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APPENDIX 1. Review of Undergrounding Power Transmission Lines
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EXECUTIVE SUMMARY

Approach to Independent Assessment
The detailed consent for the Beauty Denny 400kV overhead line requires SPT to address the issue of visual mitigation in the Stirling area (Condition 19). Scottish Government has requested a further detailed review of proposed mitigation with SPT submitting amended details of the Stirling Visual Impact Mitigation Scheme (SVIMS) in August 2011.

This report presents an independent view of the landscape and visual issues and the merits of the potential mitigation solutions. Ironside Farrar completed the assessment August-October 2011 with reference to the Public local Inquiry (PLI) information and SVIMS Reporting.

Summary of Findings
Ironside Farrar concurs with the findings and conclusions of the Inquiry Reporters on levels of landscape and visual impact in the Stirling area. The impacts would be adverse but are in the main of low or moderate significance, with some notable exceptions where impacts on sensitive receptors (primarily a small number of residential properties) are of major adverse significance.

Our assessment confirms the view recorded at the inquiry that key highly sensitive receptors including the Wallace Monument, Stirling Castle and the Ochils AGLV would in the main not be significantly affected.

The issue of sensitivity of the receiving environment and the magnitude of change are critical to understanding and developing an objective assessment of the significance of impacts and the level of input required to mitigate impacts. Mitigation measures should objectively be weighed against the significance of the impacts and their effectiveness and proportionality in reducing these impacts.

Our assessment advises that:

- overhead route selection has been thorough and included an appropriate range of alternative route options based on extensive consultations. The proposed route is a logical result of this process based on the information and key stakeholder views available at the time.

- undergrounding involves lifetime costs that are acknowledged as being in the order of 5-15 times higher (and sometime more) than that of an overhead line. Reasonably undergrounding should therefore be considered as a mitigation intervention only to address extra-ordinary circumstances; where major adverse impacts are predicted; and where it would be effective when other mitigation options (see below) are ruled out as ineffective.

The assessment concludes these conditions do not apply in the Stirling area where the majority of impacts have not been assessed as major adverse, and other mitigation measures are available. Mitigation as part of any assessment needs to consider the full range of available measures including: avoidance; reduction; remedy/compensation; and enhancement/net benefit recognised within the EIA Regulations.

SPT (SVIMS Report) have investigated approaches to mitigation, culminating in an options appraisal which examines seven approaches in 23 varied options. The mitigation methods included undergrounding of the 400kV overhead line, the Fallin-Glenbervie 132kV line and low voltage lines; alternative overhead line route sections; low height towers; planting and landscape reinforcement and tower painting.

SPT (SVIMS Report) mitigation conclusion is that landscape proposals, low voltage undergrounding and tower painting offer the best mitigation response. These are presented as being more proportionate (cost) and result in little or no project delay and are technically achievable. SPT considers that the proposals meet the requirements of condition 19 and their statutory and regulatory duties.

Mitigating the impact of a 400kV line should address avoidance through careful route alignment as the primary mechanism to reduce impact. Early alignment options dismissed a number of routes including the alignment following the existing 132kV line through Durieshill. This route was rejected in 2004 due to the impacts on Durieshill and West Sauchenford (since deleted) proposed Growth Areas. The assessment suggests that only through reconsideration of earlier alignments and undergrounding south of the M9 could some of the main concerns of objectors and the most major impacts be addressed. The route with greatest potential would follow the existing 132kV line and underground the section through the proposed Durieshill Growth Area (Housing) to Denny, together with undergrounding the parallel section of the Fallin-Glenbervie 132kV line.

Further technical feasibility and impact assessment would be required and the proposal would incur delay and additional cost. Nevertheless, the route is approximately 15% shorter and pro-rata could be anticipated to involve nine fewer pylons even without an undergrounded section. On this alignment, the landscape and visual impacts of the new line would be directly balanced against removal of the existing 132kV line and, if combined with undergrounding the parallel section of Fallin-Glenbervie 132kV line, there would be a significant overall reduction in wirescape in the area south and east of Stirling.

We would note that line re-alignments would not address Stirling Councils key concerns, including effects on the Ochils, Stirling Castle and the Wallace Monument. Re-alignment would result in significant programme delay due to requirement for further detailed alignment consideration; planning / EIA and consultation requirements. At this stage of the project and given the previous rejection of the 132kV corridor alignment we conclude comprehensive re-routing is not an option and that the most viable current solution is a significant enhancement of the SVIMS proposals offered by SPT.
Conclusion to the Review

SPT’s comparison of options is limited in so far as each option considers only a single mitigation method. Scenarios could have been developed in which a range of mitigation methods sought out opportunity to introduce innovation and offer effective, targeted, combinations of measures to achieve more significant reduction to both landscape and visual impact; introduce compensatory provision and address enhancement/net benefits.

We do not fundamentally dispute SPT’s assessment of costs, delays and effectiveness of the measures in achieving mitigation. We consider that the SVIMS proposals offered by SPT would provide a level of mitigation but more extensive options are available.

SPT in our view has been too ready to create discrete options rather than address more innovative, design led and technically challenging mitigation methods, based on securing positive impact mitigation and delivering wider project and area outcomes at reasonable and proportionate cost.

Our assessment concludes that only through a more holistic all-landscape approach can an effective mitigation strategy be developed that includes for reducing impacts and offsetting impact by compensatory provision.

Securing Enhanced Mitigation:
Developing the Green Network Through Wider Landscape Enhancement

Develop a more holistic landscape and visual mitigation approach based on ‘all-landscapes’ approach integrating mitigation by a landscape masterplan-led approach incorporating: reduction; compensation and enhancement measures. This approach adopts all SPT’s SVIMS landscape proposals (planting, tower painting, landscape enhancement) and develops them into a more comprehensive and effective approach.

This approach would support partnership delivery and would accord and support links to:
- National Planning Framework (NPF2) - Action 22 Central Scotland Green Network
- Scottish Planning Policy (SPP)
- Climate Change Delivery Plan - Rural Land Use
- Scottish Forestry Strategy
- Stirling Greenbelt Review Recommendations

This approach requires a wide scale landscape vision and a real commitment to turning the challenge of mitigating impact into an opportunity to create a ‘new landscape’ with a real legacy for Stirling. It is built on the principles of Green Networks and partnership working, with assured and measurable targets reinforced by a financial performance bond for implementation and management.

Mitigation should mean more than funding token impact reduction or solely thinking of mitigation in terms of pylon towers or non-proportionate interventions such as undergrounding. An all-landscape commitment with appropriate funding could deliver far more to local communities, wider stakeholders and the setting of the Wallace monument and Upper Forth. The option offers a more valuable legacy (social / economic and environmental) that inclusively assists the delivery of wider policy in the National Planning Framework (NPF2) and Scottish Planning Policy (SPP).

This solution has no timetable or programme delays and would have a lower cost than undergrounding or re-routeing mitigation proposals.
1.0 BACKGROUND

Summary: This section introduces the context of the Beauly-Denny 400kV transmission line and the initial Stirling Visual Impact Mitigation Scheme (SVIMS) submitted by Scottish Power Transmission (SPT) and the request by Scottish Ministers for SPT to revisit their original mitigation options.

1.1 Scottish Government Policy Context

Scottish Government energy policy has increasingly supported the development of renewable energy in Scotland. The Scottish Government has set a target that 100% of electrical energy consumption to be provided by renewable sources, including wind, hydro, wave and tidal, by 2020. The Beauly-Denny 400kV transmission line proposal is considered an essential enabling infrastructure to support the delivery of this target.

The proposed transmission line passes from Beauly, west of Inverness, to Denny substation south of Stirling. The line has two promoters: SHETL over the majority of the route between Beauly and Wharry Burn; and Scottish Power Transmission (SPT) between Wharry Burn and Denny. Over recent years it has been subject to detailed routing options, appraisals and consultations. A substantial number of representations and objections were made, based on the potential significant adverse impacts of the scheme particularly in the areas of landscape and visual impact, health and effects on wildlife. Many of the representations requested that the line should be an underground cable, either for its total length or in sections over the most environmentally sensitive areas. The currently proposed overhead line route has been subject to detailed environmental assessment and an extended public inquiry process. The reporters recommended approval without any requirement to underground sections of the route but two areas in which consent should be withheld until towers have been moved (Auchilhanzie House near Crieff and Glenside near Denny Substation). Subsequently, the scheme has gained ministerial approval under Section 37 of the Electricity Act (2010).

1.2 Planning Inquiry – Reporters Findings

The Reporters recommended that detailed conditions be imposed over the Stirling section promoted by Scottish Power Transmission. The Stirling Visual Impact Mitigation Scheme (SVIMS) is required under Licence Condition 19. The purpose of the SVIMS is to address the mitigation of landscape and visual impacts of the line between the Ochills Scarp and Airthrey Castle and between Logie and Glenside. The requirement is for SPT to produce proposals for consideration and approval by Scottish Ministers after consultation with Stirling Council.

1.3 Stirling Visual Impact Mitigation Scheme (SVIMS)

A SVIMS report with detailed proposals was produced by SPT in March 2011. This provided detailed visual mitigation measures including tree planting, tower painting and undergrounding sections of adjacent minor overhead lines. The report did not propose undergrounding any of the 400kV transmission line, as the considerable additional cost involved in this was considered by SPT to be in conflict with their requirement to provide a grid transmission system that balances cost and environmental considerations. None of the environmental impacts were considered to outweigh the potential costs and project programme delays of undergrounding.

This approach has not addressed the concerns of Stirling Council. SPT have been asked by Scottish Ministers to revisit the SVIMS and investigate the possibility of undergrounding visually critical sections of the route as part of the mitigation proposals. SPT have provided revised proposals to Scottish Ministers in an updated SVIMS report dated August 2011.

Ironside Farrar has been appointed by the Scottish Government to provide an independent assessment of these proposals and the process that has led to their formulation.
Beauly-Denny Transmission Line Project

Scottish Government

Stirling Visual Impact Mitigation Scheme

Independent Assessment of Proposals

Ironside Farrar

7727/ November 2011

View from Wallace Monument to Ochil Scarp
Typical 400kV Tower
2.0 PURPOSE & SCOPE OF ASSESSMENT

Summary:
This section reviews the scope of, and approach to, the independent assessment relative to the consideration of undergrounding and environmental mitigation and provides a brief summary of the expertise and experience of the assessment team.

2.1 Assessment Requirement
The purpose of this commission is the provision of independent expert advice to Scottish Ministers in relation to the Stirling Visual Impact Mitigation Scheme (SVIMS) for the Beauly Denny 400kV overhead line. In summary the requirement is twofold:

- to review existing information on transmission line undergrounding studies and practice in the UK and Europe; and
- to advise Ministers on the specific proposed options and costings produced by Scottish Power Transmission (SPT) for the SVIMS.

The advice is required to assist Ministers in their deliberations in relation to the approval of condition 19 of the consent for this section of the overhead transmission line.

Ironside Farrar has developed a methodology based on desk and field studies to address both elements of the assessment requirements. To ensure specialist expertise was available to undertake the review Ironside Farrar are working with Newcastle University School of Mechanical and Systems Engineering to review potential for undergrounding and have progressed the visual impact and mitigation review using in-house staff.

The two main areas of assessment include:

- a specific review of undergrounding of high voltage electricity lines, including the arguments relating to the Stirling OHL
- a review of the development of the specific mitigation measures for the Stirling section, including the initial SVIMS proposals (March 2011) and subsequent development of mitigation measures detailed in SPT’s submission to Ministers

2.2 Technical Expertise & Experience of Assessors
Ironside Farrar has extensive experience in Environmental Impact Assessment and specifically Landscape and Visual Assessments associated with major infrastructure. Expertise includes preparation of the DMRB Landscape and Visual Guidelines for the Scottish and UK Government and extensive assessments associated with windfarms; O/H transmission lines; Trunk Roads; railways and other infrastructure projects. The commission has been led by experienced, qualified professional staff based on the GLVIA Methodology adopted by the Landscape Institute and Scottish Natural Heritage.

The School of Mechanical & Systems Engineering has relevant expertise on cable undergrounding and HV power transmission systems. Experience has included analysis of undergrounding at shallow depth as well as deep undergrounding and tunnelling. The work has reviewed international approaches and examined the civil engineering (directional drilling, microtunelling), thermodynamics (cooling, ventilation) and mechanical engineering aspects (installation, repair, joining, etc) as well as the economic and environmental aspects of the application of those techniques.
2.3 Brief to Review Undergrounding

The study on undergrounding reviews information and studies on undergrounding of transmission lines in UK and Europe. The review methodology is as follows:

- an exploratory review phase, where all relevant publications are identified and categorised.
- a focused literature review, where a library search of international scientific databases is carried out (including international conference proceedings) that focuses on the specific questions of the subject under investigation. This phase includes interviews with relevant industry contacts in the UK and internationally.

Subjects covered include:

- Reasons for undergrounding
- Methods of undergrounding including trenching, tunnelling
- Requirements for sealing end compounds, converters etc
- Methods of heat dissipation
- Advantages and disadvantages of undergrounding in construction and maintenance
- Orders of costs relative to overhead transmission
- Examples of schemes in UK and Europe

The reports on undergrounding are included in Appendices 1 and 2. Information from these reports has informed the assessment of SPT’s proposals.

2.4 Brief to Review Environmental Mitigation

The study requires a review of the development of the specific mitigation measures for the Stirling section, including the initial SVIMS proposals. Ironside Farrar has approached the assessment by reviewing the following stages of the project’s development in the Stirling area:

- The design development history of the proposed line including route options considered and consultation responses received;
- The environmental assessment process: specifically the landscape and visual impact assessment of the proposed line;
- The Public Inquiry report and Reporters’ conclusions on landscape and visual matters and on undergrounding;
- Further discussions and consultations between Stirling Council and SPT leading to the March 2011 SVIMS report;

In reviewing the overhead line proposals and mitigation proposals we have reviewed the background reports and visited the route of the line and key receptors in the Stirling area. Our assessment concentrates on the options appraisal matrix in the Report on Engagement in which various methods of mitigation are assessed including undergrounding, re-routing, low voltage undergrounding, planting and tower painting. In this process we have considered the following main issues in relation to the proposed overhead line:

- The sensitivity of the potentially affected landscape and visual receptors;
- The nature, magnitude and significance of the landscape and visual impacts;
- The potential for mitigation of the impacts by the various methods proposed;
- The effectiveness of the proposed mitigation;
- Any further mitigation measures that could be considered.
The effectiveness of mitigation methods and proposals is assessed firstly by categorisation in terms of the mitigation hierarchy in the Scottish Government PAN 58 guidance, i.e.

- Prevent or avoid impact;
- Reduce impacts by minimise at source or abatement at source/receptor;
- Offset by remediation or compensation;

Secondly it is assessed by the degree to which the mitigation proposal is effective in reducing or eliminating impacts.

In our assessment we consider to what degree the various mitigation methods would be effective, and their main drawbacks if any. We then assess the extent to which the current SVIMS proposals are effective and how they might be enhanced.

In this assessment we are aware that certain forms of mitigation may result in significantly increased capital or whole life costs and potential impact on project programming including project delays. This context is acknowledged in the assessment but we do not make a balancing judgement between the mitigation and its potential costs.

2.5 Landscape Designations

Some areas of rural landscape in Scotland are given a landscape designation marking their special qualities over and above wider surrounding areas. The purpose of designation is to recognise and protect the special qualities of these landscapes and develop policies to control development and promote landscape conservation to serve that end.

There are two main levels of landscape designation: local and national.

Local landscape designations are determined by local authorities within their boundaries. Typically they are entitled Area of Great Landscape Value (AGLV), Scenic Landscape Area, Regional Scenic Area etc depending on the terminology used by that local authority. There is currently an ongoing review throughout Scottish local authorities to provide more detailed, consistent justification and defensible boundaries for locally designated landscapes, which will be called Special Landscape Areas (SLAs). Currently the Ochils is designated an AGLV as are the Touch Hills to the west of Stirling.

National designations include National Scenic Areas (NSAs) and National Parks. The extents and interests of these are determined and managed by SNH, the Government’s advisor on natural heritage and by dedicated planning authorities in the case of National Parks. They are designated on their exceptional, national level of value. NSAs are a primarily landscape conservation designation, whereas National Parks balance landscape, recreation and tourism interests.

