Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma
Section 1: Application Summary

1.1 Application Title

Holistic Overhead Line Survey Strategy (HOSS)

1.2 Estimated Total Cost

In 2012/13 Prices:

SPD: £10.08m
SPM: £11.18m
Total: £21.26m

1.3 Total Funding Request

In 2012/13 Prices:

SPD: £9.51m
SPM: £9.89m
Total: £20.04m

1.4 Start date / End Date & Date of Relevant Adjustment

Start Date: April 2018
End Date: March 2023 (end of regulatory year 2022/2023)

Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma

Section 1: Application Summary Continued

1.5 Application Executive Summary

This application seeks funding under the Innovation Roll-out Mechanism (IRM) to implement a revolution in the inspection of Overhead Line (OHL) distribution networks through the introduction of a Holistic Overhead line Survey Strategy (HOSS).

This submission has been borne out of a combination of an imperative need to do things differently in RIIO, and the emergence of several highly innovative but proven technologies which, when combined, will revolutionise the approach DNOs take to inspecting and managing overhead line (OHL) assets.

Experience shows us the OHL network is effectively managed and maintained through the outputs of existing inspection practices. However, looking forward, the demands placed on OHL network to ensure energy security, sustainability and affordability will increase significantly. This proposal will serve as a catalyst to bring about substantial change to the way SPEN manages and maintains the OHL network. It will lead the transition towards this new approach, delivering significant additional benefits for customers whilst ensuring network security and safety can be maintained and enhanced. This will be achieved by initially ensuring that current levels of inspections are maintained during ED1 to ensure that programmes, policies and practices can be developed and enhanced whilst transitioning to our new asset management approach. This means that whilst the majority of benefits will be realised in ED2, benefits in reduced foot patrol surveys, vegetation management surveys and CI/CMLs will start to be seen in the last two years of ED1.

1.5.1 Why are we introducing this Strategy?

HOSS will transform SP Energy Network (SPEN)'s current inspection strategy, which traditionally has been based on foot patrols and gathering data manually for OHL asset condition, and vegetation management programmes separately.

Adopting this holistic approach is not about introducing technology piecemeal to obtain targeted individual benefits, but to leverage the increased benefits they will bring collectively by changing the whole way of working around OHL inspections. Technology related to surveys (LiDAR (Light Detection And Ranging), analytics and new asset testing devices) is developing rapidly, but the full benefits will only be realised if there is a complete change in strategy to move to a world with asset data and data analytics at its core, enabling new processes to be derived for a range of business functions including vegetation management, asset management, regulatory reporting and the provision of new connections.

This strategy will lead to significant changes in existing business processes and will require a number of years of learning to optimise new management techniques and to realise the full benefit of the investment, but ultimately will build a solid and lasting foundation for a new way of working for SPEN in which OHL inspections are centred on technology and analytics.

If this project does not go ahead, it will be possible to introduce new technology on a case by case basis, but SPEN and their customers will miss out on the full set of benefits provided by a coordinated strategy.

Section 1: Application Summary Continued

1.5.2 What is the new Strategy?

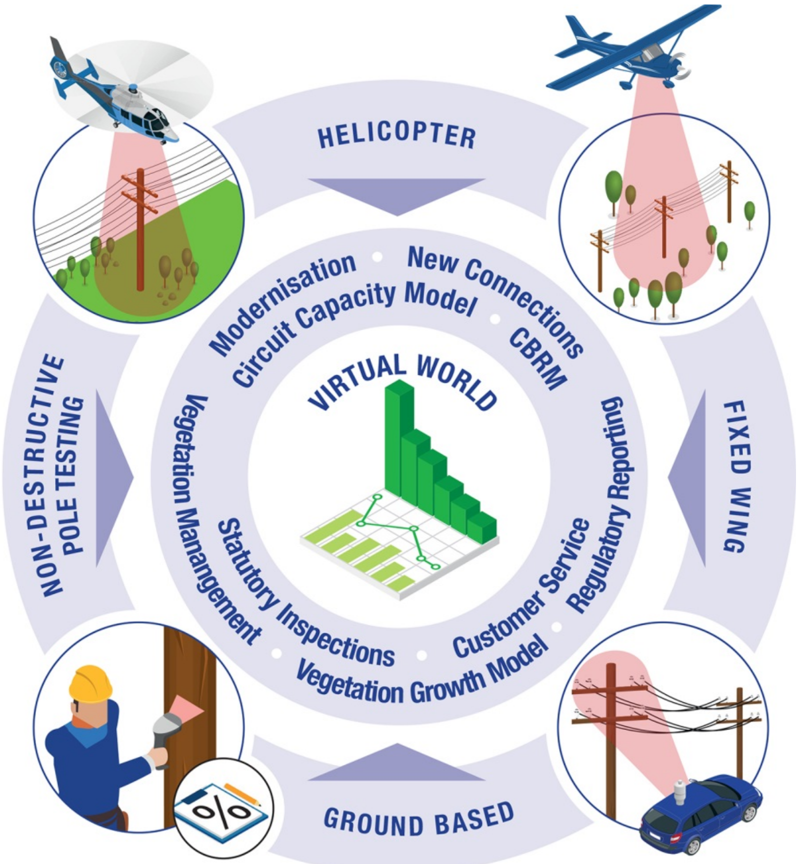


Figure 1 – Holistic Overhead Line Testing and Analytics Strategy

HOSS is represented visually in Figure 1, and comprises multi-purpose surveys undertaken through a combination of:

- Fixed Wing (“Aeroplane)”);
- Helicopter;
- Ground Based (“Vehicular”); and
- Enhanced Manual Inspections utilising Non-Destructive Pole Testing devices.

These surveys will use proven technologies (LiDAR & HD Photography) to enable the capture of a rich source of asset condition information. LiDAR is a surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor. Differences in laser return times and wavelengths can then be used to make accurate digital representations of the target and surrounding environment.

This accurate and consistent source of data will be analysed within a single holistic Virtual World and Analytics platform, enabling sophisticated models to be leveraged from the data and providing additional benefits to network operator and customers. In addition, the following will be incorporated:

1] A growth model, which will be used to maximise the benefit from Fixed Wing surveys in terms of efficient vegetation management. The growth model is part of the analytics package, but as the project and analysis develops, new input data will be combined and used to further optimise the vegetation management programme.

2] A circuit capacity model. The accurate LiDAR data captured can be used as an enabler to optimise overhead line capacity, if there is investment in relatively low cost software and training for staff. Use of readily available data therefore provides a relatively simple means to maximise use of existing OHL assets.

