauly-Blackhillock 275kV circuit, a further circuit of 810MVA capacity is available on the Beauly-Denny line itself.

10.5.3.6 The proposed Beauly-Denny line provides a significantly greater capacity increase, at 2191MVA, than either of these options, because its 275kV circuit provides a significant increase of additional capacity. This additional capacity is of value both in the immediate phase of generation connection, and in any subsequent phases of renewable generation development which requires further grid upgrades.

10.5.3.7 It is shown that the Beauly-Denny reinforcement as proposed provides an increase in operational boundary capacity of over four times that provided by a single 1.2GW HVDC submarine cable link.

10.6 Economic Constraint Analysis

10.6.1 National Grid Electricity Trading (NGET), as GB Grid System Operator (GBSO) is required to balance the volumes of generation seeking to use and access the GB transmission system with the demand on a continuous basis. In so doing, it must ensure that the system is operated to safe limits, allowing for contingency of a loss of a critical transmission circuit, and taking account of the planned outages on the network.

10.6.2 In order to achieve its objectives, NGET must constrain generation in an area when generation volumes seeking access to the system are in excess of the capacity of the system in that area. NGET may incur costs in compensating the generator for loss of opportunity, and may then have to buy energy from other generators on the other side of a boundary constraint, perhaps in England, in order to match the generation/demand balance.

10.6.3 The annual costs of constraining and buying replacement energy faced by the GBSO, provides a signal for when capital investment is justified to relieve the volume of constraints by reinforcing the transmission system and increasing the transfer capacity across a boundary.

10.6.4 SKM Consultants undertook work for OFGEM (Doc.No. APL-L16) to evaluate the cost-benefit analysis of the proposed Beauly-Denny line. SKM have updated this work, and have also assessed the cost-benefit analysis of alternative upgrades (Doc.No.APL-4/6). These alternatives included HVDC subsea links, and the work assessed the constraint costs.

10.6.5 The approach used in the assessment is to consider, not only to balance the constraint costs with the capital cost of each of the alternatives, but also to assess the remaining system constraints in order to calculate the true cost and merits of each reinforcement alternative.

10.6.6 In making this assessment, the additional costs of £175M for the necessary generation harvesting works on an overhead line basis along the Beauly-Denny route, provides the total option costs to reinforce the Northwest boundary as shown in Table 3 below. The costs exclude dynamic reactive compensation costs of some £36m for each option.

Table 3: Comparison of Costs, including associated Harvesting Costs

Option	Subsea Distance (km)	Land Distance (km)	Estimated Cost (£M)
Beauly-Hunterston	163	100	600
Beauly-Cockenzie	380	15	640
Beauly-Teesside	480	15	730
Beauly-Deeside	430	90	820

The lowest of these subsea options at £600M is some £250M more expensive than the proposed Beauly-Denny Line at £350M.

10.6.7 We have taken the Beauly-Hunterston route as the lowest capital cost option of these alternatives in assessing it against the proposal. Table 2 in the SKM report (Table 4 here, see below) shows the installed wind capacity at which the avoided costs of constraints and reduction in losses match the capital cost of reinforcement option, i.e. when the capitalised difference in annual costs matches the capital cost of the reinforcements. The table also shows the annual energy costs of constrained generation and losses that will be incurred in the period leading up to the time that the reinforcement is justified.

Table 4: Table 2 of SKM report: Assessment of Alternatives – Capital and Annual Constraint Costs

Reinforcement Option	Capital Cost (£M)	"Break-even Wind Capacity" (MW)	Annual Constraint Cost (£M)
Proposed Beauly-Denny Line	350	878	42
Beauly-Denny Light 275kV	290	861	40
1 x 1.2 GW HVDC (Beauly-Hunterston) incl. harvesting	600	1,268	89
2 x 1.2 GW HVDC (Beauly-Hunterston) incl. harvesting	1,025	1,457	120

10.6.8 However, this approach on its own does not consider the costs of constraints that remain in the system following reinforcements. As a result the value of reinforcements which provide enhanced network capacity are undervalued when compared with those that provide lower degrees of capacity enhancement. In order to assess the overall benefit, it is necessary to assess the value of the future constraint costs and provide a Net Present Value (NPV) for the whole of the project life. We have taken a period up to 2027.

10.6.9 Table 3 in the SKM report (Table 5 here) shows the NPV of the alternatives with those of either a single or double HVDC link being significantly higher than that of the proposed Beauly-Denny line.

10.6.10 Table 5: Ranking of alternatives using discounted cash flow for the investment and expenditure streams up to 2027.

SKM Case	Case Name	NPV (£M)
1	Proposed Beauly-Denny Line	**994**
3	Beauly-Denny Lower Rating Line	1,057
6	HVDC 2x1.2GW (Beauly-Hunterston)	1,643
7	HVDC 1x1.2GW (Beauly-Hunterston)	1,705

10.6.11 The results show that the proposed Beauly Denny reinforcement is the one that provides the greatest long term benefits. It is followed closely by the option of using a lower rating 275kV line, whose towers are unsuitable for future operation at 400 kV.

10.6.12 The single HVDC link across the Northwest boundary has higher capital costs relative both to the proposed Beauly-Denny Line and the lower capacity 275kV overhead line alternative. However it also exhibits poor boundary transfer capacity relief relative to both the options. Consequently, the NPV is some £700M (70%) higher than the proposal.

10.6.13 The option of two HVDC links demonstrates exhibits better constraint relief, comparable with that of Beauly-Denny proposal. However, the very high capital costs, some £700M above that of the proposal, account for much of the difference in the Net Present Values of the two alternatives. The use of a double circuit subsea option is extremely expensive at over £1Bn and runs a significant risk of stranded assets in the subsea link.

10.6.14 DTI - The Transmission Issues Working Group – Final Report, June 2003 (Doc.No.CD-L09) states: *'The main disadvantage of a subsea cable is that significant upfront investment would be needed and there is danger that assets may be stranded if the capacity of the cable is not fully utilised. This issue is less for the onshore grid as* *development can take place incrementally in response to demand'.*

10.7 Concluding remarks

10.7.1 I have described how a HVDC subsea alternative to the proposed Beauly-Denny reinforcement has been assessed in terms of system benefit across the Northwest transmission boundary.

10.7.2 It is shown that the Beauly-Denny reinforcement as proposed provides an increase in operational boundary capacity of over four times that provided by a single 1.2GW HVDC submarine cable link.

10.7.3 The initial investment cost of the Beauly-Denny reinforcement is around 20% lower than the lowest-cost option of the HVDC link alternatives (that is, to Hunterston). After the addition of costs of connecting generation along the Beauly-Denny route, the initial investment cost of the shortest subsea link (Hunterston) increases to £250M above that of the proposal.

10.7.4 It is demonstrated in Applicants' paper 'Cost-benefit analysis of the Beauly-Denny proposal and alternative reinforcements' (Doc.No. APL-4/6) that the option of providing a single HVDC link from Beauly to the south, in order to reinforce the northwest transmission boundary, results in a Net Present Value (NPV) of some 70% more expensive than the proposal.

10.7.5 It has been shown that the Beauly-Denny reinforcement as proposed provides the largest amount of system benefit for the lowest investment and capitalised constraint costs.

10.7.6. On the basis of these assessments, and to meet the transmission licence obligations of SHETL, the option of a HVDC subsea option has been discounted in favour of the proposal.