The NSAs and National Parks are protected by national and local planning polices. A review of the NSAs has recently been carried out by SNH, providing more detailed justification through enhanced description of the features, special qualities and boundaries. There are no NSAs in the Stirling area, the closest being the Trossachs to the west. This NSA lies in the Loch Lomond and Trossachs National Park which also lies to the west of Stirling. In England, the equivalent designations are Areas of Outstanding Natural Beauty (AONBs) and National Parks.

The only designations in the area effected by Stirling section of the Beauly Denny line is the Ochil Hills AGLV and the Stirling Greenbelt area. To our knowledge no protective landscape designations have been proposed or considered for the carse area.

Green Belts are primarily a local spatial planning designation whose purpose is to protect the open countryside around towns and cities, thereby protecting their setting, preventing urban sprawl or coalescence of settlements and providing access to countryside. There is an area of Green Belt to the east of Stirling. This has been recently reviewed based on the above green belt criteria and landscape character, and recommendations made on boundaries and improvement of landscape components such as hedgerows and footpath access (Stirling Greenbelt Study, LUC., 2009).
The blue line was the preferred route but rejected in favour of the yellow and red due to Stirling Major Growth Areas.

(Red Diagonal Hatch)
3.0 REVIEW OF EIA & PUBLIC LOCAL INQUIRY

Summary:
This section summarises the development of the present proposed route and the assessment of its landscape and visual impacts within the EIA and associated mitigation as prepared by SPT and considered by the Reporters at the Public Local Inquiry.

3.1 Route Selection Process
The Environmental Statement appendices include consultation reports in which various indicative route options were assessed against environmental constraints and their performance against the Holford Rules for routing of overhead transmission lines.

All indicative overhead route options crossed the Ochils on the current Sherriffmuir/Yellowcraigs route of the existing 132kV line. The initially preferred route option crossed the Forth plain and river further east than the existing 132kV line and the current proposed route. It then passes between Fallin and Stirling before closely following the route of the existing line to Denny substation between Bannockburn, Cowie and Plean.

The Interim Report on Consultations (June 2004) assesses this preferred route and three other options. It rejects the preferred route in favour of a less direct route similar to the currently preferred route passing east of Cowie and Plean. The principal reasons for rejecting the more direct route include adverse effects on visual amenity and Stirling Council’s request that the route be moved away from its two proposed Major Growth Areas lying either side of the M9 between Bannockburn, Cowie and Plean.

The chosen route became the Indicative Proposed Route. This was further developed and assessed in the EIA and examined at the Stirling session of the Beauly-Denny Inquiry and has become the currently proposed route.

In the subsequent period the Major Growth Area north of the M9 has been dropped from the Stirling Local Development Plan, although the area south of the M9 (Durieshill) remains a current proposal.

3.2 Environmental Assessment
The ES for the Beauly to Denny overhead line was published in 2005. It covers the whole of the proposed line route but each chapter is divided into route sections. The Stirling area is covered by the Braco to Denny Substation section. Landscape impacts are covered in Chapter 23, Visual Impacts in Chapter 24 and Cumulative Visual Effects in Chapter 25. As a result of some changes in the route a further assessment of some impacts is made in an Addendum published in 2006.

3.2.1 Landscape Effects
In the assessment of landscape impacts no significant operational impacts on landscape character are identified in the Stirling mitigation area. The only significant landscape effects identified are at a moderate level and include:

- recreational area of Hermitage Wood by Airthrey Castle
- temporary construction impacts in Yellowcraigs Wood
- temporary cumulative impacts east of Bridge of Allan if the existing 132kV line is not dismantled prior to construction of the proposed line
- dismantling of the 132kV line in the Ochil Hills AGLV
- cumulative landscape effects with other 132kV lines west of Fallin

The effects are considered to be adverse in nature. All effects except on Hermitage Wood are considered capable of reducing to not significant (i.e. below moderate) as a result of mitigation.

The effects of removal of the existing 132kV line are assessed as minor beneficial in the area between Bannockburn, Cowie and Denny substation although the summary of residual impacts claims these as moderate beneficial.

The ES Addendum identifies further moderate significant landscape impacts in the Bridge of Allan area resulting from design changes to the proposed 400kV line.
Our assessment of the landscape assessment in the ES/ Addendum is as follows:

- that it underestimates the landscape impacts of the proposed line in more sensitive locations such as the Ochils scarp and AGLV;
- the balance of adverse and beneficial impacts resulting from removal of the 132kV line and replacement by the proposed line is not clearly explained;
- we do not fully understand the contention that, in the long term the landscape in the vicinity of Fallin, Cowie and Plean would ‘accommodate’ the impacts of the line thereby reducing impacts from moderate to minor
- it is hard to justify the assessment summary that removal of the 132kV line would have a moderate beneficial impact to the west of the Cowie and Plean area whereas the proposed 400kV line would have a minor impact to the east.

3.2.2 Visual Impacts

The assessment of visual impacts identifies a number of significant adverse visual impacts in the Stirling area on settlements, properties, roads, paths and designated areas. Most notable it identifies:

- moderate adverse effects on properties with views of the proposed line located within the villages of Fallin, Throsk, Cowie and Plean
- major adverse effects on 7 isolated properties close to the proposed line
- moderate adverse effects on 11 isolated properties close to the proposed line
- moderate adverse effects on a number of roads and footpaths
- moderate beneficial effects on properties in very close proximity to the 132kV line that is to be removed

However the ES has assessed the visual effects on Stirling Castle, the Wallace Monument and the Ochil Hills AGLV to be minor and not significant.

The ES Addendum identifies an increased visual impact resulting from design changes: at Broomhill in Logie Wood (moderate increasing to major adverse) and two further moderate adverse significant impacts: on houses at Cardrowan Road, Plean and on users of the A9 near the overhead crossing at Carbrook Mains.

Our assessment of the visual assessment in the ES/ Addendum is that the assessment of visual impacts is credible.

3.3 Public Inquiry - Stirling Section of the Beauly Denny Line

The report on the public inquiry for the Stirling section of the Beauly Denny line includes findings of fact relating to SPT's and other organisations' assessment of impacts as well as the Reporters’ assessment and conclusions.

In general the Reporters have found many of the impacts on more sensitive receptors to be more significant than found in the ES. This includes:

- major adverse visual effects over a limited area around the angle tower at the top of the Ochils scarp
- moderate adverse visual impacts on Yellowcraigs Wood, Logie Kirk and Witches Craig caravan site
- major adverse visual impacts on Glenside Farm being at an unacceptable level.

Nevertheless the Reporters agree that the effects on views from and towards the Wallace Monument, Stirling Castle and the Ochils are in the main not significantly affected.

The Inquiry examined the issue of undergrounding in detail. Whilst the technical assessor concluded that there was a case to be made for undergrounding short sections of the route in environmentally sensitive areas, the Reporters did not recommend that any of the route be undergrounded.
3.4 Key Landscape and Visual Impacts

Ironside Farrar has reviewed the development of the route design, the LVIA and inquiry report on landscape and visual impacts as well as visiting the site and undertaking a visual assessment.

We concur very substantially with the Reporters’ findings on the significance of impacts. In summary:

- landscape impacts over the majority of the line will be of a minor significance due to the developed character of the landscape to the east of Stirling
- there will be significant but localised adverse landscape impacts on the Ochils escarpment and in some locations where there are cumulative wirescape impacts with other overhead lines
- there will be a number of properties in close proximity to the line which will experience major adverse impacts but settlements will generally experience moderate or minor adverse impacts
- effects on views from or to Stirling Castle, Wallace Monument and the Ochils are in the main not significant, with the exceptions of moderate adverse impacts when the Wallace Monument and Ochils Scarp are seen from roads and other receptors with the proposed line in the close foreground (within ca. 1km).

Any mitigation proposals employed should be proportionate to the significance of the above impacts and effective in reducing the impacts.

Ironside Farrar in reviewing the documents relating to the Stirling section of the Beauly Denny proposals consider the key issues are:

1. The landscape and visual impacts of the proposed route would be adverse, but in the main of low or moderate significance. However there are some individual residential receptors and limited landscape areas that would experience major adverse visual impacts.
2. There are some locations, principally between Stirling and Fallin and between Plean and Denny substation in which cumulative wirescape impacts would be adverse and highly significant.
3. Removal of the existing 132kV Beauly-Denny line on or off the route of the proposed line would provide mainly minor beneficial impacts.

4. Views from Stirling Castle and the Wallace Monument are not significantly affected as the line would be seen in the context of a large scale, busy, developed landscape with many other linear and vertical features. However some views from roads and residential properties towards the Castle and Monument may be moderately adversely affected if the line appears in the foreground and breaks above the skyline.

5. The proposed line would not significantly affect the landscape or views from or to the Ochils AGLV as a whole but there would be localised significant adverse effects on the scarp/ Yellowcraigs Wood area due to the increased scale of the proposed line by comparison with the existing 132kV line it is to replace.

6. SPT consider that the effects of the proposed line in the Stirling area are not of sufficient magnitude or adversity to justify the expense, technical difficulty and delays caused by undergrounding all or part of it, and that there would be other impacts, such as the construction of sealing end compounds (SECs), resulting from undergrounding. This is also the conclusion of the Inquiry Reporters.

7. SPT consider that the mitigation measures they have proposed would reduce impacts or provide compensatory mitigation, although it is conceded that planting measures will take a number of years to become effective.

These issues are considered in the next chapters which review SPT’s revised SVIMS proposals.
Option 1, 400kV OHL—As Approved
Option 2, Stirling LV undergrounding
Option 3, Landscape Planting
Option 4, 400kV Tower Painting

Option Appraisal Examples
4.0 REVIEW OF SVIMS PROPOSALS

This section summarises the SVIMS reports including the re-submission by SPT of a Report to Scottish Ministers (August 2011) that further develops initial reporting of landscape and visual mitigation based on: landscape reinforcement; low voltage line undergrounding; and, painting of towers. The detailed assessment of the effectiveness of these measures is assessed in Sections 5 and 6.

4.1 SVIMS Initial Proposals (March 2011 Report)

The Stirling Visual Impact Mitigation Scheme initial report sets out SPT’s formal response in fulfilment of condition 19 of the consent. The SVIMS report explains the process by which the proposals were developed:

- The findings of the Inquiry including Condition 19
- The consultations with Stirling Council in relation to Condition 19
- The preparation of a Consultation Report and the process by which various potential mitigation measures were explored
- A reiteration of the reasons for not undergrounding all or part of the route (namely high cost, technical difficulties and limited environmental benefit)
- An explanation of SPT’s statutory duties in relation to balancing effects on the environment and the requirement for development of an economical and efficient system of electricity delivery, and the role of The Regulator, Ofgem.

The report then details the mitigation suggestions, other than undergrounding, raised in the consultation, and details SPT’s response. It does, however, acknowledge that undergrounding was the most common mitigation request in the consultation. Following this the SVIMS proposals are detailed and illustrated. The proposed measures include:

- Screen planting;
- Broader landscaping proposals (as a combination of soft and hard works);
- Tower painting; and
- Undergrounding of low voltage lines

SPT assess the mitigation provided by the proposals. The assessment is that:

- the planting and other landscape measures would significantly reduce landscape and visual impacts on particular locations but take 10-15 years to achieve this;
- the tower painting slightly reduces landscape and visual impacts on the Ochils Scarp and at Carbrook Mains south of Plean;
- the low voltage undergrounding does not directly mitigate the effects of the proposed line but provides visual enhancement in the affected areas.

This report was rejected by Stirling Council and local campaigners, as not offering sufficient mitigation for the perceived level of impact with objectors retaining the view that the only effective mitigation approach needs to involve, in part or whole, undergrounding of the transmission line.

4.2 Scottish Ministers Request for SPT to Review Mitigation

In March 2011 the Minister for Energy, Enterprise and Tourism requested that SPT consider further the mitigation of impacts in the Stirling area and to consult with Stirling Council on the means of mitigation.

The SPT SVIMS mitigation review has included a consultative process in which a Technical Committee comprising SPT, Stirling Council and Scottish Government have engaged to review earlier reporting and consider in more detail options and alternatives.

SPT in response to the request from Scottish Ministers have developed a revised SVIMS proposal (August 2011) which updates the previous reporting and informs this independent assessment.
4.3 **SVIMS Re-assessed Mitigation Report (August 2011)**
The revised SVIMS proposals were published in August 2011. They comprise two volumes:

- The main Stirling Visual Impact Mitigation Scheme report which summarises the background to the proposals; the consultation process leading to them and details the proposals themselves
- The Report on Engagement which provides more detail to the background; process and options appraisal from which the proposals have been derived

The SVIMS report provides a concise background to Condition 19 and the development of the SVIMS proposals. It details SPT’s understanding of their statutory and licence duties and argues that this offers clear justification for the approach SPT has adopted.

It details the evaluation of the mitigation methods considered in a series of 23 options. Of seven methods tested through the matrix it concludes that only three are viable in terms of SPT’s criteria. These are detailed in section 4.6 below. Finally it describes and illustrates the detailed SVIMS proposals as summarised below, detailing considerations including delivery, timescale and maintenance. In the broad approach to mitigation the revised report is little changed from the initial SVIMS report of March 2011.

4.4 **Report on Engagement**
The report on engagement is more substantial than the SVIMS report. It provides more background and detail to the development and appraisal of mitigation options leading to the revised SVIMS report. 23 options have been developed in outline, quantified, budgeted and assessed for effectiveness in terms of SPT’s criteria. The options are assessed in a matrix, reviewed in detail and conclusions drawn as to whether they meet SPT’s criteria on cost and reduction of impacts.

4.5 **Mitigation Options Considered**
SPT has considered and reviewed a number of methods of mitigation on various locations in the Stirling area. These are over and above the mitigation offered by the routeing process to date and by the Stirling wirescape rationalisation which addresses Condition 18. SPT has considered in all 7 methods of mitigation:

1. Undergrounding the 400kV overhead line, as a whole or in sections
2. Alternative Overhead Line Route Sections
3. Alternative Tower Designs in particular the Use of Low Height Towers
4. Undergrounding the Fallin to Glenbervie 132kV Overhead Line south of the wirescape rationalisation
5. Planting and Landscape Reinforcement
6. Undergrounding of Low Voltage Overhead Lines
7. Tower Painting

Each of these mitigation methods has been considered at various locations in the options appraisal exercise and conclusions drawn concerning their viability in terms of reducing impacts and likely cost. SPT concludes that methods 1 to 4 do not meet their environmental, cost and programme criteria and these are not further developed as part of the SVIMS. Methods 5 to 7 do however meet their criteria and these are further developed in the SVIMS proposals.
4.6 Mitigation Options Employed in SVIMS

The detailed SVIMS proposals employ three primary mitigation methods:

1. **Planting and Landscape Reinforcement** including native tree and shrub planting and landscape improvements in the broad corridor surrounding the overhead line route.
   - The planting would involve hedgerow trees, woodland strips and clumps to provide a level of screening and a stronger landscape structure in which the proposed overhead line would become less prominent and visible than in the current open landscape.
   - The landscape improvements include rebuilding of drystone walls, footpath construction and improving informal car parking areas on the Ochils scarp.

2. **Undergrounding of Low Voltage Overhead Lines** in several locations:
   - Logie Kirk and roundabout
   - Powis Mains
   - Manorneuk
   - Bolfornought
   - Burnhead
   - Carbrook Mains

3. **Tower Painting**:
   - in locations where they are seen against a vegetated backdrop, in this case against the Ochils escarpment when seen from the Wallace Monument and Stirling Castle;
   - to match other towers, in this case the 275kV double line which is crossed and paralleled to the south of Plean.

The SVIMS Report provides details of all of the measures including plans, photomontages and indicative costings. It also carries out an assessment of the effectiveness of the measures in reducing landscape and visual impacts.

It is concluded that the proposed combination of measures will provide significant mitigation in some locations as well as short or longer term improvement to the landscape and visual environment in the Stirling area.
Visual Assessment

The viewpoint is taken from the top of the tower of the Wallace Monument, which is located on the Abbey Craig at the northern end of Stirling. The view shown looks to the east over the broad flat cane of the river Forth, and shows the line of the Ochil Hills, which lie on the northern side of this valley. The cane appears largely as a patchwork of agricultural fields broken up by woodland blocks and lines of trees and the meandering river Forth. Scattered transport are noticeable within this landscape, however the industrial park in the foreground, to the left of the view, and the building warehouse is in the distance, to the right of the view, from more prominent visual features. The flat patchwork of smooth greens and browns on the cane contrasts with the rough textured land cover and knobby terrain of the Ochil Hills. The trees of the existing 132kV overhead line are not visible on the valley amongst the patchwork land cover. Two existing towers are just visible against the high ground at the left of the view.