1.5.3 What are the Benefits?

The benefits associated with a holistic overhead line surveys approach are summarised in Figure 2. The benefits denoted in green have been quantified and feed into the business case for the bid (see Section 3 and Section 4), whilst the benefits denoted in blue have been described qualitatively (see Section 2 and Section 4). It can be seen that due to the scale, level and detail of the data that will be gathered through surveying and the data analytics available, a wide range of benefits have been identified. The advantages of some of these benefits will only be fully recognised once the project has been implemented, but many of these benefits build on smaller scale trials that have been carried out by SPEN previously.

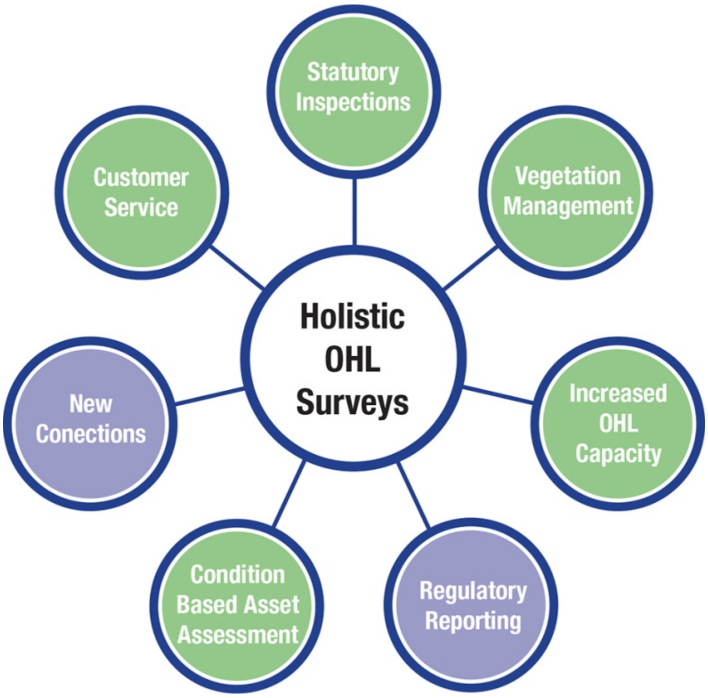


Figure 2 - Benefits of HOSS. Green denotes those benefits that have been quantified in the bid and blue denotes qualitative benefits

1.5.4 Summary of CBA

Detail of the Cost Benefit Analysis (CBA) and the Business Case is given in Section 3. The following costs and benefits have been quantified as part of the business case:

- Survey costs and benefits;
- Wood pole testing device costs and benefits;
- Vegetation management; and
- Health and safety benefits.

Section 1: Application Summary Continued

However, other benefits have not been possible to quantify at this stage due to insufficient learning. These include the reduction in outages due to better vegetation management processes, quicker identification of asset issues and a common approach to regulatory reporting. The overall CBA, when all benefits are quantified and combined, could therefore be significantly higher than the numbers presented below.

The outcome of the CBA, based on the benefits that have been quantified, is given in Table 1 and Table 2 below.

Table 1 – Summary of Costs and Benefits

	ED1 Total (£m)	**ED2 Total (£m)**	**ED3 Total (£m)**
Baseline Scenario			
Foot Inspection	XXXX	XXXX	XXXX
Vegetation Inspection	XXXX	XXXX	XXXX
Tree Cutting	XXXX	XXXX	XXXX
Total	**138.73**	**165.80**	**183.88**
Scenario 1 (Mid)			
LiDAR Costs*	XXXX	XXXX	XXXX
Software Costs*	XXXX	XXXX	XXXX
Pole Testing Costs*	XXXX	XXXX	XXXX
Foot Inspection	XXXX	XXXX	XXXX
Vegetation Inspection	XXXX	XXXX	XXXX
Tree Cutting	XXXX	XXXX	XXXX
SPEN FTE Costs*	XXXX	XXXX	XXXX
Total	**168.86**	**144.78**	**160.25**
Scenario 2 (Worst)			
LiDAR Costs*	XXXX	XXXX	XXXX
Software Costs*	XXXX	XXXX	XXXX
Pole Testing Costs*	XXXX	XXXX	XXXX
Foot Inspection	XXXX	XXXX	XXXX
Vegetation Inspection	XXXX	XXXX	XXXX
Tree Cutting	XXXX	XXXX	XXXX
SPEN FTE Costs*	XXXX	XXXX	XXXX
Total	**168.86**	**151.26**	**167.55**

**Project Cost*

Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma

Section 1: Application Summary Continued

These figures correspond to the following calculated NPV values within the CBA tool.

Table 2 – NPV Results

		Calculated NPV Values		
Option	**Comment**	8 years (ED1)	16 years (ED2)	24 years (ED3)
Baseline	**Business as usual – LiDAR and related technologies not adopted**	0	0	0
Scenario 1 (Mid)	**Mid case benefits assumptions applied**	-5.12	7.75	29.92
Scenario 2 (Worst)	**Worst case benefits assumptions applied**	-5.12	4.15	21.17

Section 2: Application Description

2 Introduction

This submission has been borne out of a combination of an imperative need to do things differently in RIIO, and the emergence of several highly innovative but proven technologies which, when combined, will revolutionise the approach DNOs take to inspecting and managing overhead line (OHL) assets.

Experience shows us that the OHL network is effectively managed and maintained through the outputs of existing inspection practices. However, looking forward, the demands placed on the OHL network to ensure energy security, sustainability and affordability will increase significantly.

SPEN believes that the introduction of HOSS, which will utilise the most up to date surveying technology, is the best way to meet the challenge of the demands placed on our network.

The remainder of this section is structured as follows:

- The need for change is outlined, which describes existing strategies around overhead line inspections and vegetation management;
- The proposed new strategy is described, including discussion around the timing of the strategy;
- The component technologies are outlined, together with visual imagery of inspection results; and
- The various benefits that are predicted to be achieved through HOSS are introduced and described.

2.1 The Need for Change

2.1.1 Existing Inspections

The Electricity Safety, Quality and Continuity Regulations (ESQCR), published in 2002 and amended in 2006, require that SPEN maintains and inspects the network with sufficient frequency, so as to be aware of what action to take to ensure compliance with the Regulations. The inspection of all Company assets is routinely undertaken to identify the current status and condition of plant and equipment, confirm the physical security of the assets, and to identify any external factors which may have an impact on both system security and the safety of SPEN staff, contractors and members of the public.

Existing OHL inspections have served the UK DNOs well; they are tried and tested and they have evolved with the emergence of mobile computing to become more sophisticated and add greater value to energy consumers. Whilst it is foreseeable that this evolution will continue, there are factors and trends that indicate that the future lies with an alternative approach:

- Existing inspections have a single focus, e.g. vegetation management and statutory inspections. Inspections are manual, and there is a limit to the quantity of equipment that a person can carry in order to gather information, and the time that can be taken to do this. There are health and safety implications in carrying heavy equipment and cost limitations in the time that can be spent.
- Inspections are heavily reliant on the ability of individuals to interpret asset conditions. Whilst inspectors are fully trained and competent, there is always an underlying risk that issues are missed or misinterpreted.