The woodland cover on the Abbey Craig provides all views to the east from the platform of the Wallace Monument and the footpath which provide access to it.

The proposed 400kV overhead line will replace the existing line, though on a slightly revised alignment. The proposed line would be located slightly further away than the existing line within the cane.

Visual Impact Assessment from Wallace Monument

FIGURE: NTS 4B
5.0 ASSESSMENT OF SVIMS PROPOSALS

This section provides an independent assessment of the SPT SVIMS Proposals and makes recommendations, where considered appropriate, on developing effective mitigation (based on PAN58 avoid/ reduce/ remediate/ compensate) focussed on the previously assessed level of significance of the impacts.

5.1 Review and Assessment Methodology

The assessment considers the SVIMS (August 2011) proposals and the process by which they were developed. It analyses and comments on:

- The methods of mitigation considered by SPT and their reasons for rejecting/ adopting them;
- The options appraisal process by which the mitigation methods were evaluated;
- The consolidated SVIMS proposals and their effectiveness.

The assessment then considers if there are any further potential mitigation options and any ways in which SPT’s proposals could be augmented or improved.

5.2 Mitigation - Undergrounding of the 400kV Line

Undergrounding of all or parts of the route is considered in several of SPT’s mitigation options. This method of mitigation directly addresses Stirling Council’s concerns and stated preference. In principle, undergrounding is clearly the most effective way of addressing most of the landscape and visual impacts of an overhead electricity line and in terms of PAN 58 would be at the top of the mitigation hierarchy as avoiding the impacts. Nevertheless, as stated by SPT, it is not without other potential environmental impacts and has a potentially high financial and programme cost. We closely consider the potential benefits and costs below.

As required by the brief we have considered undergrounding in detail. This has included a technical and cost review of generic and specific measures undertaken by Newcastle University (see Appendix 1 and 2 of this report). We assess below the viability and cost of undergrounding; the options considered by SPT and any other possible options.

It is clear from the review of projects and literature carried out by Newcastle University that undergrounding of high voltage lines is technically possible in most situations and can provide a sound, low maintenance alternative to overhead cables. Undergrounding also usually addresses the key environmental impacts on the landscape and visual environment as well as any potential health related issues. It is also clear from the review that in most circumstances it is a significantly more costly option and may have some other adverse environmental consequences that overhead cables would not.

The review demonstrated that there has been continuous development and improvement in types of underground cable and methods of undergrounding. These all contribute to the potential for reducing costs, reducing environmental impacts, increasing reliability and overcoming technical construction and maintenance problems. Nevertheless it is still the case that costs and construction difficulties of undergrounding are likely to be significantly greater (by a considerable multiple of cost) than for an overhead cable on the Stirling section.

Recent examples of undergrounding high voltage lines in England include:
- sections of 132kV and 275kV lines at the London Olympics site
- a 3km section of 400kV line in an Area of Outstanding Natural Beauty (AONB) near Ross-on-Wye.

Both were undertaken at considerably higher cost than overhead lines and justified by a national level of profile or designation. The Olympics undergrounding is in an urban redevelopment site. The Ross-on-Wye scheme replaces an existing undergrounding section.

Our reading of the LVIA in the ES section and the conclusions of the Reporters is that whilst there would be significant adverse landscape and visual impacts on sections of the route, the majority of these would be at a moderate level, with significant sections in which landscape and visual impacts are at a low level and not significant. Nevertheless a few locations have been identified where impacts would be major adverse and properties close to the line where visual impacts would be major adverse, and in one case at Glenside ‘unacceptable’. Two locations have been identified in which there would be significant cumulative ‘wirescape’ impacts.
The route is considered in sections below. These approximate to the five ‘Pinch Points’ accepted at the Inquiry. Detailed below is our assessment of each section.

5.2.1 Ochils Scarp

This section of the route passes from the upland landscape of the Ochils, down the wooded escarpment to the Hillfoot area where the plain of the Forth abuts the Ochils scarp. The proposed route closely follows the existing 132kV line which is to be removed. Key landscape and visual issues include:

- effects on the landscape of the Ochil Hills AGLV;
- views of the hills from within the AGLV;
- views from the Wallace Monument and Stirling Castle; and
- views of the hills and escarpment from roads and properties in the scarp and Hillfoots area.

Landscape and visual impacts on the slope are generally considered to be moderate, with higher localised impacts at the top of the slope where the line crossing the Ochils turns sharply to descend the escarpment. Views from the Wallace Monument and Stirling Castle are not considered to be significantly affected. We agree with most of these conclusions although consider that there is a case for arguing that the ‘stacking’ of towers on the proposed line as it crosses the Ochils skyline to the scarp will be of moderate significance to views in this direction from the top of the Wallace Monument. We do not consider that this would be a significant effect on the full visual experience from the monument.

SPT’s Options 7, 10, 11 and 23 include undergrounding on or close to the current alignment from the top of the Ochils Scarp to the Hillfoot area at the base of the hills. This would involve tunnelling and working on sometimes steep slopes. Whilst undergrounding would reduce impacts on the slope itself, impacts at the top and foot of the slope would not be eliminated, and would possibly be exacerbated due to the requirement for sealing end compounds (SECs) and tunnel maintenance buildings. To address the views from the top of the Wallace Monument and the Hillfoot area would require undergrounding for considerable sections northwards into the Ochils or southwards towards the Forth. In both cases this would displace, rather than eliminate landscape and visual impacts. Option 12 shows a scenario in which a section from Cockburns Wood to the top of the scarp is undergrounded. This would require SECs at the wood and on the Scarp unless combined with tunnelling down the scarp.

Options 19 to 22 consider an alternative undergrounding route down the scarp to the east, following the Menstrie glen which is partly concealed from wider views to the south and west. One advantage of the route would be its partial avoidance of visual ‘stacking’ of pylons and an SEC on the Ochils skyline when seen from the Wallace Monument. Whilst not involving rock tunnelling, the route moves away from what is considered to be the least visually sensitive part of the scarp and involves many of the same technical problems associated with undergrounding on slopes.

5.2.2 Ochils Hillfoot to River Forth

This section of the route passes south from the foot of the Ochils, crossing the open, farmed floodplain of the River Forth. It follows the same corridor as the existing line as far as south of the river west of Fallin. Key landscape and visual issues include visual impacts on views to and from the Wallace Monument and Stirling Castle, from main roads and from settlements/properties.

The landscape impacts on this section are considered to be low and not significant due to the low sensitivity of the working landscape. Visual impacts on views from the Wallace Monument and Stirling castle are not considered to be significant. However some views from roads towards the monument and castle or towards the Ochils scarp, with the line within 1km of the receptor, are considered to be affected to a moderate adverse degree.

Options 10, 11, 13, 18 and 23 include undergrounding of this section. Impacts on views and on the landscape would be much reduced or eliminated. However if only this section is undergrounded there would be landscape and visual impacts resulting from SECs in the Hillfoots area and close to the River Forth.
Impacts of SECs on Logie Kirk and Yellowcriags caravan site in the former area in particular are likely to be significantly adverse. Avoiding this problem would entail extending the undergrounding up the Ochils scarp and/or to the south of Fallin with attendant landscape and visual issues.

5.2.3 River Forth and Fallin
At this point the route deviates from the existing 132kV line corridor to pass west and south of Fallin. The main landscape and visual impacts include the potential for wirescape impacts between Fallin and Stirling and the potential for visual impacts on residents of Fallin and Stirling.

The landscape and visual impacts in this area are generally considered to be of low significance, with the exception of views from some properties on the Forth floodplain and on the western and southern edges of Fallin.

Potential cumulative/ wirescape issues in the area between Fallin and Stirling would be significantly reduced by undergrounding of the three 132kV lines between Fallin, Stirling and Tullibody as required by condition 18 (Stirling wirescape rationalisation), and by dismantling of the existing Beauly-Denny 132kV line. Undergrounding of all or part of this section is not considered except as part of much more extensive undergrounding options (13, 20 and 23). In options 20 and 23 SPT have not included for the condition 18 undergrounding as cumulative wirescape would not be an issue.

5.2.4 Fallin and Cowie to M9
Between Fallin and the M9 the route passes to the east, well away from the existing 132kV line corridor. It passes ca. 1km to the south of Fallin and ca. 1km east of the small town of Cowie before heading southwest to the M9.

Landscape impacts are considered to be low and not significant due to the low character sensitivity of this area. However a number of settlements including Fallin, Throsk and Cowie would experience moderate adverse visual impacts and some individual properties, including Plean Castle, would experience major adverse visual impacts.

Only option 15 considers undergrounding on this route, to the east of Cowie. All other undergrounding routes in this area follow alternative routes including west of Cowie (options 20, 22 and 23) and/or east of Fallin (options 21 and 22). Options 15 and 21 would require SECs in the area, leading to significant landscape and visual impacts.

5.2.5 M9 to Denny Substation
The proposed line heads southwest from the M9, where, to the southeast of Plean it crosses the existing 275kV double line from Longannet to Denny Substation. It then broadly parallels the 275kV lines west and south to Denny, passing to the southwest side of Glenside Farm.

Landscape effects on this section are in the main low due to the already high prevalence of overhead electricity lines. However it is noted that there will be significant cumulative wirescape effects on the approach to Denny substation. A number of properties on the southern edge of Plean and Carbrook Mains Farm will experience moderate or major adverse visual impacts. Glenside Farm will experience major adverse impacts due to the close proximity of the line and the existing 275kV lines (subject to further assessment under Consent Condition 20).

Cumulative and wirescape issues have been addressed to some extent in the SVIMS by the proposed re-conductoring of the 275kV lines, undergrounding of low voltage cables around Carbrook Mains and the painting of towers to match new painting of the 275kV line towers.

None of the options consider specifically undergrounding this section along this route. Undergrounding is considered in whole route undergrounding options which pass west of Plean (20, 22 and 23).

5.2.6 Summary on Mitigation Secured by Undergrounding
Our conclusions in respect of undergrounding and the justification for undergrounding are as follows:

- SPT’s costs for undergrounding reflect the non-standard nature of the work in the UK and will include significant contingencies that are likely to offer a conservative/ precautionary view of costs. The fundamental order of cost multiple for undergrounding compared with overhead transmission is however not disputed.
The SPT costing for rock tunnelling and undergrounding on slopes could reasonably be expected to include high contingency elements and represent in our view a conservative/precautionary assessment of costs.

That the level of adverse impacts resulting from the proposed overhead line is in the main low or moderate, albeit with some localised impacts of major significance. Most notably:

- The route of the existing and proposed overhead lines crosses the Ochils scarp at its least sensitive point, compared with the much larger, more open and visible scarp to the east;
- Impacts on the key sensitive receptors (Ochils AGLV designation, Wallace Monument and Stirling Castle) are in the main not significant.

The undergrounding of some sections of the route, particularly on the Ochils scarp, would not necessarily reduce landscape and visual impacts due to the requirement for SECs, or would require undergrounding of extensive sections, displacing impacts to another location.

Areas where undergrounding may be most effective in providing mitigation are between the B9124 and Denny where there are significant wirescape impacts and major adverse visual impacts on properties.

5.3 Mitigation - Re-routing of Overhead Line
SPT has developed the current overhead route through a process of developing alternative overhead route corridors and evaluating their environmental benefits and dis-benefits. The previous preferred route considered in the Stirling area passed closer to Stirling, in the same corridor as the current Beauly-Denny 132kV line. However this was rejected as it passed through two proposed Major Growth Areas between Stirling and Plean identified at that time in the Stirling Local Development Plan (Durieshill and West Sauchenford).

The options appraisal considers one alternative overhead route only, in Option 17. A number of underground routes on alternative alignments are considered in options 19 to 23 (see above). In options 19 and 21, where there is an overhead section between undergrounding, it follows the proposed route. These options are not considered further in this section.

In Option 17 the route south of Fallin follows the corridor between Bannockburn, Cowie and Plean, entering the Denny substation on a parallel alignment to the existing 132kV OHL. The route is similar to the preferred route rejected in 2004.

It is noted by SPT that this route would be shorter than the proposed route, with fewer angle towers. As a result, the estimated capital and overall costs associated with the route are slightly less than those for the proposed route. Nevertheless, this route is rejected on two main grounds:

- By comparison with the proposed route it does not reduce overall the landscape and visual impacts in the Stirling area, and is indeed closer to more properties than the proposed route;
- It passes through the proposed Durieshill Major Growth Area which remains a proposal in the Development Framework. The line would adversely affect the landscape of the growth area and visual amenity of future properties within it.

Our conclusions in respect of alternative overhead routes are based on consideration of cumulative effects and the possibility of combining this form of mitigation with others:

- We note that there would be reduced capital costs due to reduced line length. However, we query the lack of project delay and constraint costs shown in the matrix. We assume that a route deviating from the would be subject to a new application and EIA, leading to delays and costs of a similar order as some of the undergrounding proposals;
- Whilst we note that more properties would be affected by the proposed rerouting, this would be in a corridor already affected by the existing 132kV line and the Fallin to Glenbervie 132kV line as
opposed to a significant length of corridor in which the currently proposed line would be a novel feature;

- The existing 132kV line would be removed and the environmental benefits of undergrounding the Fallin - Glenbervie line are viewed favourably by SPT in their consideration of Option 6 (see below). A scenario in which two smaller lines are removed and the proposed line built could see a balancing of adverse and beneficial landscape and visual impacts for many receptors and the avoidance of cumulative wirescape effects;
- The alternative route would avoid the significantly adverse and largely unmitigated, cumulative and wirescape effects that result from crossing and paralleling the double 275kV lines between the B9124 and Denny substation.
- Combining the alternative route with a section of undergrounding between the M9 and Denny substation would largely avoid adverse effects on the Major Growth Area; would require only one free-standing SEC close to the motorway and would avoid cumulative wirescape effects in the vicinity of Denny substation.

We conclude that, whilst the alternative overhead route proposal considered would have some significant impacts, there is potentially significant merit in an alternative route along this corridor combined with other mitigation measures. In particular by comparison with the existing proposed route it would on balance either reduce or avoid certain impacts by:

- significantly reducing cumulative wirescape effects;
- Being approximately 15% shorter than the proposed route with circa nine fewer towers and fewer angle towers;
- balancing the landscape and visual effects of introducing the proposed line against removal of existing lines within the same corridor;

The proposals for undergrounding south of the M9 could be more easily justified due to its proposed future urban location and the need for only one SEC as the undergrounded section would finish in Denny substation.

We acknowledge that the above routeing considerations would need to be investigated in detail through developing and appraising a detailed route and would require a new application and EIA in common with all the new routeing and undergrounding options. This would result in programme delays of a similar order to the undergrounding Options. The significant additional costs of mitigation measures and programme delay would need to be considered against the level of impact reduction achieved.

5.4 Mitigation - Alternative Towers
SPT have considered the use of low profile towers in locations where there are views in which the standard towers would significantly break the skyline. These are considered in options 8, 14 and 16.

Low profile towers would provide some mitigation by reducing impacts on specific viewpoints in which the full height towers are seen to significantly project above the skyline, particularly in views towards the Wallace Monument and Stirling Castle. However, the disadvantages include the requirement for more towers due to closer spacing and more angle towers on bends. Furthermore, from closer viewpoints the structures appear very heavy.

A further alternative not considered in the options appraisal would be the use of architecturally designed towers that could be features that enhance the landscape rather than structures of an industrial character. However, our assessment of such towers is that they:

- tend to be solid structures and would probably be more visible in the landscape than lattice towers;
- would be of a similar scale to the lattice structures;
- are likely to be untested, leading to long design/ development delays and associated costs.

'Architectural' pylons (e.g. recent Department of Energy and Climate Change and the Royal Institute of British Architects Open Competition) would be more suited to an urban context, seen against buildings, and are likely to be intrusive and out of context in a predominantly rural setting. Together with potential design/ development delays we consider they are not a viable alternative.
5.5 Mitigation - Undergrounding Fallin to Glenbervie 132kV line
Undergrounding of approximately 7km of the existing 132kV Fallin to Glenbervie overhead line is considered in Option 6. This involves undergrounding the existing overhead line south of the Stirling wirescape mitigation carried out as part of condition 18. The Fallin-Glenbervie line south of this point is largely remote from the route of the proposed line.

Nevertheless, it is reasoned that removing this line from the landscape should be considered as part of a general improvement to landscape and visual amenity by reduction of wirescape east of Stirling. This is supported.

There are merits in terms of reduction of wirescape and there are unlikely to be programme delays for the proposed line. However, SPT concludes that the cost of undergrounding the Fallin to Glenbervie line would be too great to justify the modest environmental gains. Our conclusions are:

- undergrounding of Fallin to Glenbervie would provide landscape and visual benefits but these would mainly be in locations that are not significantly affected by the proposed line and therefore should be regarded as an indirectly offsetting the direct impacts;
- undergrounding this line would not affect the programme for the proposed line and would not require a further SEC as it is an extension of committed undergrounding under the Stirling wirescape rationalisation;
- there would be direct landscape and visual benefits offsetting the impacts of the proposed line east and south of Plean, where the proposed line and Fallin-Glenbervie cross the 275kV double line route. However the benefits would be of a relatively minor scale compared with the effects of the proposed line in combination with the double line;
- undergrounding of 132kV lines has on average a significantly lower cost multiple than undergrounding of 400kV overhead lines and SPT have reflected this in their capital cost estimate. However we do not fully accept SPT’s 160% cost factor argument for not undertaking the undergrounding as this cost includes the Stirling wirescape rationalisation which is a mandatory part of the proposed development.

The benefits of the Fallin-Glenbervie undergrounding would be best considered as offsetting the impacts of the proposed line, in the context of wider scale environmental improvements associated with mitigation. A more direct effect would be achieved were the proposed line to be routed in the same corridor (see 5.3 above).

5.6 Mitigation - Planting and Landscape Reinforcement
The principal mitigation measure in Option 3, subsequently promoted by SPT in the SVIMS, is the planting of trees and shrubs in hedgerows, strips and clumps in the proposed route corridor; together with other landscape improvement measures.

The purpose of the measures is to mitigate views of the proposed line by full or partial screening; to strengthen and improve the landscape structure in the Stirling area and improve recreational access in some locations.

We have examined the landscape proposals in detail and conclude the following:

- The planting measures would, in time, provide mitigation by reducing impacts to affected locations. This screening effect can be seen in existing mature roadside planting east of Stirling. However it would be several years before the benefits became widely noticeable;
- The other proposed landscape improvements provide no direct mitigation of the effects of the line but are in effect compensatory, offsetting the impacts;
- The illustrations provided in the SVIMS show planting in summer and it is assumed that all the planting will become established and grow well. No detail is provided as to how effective mitigation can be assured. It is likely that mitigation would be relatively more limited than shown, especially in winter views, unless planting was developed into a wider new landscape framework.

We consider the SVIMS landscape proposals to be a legitimate and potentially effective form of mitigation if carried out on a sufficient scale. To be truly effective in mitigating a development of this extent planting needs to be considered on a wider landscape character scale, and preferably linked in with wider green network measures and initiatives.
5.7 **Low Voltage Undergrounding**

SPT has proposed in Option 2 the undergrounding of a number of lower voltage overhead cables in the vicinity of the route. The purpose of this is to reduce the appearance of wirescape in some views of the line by the removing foreground clutter of 11 and 33kV lines. SPT has adopted this measure in its SVIMS proposals.

Our conclusions regarding wirescape rationalisation are that it is an effective but very localised measure:

- It reduces cumulative visual clutter;
- It is a measure that is immediately effective but clearly limited to locations in which low voltage overhead lines are located in the foreground of views;
- It would in effect be a compensatory offsetting measure as it would not directly mitigate the impacts of the proposed line;
- There would be no programme delays to the proposed overhead line project.

We conclude that wirescape reduction, in tandem with other wider scale landscape mitigation and improvement measures, would provide tangible mitigation offsetting the effects of the proposed line.

5.8 **Tower Painting**

SPT has proposed tower painting in Options 4, 5 and 9. The purpose of tower painting is to reduce the perceptibility of the proposed line towers by visually blending them with background colours or matching with adjacent towers.

In Option 4 it is proposed that the towers on the Ochils scarp are painted to blend in with the background vegetation when seen from the Wallace Monument, Stirling Castle and from local roads and properties. Option 5 proposes painting of towers where the proposed line crosses the existing 275kV lines in order to visually match the existing towers. Option 9 proposes the painting of all towers on the route. SPT has adopted Options 4 and 5 as part of their SVIMS measures.

We conclude in respect of tower painting:

- The painting of towers on the Ochils Scarp would provide effective visual mitigation by reducing the perceptibility of the towers against the backdrop when seen from more distant viewpoints. The effectiveness of colouring can be already be seen on the existing 132kV towers which are rusty and often difficult to see against the backdrop;
- A detailed colour study is required to select colours that would work best over the seasons and in different lighting conditions;
- The painting of the towers at Plean, whilst providing visual consistency, would provide negligible mitigation of the highly significant impacts and cumulative wirescape effects along this section of the route;
- We agree that there would be no tangible benefit from painting towers along the whole route as, in this relatively flat landscape, the majority of significant impacts are experienced from seeing the towers against the sky. However there may be benefits from painting some more of the towers at the northern end of the route to address views from and to the Wallace Monument;
- The painting of towers can be accomplished with only nominal delay to programme.

We consider that tower painting in selected locations will provide tangible mitigation by reducing the perceptibility (and therefore landscape and visual impact) of the proposed line in the wider landscape when seen from some key viewpoints.

5.9 **Potential Programme Considerations**

A secondary consideration in addressing mitigation is the implications on project programme. In our view this should represent a secondary consideration recognising that a robust and effective mitigation strategy should be the priority that offers effective mitigation and a sustainable mechanism to address impacts.

A number of mitigation options have been reviewed as part of the Stirling Visual Impact Mitigation Strategy.
Proposed 15 years growth

Proposed 25 years growth

View south-east from the A91, looking towards Powis House and the ‘avenue’ of trees lining the existing access track

*Note:* Towers and conductors as proposed are represented by a graphic model and are not true visual images.

Proposed planting shown after 15 and 25 years growth
Planning obligations would require any undergrounding; realignment or significant material changes to follow due planning process requiring:

- Additional design development; surveys (environmental and geotechnical); EIA and technical studies.
- S37/ Planning Applications including all necessary consultations and any review or inquiry processes.
- Securing agreement on wayleaves; CPO’s, licenses requirements.

Programme allowances for site investigations; surveys; design planning and licensing and wayleaves all have different programme requirements and the level of overlap and parallel working includes assumptions that the intent and goodwill existed to secure an early conclusion to the consent processes.

Assessment suggests that in broad terms project planning must make the following programme allowances for the alternative mitigation approaches:

**Undergrounding (whole route)**
- Programme Risk: Moderate
- Risk Implication (mainly technical): -3mths/+6mths
- Duration: 30 months

**Undergrounding (part)**
- Programme Risk: Moderate
- Risk Implication (technical but reduced cf. whole route): -6mths/+0mths
- Duration: 30 months

**Realignment O/H 400kV**
- Programme Risk: Moderate/ High
- Risk Implication (mainly public/ consultee opposition/PLI): -3mths/+6mths
- Duration: 24 months

**Tower Amendments/ Low Profile**
- Programme Risk: Moderate/ Low
- Risk Implication: 0mths / +3mths
- Duration: 6 months

**Landscape Mitigation/ New Landscape activity**
- Programme Risk: none
- Risk Implication: none

5.10

Re-programming is difficult to assess without dialogue with the SPT Project Programmers or wider stakeholders and allowances will have been made that assume staged and sequential activity where a more fast-track approach may be possible. Programme risk, particularly where additional surveys (environmental and geotechnical), consultation and consent procedures are involved is however notoriously high. A range of delay for the undergrounding and/or re-alignment options would in our view be expected to extend between 24 months to 30 months with a risk provision of a further 6 months for full undergrounding or realignment.

**Summary on Mitigation Secured by Environmental Measures**

SPT has developed seven approaches to mitigation. The options appraisal matrix has allowed the consideration of mitigation measures to be presented in a simple, practical, and comparative manner, illustrating:

- Methods of mitigation and their location(s);
- Criteria applied in considering effectiveness and performance against regulatory duties;
- Beneficial and adverse impacts;
- Capital and whole life costs;
- Potential for programme delays and consequential costs.

The matrix evaluation clearly shows the benefits and dis-benefits of each of the options and mitigation methods and why particular measures have been adopted and others not adopted.

In our view the main weakness of the process is that each option considered only employs a single mitigation method and appears to stand or fall on the merits of the generic mitigation method rather than specifically designed mitigation proposals. Further consideration could have been given to innovative, designed combinations of mitigation methods targeted at the most effective locations to maximise mitigation benefits in proportion to costs. This would be similar in essence to the consolidation of measures undertaken by SPT in the SVIMS proposals.
Key Views from Carnbrook Mains
6.0 OVERALL ASSESSMENT OF MITIGATION

This section evaluates the merits of the mitigation approaches tested by SPT and the justification behind their decision to reject or adopt specific methods. A combined mitigation approach involving an alternative route is tested and other mitigation measures evaluated. It is concluded that the most viable mitigation approach needs to address the full range of mitigation measures and significantly enhance the level of mitigation presented in the SVIMS report including a greater level of assurance and partnership working around SPT’s mitigation strategy.

6.1 Assessment of the Potential for Mitigation

SPT in the development of its SVIMS proposals has investigated a number of possible methods and approaches to mitigation, culminating in an options appraisal which examined seven primary methods of mitigation. The mitigation methods included:

- Undergrounding the 400kV overhead line, in whole or in sections
- Alternative Overhead Line Route Sections
- Alternative Tower Designs, in particular the Use of Low Height Towers
- Undergrounding the Fallin to Glenbervie 132kV Overhead Line
- Planting and Landscape Reinforcement
- Undergrounding of Low Voltage Overhead Lines
- Tower Painting

Our assessment of the SVIMS proposals concludes that successful mitigation would best be delivered through a mix of complimentary measures, each targeting specific concerns or mitigation opportunities on the line route.

Our conclusions on the main mitigation options are detailed below together with additional measures considered to support the project objectives of mitigating environmental effects and securing a scheme that avoids, reduces or offsets significant adverse impact on landscape and visual amenity.

6.2 Undergrounding of 400kV Overhead Line

SPT has ruled out the possibility of undergrounding the proposed line on the basis of cost, technical difficulty and limited environmental gains. We concur that there would be significant cost associated with undergrounding and delays to programme. We also concur that the net reduction in landscape and visual impacts from undergrounding the route would be relatively modest in most locations, including the Ochils scarp, if the potential impacts of sealing end compounds and vegetation clearance are taken into account.

However we note that the options appraisal has not considered undergrounding in the context of a suite of co-ordinated mitigation measures. This approach would include an alternative route as discussed in 6.3 below, together with other measures including the SVIMS proposals that have been adopted by SPT.

We have considered the possibility of undergrounding the final section of the line between the M9 and Denny substation as part of an alternative route lying between Bannockburn and Plean (see 6.3). Undergrounding this section would substantially address a number of key objections to this alternative route:

- reduced effect on the proposed Durieshill Major Growth Area where the undergrounding corridor could be integrated with greenspace provision;
- enhanced justification for SPT to underground the cables due to location in a proposed built up area;
- undergrounding would require only one free-standing sealing end compound if extended to the Denny substation.

We conclude that:

- undergrounding of the 400 kV line is not warranted on the basis of the assessed landscape and visual impacts on the alignment as proposed;
- undergrounding would offer the greatest benefits in the ‘wirescape area’ between the B9124 and Denny substation;
- an alternative route alignment (see 6.3) with local undergrounding potentially offers the least impact option and most effective mitigation.
6.3 Alternative Routeing of Proposed 400kV Line

Only one alternative overhead route is considered by SPT: to the west of the proposed line along the corridor between Fallin, Cowie, Bannockburn and Plean. However this is rejected as an overhead route on the basis of planning delays and associated constraint costs, together with a lack of net environmental gains due to effects on the visual amenity of residential properties and on the proposed Durieshill Major Growth area between Bannockburn and Plean.

Nevertheless, we consider that re-routing along this corridor would have some fundamental advantages over the proposed alignment, to be balanced against the environmental disadvantages:

- It would be located in area which is already associated with overhead electricity lines including the existing 132kV line which is to be removed;
- The route would be significantly shorter (reducing the number of towers) and with fewer sharp bends and angle towers;
- The major visual impacts and wirescape issues associated with the area between the B9124 and Denny substation would be avoided;
- In combination with undergrounding the proposed 400kV line south of the M9, and the Fallin-Glenbervie 132kV line between Fallin and the M9, as described below, a more acceptable balance of impacts and significant wirescape reduction could be achieved on this alternative route.

The SVIMS measures that have been adopted by SPT could also be adapted to this corridor where appropriate to further mitigate impacts.

We conclude that:

- no realignment would be possible without further Environmental Impact Assessment, planning process and delays, re-opening the detailed consideration provided by the PLI, however in our view and with the benefit of hindsight, this alignment with limited undergrounding would offer gains in reducing the impacts on the landscape and visual environment.

6.4 Undergrounding of Fallin-Glenbervie 132kV Overhead Line

It is accepted that the undergrounding of Fallin-Glenbervie 132kV line would result in landscape improvements in the area east of Stirling and visual amenity improvements along its corridor, offsetting the impacts of the proposed line. This could be achieved without delaying the programme for the proposed line. As the route is largely remote from the proposed line this would be mainly indirect mitigation, although minor direct benefits would be apparent in the vicinity of Plean and Carbrook Mains where this line crosses the ‘shuffle’ junction of the double 275kV Longannet line and the proposed 400kV line. SPT has rejected this option on the basis that the environmental gains would not justify the cost.

In 5.3 we have proposed routeing the Beauly-Denny line in the corridor between Bannockburn and Cowie. In this scenario the undergrounding of the Fallin-Glenbervie line would be more effective than currently proposed:

- The offsetting would be more directly associated with the other changes in this corridor, i.e. the erection of the proposed line and the removal of the existing 132kV line, affecting the same landscape areas and views from most of the same receptors.
- The length of undergrounding required for effectiveness could be limited to the area between Fallin and the M9, as an extension of the Stirling wirescape reduction already committed to under condition 18.
- No additional SECs would be required.

Again the re-routeing of the proposed line along this corridor would result in a more clearly co-ordinated set of changes and more effective application of mitigation measures.

We conclude that:

- The undergrounding of the Fallin-Glenbervie 132kV line provides complimentary mitigation. However, whilst modest in scale, there would be landscape and visual benefits, particularly at the crossing of the double 275kV Longannet lines near Plean.
6.5 Alternative Tower Designs – Low Profile Towers

We concur with SPT that alternative tower designs are of marginal benefit and have potential disadvantages outside of the specific viewpoints which they mitigate. The main benefit would be to reduce skylining effects on views towards the Wallace Monument and Stirling Castle between the A91 at the Ochils Scarp and the A907. Other mitigation measures in this area could be more effective.

We conclude that:
- Low profile towers are likely to create as many impacts as they mitigate and their widespread use is not recommended.

6.6 Planting and Other Landscape Measures

We consider SPT’s landscape measures go some way to offering effective long term mitigation that would reduce the adverse impacts of the proposed line albeit that, as proposed, the full effectiveness would take 10-15 years to begin to be effective.

Our assessment would suggest that a bolder, more holistic solution to landscape enhancement could extend mitigation, offer new opportunity for compensatory provision and introduce real design innovation to support a new landscape structure with wider environmental and societal benefit.

An exemplar ‘New Landscape’ approach developed in partnership, with an appropriate level of committed funding, could offer substantive landscape and visual mitigation or enhancement opportunities across local communities.

Landscape mitigation is frequently constrained by the vision and capacity to deliver long term goals. Opportunity exists as part of Beauly-Denny to create a more innovative and holistic potential working with local partners (Stirling Council and Central Scotland Green Network) to secure a new landscape setting embracing established concepts associated with Central Scotland Green Network; Stirling Greenbelt Enhancement and Design for Biodiversity. The Stirling Green Belt Review (LUC, 2009) recommends enhancement of landscape structure in much of the area east of Stirling.