Section 2: Application Description continued

- The widespread adoption of a Condition Based Risk Management (CBRM) approach is dependent on DNOs being able to provide quantitative rather than qualitative data on assets. The present approach to assessing the strength of wood poles and their corresponding Health Index is a prime example of this issue, as the existing hammer strength test applied to wood poles is subjective in nature.
- There is a limit to what data can be captured by manual inspections based on the physical location of the inspector relative to the OHL; for example, pole top conditions are not detectable from the ground without the use of specialist equipment. Likewise there is a physical limit in the amount of hardware each inspector can safely carry given that they are patrolling several kilometres of OHL a day. Digital collection and preservation of data through manual inspection processes is also limited particularly from a spatial sense, and there is often no digital representation of the asset that would enable deep interrogation throughout its lifecycle (e.g. granular change detection). This can lead to increased costs and risk, reduced network reliability and resilience, and reactive asset investment and maintenance programs.
- The cost of manual inspections will not decrease given its obvious reliance on human resources.
- As with any manual task there is also an inherent health and safety risk associated with inspections, compounded by the fact that this is traditionally a lone working activity. Any reduction of network length patrolled on foot should result in a decreased risk of Lost Time Injuries (LTIs).
- With recent developments in the maturity and affordability of remote sensing technology, big data processing and cloud based information delivery, DNOs now have a viable alternative to capturing OHL data.
- The performance of this technology is increasing year on year as it has emerging applications within Unmanned Aerial Vehicles (UAVs) and driverless cars. At the same time these applications are driving down the size and cost of remote sensors, as well as opening the door to the use of UAVs for inspections in the near future.

2.1.2 Vegetation Growth Rate

Whilst striving to maintain and manage the OHL network in the most cost efficient manner, there is an acceptance that the network is part of the living environment which is constantly changing due to external factors. SPEN's vegetation management and inspection policy is based upon industry best practice[1] and aims to improve the overall performance of the network by improving resilience to vegetation related faults that occur both in abnormal and normal weather conditions. This therefore requires the inspections programmes to be flexible to accommodate changing or localised factors such as growth rates and land use changes. Moving forward, SPEN is convinced there needs to be greater consideration to the ongoing societal impact and cost of vegetation management when assessing OHL proposals. This conviction is based in part on the internal expertise of our vegetation management team and also on significant learning generated through a series of innovation projects, which are described further in the boxes below.

[1] Engineering Technical Report 132 – Improving the network performance under abnormal weather conditions by the use of a risk based approach to vegetation management near electric overhead lines
Engineering Technical Report 136 – Vegetation Management near electricity equipment – principles of good practice

Vegetation Management[2]

This £1.7m, 4 year collaboration project between SPEN, SSE, WPD and NG (delivered by ADAS) determined the average annual growth rate of vegetation with respect to utility space. The concept of Utility Space Degradation (USD) was introduced and measures the physical volume occupied by an OHL and the additional space required to ensure its safe and reliable operation. Significant regional variations in USD were calculated with sites located in the warmer areas of southern England experiencing the highest average rates of vegetation growth and the relatively cooler SPEN sites in Scotland observing the lowest rates. The past impact of climate change witnessed, and future predictions out to 2080 on USD across the UK were considered, along with different species growth rates.

This report concluded that the average USD in both SPD and SPM had already increased over a 10 year period leading up to 2000, with SPD having a USD of 0.57m (1.8% increase) and SPM a USD of 0.8m (6.3% increase), furthermore growth rates were forecast to continue to increase significantly for each licence area to 2020-2080. The following values were obtained:

- 0.79m and 1.01m for SPD and SPM respectively by 2020 (mid-ED1)
- 0.99m and 1.20m for SPD and SPM respectively by 2028 (mid-ED2)

ROAMES LiDAR[3]

Prior to registering the VWAM NIA4 project, SPEN undertook a small Proof of Concept pilot project, IFI 1416 ROAMES LiDAR. This pilot covered a limited area of OHL network in the Llyn Peninsula, North Wales, covering some 200km and captured fixed wing LiDAR data in late November 2014. During the subsequent VWAM innovation project this area of network was again captured (over period from mid to late July 2015) and therefore allows for the comparison between the two sets of data. In particular, it is possible to imply growth rates for the period between the two flights. Although it does not constitute a full growing season (approximately 65%) we were able to calculate average growth rates for the sections of network to be in the region of 72cm. This data is provided in Appendix a.

The ability to trend the average growth rates of an area is a good indication of likely volumes of vegetation increase; however it can be seen from Appendix a that there is significant variation between circuits. The ability to assess the vegetation growth rates on a span, circuit or regional basis will enable SPEN to identify new practices for each feature, and implement the most suitable strategy.

Virtual World Asset Management (VWAM)[4]

Following the Proof of Concept pilot completed over the Llyn Peninsula, SPEN commenced a trial project predominantly looking at vegetation management opportunities. The project, now in its second year, follows a Six Sigma methodology which has enabled a systematic approach to identifying and measuring the benefits that VWAM could bring to SPEN, UK DNOs and our customers. The project has identified a

[2] IFI_0625 Vegetation Management
[3] IFI_1416 Roams LiDAR
[4] NIA_SPEN 002 Virtual World Asset Management

number of hard and soft benefits which provide a robust business case for BaU adoption for network inspections using LiDAR.

Potential benefits identified include:

- Reduction in faults cause by ‘Growing of Falling Trees’ through the use of improved auditing and targeted vegetation management.
- Reduction in inspection costs through the collection of automatic ground clearance information.
- Audit of Vegetation Management and improved proximity information leading to improved network safety performance.
- Improved network visibility leading to greater ability to plan, prioritise and audit ESQCR work load, including low ground clearance, pole lean, sag and vegetation / structure intrusions.
- Improve understanding of network location aiding network design
- Improved customer service.
- Improved location information leading to greater understanding of potential wayleave issues.
- Improved information for ETR 132 reporting and auditing.

2.2 The Change

This proposal is intended to expedite the introduction of a Holistic Overhead line Survey Strategy (HOSS) that will serve as a catalyst to bring about substantial change to the way SPEN manages and maintains the OHL network. It will lead the transition towards this new approach, minimising costs for customers whilst ensuring network security and safety can be maintained and enhanced. This will be achieved by ensuring that current levels of inspections are maintained during ED1 to ensure that programmes, policies and practices can be developed and enhanced before transitioning to the new approach at the start of ED2.

HOSS looks to replace the majority of the discrete manual OHL surveys presently undertaken with a combination of state of the art surveys that provide a holistic OHL data set that can be utilised far beyond existing applications.