Further mitigation could be gained by co-ordinating with the planting and landscape improvement measures other mitigation associated with core paths; low voltage wirescape improvements; tower painting and environmental management. Committed to as a partnership project with local engagement, a comprehensive mitigation strategy could be conceived that also included innovation in delivery and a financial bond providing greater assurance around effective delivery and long term maintenance.

Enhancement of the local green network could be at a large enough scale to provide long term positive change and reinforcement to the landscape east of Stirling. This would create an environment in which the proposed line would be better absorbed by the landscape:
- More enclosed landscape reduces visibility of the overhead line;
- More screening or foreground interest from specific viewpoints/receptors;
- Enhanced level of woodland cover supporting climate change adaptation and contributing to national targets for forestry and woodland;
- Tree belts/hedges create more linear and vertical features drawing attention from and absorbing the proposed line in views from panoramic viewpoints such as the Wallace Monument; Stirling Castle and Ochil hills;
- Provision/improvement of footpaths/cycleways offering offsetting or compensatory benefits;
- Design specific responses to address sensitive viewpoints including Castle and Wallace Monument in terms of creating a stronger landscape framework.

Nevertheless, we acknowledge that this approach would require time to become fully effective and that not all of the most significant impacts (e.g. Plean-Denny wirescape) would be effectively mitigated.

We conclude that:
- Landscape mitigation can secure very significant benefits if addressed comprehensively with innovation and committed budgets and/or bond ensuring delivery and long term maintenance. This could be an exemplar for SPT and partnership working.
6.7 Low Voltage Undergrounding
We have endorsed SPT’s proposals for low voltage undergrounding as a relatively minor part of wider landscape improvements that would offset the adverse effects of the proposed line.

We conclude that:
- Low voltage undergrounding as proposed be implemented.

6.8 Tower Painting
We consider that tower painting is an effective measure in reducing potential impacts from specific viewpoints, especially when co-ordinated with other mitigation measures. The extent of this measure, approaches taken and colours used should be fully examined at the detailed design stage prior to implementation.

We conclude that:
- Tower painting should be undertaken for all towers on the Ochils Scarp and elsewhere if colour treatment studies demonstrate effective mitigation.

6.9 Potential for Further Mitigation
We have examined the potential for further mitigation of the proposed line, considering methods rejected by SPT and those adopted and developed by SPT.

IFL consider that SPT has followed a robust and detailed method of assessing alternative mitigation methods and has drawn reasonable conclusions based on the evidence available and the approach adopted. However, SPT’s approach has a weakness in not investigating options with a mixture of targeted mitigation methods.

The outline proposal detailed in 5.3 and 6.3 is illustrative of how mitigation measures could be combined to provide more effective overall mitigation. This entails a re-routing of the 400kV line following the existing 132kV corridor with partial undergrounding from the M9 through to Denny.

The outline route could have significant environmental advantages by comparison with the existing proposed route. It offers the potential to:
- balance the landscape and visual effects of introducing the proposed 400kV overhead line against removal of two existing 132kV overhead lines within the same corridor; and
- avoid cumulative wirescape effects and major adverse impacts in the Plean-Denny area;
- create a stronger justification for the expense of undergrounding a section due to its future/planned urban location and the need for only one SEC as the undergrounded section would finish in Denny substation.
- adopt a straighter route, undergrounding a section, together with undergrounding of a section of Fallin-Glenbervie, lead to a significant overall reduction in pylon numbers and wirescape east of Stirling.
This route is similar to that discounted at route selection stage in 2004 primarily due to its passing through two Major Growth Areas promoted by the Stirling Local Plan at the time, as well as other visual impacts on residential properties. At the time of route selection an undergrounding solution was not considered. At present only one Major Growth Area remains in the Local Plan.

We acknowledge that this solution, whilst including undergrounding, may not address Stirling Council’s key concerns, including views to and from the Ochills, Wallace Monument and Stirling Castle. We have already considered that, despite the sensitivity of these locations, the relatively low level of impact and other impacts consequent of undergrounding, as identified at PLI, means that the scale of investment required to underground these sections would not be proportionate to the predicted level of impact or level of mitigation achieved.

We also acknowledge that any alternative route would need to be developed and assessed in more detail to ensure that the balance of impacts is favourable and routeing is technically possible. Such a route would also require a new application and EIA in common with all the new routeing and undergrounding options. This would result in programme delays of a similar order to SPT’s undergrounding options. Alternative route alignments for these reasons, together with their lack of support at earlier review stages, suggest that this approach is not a viable option.

Given the significant programme drawbacks to re-routeing, we would have to conclude that this route is non-viable. Any revisiting of re-alignment options would effectively require the re-opening of the inquiry process and involve and exhaustive and lengthy review process. The remaining, and in our view most viable, solution is further enhancement of the SVIMS measures proposed by SPT. This would involve considering a more holistic and wider ranging scale of landscape improvements linked in with local Green Network initiatives.

6.10 Proposed Green Network / New Landscape Approach
This approach adopts a comprehensive Green Network / New Landscape approach to mitigation and landscape compensation connecting Green Network and Green Belt Enhancement policies

The outline proposal we would advocate would have significant environmental advantages by comparison with the currently proposed landscape mitigation. It would:

- Seek to develop a new landscape framework for the eastern Stirling Greenbelt, developing through the green network a new landscape with significant additional capacity to absorb the amended overhead transmission lines
- balance the needs for mitigation with compensatory provision that offer wider environmental and societal and planning gain benefits and a capacity to contribute to climate change adaptability
- reduce the visual impacts on iconic heritage assets such as the Wallace Monument, Stirling Castle and Ochil Hill views

Such an approach would accord with recommendations for landscape and access enhancement made in the Stirling Green Belt Study (LUC, 2009). The approach needs commitment to an ambitious mitigation vision that offers a long term sustainable legacy securing for the Stirling area combining mitigation and a contribution to climate change adaptation whilst securing meaningful landscape enhancement. The approach requires:

- A formal Development Agreement including commitment to partnership working;
- A confirmed and substantial funding commitment commensurate with the scale of the scheme and mitigation ambition;
- Develop appropriate design and delivery mechanisms with verification of measurable outcomes for mitigation and management;
- Agree a Performance Bond for capital and revenue investment.
6.11 Conclusion

It is difficult to support undergrounding on the currently proposed route in terms of assessed level of impact, the degree of mitigation achieved relative to the degree of infrastructure investment required and delays incurred to the scheme.

Our review of SPT’s mitigation options concludes that at an earlier stage it could have been possible to revisit the route assessment process and identify a route with the shortest length, fewest towers and angles along an alignment already impacted by the existing 132kV and Fallin-Glenbervie 132kV transmission lines. By a combination of targeted mitigation methods including a section of undergrounding we consider that this would have offered the opportunity to avoid some of the most significant impacts of the current proposal and create synergies between mitigation methods without the levels of infrastructure investment envisaged by some of SPT’s single method options. However, at this stage in the development process significant re-routeing may not be viable.

An all-landscape or Green Network response represents in our view a mitigation approach that offers opportunity to introduce impact reduction and offset / compensatory provision (PAN58). This progressive approach addresses landscape opportunity ensuring investment in mitigation is capable of securing compensatory long-term benefits for local communities alongside the mitigation of sensitive views and viewpoints.

It is recognised that a comprehensive new landscape approach well be most effective associated with the East Stirling Greenbelt and that landscape provision alone offers only limited mitigation of the wirescape impacts between B914 and Denny.

This approach requires a significantly different form of intervention representing an opportunity based approach to mitigation and landscape compensation. This alternative would have little or no implication on programme and would be delivered over a number of years. However it must offer a fully assured alternative mitigation approach and be secured by committed funding of an appropriate scale, partnership working, with defined agreements and verifiable targets underpinned by a performance bond.
Beauly-Denny Transmission Line Project
Scottish Government
Stirling Visual Impact Mitigation Scheme
Independent Assessment of Proposals
Ironside Farrar
7727/ November 2011

View of Upper Forth Landscape Structure
7.0 SUMMARY AND CONCLUSIONS

7.1 Approach to Independent Assessment

The detailed consent for the Beauly Denny 400kV overhead line requires SPT to address the issue of visual mitigation in the Stirling area (Condition 19). Scottish Government has requested a further detailed review of proposed mitigation with SPT, submitting amended details of the Stirling Visual Impact Mitigation Scheme (SVIMS) in August 2011.

Ironside Farrar has been commissioned by Scottish Government to review the development of the Beauly to Denny proposals in the Stirling area and their mitigation. This report presents an independent view of the landscape and visual issues and the merits of the potential and proposed mitigation solutions including undergrounding.

In carrying out this assessment we have firstly studied the background development and environmental assessment of the Beauly to Denny proposals in the Stirling area including:

- Route corridor alternatives and the results of consultations
- Selection of preferred route and justification
- EIA/landscape and visual impact assessments of proposed route
- Public Inquiry reports and Reporters’ decisions

In our assessment of the SVIMS proposals we have reviewed the issues surrounding undergrounding of high voltage electricity lines and the specific technical and environmental issues associated with the Beauly to Denny overhead line in the Stirling area, leading up to the publication of SPT’s SVIMS proposals.

Ironside Farrar is appropriately qualified to undertake the review and has extensive experience in Landscape and Visual Impact Assessment including the preparation of Technical Guidance on methodologies for Landscape and Visual Impact for the Design Manual for roads and Bridges (DRMB). Ironside Farrar completed the assessment during the period August-October 2011 with reference to all the Public local Inquiry (PLI) information and SVIMS Reporting.

7.2 Summary of Findings

Ironside Farrar concurs with the findings and conclusions of the Inquiry Reporters on levels of landscape and visual impact in the Stirling area. The impacts would be adverse but are in the main of low or moderate significance, with some notable exceptions where impacts on sensitive receptors (primarily a small number of residential properties) are of major adverse significance.

Our assessment confirms the view recorded at the Inquiry that key highly sensitive receptors including the Wallace Monument, Stirling Castle and the Ochils AGLV would in the main not be significantly affected.

The issue of sensitivity of the receiving environment and the magnitude of change are critical to understanding and developing an objective assessment of the significance of impacts and the level of input required to mitigate impacts.

The Ochil Hills are designated an Area of Great Landscape Value by Stirling Council. The area south of the Ochils, across the carse of the Forth through to Denny has no landscape designations. All landscape types have value and contribute to quality of place and represent important environmental assets. However no landscape character assessments have supported either national or local level landscape designations in the carse area. The Stirling Greenbelt Review (2009) acknowledges future overhead transmission lines. The review also recommends landscape reinforcement measures to strengthen the greenbelt.

Mitigation measures should objectively be weighed against the significance of the impacts and their effectiveness and proportionality in reducing these impacts.

On the issue of undergrounding we understand that cable and drilling technologies are constantly improving and that high voltage cables have been undergrounded extensively around the world and in the UK. Nevertheless we also understand that, even with the most efficient technologies and benign conditions along undergrounding corridors, the lifetime costs of undergrounding are many times that of an overhead line.
This is a fact accepted by all parties although there is disagreement on the likely range of the multiple of cost. Consequently the vast majority of high voltage cables are overhead. We appreciate why SPT have been reluctant to consider undergrounding but consider their approach to this has been conservative.

Our assessment advises that:
- overhead route selection has been thorough and included an appropriate range of alternative route options based on extensive consultations. The proposed route is a logical result of this process based on the information and key stakeholder views available at the time.
- undergrounding involves lifetime costs that are acknowledged as being in the order of 5-15 times higher (and sometime more) than that of an overhead line. Reasonably undergrounding should therefore be considered as a mitigation intervention only to address extraordinary circumstances; where major adverse impacts are predicted; and where it would be effective when other mitigation options (see below) are ruled out as ineffective. We highlight two examples in England where very high profile/national level designation has been addressed by undergrounding.

Mitigation as part of any assessment needs to consider the full range of available measures including: avoidance; reduction; remedy/compensation; and enhancement/net benefit recognised within the EIA Regulations.

SPT (SVIMS Report) has investigated approaches to mitigation, culminating in an options appraisal which examines seven approaches in 23 varied options. The mitigation methods included:
1. Undergrounding the 400kV overhead line, as a whole or in sections
2. Alternative Overhead Line Route Sections
3. Alternative Tower Designs in particular the use of Low Height Towers
4. Undergrounding the Fallin to Glenbervie 132kV Overhead Line
5. Planting and Landscape Reinforcement
6. Undergrounding of Low Voltage Overhead Lines
7. Tower Painting

Further to the options appraisal SPT rejected methods 1 to 4 on the basis of: significant cost (including cost resulting from project delay); technical difficulty and/or lack of significant mitigation. SPT’s (SVIMS Report) mitigation conclusion is that landscape proposals, low voltage undergrounding and tower painting offer the best mitigation response. These are presented as being more proportionate (cost) and result in little or no project delay and are technically more easily achievable. SPT considers that the proposals meet the requirements of condition 19 and their statutory and regulatory duties.

Assessment of SPT’s Approach
Having examined SPT’s approach via the detailed options appraisal we do not fundamentally dispute the assessment of costs, delays and effectiveness of the measures in achieving mitigation. We also consider that the SVIMS proposals offered by SPT would provide some mitigation and are worth implementing, although we note that the planting measures would take a significant time to develop and are not guaranteed to be as effective as the SVIMS report illustrates and assesses.

Nevertheless, SPT’s approach is limited in so far as each option considers only a single mitigation method. Scenarios could have been developed in which a range of mitigation methods sought out opportunity to introduce innovation and offer effective, targeted, combinations of measures to achieve more significant reduction to both landscape and visual impact; introduce compensatory provision and address enhancement/net benefits.

SPT, in our view, has been too ready to create discrete options rather than address more innovative, design led and technically challenging mitigation methods, based on securing positive impact mitigation and delivering wider project and area outcomes at a more proportionate cost.

Potential for Alternative Routeing
Our assessment explored an alternative routeing approach, based on the available mitigation methods.

This combines mitigation methods rejected by SPT. It entails re-routeing the southern half of the proposed 400kV line between Fallin, Bannockburn,
Cowie and Plean and undergrounding the section through the proposed Durieshill Major Growth Area (Housing) to Denny, together with undergrounding the parallel section of the Fallin-Glenbervie 132kV line.

The alignment broadly follows the existing 132kV overhead line (to be removed) on a previously preferred route identified but rejected at route selection stage in 2004. The reasons for rejection were primarily due to the impacts on Durieshill and West Sauchenford proposed Major Growth Areas promoted by the Stirling Local Plan. West Sauchenford has since been dropped from the Local Plan. The approach has a number of advantages:

- It is approximately 15% shorter than the proposed route;
- Pro-rata it could be anticipated to involve approximately 9 fewer pylons without an undergrounded section and up to 20 fewer pylons with an undergrounded section south of the M9;
- On this alignment, the landscape and visual impacts of the new line would be directly balanced against removal of the existing 132kV line, strengthening this mitigation measure.
- If combined with undergrounding the parallel section of Fallin-Glenbervie 132kV line, there would be a significant overall reduction in wirescape in the area east of Stirling, particularly in the area between the B9142 and Denny substation and in the area of Glenside.

This option would require further technical feasibility and impact assessment and would be likely to incur delay and additional cost of a similar order to the undergrounding and re-routeing options examined by SPT. We would note that line re-alignments, would not address Stirling Councils key concerns, including effects on the Ochils, Stirling Castle and the Wallace Monument. Re-alignment would result in significant programme delay due to requirement for further detailed alignment consideration; planning / EIA and consultation requirements. Given the previous rejection of the 132kV corridor alignment we conclude comprehensive re-routeing is not an option and that the most viable current solution is a significant enhancement of the SVIMS proposals offered by SPT. The project is now at a stage where this may result in unacceptable delays and costs.

7.4 Green Network – Wider Landscape Enhancement

We consider that the most viable mitigation approach is to develop a more holistic landscape and visual mitigation strategy based on an ‘all-landscapes’ concept integrating mitigation by a landscape masterplan-led approach. This incorporates: reduction; compensation and enhancement measures. This approach adopts all SPT’s SVIMS landscape proposals (planting, painting, landscape enhancement) and develops them with a significantly more comprehensive and effective approach.

This concept requires a wide scale landscape vision and a real commitment to turning the challenge of mitigating impact into an opportunity to create a ‘new landscape’ with a real legacy for the Stirling area. The approach would be based on the principles of Green Networks and partnership working, with assured and measurable targets reinforced by a financial performance bond for implementation and management.

Mitigation should mean more than funding token impact reduction or solely thinking of mitigation in terms of pylon towers or non-proportionate interventions such as extensive undergrounding. An all-landscape commitment with appropriate funding could deliver far more to local communities, wider stakeholders and the setting of the Wallace monument and Upper Forth. This approach offers a more valuable legacy (social, economic and environmental) that inclusively assists the delivery of wider policy in the National Planning Framework (NPF2) and Scottish Planning Policy (SPP). It also accords with the recommendations made in the Stirling Green Belt Review (2009) for enhancement of the landscape structure to the east of Stirling.

This approach has no timetable or programme delays and involves significant investment, albeit at a lower cost than most other mitigation proposals, particularly re-routeing or undergrounding. Nevertheless it is recognised that not all significant impacts would be effectively mitigated by landscape measures alone. Impact reduction through detail design micro-alignment and other SVIMS measures may be required.
APPENDIX 1

Review of Undergrounding Power Transmission Lines
Summary

Undergrounding of higher voltage power lines is nothing new and there are several thousand miles of underground cables laid down by electricity companies throughout the world. Transporting high voltage electric power underground is a complex undertaking and is accepted as a more costly approach than overhead lines. The reasons for the higher costs arise from the higher cost of conductors (underground cables are made of copper as opposed to aluminium for overhead lines), the civil engineering aspects of placing the cables underground, (extra land for sealing end compounds, ventilation/cooling in case of tunnels, compensation/substations along the cable route for reactive power, accessibility to the full length of the cable route) and the cost of repair should an underground cable fail.

It is very difficult to make accurate estimates of cost for undergrounding high voltage transmission lines. The costs for each transmission line route have to be considered individually. Nevertheless, it is reported that cable undergrounding costs can vary from four times to eighteen times that of an overhead line. Studies of the offsetting benefits of undergrounding transmission lines in monetary terms (house prices, disruption costs etc) have been performed for urban settings but no such study exists for rural areas such as nature reserves, areas of natural beauty etc.

There are several approaches that can be used for undergrounding high voltage cables such as placement is shallow trenches (approximately 1 metre depth) or deeper purpose built tunnels or ducts (over 5 metres depth). Costs for those approaches also vary because they depend on the details of the local geography and the underground soil morphology.

One option that seems a more economical option for underground power transmission is DC power transmission as it requires less cabling and is a more efficient method of carrying power long distance.
Introduction

Demand for reliable electricity supplies is growing worldwide and global warming and other environmental concerns require for renewable, non polluting energy sources to be utilised, such as solar, wind, wave or tidal power generation. The nature of these power generation modes requires for their installation to be in remote areas on land or out to sea. The distribution of power from those remote areas to urban areas poses a secondary problem and that is the route of the power lines from the power generation sites.

Electricity is transmitted at high voltages (110 kV or above) to reduce the energy lost in long distance transmission. For decades high voltage electric transmission has been carried out via overhead lines but recent concerns over public health relating to overhead transmission lines lying in proximity to inhabited areas and other environmental issues, such as “visual pollution” in the countryside, have urged power distribution companies to adopt undergrounding of transmission cables either for the full length of the route or sections thereof.

The principal advantages of underground cables are that they cannot be seen and that they are less prone to storm or accident damage. There are also other benefits for utilities, customers and local communities. Transmission losses are lower with underground cables than aerial lines because the resistivity of copper cables is lower than aluminium overhead lines. However, most losses (around 80 percent) of any transmission network (from generation to consumer, irrespective whether it is an underground or overhead line transmission), occur within the lower voltage distribution networks. Even at these lower voltages of the distribution network, although undergrounding is a factor in controlling losses, most occur during the process of transformation or are due to other non-technical issues.

Undergrounding of high voltage transmission lines is not new and there are several examples of such schemes worldwide. This report gives an overview of the technologies utilised, including the underground electrical cable technologies, the civil engineering aspects of constructing the underground cable route, and some aspects of electricity transmission, namely use of high voltage direct current (HVDC) as opposed to high voltage alternating current (HVAC) transmission.

Undergrounding of power lines

Undergrounding of low power electric transmission lines is the norm throughout Europe where the entire power supply network in urban centres is provided by cables placed in shallow trenches under roads and pavements. High voltage electricity transmission (in excess of 110kV) from power generating sites is a more complex undertaking and has traditionally been carried out by overhead lines which are widely accepted as an efficient and economic means of transporting power.

Over the past two decades though concerns over health issues associated with electromagnetic radiation in the proximity to high voltage overhead lines, as well as objections over the placement of such lines in sensitive areas such as archaeological sites, nature reserves etc, there has been an increasing demand for undergrounding of power transmission lines and there are several such installations in the UK and throughout Europe, as shown in table 1.

One of the longest underground transmission lines in the world is the 500kV Shin-Toyosu Line. This is a 39.8km underground transmission line connecting the Shinkeiyo Substation on the 500kV overhead grid line system surrounding Tokyo, to the Shintoyosu Underground Substation newly constructed in central Tokyo. The line has been in operation since 2000.
The line utilises a 500kV XLPE cable; the first time such cable has been used in a long-distance electricity transmission anywhere in the world. Virtually the entire route, with the exception of ducts under bridges and elevated expressways, is enclosed in a tunnel. The line specifications are as follows:

- Number of circuits 2 (3 in future)
- Transmission capacity 900MW/cct (1200MW/cct in future)
- Laying configuration: Trefoil formation in tunnel troughs, and in ducts under bridges and elevated expressways.
- Number of intermediate joints per phase 40
- Type of joints: Extrusion moulded joints (EMJs)
- SF6 gas-immersed sealing ends: Silicon oil impregnated.

Undergrounding is not a simple task and poses several challenges to electricity providers. There are three fundamental challenges that have to be overcome in high voltage power transmission:

- provision of sufficient insulation round the conductor,
- dissipation of the heat generated in the conductor as a result of the flowing electric current,
- ease of maintenance and repair

Overhead lines are separated from each other and surrounded by air. Open air circulating between and around the conductors cools the wires and dissipates heat very effectively. Air also provides insulation that can recover if there is a flashover. Undergrounding of power cables therefore has to be able to address these issues in order to maintain a reliable power supply to the consumer.
Cable technologies

There are currently four types of cable used for undergrounding high voltage electric transmission lines:

- **High-pressure, fluid-filled pipe (HPFF)**
- **High-pressure, gas-filled pipe (HPGF)** – Often called Gas insulated Line (GIL)
- **Self-contained fluid-filled (SCFF)** - Often used for underwater power transmission
- **Solid cable, cross-linked polyethylene (XLPE)**

**High pressure fluid filled pipe (HPFF)**

A high-pressure, fluid-filled (HPFF) pipe-type of underground transmission line, consists of a steel pipe that contains three high-voltage conductors. Figure 1 illustrates a typical HPFF pipe-type cable. Each conductor is made of copper or aluminium; insulated with high-quality, oil-impregnated kraft paper insulation; and covered with metal shielding (usually lead) and skid wires (for protection during construction). The outer steel pipe protects the conductors from mechanical damage, water infiltration, and minimizes the potential for oil leaks.

The three conductors are surrounded by a dielectric oil which acts as an insulator and does not conduct electricity and prevents electrical discharges in the conductors’ insulation (an electrical discharge can cause the line to fail).

The fluid also transfers heat away from the conductors. The fluid is usually static and removes heat by conduction. In some situations the fluid is pumped through the pipe and cooled through the use of a heat exchanger. Cables with pumped fluids require aboveground pumping stations, usually located within substations. The pumping stations monitor the pressure and temperature of the fluid.

There is a radiator-type device that moves the heat from the underground cables to the atmosphere. The oil is also monitored for any degradation or trouble with the cable materials.

Problems associated with HPFF pipe-type underground transmission lines include maintenance issues and possible contamination of surrounding soils and groundwater due to leaking oil.

**High-pressure, gas-filled pipe (HPGF)**

This type of cable, also called a Gas Insulated Line (GIL) is very similar in construction to the HPFF cables except that the oil has been replaced by Nitrogen gas to insulate the conductors. This cable addresses the problem of contamination of surrounding soils if a leak takes place. Nitrogen gas though is less effective than dielectric fluids at suppressing electrical discharges and cooling. To compensate for this, the conductors’ insulation is about 20 percent thicker than the insulation in fluid-filled pipes. Thicker insulation and a warmer pipe reduce the amount of current the line can safely and efficiently carry.

**Self-Contained, Fluid-Filled Pipe-Type (SCFF)**

The self-contained, fluid-filled (SCFF) pipe-type of underground transmission is often used for underwater transmission construction. The conductors are hollow and filled with an insulating fluid that is pressurized to 25 to 50 psi. In addition, the three cables are independent of each other. They are not placed together in a pipe.

Each cable consists of a fluid-filled conductor insulated with high-quality kraft paper and protected by a lead-bronze or aluminium sheath and a plastic jacket. The fluid reduces the chance of electrical discharge and line failure. The sheath helps pressurize the conductor’s fluid and the plastic jacket keeps the water out.

This type of construction reduces the risk of a total failure, but the construction costs are much higher than the single pipe used to construct the HPFF or HPGF systems.
Cross-linked polyethylene (XLPE)
The cross-linked polyethylene (XLPE) underground transmission line is often called solid dielectric cable. The solid dielectric material replaces the pressurized liquid or gas of the pipe-type cables. This type of cable uses vulcanised polyethylene insulation, which is solid insulation extruded onto the conductor during cable manufacturing. This process involves chemically treating the polyethylene at high temperatures to enhance its mechanical properties.

The flexibility, lightness, strength and lower capital and maintenance costs, are the most important advantages of XLPE cables. This simplified design compared to oil-filled cable design has eliminated the need for an auxiliary fluid-pressure system. XLPE cables has made many advances during the last decade which so far no other power cables have had such an elevated scale of improvement.

In terms of cost, analyses and comments made by Transmission companies, indicate that XLPE is generally considered to be the cheapest and most developed of the cable technologies, with HPFF and HPGF being the most expensive, although HPGF may be a cheaper solution where very high load levels need to be transmitted in short stretches, particularly in urban areas and from power plants to substations.

**Long-Term Durability of underground power lines**

One of the issues that affect the selection of underground cable type is their long term durability. Most overhead power lines, are designed for a 40 year service. However, some companies such as Dominion in the US indicate in their cost analyses that its overhead lines can be expected to last 70 years. This is supported by a document of the Public Service Commission of Wisconsin which states that overhead lines in the northern part of that state are assumed for accounting purposes to last about 32 years, but the lines have actually been lasting about twice as long. The Georgia Transmission Company states that "overhead cable easily can last 70 years."

Dominion also assume the same long life for underground HPFF cables supported by several sources indicating that HPFF lines have lasted 50 years and more. However, for XLPE cable, the assumed life worldwide is approximately 35 years. The main reason for this is that the long-term durability of XLPE is not well-established. The industry view is that the success of a new type of high-voltage cable is not secure until at least 20 years of service experience is at hand. The uncertainty relates not only to the cable but also the performance of the jointing and terminating systems.

**Electric and Magnetic Fields (EMFs)**

Electric and Magnetic Fields (EMFs) have been the centre of major studies worldwide over the past three decades. The focus of these studies was to examine the existence of electric and magnetic fields (EMFs) having a harmful effect on health.

Electric fields are generated by voltage, this field is proportioned to the amount voltage and current, meaning a higher voltage or current will generates a higher electric field which is measured by volts per meter (V/m), whereas Magnetic fields are measured in micro Teslas (mT). The Electric fields transmits via different means such as air, buildings, trees and fences but magnetic fields can pass promptly through most structures.
The threshold of electric and magnetic fields exposure has been set by the European Union in 1999 to 100 microTeslas (mT) for magnetic fields and 5,000 volts per metre for electric fields. Also limits on the minimum height clearance for overhead lines and a "buffer zone" each side of the line have been placed. In some countries, such as Sweden, Norway and the US legislation has been introduced preventing the construction of new homes being built near overhead power lines.

Generally, the underground cables can generate higher magnetic fields directly above them than an overhead line does directly below, as a result of smaller physical distance from the underground cable. For example, 400kV underground cables can produce over 30 mT at ground level falling to 10 mT at 2 meters above the ground, although, the field falls rapidly with distance to the side and the way the cable is structured. In addition, placement of cable in tunnels at larger depths can also eliminate the EMF and some cable structures produce almost no electric field.

**Methods of undergrounding**

There are two main methods of placing high voltage electric cables underground. These are
- direct burial in specially designed trenches and installation in underground tunnels or ducts.

**Trenching**

Trenching is the most common method used. It involves the digging of a suitable depth and width trench into which the cables are placed a specific distance apart, surrounded by a fluidized thermal backfill (FTB). This is a special type of sand developed to meet low thermal resistivity, thermal stability, strength and flow criteria. Figure 3. The burial depth is relatively small, usually approximately 1 metre. The reason for this is to allow for the generated heat to dissipate through conduction into the surrounding soil which is then removed by air through convection on the surface.
Trenching does cause some surface disruption and there are some environmental issues associated with this process.

Trenching works are carried out along the entire buried cable section, and blasting may be required if there are large rocky areas, which may pose some environmental concerns. In addition, an access road is needed along the cable section, for the heavy equipment needed during installation, for patrolling, for maintenance and for heavy equipment in the event of a cable failure.

Utilities do not permit woody vegetation on a cable route, in order to allow access for maintenance and repairs. This access for vehicles must be maintained for the full length of the cable route. The cable right of way would therefore need to be a cleared swath of land as is sometimes seen for gas line right of way.

Another important issue is that woody vegetation removes moisture from the soil which in turn can reduce the thermal conductivity of the soil and cause the cables to overheat.

The heat generated by the conductors can also increase the earth surface temperature by a few Celsius degrees right above the cables. This is not deemed a problem though as the only reported problem has been premature germination in farmed areas.

**Tunnelling**

An alternative method of cable burial is to install the cables in purpose built tunnels or suitable size ducts. The burial depth is much larger than that of trenching but there is much less disruption on the surface as the only places where access for heavy equipment is necessary is at the entry and exit points of the tunnel.

Building a tunnel deep underground is more expensive than trenching but some recently developed techniques have reduced the cost. These techniques are pipejacking and horizontal directional drilling.

**Micro-tunnelling or Pipejacking**

In micro-tunnelling or pipejacking small boring machines, similar to tunnel boring machines, varying from 0.61 to 2.1 metres in diameter are used to construct a tunnel. Because of their size these boring machines cannot accommodate an operator and hence are controlled remotely from the surface. The technique is used for the installation of pipelines, culverts and ducts.

The basic concept of pipe jacking is not complex. A small boring machine opens a small diameter tunnel while a series of pipe segments are pushed behind it by utilising powerful hydraulic jacks. Steering jacks control the line and level of the leading pipe, which has a shield fixed to it. Generally it is necessary to excavate and support a pit at each end of the tunnel, down to the required tunnel invert.

Modern techniques in micro-tunnelling have meant that the distances covered are no longer restricted to short drives under highways or railways. Much greater distances can be achieved by the use of inter-jacking stations along its length and the injection of bentonite around the outside of the pipe in order to reduce pipe friction. Several contractors claim no limit on the length of tunnel that can be produced by this technique.

**Figure 6 Pipe jacking technique. Pipe segment pushed into tunnel (left), finished tunnel (middle), conveyor belt removing earth (right)**

Micro-tunnelling offers several advantages over trenching and other tunnelling techniques, namely:

- Reduced disruption at surface level
- Construction of a complete tunnel with fully supporting smooth walls
- Improved financial viability compared with other tunnelling techniques

In Japan there are 14 projects that utilised micro-tunnelling for electricity transmission over the period from 1982 to 1997.

There are no reports of micro-tunneling being used in the UK for electricity transmission. The largest microtunnelling project in the UK is the West East Link Main (WELM) pipeline scheme commissioned by United Utilities in Bury, UK. This is a 54.5 km long, 1,200 mm diameter welded steel pipeline to enable the transportation of potable water bi-directionally from Prescot Reservoir near Liverpool, to Woodgate Hill Reservoir in Bury, Greater Manchester. The initial design of the £125 million WELM project included 15 tunnels, but United Utilities has since increased the number to 27, to further minimise disruption to transport routes and woodland, making the project one of the most ambitious water pipeline projects undertaken in the UK. In total there are now 5.2 km of tunnels on the scheme.
Horizontal Directional Drilling

Horizontal Directional Drilling (HDD) is an alternative to micro-tunnelling which permits the installation of a pipe, duct or cable underground without disturbing surface structures and thereby avoiding the disruption caused by traditional open trenching methods.