This approach will greatly increase the efficiency of multiple DNO programmes and activities but not to the detriment of the quality of data captured. It is our belief that the proposed solution will also deliver an improvement in health and safety through more frequent checks, quantified assessments of pole strength and more precise measurement of low ground clearances and network intrusions.

This approach optimises the use of several new survey technologies that will continually improve and become more cost effective year on year. The advancement of these technologies will be far more rapid than improvements in manual inspections. Therefore, to ensure the network continues to be maintained in the most cost efficient and effective manner, it is SPEN’s opinion that there needs to be a complete shift in the current way of working in order to take advantage of these rapid advancements in technology into the future.

2.2.1 Overview of HOSS

The HOSS is represented visually in Figure 4, and comprises multi-purpose surveys undertaken through a combination of:

- Fixed Wing (“Aeroplane)”);
- Helicopter
- Ground Based (“Vehicular”)
- Enhanced Manual Inspections utilising Non-Destructive Pole Testing devices.

These surveys will use proven sensing technologies (LiDAR & HD Photography) to enable the capture of a rich source of asset condition information. HOSS is technology agnostic and will enable the use of additional innovative technologies as and when developed. This accurate and consistent source of data will be analysed within a single holistic Virtual World and Analytics platform, enabling sophisticated models to be leveraged from the data, providing additional benefits to network operator and customers.

1] A growth model, which will be used to maximise the benefit from Fixed Wing surveys in terms of efficient vegetation management. The growth model is part of the analytics package, but as the project and analysis develops, new input data will be combined and used to further optimise the vegetation management programme.

2] A circuit capacity model. The accurate LiDAR data captured can be used as an enabler to optimise overhead line capacity, if there is investment in relatively low cost software and training for staff. Use of readily available data therefore provides a relatively simple means to maximise use of existing OHL assets.

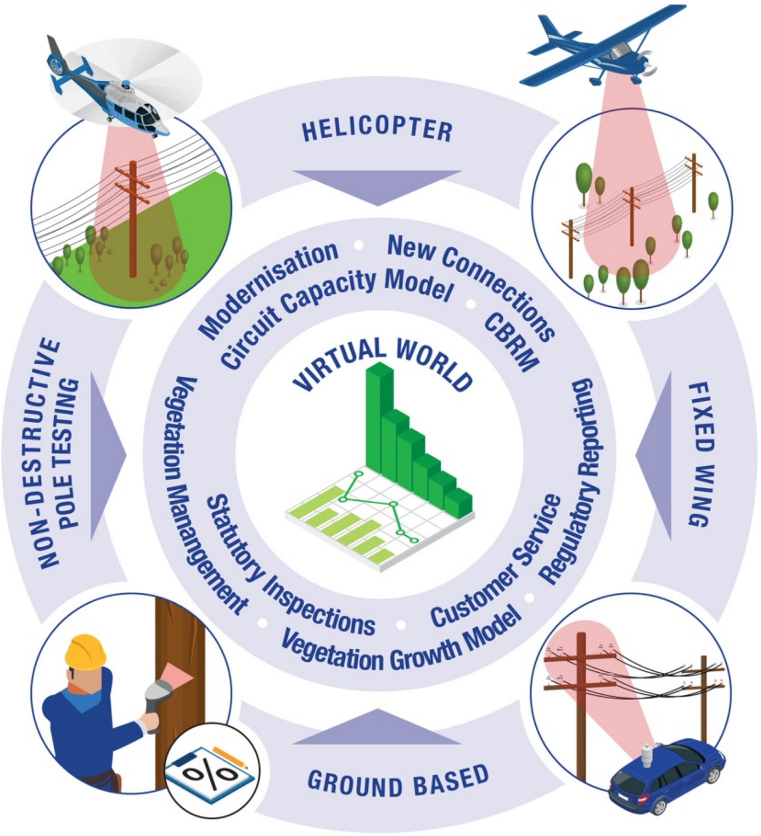


Figure 3 – Holistic Overhead Line Testing and Analytics Strategy

2.2.2 Why These Technologies?

The uptake in LiDAR techniques is increasing and network companies are starting to see benefits in adopting technologies which utilise this proven technology. The combination of solutions, including Fixed Wing, Ground Based and Helicopter surveying techniques also enables a highly accurate database and visualisation of the assets themselves to be built up, for example ground clearance of OHL, position of poles and pole lean. This provides a number of benefits, including the:

- Identification of conductors which are not within the allowable ground clearance limits (perhaps due to changing land use),
- Identification of the state of other assets such as cable guards and stay wires
- Identification of any pole leaning issues, and therefore enables statutory inspections currently performed by ground based personnel to be reduced and replaced with a full and accurate database of distribution assets.

The final piece of information that cannot be gathered from LiDAR is the strength of the pole itself, which is currently tested using a hammer test. However, pole strength testing devices are now available which greatly increase the accuracy in terms of determination of pole strength, and it is estimated that a significant benefit could be achieved due to deferment of replacement of wood poles.

2.2.3 Why Now?

The decision to pursue the adoption of the HOSS has been made based on the findings from several innovation projects undertaken by SPEN and UK DNOs. These projects have highlighted the scale of the challenges faced by the OHL network over ED1, ED2 and beyond, as well as proving that the innovative surveying technology is ready for adoption into business as usual.

Without IRM funding the adoption of each component technology is likely to happen over the course of ED1 and ED2, but this adoption will be piecemeal and will not allow a fundamental change to OHL strategy to take place until all of the technologies are adopted.

2.2.4 How will the strategy change?

The change in strategy from business as usual to HOSS is summarised in Figure 4 below.

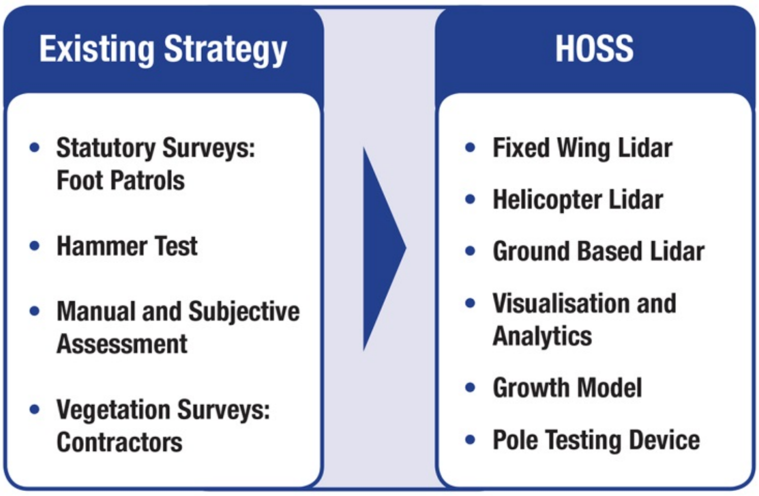


Figure 4 – Change in Strategy for Surveys

The overall objective is to move from a manual, subjective approach with foot patrols at the centre of the strategy to an inspection regime centred on new technologies. A range of technologies is required in order to cover the wide range of surveys that are currently carried out via foot patrols. Initially, it will still be necessary to cover some of the surveys, particularly for LV infrastructure, via foot patrols but the amount of surveys done using this method will be greatly reduced. For this bid, information regarding likely coverage of the various LiDAR techniques is used to gain a detailed understanding of the new approach. However, in the future it is envisaged that all, or virtually all of the foot patrol surveys will be replaced via LiDAR technologies and potentially drones to cover the full network down to LV.