HDD utilises a removable drill head, matched to soil conditions by the operator and a series of drill stems to push and rotate the head. Once the pilot bore is completed, a reamer/backreamer is attached to the drill stem string and pulled back, enlarging the bore wall to comfortably accommodate the product wire, conduit or pipe that is subsequently pulled into place.

Pipes or ducts up to 1200mm diameter have been installed using this method in lengths exceeding 1.5km. Small utility pipe works utilising this method are carried out day to day throughout the UK and indeed the world. Installations under motorways, waterways, railways, airport runways and sites of special significance are routine.

The cost savings resulting from the application of this technology, in both direct and consequential terms, can be very significant. HDD is fast, and more economical than micro-tunnelling. One issue of concern has been the problems arising from drilling in different ground formations but advances in tooling and mud technology have resulted in successful installation in most ground formations.

In the UK the most recent use of HDD for undergrounding of power transmission lines is the SEESA and Magnox South project. The project involved the installation of 4 x 132kV cable circuits from the main Sizewell power station to a new power station currently under construction. The purpose of the work was to connect the existing power station to the new power station which will take electricity from the Greater Gabbard offshore wind farm which is due to go into service in 2012.

The project was to fabricate and install 5 way 180mm HPPE duct configurations under areas of engineering difficulty along the cable route. In all, a total of 12 drills were carried at three locations each ranging from 60m to 380m in length.

One disadvantage of the directional drilling technique used for cable installation concerns the cable repair in case of a failure. A fault in a directionally drilled section of the line could require replacement of the entire section. The cables in the directional drilled section twist around each other in the pipe during installation so they all would have to be pulled out for examination.

![Figure 7 Principle of horizontal directional drilling.](image-url)
Cooling

Once a tunnel has been built and the cables inserted provision needs to be made for the removal of heat from the conductors. Unlike trenching where the heat is dissipated through conduction to the surrounding soil, this is not possible within a tunnel placed deep underground (between 5m and 10m depth). Cooling is provided either through forced air flow through the tunnel or water cooling. Water cooling can be either direct (i.e. in contact with the conductors) or indirect (water flowing through pipes parallel to the cables to remove the heat). Such techniques have been used in many tunnels, e.g. Japan (Shin Toyosu line) and Germany (Berlin City line).

Figure 8  6.3km tunnel, carrying 1100MW, 400kV, supply cables below the city centre of Berlin

Cost of tunnelling techniques

It is very difficult to obtain reliable information on the cost of micro-tunnelling or directional drilling for two reasons. First the prices vary greatly depending on the morphology of the soil the tunnel is drilled through and second the unwillingness of contractors to disclose any cost information.

A recent report by the Public service Commission of Wisconsin on cable undergrounding, states that the cost for directional drilling for the installation of HPGF cables is $25 per foot per cable.

For micro-tunnelling and pipejacking the figure of £1 per millimetre diameter per metre length (i.e. £1,000/metre for a 1 metre diameter tunnel) is quoted as a rule of thumb by civil engineers but has been difficult to verify this with contractors.

Maintenance and repair

Power outages in the electricity network are of concern according to their frequency and duration. As with overhead lines, underground power transmission cable systems are expected to have lives of 40 years or more, with minimum preventative maintenance and certainly minimum interruption of duty. Underground power cables are therefore designed with the aim of much better reliability in terms of outage frequency, because the outage duration, for repair to take place, is much longer than for an overhead line, and this is reflected on the cable cost. Of course material failures are inevitable in any system and zero outage cannot be guaranteed for any cable system. Table 2 below gives estimates of power outage time scales from the Joint Legislative Audit and Review Commission (JLARC) of the state of Virginia in the US.

The cause of power outages fall in three categories: Accident, Acts of nature and short power cuts.

- Accidents are normally due to: third party damage or insulation failure
- Acts of nature involve strong winds, heavy rain, floods and lightning.
- Short power cuts are caused by lightning, birds or airborne debris and are caused by automated switching off of the supply to the conductor to avoid permanent damage and switched back on within a few seconds when the fault has been identified and removed.
- Of all the above causes of power outage only the cable insulation failure, arising from material failure or third party damage for example through excavation in urban environment settings, is related to underground power transmission. It is one of the advantages of underground transmission that operation is unaffected by most of the causes of failures associated with overhead lines. In an Australian (Ausnet SP) report it is stated that the top predominant causes of outages which account for over 50% of all power outages were external and due to falling tree damage and conductor failure. It has to be noted that damage due to trees is a threat for low height pylons.
Table 2 Length of Time for Overhead and Underground Line Repairs

The same Ausnet/SP report states that the net benefit of putting cables underground due to the reduction of power outage due to accidents or acts of nature was estimated to be 10.8% of the total cost.

There are no specific data available in the public domain of percentage of failures in underground and overhead lines in Europe but some information has been obtained from Khalidi et al again from an Australian study. Based on the System Average Interruption Duration Index (SAIDI) of an Australian power distribution company, it is predicted that 70% of outages are encountered on the overhead network and 30% on the underground network, with an average duration for an overhead fault of 50 minutes and an average duration of approximately 65 minutes for an underground fault. The longer time it takes to repair an underground faulty cable, reflects a higher duration for the underground network fault.

This is a reflection of the time it takes to effect repairs. On a per unit basis an underground fault will take about 10 times longer to repair (with a similar cost ratio). Due to the longer time needed to conduct a repair on underground transmission lines, a double circuit is usually installed so that power can be restored to the customer by switching to the second circuit while a repair is carried out on the damaged section. This increases the installation costs because a second trench or tunnel has to be built alongside to accommodate the second circuit. For HVAC 3 phase transmission therefore a total of six conductors will be needed. In case of a 400kV cable burial in a trench this means that a strip of land approximately 10-15m wide would be required along the full length of the underground route (In the case of tunnelling two entry and exit points will be needed approximately 5-6m apart).

In terms of maintenance costs it is generally accepted that the maintenance costs for underground cables are minimal. For direct burial in trenches, maintenance usually involves inspection of the cable route and clearing of vegetation directly over the trench. Undergrounding in tunnels, involves a visual inspection of the tunnel condition and maintenance of the cooling/ventilation arrangements. For overhead lines maintenance involves inspection of the pylons, and remedial action (usually involving component replacement) for corrosion effects on both the pylons and the conductors, condition assessment and replacement of insulators. Severe weather may also increase the frequency of inspection and maintenance of overhead lines. Some data have been obtained by National Grid in the UK from 1999 cost data where:

- Overhead line maintenance is valued at £600/circuit-km/year;
- Underground cable maintenance is valued at £700/circuit-km/year.

Similarly Terna Spa in Italy reported a similar annual amount, of approximately Euro 1,000/km for overhead line maintenance and their experience with underground cables to date is that maintenance costs are minimal.

Similar results have been reported by a study conducted for the European Commission DG/TREN which also reports that maintenance costs for underground lines are a tenth of those for overhead lines.
More recent data have been obtained by the Australian study on cable undergrounding mentioned earlier. The associated maintenance costs are given in table 3.

### Costs of undergrounding high voltage transmission cables

Undergrounding of cables for high voltage transmission is a more expensive option than overhead lines for the following reasons:

- The conductors (cables) are made of copper (as opposed to aluminium for overhead lines) and additional insulation is required because the cables are often only laid one metre below ground. If the cables are buried in tunnels at greater depth, provision of some form of ventilation/cooling will also be necessary.
- There is a need for extra land (typically 2,000m²) to be made available for the sealing end where the cables need to be connected to overhead lines;
- Access to the full cable route is essential for repairs and maintenance purposes;
- Compensation/substations are required to be built along the route to provide for reactive power.

There are several different cost multiples between underground cables and overhead lines reported from different parts of the world. These vary from underground cables being 4 times to 20 times more expensive than overhead lines because they are highly dependent on local circumstances (including terrain, land costs and power flows). A few cost examples from the international literature are given below.

A comparison of the costs of oil-filled, XLPE and HPGF (GIL) conductors was carried out by Terna Spa of Italy in 1999/2000 as part of a feasibility study into a proposed 7 km link between the 2,500 MW Torre Valdaliga Nord Power Plant and Aurelia Nord substation, just to the west of Rome. The plan was to replace the existing double circuit overhead line with cables along a number of possible routes (including a direct tunnel, along the roadside and across a turnpike/fields.

The HPFF and XLPE cable solutions (4 circuits/12 cables) had a rated power of 1,000 MVA whilst the HPGF solution (2 circuits/6 cables) had a rated power of 2,000 MVA. The total estimated costs for the three alternatives were:

- Oil-filled Euro 6.3 million/km;
- XLPE Euro 5 million/km;
- HPGF Euro 9 million/km.

**Note:** These are the total construction costs only. They do not include through life costs including maintenance.
XLPE was cheaper than HPFF due to lower cable costs and HV switchgear. HPGF was more expensive due to higher cable costs and accessories, but would have twice the capacity. Although XLPE was considered to be the cheapest solution and had the lowest maintenance requirement, Terna Spa favoured HPGF (or GIL) as it was deemed important to develop this technology.

Terna Spa estimated that for a 380kV overhead line over flat terrain the average construction costs were estimated in the region of Euro 300,000/km for a single circuit and Euro 500,000/km for a double circuit. This makes the HPGF option 18 times more expensive than overhead and the XLPE option 10 times more expensive.

In the US a study was carried out by the Public Service Commission of Wisconsin estimates that for a new 138 kV overhead line the cost would be approximately $390,000 per mile as opposed to $2 million per mile for underground (without the terminals), i.e. a 5 time multiple.

A Report compiled for the European Commission DG TREN, taking account of operation and maintenance costs for cables as well as lifetime costs (electric losses in cable are lower than overhead lines), states that the cost multiples fall to be between 7 and 12 times.

In addition, there is currently over capacity in the European market for transmission cables which has led to falling prices and a current project in Denmark shows that the cost of burying 400kV lines is only 3-4 times more expensive than the overhead line. It has to be mentioned though that the Danish project took place at a time of a downturn in the transmission cable industry and the cables were procured at very competitive prices.

Another issue that affects the through life costs of underground lines is the cost of repair which are usually greater than costs for an equivalent overhead line. In the US where HPFF and HPGF cables are used, leaks can cost $50,000 to $100,000 to locate and repair. A leak detection system for a HPFF cable system can cost from $1,000 to $400,000 to purchase and install depending on the system technology.

Moulded joints for splices in XLPE line could cost about $20,000 to repair. Field-made splices could cost up to $60,000 to repair. The higher cost of undergrounding high voltage transmission lines also has an impact on consumer electricity prices. National Grid has reported that undergrounding a quarter of the overhead line EHV network will result to average rise in industrial electricity prices of about 9 percent and domestic prices by 3 percent. This calculation was based on their view that cables are 20 times more expensive than overhead lines to install.

Cost ratios are often thought of as simple way of comparing costs, for example saying an underground cable is 10 times as expensive as overhead line. In reality there can be a wide range of values quoted for apparently similar circuits and this leads to confusion. Small changes in the design of the circuit can produce large changes in cost ratios and, in financial terms, the ratios have little meaning. It is the added cost of undergrounding that is important and must be weighed against the benefits (largely visual) that it brings.

Furthermore, deriving cost ratios from historic values of underground and overhead costs are often a poor guide to present day costs. The price of underground cable is strongly influenced by fluctuations in the commodity price of raw materials such as copper.

The only reliable method of comparing overhead and underground costs is on a case by case basis. Estimates for the costs of underground and overhead options for a specific project must be calculated and then weighed against the advantages and disadvantages of each option.
AC vs DC transmission

The transmission and distribution of electrical energy started with direct current (DC) in the late 19th century, but it was inefficient due to the power loss in conductors. Alternating current (AC) offered much better efficiency, since it could easily be transformed to higher voltages, with far less loss of power. AC technology was soon accepted as the only feasible technology for generation, transmission and distribution of electrical energy.

However, high-voltage AC transmission links have disadvantages and engineers were engaged in the development of a technology for DC transmissions as a supplement to the AC transmissions. The invention of mercury arc rectifiers and the thyristor valves, made the design and development of line-commutated current sourced converters possible.

High Voltage Direct Current (HVDC) transmission finally proved to be technically feasible. The world's first commercial HVDC transmission link, was built in 1954 between the Swedish mainland and the island of Gotland, with a rating of 20 MW, 200 A and 100 kV. There are nowadays several HVDC transmission lines worldwide and these are shown in Figure 8.

Figure 9  HVDC transmission lines in operation worldwide

HVDC Technology

The HVDC transmission systems are point-to-point configurations where a large amount of energy is transmitted between two regions. The traditional HVDC system is built with line commutated current source converters, based on thyristor valves. The operation of this converter requires a voltage source like synchronous generators or synchronous condensers in the AC network at both ends. The current commutated converters can not supply power to an AC system which has no local generation. The control of this system requires fast communication channels between the two stations.

A disadvantage of HVDC transmission is the cost involved because of the equipment required and the considerable land that needs to be made available for a HVDC station. Normally the transformers, filters and phase correction capacitors are placed outdoors, while the valves and control equipment are placed in a closed air-conditioned/heated building. This arrangement is preferable because a completely enclosed system would require a large building that would be too expensive.

The cost of a HVDC transmission system depends on many factors, such as power capacity to be transmitted, type of transmission medium, environmental conditions and other safety and regulatory requirements. Even when these are available, the options available for optimal design (different commutation techniques, variety of filters, transformers etc.) make it difficult to give an accurate cost figure for a HVDC system. Nevertheless, a typical cost structure for the converter stations is shown in Figure 10.

Figure 10 HVDC cost structure
The most common arguments favouring HVDC are:

**Investment cost.** A HVDC transmission line costs less than an AC line for the same transmission capacity. However, the terminal stations are more expensive in the HVDC case due to the fact that they must perform the conversion from AC to DC and vice versa. On the other hand, the costs of transmission medium (overhead lines and cables), land acquisition/right-of-way costs are lower in the HVDC case. Moreover, the operation and maintenance costs are lower in the HVDC case. Initial loss levels are higher in the HVDC system, but they do not vary with distance. In contrast, loss levels increase with distance in a high voltage AC system. Above a certain distance, the so called "break-even distance", the HVDC alternative will always give the lowest cost. The break-even-distance is much smaller for submarine cables (typically about 50 km) than for an overhead line transmission. The distance depends on several factors, as transmission medium, different local aspects (permits, cost of local labour etc.) and an analysis must be made for each individual case. In general the power industry accepts that HVDC becomes competitive over a transmission distance in excess of 400miles.

It is worth noting that the optimum transmission distance before HVDC becomes competitive varies significantly between different projects. A recent study compiled by the National Grid in the UK for the Crown Estate Office relating to the development of an offshore wind farm round the Norfolk Coast reports that the cable route length at which HVDC Voltage Source Converter solutions become more economic than an equivalent HVAC solution is between 60km and 80km.

**Lower losses.** An optimized HVDC transmission line has lower losses than AC lines for the same power capacity. The losses in the converter stations have of course to be added, but since they are only about 0.6 % of the transmitted power in each station, the total HVDC transmission losses come out lower than the AC losses in practically all cases. HVDC cables also have lower losses than AC cables.

**Asynchronous connection.** It is sometimes difficult or impossible to connect two AC networks due to stability reasons. In such cases HVDC is the only way to make an exchange of power between the two networks possible. There are also HVDC links between networks with different nominal frequencies (50 and 60 Hz) in Japan and South America.

**Controllability.** One of the fundamental advantages with HVDC is that it is very easy to control the active power in the link.

**Limit short circuit currents.** A HVDC transmission does not contribute to the short circuit current of the interconnected AC system.

**Environment.** Improved energy transmission possibilities contribute to a more efficient utilization of existing power plants. The land coverage and the associated right-of-way cost for a HVDC overhead transmission line is not as high as for an AC line. This reduces the visual impact. It is also possible to increase the power transmission capacity for existing rights of way. In underground HVDC transmission a single conductor is needed, or two if a dual circuit is used and conductors can be placed in close proximity. This reduces the cost of cable burial (trenching or tunnelling). Figure 9 shows schematically the difference in trenching requirements between an HVAC and HVDC system.
Conclusions

A literature review has been carried out on the current high voltage underground transmission technologies worldwide.