Statutory surveys include a large number of checks and inspections including the following:

- Checking clearances on structures, lines and towers such as checking for vegetation and foreign object intrusions;
- Checking that certain elements are in place and that asset condition is satisfactory such as conductors, arcing horns, crossarms, cable terminations, jumpers, surge arresters etc;
- Inspecting signage, such as the presence of name and number plates, hazards or warning signs, phasing plate, ownership plate etc;
- Measuring aspects including pole height, diameter, span length and lowest conductor height; and
- Checking the pole itself such as for rot and whether it is loose, deformed or off-plumb.

From a consideration of the proposed technologies, it can be seen that these can be used to gather the information that would have been gathered manually. Figure 5 provides a mapping of the inspections that are currently carried out via foot patrols, and the technology that would be used to fulfil the same functions within the HOSS.

2.2.5 How will we know it is working?

The HOSS proposal is centred on providing accurate, consistent and transparent data for the entire OHL network. This will enable SPEN to confirm assumptions are true, undertaken an objective assessment of business performance brought about by the OHL management changes introduced. These improvements will be reflected in RRP submissions and will provide an understanding of the viability of the innovation prior to the end of ED1

	Possible with existing technology, meeting all requirements			
	Possible with existing technology, meeting most requirements			
	Possible with existing technology but with limitations			
	Not possible with existing technology			
OHL Checks	**Manual Inspections**	**Fixed Wing**	**Helicopter**	**Ground Based**
Clearance to Structures / Trees	✓ Ltd to isolated point measurements	✓	✓	✓
Conductor Condition	✓	×	✓ Ltd to sections in vicinity of pole with mid-span defects	✓
Earthing Condition	✓	×	✓ Limited to what is visible from approach vector (full 360° view not possible)	
Equipment Checks	✓ Ltd to what is visible from ground level	×	✓	✓ Ltd to what is visible from ground level
Ground Clearance	✓ Ltd to isolated pt measurements	✓ Limited to OHL conductor, does not	✓	✓
Insulator Checks	✓ Ltd to what is visible from ground level	✓ Only failed/ missing insulators	✓	✓ Ltd to what is visible from ground level
Pole Defects	✓ Ltd to what is visible from ground level	✓ Ltd to verticality checks only	✓ Limited to what is visible from approach vector (full 360° view not possible)	
Pole Top Condition	×	×	✓	×
Pole Strength / Rot	✓	×	× Cannot quantify strength and rot but can detect obvious problems	
Pole / Span Measurements	✓ Ltd to isolated point measurements	✓ Pole height possible but not diameter	✓	✓
Signage & Guarding	✓	×	✓ Limited to what is visible from approach vector (full 360° view not possible)	
Stays	✓	× Not possible for all types of stay at present	✓	✓
Tower Checks	✓ Limited to what is visible from ground level	×	✓	✓ Limited to what is visible from ground level
Vegetation Intrusion Measurements	✓ Requires arborist	✓	✓	✓

Figure 5 – Mapping of Existing Surveys to New Technologies

2.3 Component Technologies

The component technologies are described in further detail below.

2.3.1 LiDAR Remote Sensors

Three of the proposed technologies incorporate Light Detection and Ranging (LiDAR) sensors that use light in the form of a pulsed laser to generate a precise three-dimensional map, capturing both natural and manmade objects as well as surface characteristics. A LiDAR instrument principally consists of a laser, a scanner, and a specialised GPS receiver. Airplanes and helicopters are the most commonly used platforms for acquiring LiDAR data when captured over broad areas; however, the technology is agnostic and can be incorporated into a wide variety of solution

LIDAR itself is not a new technology and it has been utilised on transmission networks for several years; however, until recently the processing of the raw data, called point cloud data, has been a relatively laborious and expensive process that has prohibited its wide scale use on distribution networks.

Section 2: Application Description continued

In the last few years significant inroads have been made in the processing of LiDAR data using machine learning algorithms and cloud processing. As a result there are now a number of vendors offering LiDAR based analytics and mapping solutions at a price point that is comparable to manual inspections to DNOs. The method of capturing LiDAR is directly proportional to the cost and level of detail and quantity of network captured. Fixed wing aeroplanes can captures large swathes of the network relatively quickly, although with a reduced level of detail due to the altitude at which the data is captured (circa 2000ft). Helicopters fly at lower altitudes (circa 300ft) and a reduced speed but are able to gather higher quality and more precise information. Ground based systems offer the cheapest alternative but with greatly reduced speed and richness of data. However, Ground Based surveying is essential in order to increase the total network coverage that can be captured via LiDAR.

2.3.2 Fixed Wing LiDAR with HD Aerial Photography

Fixed Wing LiDAR has been identified by SPEN and other DNOs in and outside of the UK to deliver the optimal solution for mapping large sections of network and the surrounding environment. Flying at an altitude in the region of 2,000 feet enables up to 300m wide corridors to be mapped at a time, ensuring blanket capture through parallel flight corridors where the network below is sufficiently dense. This is shown in Figure 6.

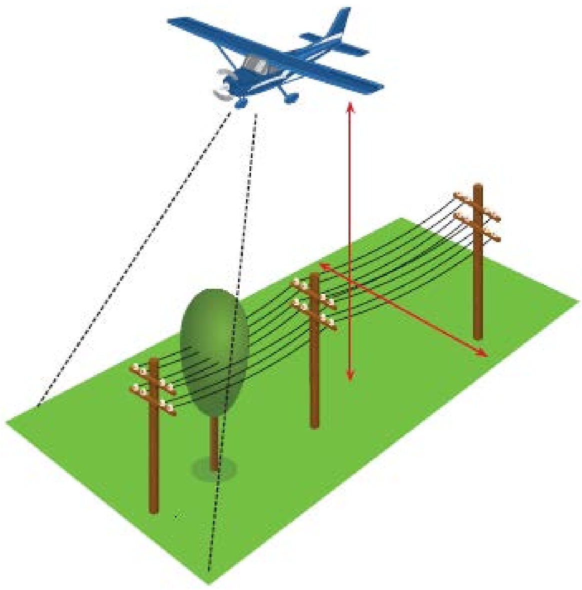


Figure 6 – Fixed Wing LiDAR Corridor Capture

At the same time as undertaking the LiDAR surveys the fixed wing solution is also able to capture High Definition (HD) aerial photographs of the corridors. These images compliment the model and analytics as they provide added context and reassurance to the findings as well as providing additional benefits when analysing the network.

The resulting point cloud is dense enough to enable the catenary of the OHL and the position of the poles to be mapped out and identified. The model generated includes the main physical attributes of the OHL such as the poles, the span, terrain, location of the pole, conductors attached to the pole, buildings, trees, roads, cars etc. An example of a point cloud image for Fixed Wing is given in Figure 7 below and a resulting Virtual World OHL survey generated from Fixed Wing is given in Figure 8.

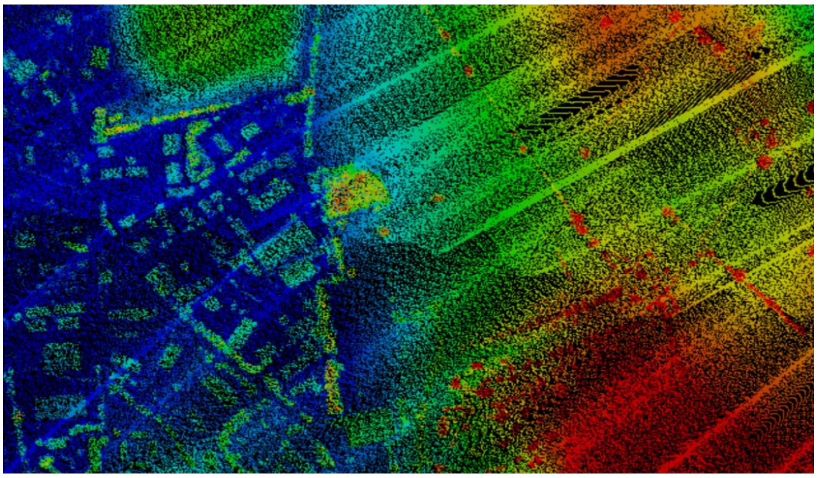


Figure 7 – Point Cloud Data for Fixed Wing LiDAR showing a large area survey with different "laserfiles" or passes visible

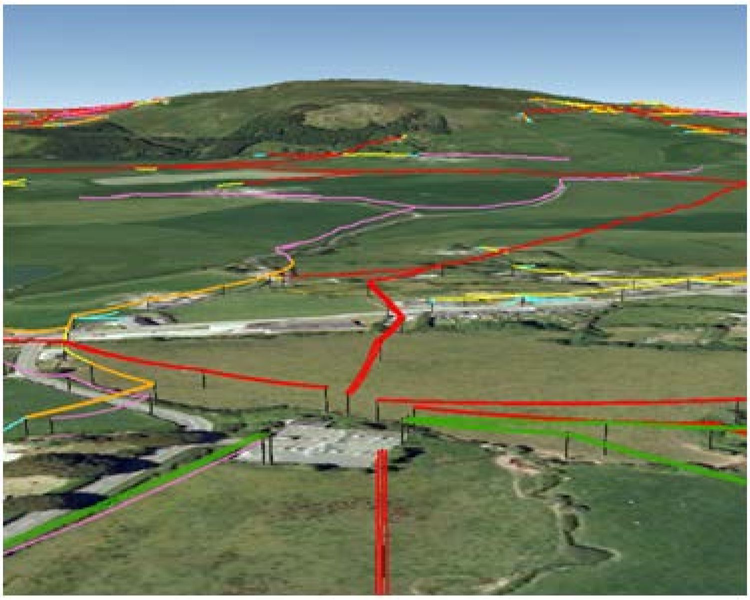


Figure 8 - Fugro ROAMES Virtual World OHL Network generated from Fixed Wing surveys

2.3.3 Helicopter LiDAR with HD Oblique Photography

Helicopter surveys are carried out at a much lower altitude and oblique to the OHL network, which enables the capture of more detailed information on OHL assets through HD imagery and a much denser point cloud data set. The survey allows each pole to be photographed from several angles ensuring the required features are captured. The point cloud data returned is of high enough quality to enable additional features of the OHL network to be detected and mapped; this includes essential components such as stays, jumpers and pole equipment.

This approach has been applied to transmission assets in the UK, but only sporadically in distribution networks to capture isolated circuits. In some European countries including Finland, Sweden, France and Italy Helicopter surveys been used down to voltages equivalent to 11 kV but not at LV. In Australia one DNO has executed a large scale program (250,000+ poles per year) capturing HD imagery of pole tops for asset condition assessment and asset inventory purposes.

It is proposed that SPEN will strategically employ helicopter surveys at a lower frequency than fixed wing surveys and only on the OHL network of 11kV and above. These flights will closely follow the network circuits as opposed to the blanket coverage provided by fixed wing surveys. Low Voltage (LV) networks will be omitted due the low level of coverage possible due to flying restrictions. The same issue has less impact upon higher voltage networks, with an expected coverage from a twin engine helicopter being XXXX for 11kV and XXXX for EHV/132kV. The quality of data returned from helicopter surveys is such that it enables almost all existing visual checks to be undertaken, as well as providing SPEN with additional, high quality information on assets through pole top imagery which would be impossible to obtain from existing manual inspections.

Figure 9 and Figure 10 below demonstrate the quality of the helicopter survey HD imagery and highlight defects (a crack in the wood pole and degradation of the insulator) which are potentially not visible from the ground.

Figure 9 - 28MB HD Pole Top Imagery from Helicopter Survey

Figure 10 - Zoomed in Image taken from previous Figure, highlight pole top deterioration and insulator damage

The point cloud data will enable SPEN to measure and ensure that sufficient clearances to the ground, structures and vegetation are possible for smaller exposed conductors not captured from fixed wing surveys, e.g. jumpers, transformer spills, fuses and switches. An example of a point cloud image for Helicopter is given in Figure 11 below.

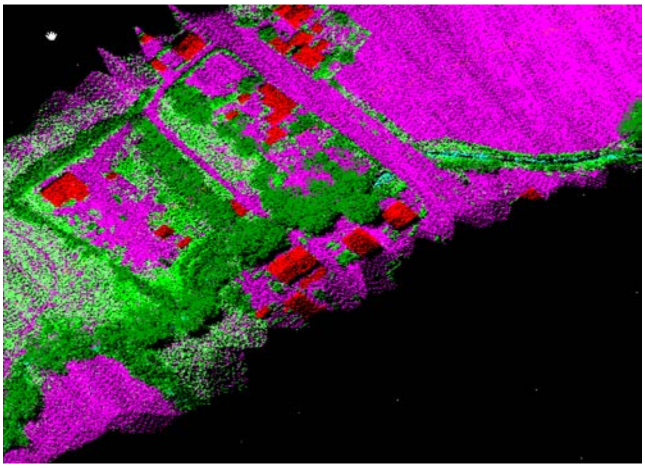


Figure 11 – Point Cloud Data Image for Helicopter LiDAR, where the different colours represent different processed point classes, purple being ground, green vegetation and red buildings.