Undergrounding a high voltage power transmission line is a complex undertaking and as such is a more expensive than transmission through overhead lines. What becomes apparent though is that it is very difficult to make estimates of cost ratios between underground cable transmission and overhead line transmission.

There are two main options for undergrounding a high voltage transmission line; burial in a specially dug trench or placed in a purpose built tunnel. Undergrounding also requires special cables which are more expensive but have lower losses and lower maintenance costs. On the other hand repair costs and more importantly repair times are much higher.

Most high voltage transmission in the UK and Europe is AC transmission but DC transmission has some merit and is an option that should be considered in any transmission route greater that 50-80 km, as it is efficient, requires less cabling and more importantly new technologies in switching gear have brought costs down. High voltage DC transmission will also be a method that could make cable undergrounding more financially attractive.

Finally, there are wide price ratios between underground cable and overhead line power transmission. These range from undergrounding being 4 times more expensive to 18 times more expensive than overhead lines. Such generalisations should not be used for every project.

Undergrounding and overhead line options should be costed for a specific project and then weighed against the advantages and disadvantages of each option.
References


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APPENDIX 2

Review of SVIMS Undergrounding Issues
1.0 INTRODUCTION

This report provides comment on the undergrounding information presented in the Stirling Visual Impact Mitigation Scheme (SVIMS) Report and particularly on the options comparison contained in the Report on Engagement issued by Scottish Power Transmission (SPT), on the Beauly to Denny 400kV power transmission project.

The SVIMS Report on Engagement describes in detail the consultation process between SPT, Stirling Council, Scottish Government and other stakeholders. The major point at issue is the Council’s insistence on undergrounding the whole or parts of the 20.2km line which SPT states is technically challenging, expensive and difficult to justify under the constraints placed by Ofgem (the Office of Gas and Electricity Markets).

The focus of the present report is to provide independent comment on aspects of undergrounding of the whole or part of the 20.2km section of the line and the proposed undergrounding of a section of the 132kV Fallin-Glenbervie overhead line as presented in the cost options matrix of the aforementioned report.
2.0 CONTEXT OF UNDERGROUNDING

The majority of Extremely High Voltage (EHV) transmission is carried out worldwide through overhead lines. Undergrounding is normally limited to congested urban areas or where physical barriers need to be overcome (e.g. river crossings). The primary reason for restricting undergrounding relates to cost but undergrounding may also be able to contribute to reducing environmental impacts and may have benefits in increasing service reliability and reducing maintenance costs. Cost of undergrounding is likely to be significantly greater by a considerable multiple of cost than for an overhead cable.

SPT operate within a regulatory framework set by Ofgem with SPT responsible for ensuring that the transmission system is developed in an economically, efficient and coordinated manner in order to protect consumers from excessive electricity transportation costs. SPT have argued in the SVIMS report that there is insufficient justification for undergrounding in the Stirling Area given the high costs associated with undergrounding balanced against the level of environmental impact and the availability of other mitigation measures.

The economic benefits of undergrounding versus overhead transmission are more readily quantifiable in urban areas where the effects an EHV line typically may impact on quantifiable land value and house prices (1). In rural areas it is much more difficult to quantify the benefits of visual mitigation by undergrounding EHV transmission.

Over the past two decades there has been site specific demands for undergrounding of power transmission lines and there are several such installations in the UK and throughout Europe. Two recent referred to examples of undergrounding in the UK are:

- The London Olympics site in which a 275kV and a 132kV overhead line were undergrounded as part of the redevelopment of an urban area. This project included xx km of 275kv and xx km of 132kV funded by the London Development Authority as part of its Olympic commitment.

- The Wye Valley AONB (equivalent to a National Scenic Area) between Brelston Green and Walford in which a six existing 2.8km undergrounded cables on a high voltage circuit are being upgraded to twelve new cables. This scheme represents an upgrading to an existing underground route.

Other undergrounding has included sites within the Peak District National Park and Vale of York.

In Europe 400kv EHV lines (see Newcastle University: Review of Undergrounding Transmission Lines (Appendix 1) are typically provided through overhead transmission. The extent of undergrounded 400kv lines (Source:UCTE Nordel) are of the order of:

- below 50km in France, Norway, Sweden and Finland
- between 50km and 100km in Germany, Italy and Austria
- above 100km United Kingdom and Denmark

The issue of undergrounding is thus one of balancing costs and benefits. According to National Grid, if a quarter of the overhead line EHV network is replaced by underground cables this would result in a three to fourfold increase in transmission prices in England & Wales. This calculation was based on National Grid’s view that cables are 20 times more expensive than overhead lines to install (3).
3.0 UNDERGROUNDING ISSUES

The SVIMS Report on Engagement (see paragraph 1.2.5) set outs SPT’s position reviewing the undergrounding issues and providing the associated costs in the form of a cost options matrix.

Undergrounding Techniques

It is evident in the SVIMS report that the preferred method of undergrounding is burial in trenches. It is accepted that undergrounding a 400kV line through trenching will in effect require a land strip approximately 30metres wide throughout the length of the underground route. The arguments brought forward in terms of surface disruption, accessibility in some areas of the route appear reasonable.

Tunnelling is mentioned as an alternative but SPT have not developed a detailed tunnelling method construction. Building a tunnel deep underground is more expensive than trenching but some recently developed techniques have reduced the cost. These alternative techniques to trenching include pipe-jacking and micro-tunnelling. Tunnelling options, may offer cost reductions but these are considered unlikely to radically change the overall costs of undergrounding.

Other potential techniques for undergrounding of cable could include horizontal directional drilling (HDD). This technique, subject to detailed feasibility studies could offer an alternative to trenching along some proposed routes. Using HDD may actually be a viable alternative as the maximum length that can be tunnelled by this technique in the UK is approximately 1,500 metres. This coincides with the maximum available cable lengths (XLPE) of 1,000 metres supplied by manufacturers. The entry and exit points of the HDD would coincide with the underground cable joint bays that will have to be constructed. A long underground ducted line can therefore be built by HDD with minimal surface disruption.

Costs of Undergrounding

The SVIMS cost options matrix provides a breakdown of the costs associated with the various visual mitigation options including assessment of the costs associated with the undergrounding options. This establishes cost multiples for trenching and tunnelling.

Twelve options for the 400kV line undergrounding have been assessed. Costs for Condition 18 have been excluded from the analysis as they are constant for all options and therefore would not affect the cost multiples.
approximately 37. However it is noted that for options 19, 20, 21, 22, 23, where the length of overhead line is small, the multiple per km for undergrounding (including both burial and tunnelling) drops to 17 times overall, which indicates that the tunneled sections do not affect the overall cost, although a slight increase in the multiple would have been expected.

Options 7, 10, 11 have a high proportion of tunnelling through rock on the Ochils escarpment and it is not easy to obtain information on tunnelling costs through different soil types from contractors. What is known though is that although tunnelling through rock is a slower process it tends to be an easier undertaking because of the stability of the bore hole. There is no information on how the costs of tunnelling were obtained and the cost should not be affected by sealing end compounds as they are not required for transition between trench and tunnel. Although tunnelling costs in Germany and the US are considered very competitive there are big variations round the world related to the tunnelling market size (where there is a big market for tunnelling (e.g. Germany) the costs tend to be lower).

There are several 400kV undergrounding projects throughout Europe (Appendix A) with Denmark having the longest route (22km) which is comparable to the length of the line considered in the SVIMS report. Despite efforts to obtain from NESA A/S (Danish Electricity Generator) a figure for the actual cost of undergrounding this has not been possible. However, the reported cost multiple (total cost of undergrounding) was approximately ten times that of the overhead line (Ref).

In general, it has been found that undergrounding costs (trenching, tunnelling) tend to be more expensive in the UK than other European countries for the same specification of work. In addition, the prices for underground cable offered by companies in the UK also tend to be somewhat higher (for the same specification cable). It is not clear what the reasons for these price variations are.

In terms of tunnelling costs, a search in the international literature has shown that costs can be high in countries where the use of microtunnelling is limited and hence there are significant cost variations. There is always a bid mark-up for micro-tunnelling companies and proposals on how this is determined are provided (5). It has not been possible to obtain information on what financial model tunnelling companies in the UK use for bidding on projects.

Detailed examples of alternative tunnelling approaches for 400kV transmission have proved difficult to source. A case study of a microtunnelling project in Enid Oklahoma reports that a tunnel 3.3 km long, 0.6m in diameter at 10m depth was constructed on a budget of $4.8 million, i.e. $1.45 million/km. Please note that this is the cost of the tunnel only. The tunnelling speed was quoted as 75 days/km. Similar prices are quoted for projects in Germany (7). In fact undergrounding of utilities by microtunnelling is considered routine in Germany which also explains the lower costs.

Microtunnelling could be used for 400kV cables, but it has to be noted that due to restrictions on the proximity of the cables the tunnel should be at least 1.2m in diameter. In addition, if a dual circuit is used, a second parallel tunnel would need to be built approximately 4m away.

It should be mentioned though that in the case of the American microtunnelling project the ground conditions were favourable for microtunnelling which in part explains the low cost. It is not known what the underground geology along the 20.2km proposed route is but the geography of the proposed underground route in Option 13 suggests that the geology may be favourable for microtunnelling.

The estimated construction programme implication reported in SVIMS is considered to be potentially high albeit that detailed site conditions and tunnelling methods are not fully understood at this time. Information from cable undergrounding construction activity in Italy and Denmark suggests a 8-10 months additional programme requirement for route trenching and 12 months for sections passing under river crossings for similar lengths of routes.
Maintenance and Repair Costs
The SVIMS report (Annex 6, section 10 “Economics – Estimated Construction, Maintenance and Constraint Costs), advises on the costs of maintenance of an underground line. It is stated that the annual maintenance costs for an overhead and underground line are 0.05% and 0.03% of capital costs respectively.

This means that for a 20.2km overhead line where the cost is estimated at £19.8 million (excluding condition 18 and assuming 40 year life) the maintenance cost would be £490/km/year. For an underground line, option 22 in the SVIMS report – 17.1km underground, where the cost is estimated at £276.6 million (excluding condition 18 and assuming 40 year life), the maintenance cost would be: £4,842/km/year. (The 7% discount rate pa over 40 years has not been taken into account).

This appears to be high for underground line maintenance as figures from the National Grid give a multiple of approximately 10 for maintenance of overhead lines compared to underground cables. In fact one of the arguments in favour of undergrounding HV transmission lines is the much lower cost for maintenance. Similar low maintenance costs are reported in reference 3.

Sometimes the quoted maintenance cost includes the cost of repair which is much higher for underground cables due to the excavation that needs to take place for repairs and the long power outage time for location and repair of the damage. If the figures include repair costs again there is a discrepancy in the prediction of failures of underground HV cables. Experience on the performance of EHV underground cables that have been used for many years worldwide shows that although underground EHV cables are expensive, they are considered reliable with quoted failures of 1 every 33 years on average (excluding third party induced damage).

It is interesting also that National Grid has recently reported (4) that underground cables are very unreliable which contradicts its earlier assertion (3) and is contrary to the generally accepted view worldwide. It is not clear what type of cable National Grid refers to. It is possible the comments relate to XLPE cables that are a fairly new development in cable technology and there is limited experience with those in the industry. The electricity transmission industry needs at least 30 years experience with a new technology before any conclusions are drawn and therefore it is very conservative in its predictions.

4.0 LOW HEIGHT TOWERS
Low height towers for 400kV lines have been used in many transmission lines in Europe and elsewhere. The argument of SPT that this option may not be visually beneficial because of the greater number of such towers that will be needed along the route is valid.

There are also issues of permitted activity below the path of the towers for safety reasons (kite flying or fishing would not be allowed. The intensity of the electromagnetic field (EMF) below the line would also be slightly increased.

The vegetation in the proximity of the line will have to be managed and any tall trees removed.

5.0 CONCLUSIONS
An analysis of the undergrounding information provided in the SVIMS report compiled by SPT has been carried out.

It is concluded that the cost multiples for EHV cable undergrounding quoted by SPT are broadly in line with those quoted by other UK utility companies, albeit at the higher end of the scale.

Although it has not been possible to obtain specific costs/km for trenching, tunnelling and horizontal directional drilling from UK contractors, it is known that costs for such civil engineering projects in the UK are higher than in Europe. In an open European services market SPT should be able to obtain quotes from European contractors offering trenching and tunnelling services that may reduce the costs for undergrounding. Nevertheless, undergrounding costs are likely to remain at least 10 times greater than overhead line costs.
References

7. Stein D., Mollers K., Bielecki R., Microtunnelling, Ernst & Sohn, Berlin, 1989
8. Tae Hwan Chung, Hyeon-Shik Balk, Dulcy M. Abraham, Sanjiv B, Gokhale, North American Society for Trenchless Technology (NASTT)

APPENDIX A

<table>
<thead>
<tr>
<th>Country</th>
<th>Rated (kV)</th>
<th>Type of joints</th>
<th>Number of joints</th>
<th>Number of terminations</th>
<th>Type of cable system</th>
<th>Number of circuits</th>
<th>Conductor cross-section/Transmission capacity in Winter</th>
<th>Conterminating year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>400</td>
<td>CPFJ</td>
<td>72</td>
<td>3/3</td>
<td>DB</td>
<td>22</td>
<td>1</td>
<td>1600 Cu / 1575</td>
</tr>
<tr>
<td>Denmark</td>
<td>400</td>
<td>PMJ</td>
<td>42</td>
<td>3/3</td>
<td>DB</td>
<td>12</td>
<td>1</td>
<td>1600 Cu / 1600</td>
</tr>
<tr>
<td>Germany (Berlin)</td>
<td>400</td>
<td>CPFJ+PMJ</td>
<td>46</td>
<td>3/2 double systems</td>
<td>T</td>
<td>5.3</td>
<td>2</td>
<td>1600 Cu / 1100</td>
</tr>
<tr>
<td>Germany (Berlin)</td>
<td>400</td>
<td>CPFJ+PMJ</td>
<td>50</td>
<td>3/2 double systems</td>
<td>T</td>
<td>5.5</td>
<td>2</td>
<td>1600 Cu / 1100</td>
</tr>
<tr>
<td>Japan (Tokyo)</td>
<td>300</td>
<td>EMJ</td>
<td>254</td>
<td>3/2</td>
<td>T</td>
<td>39.8</td>
<td>2</td>
<td>2590 Cu / 2400 T4</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>400</td>
<td>PMJ</td>
<td>12</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>1.7</td>
<td>4</td>
<td>900 Cu / not available</td>
</tr>
<tr>
<td>Spain (Madrid)</td>
<td>400</td>
<td>CPFJ+PMJ</td>
<td>96</td>
<td>3/3</td>
<td>T</td>
<td>12.9</td>
<td>2</td>
<td>2590 Cu / 1700</td>
</tr>
<tr>
<td>Denmark (Jutland)</td>
<td>400</td>
<td>PMJ</td>
<td>96</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>14.5</td>
<td>2</td>
<td>1200 Cu / 1200</td>
</tr>
<tr>
<td>United Kingdom (London)</td>
<td>400</td>
<td>CPFJ</td>
<td>60</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>2.25</td>
<td>1</td>
<td>1600 Cu / 1000</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>400</td>
<td>PMJ</td>
<td>3</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>2.25</td>
<td>1</td>
<td>1600 Cu / 1000</td>
</tr>
<tr>
<td>Austria (Wien)</td>
<td>300</td>
<td>PMJ</td>
<td>20</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>5.2</td>
<td>2</td>
<td>1200 Cu / 1600</td>
</tr>
<tr>
<td>Italy (Milan)</td>
<td>300</td>
<td>PMJ</td>
<td>66</td>
<td>3/3</td>
<td>D &amp; M</td>
<td>8.4</td>
<td>2</td>
<td>2000 Cu / 2000</td>
</tr>
</tbody>
</table>

(1) CPFJ = Composite Prefabricated joint, PMJ = Premoulded Joint, EMJ = Extruded Moulded Joint
(2) T = Tunnel, DB = Directly Buried, D = Ducts, D&M = Ducts and Manhole
(3) Cable system prequalified following Japanese Specification [48]
(4) 1200 MVA / circuit with forced cooling in the future, 900 MVA / circuit now
(5) 15 core kms / 4 circuits X3 phases = 1.3 km

T