Looking to the future there is a distinct possibility that, with the further miniaturisation of sensors and cameras and the permission to fly beyond visual line of sight, it will be possible for this type of survey to be undertaken by UAVs. If so, the cost of the survey will decrease significantly, and the ability to undertake the surveys more frequently will increase. UAVs are likely to enable higher network coverage to be achieved.

2.3.4 Ground Based LiDAR with HD Oblique Photography

This survey consists of a ground based GPS-tracked vehicle, equipped with multiple HD cameras and infrared or green wavelength laser LiDAR sensors, which can map objects from 1 – 1000m with high accuracy in the order of millimetres to a few centimetres. The technology enables vehicles to accurately survey OHL in the proximity of the road.

SPEN have trialled this technology as part of the NIA VWAM innovation project, with Figure 12 below showing a survey undertaken in Ruthin, North Wales. The technology is already widely deployed in other industries, particularly rail and roadway management.

Figure 12 - Fugro Ground Based Survey of LV OHL Network in Ruthin

Figure 13 and Figure 14 provide examples of the returned information provided by the survey in Ruthin. Figure 13 is an example of an image still that enables items such as signage, pole furniture and conductor type to be assessed. The trial in Ruthin successfully enabled SPEN to capture the LV OHL with the Ground Based LiDAR.

SPEN propose to utilise this technology in place of the helicopter surveys for the LV OHL network. It will enable SPEN to replace manual statutory inspection checks through the capture of images and measurements of key OHL assets such as cable guards, anti-climbing guards and stay wires.

Figure 13 - Example of HD Image Captured by Ground Based Survey

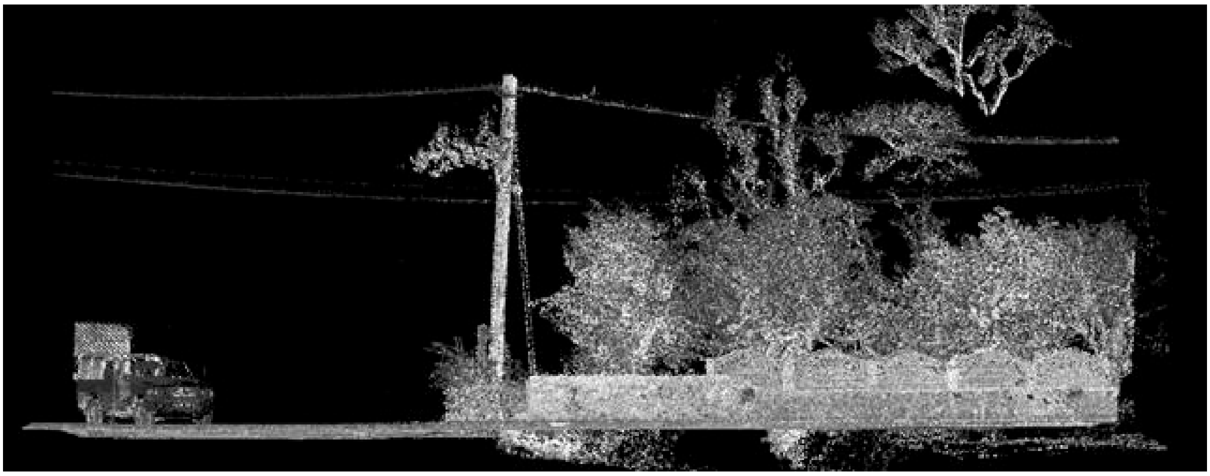


Figure 14 - Example of LV OHL Network Point Cloud from Ground Based Survey

It is SPEN's expectation that it will be possible to XXXX of the LV OHL network through this technology; this is based on the volume of network within XXXX of roadways (excluding driveways). It is our intention to survey the residual LV OHL network manually for the time being, but looking forward we expect technological developments to enable this coverage to increase. For example, this would include the development of UAV technology and mobile imagery and LiDAR capture through technology such as the backpack sensor shown below in Figure 15.

Figure 15 - Backpack LiDAR Sensor

2.3.5 Non-Destructive Pole Testing Device

Currently poles are tested on a cyclic basis using the hammer test and the recorded condition is ultimately based on the judgement of the inspector. The test is subjective and is dependent on listening for changes in sound to indicate decay. In addition, most pole decay tends to occur at or below the ground line, and the hammer test does not easily detect pole weakness below the ground. This pass or fail method does not provide any means of forecasting when a pole is likely to reach the end of its serviceable life.

There have been previous endeavours by DNOs to replace the hammer test with pole strength testers that provide a numerical measurement of a pole's residual strength. Unfortunately these endeavours have not resulted in the widespread adoption for a number of key reasons:

- Many of the devices require a sample hole to be made in the pole; repeated invasive testing of this nature has an inherent impact on the poles condition. Figure 16 is an example of one such test and the impact multiple tests has on pole condition.
- In some instances the physical size and weight of the testing device is unsuitable to be included on foot patrols covering several kilometres a day.
- Most crucially, the ease and time to undertake the tests has been prohibitive and prevented widespread use. The devices trialled required skilled operators and more than tripled the time spent at each pole during an inspection.

Figure 16 - Invasive Pole Strength Test and Resulting Pole Damage

There are now a number of scientific Non-Destructive Pole Testing (NDPT) devices that have been developed and made available. These devices are relatively lightweight, simple and quick to use, meaning they will not have any noticeable impact on the efficiency of surveys. They enable inspectors with minimal training to produce a numerical measurement of a pole's residual strength in a matter of seconds. Many of the devices have further sophistication enabling the pole's hardness, mobility, and dynamic stiffness to be measured to provide a far more comprehensive view of the asset condition. Figure 17 shows examples of two types of pole testing device.

Figure 17 - THOR (left) and VONAQ (right) Pole Strength Testers

Furthermore, the NDPT devices have inbuilt GPS and user profiles, enabling the time, date, user, location and test device details all to be assigned to a pole with the same geospatial coordinates with minimal effort. The data can then be transferred from the field to a central data repository such as the aforementioned Virtual World and Analytics system. This added functionality provides a full audit trail of when poles were tested, by whom and using what equipment.

To date several NDPT devices have been trialled by DNOs in ED1, in particular SPEN have undertaken a collaborative NIA project[5] which tested an Italian device and produced results of sufficient quality to pursue the adoption by the business. Figure 17 shows the THOR and VONAQ pole strength testers. As part of the HOSS proposal SPEN intend to strategically deploy NDPTs to all OHL manual inspections and pre-climbing checks. This will require every lines team and in-house inspectors to be furnished with a device as well as ensuring contractors also have readily available access also. Through the use of NDPTs SPEN expect to be able to extend the frequency of manual inspections for the vast majority of poles with confidence that the poles strength will not have deteriorated to an unsafe level in-between inspections. The measure pole strength characteristics will also be factored into the Condition Based Risk Model (CBRM) for wood poles to facilitate greater accuracy in forecasting pole replacements year on year. Figure 18 highlights the quantified output of the THOR NDPT.

[5] NIA_NPG_0001 Vonaq Pole Strength Tester

Section 2: Application Description continued

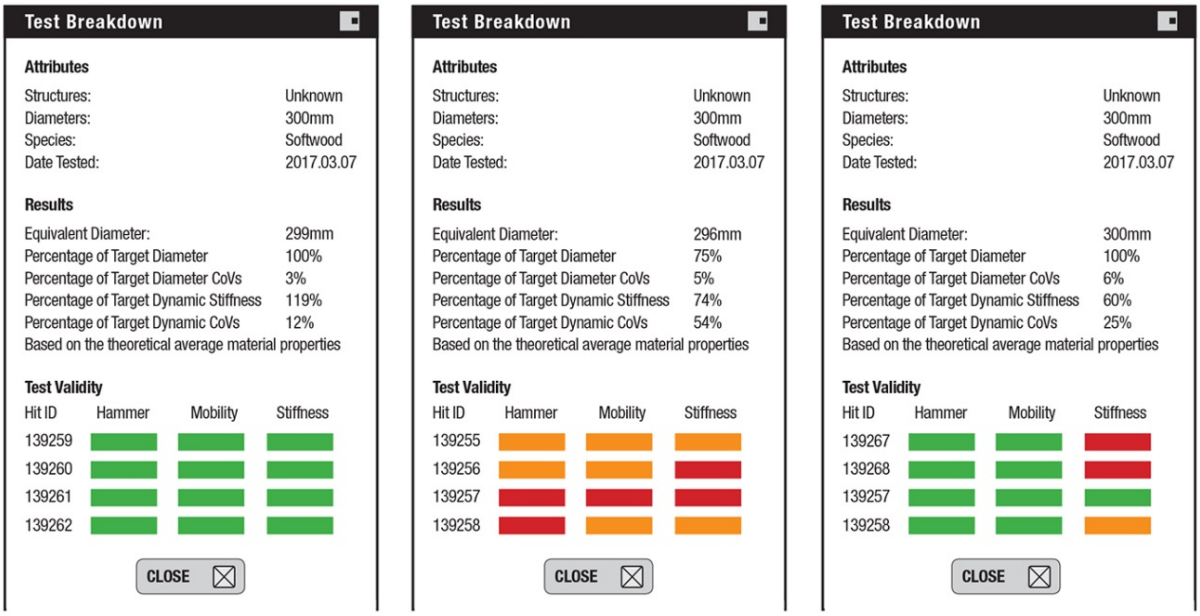


Figure 18 – THOR NDPT Results for Healthy Pole (left), Unhealthy Pole (middle) and a Healthy Pole Installed Poorly (right)

SPEN expect the deployment of NDPTs to deliver significant benefits through the reduction of pole wastage via the re-classification of the pole Health Index (HI), with the new HI being based on a measured strength as opposed to a subjective judgement. This reduction will introduce cost savings as well as environmental benefits which are outlined in Sections 3 and 4.

2.3.6 Virtual World and Analytics

Key to delivering benefits from the LiDAR and HD imagery surveys is the use of integrated Virtual World and Analytics software solutions that utilise cloud hosting to provide DNOs ready access with minimal requirement for additional hardware and data storage. As surveys are completed, the data source can be continually updated through the cloud, with minimal interruption to the end user and enabling the DNO to have access immediately after the data has been processed.

2.3.6.1 Virtual World

The Virtual World provides a precise geospatial 3D model of the network and complementary 2D layers generated from the LiDAR and photographic surveys. Through the Virtual World users can access the model of the entire OHL network and using inbuilt tools can undertake a range of assessments from their PC. Users can:

- Identify the precise geospatial location of every OHL asset, both from the 3D model and corresponding imagery layers. Figure 19 provides 3 examples where the Virtual World has identified geospatial corrections required in SPEN's GIS model, ranging from 8.2m, 25.5m and 60m in the most extreme example.
- Assess the construction on the OHL, e.g. confirm the cross arm configuration and number of phases, understand whether the conductor is insulated and whether there are any underslung pilot cables or 3rd party communications.
- Assess the conductor ground clearance, including the clearance to infrastructure beneath the OHL such as roads, railway and waterways. Figure 20 shows how the user can identify the lowest section of any span as well as the ground clearance at every point along the span.

Section 2: Application Description continued

- Identify any clearance intrusions from structures and identify any changes in land usage. Figure 21 shows an example of a LV conductor that was found to be in close proximity to a new structure built beneath the line.
- Undertake a detailed assessment of the vegetation intrusion of every span. Figure 22 highlights an example of how the Virtual World vegetation mapping ties in with the onsite conditions; in this instance this highlighted the need to rearrange a tree cutting site after first attempt had to be cancelled.
- Identify excessive pole lean and flag up defects such as missing insulators or 3rd party attachments.
- Access HD imagery of geospatially tagged OHL assets as shown in Figure 23.

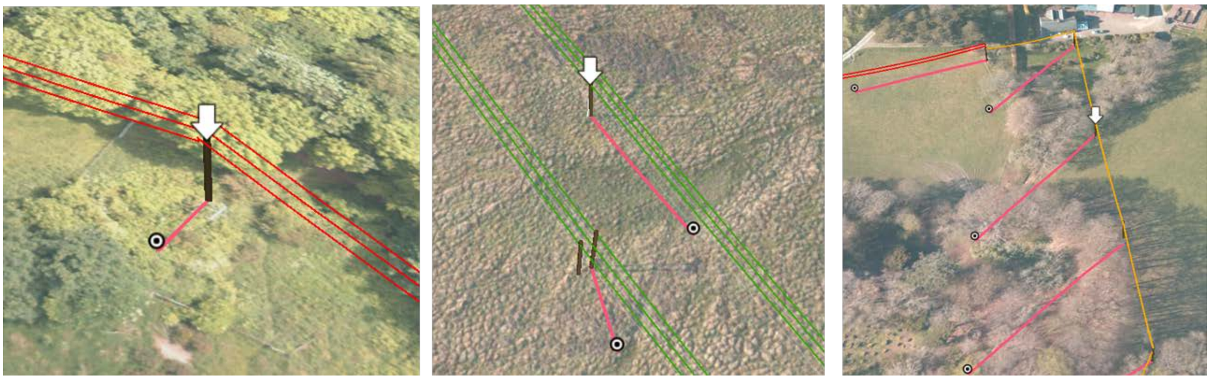


Figure 19 - Geospatial Variances between Virtual World and GIS

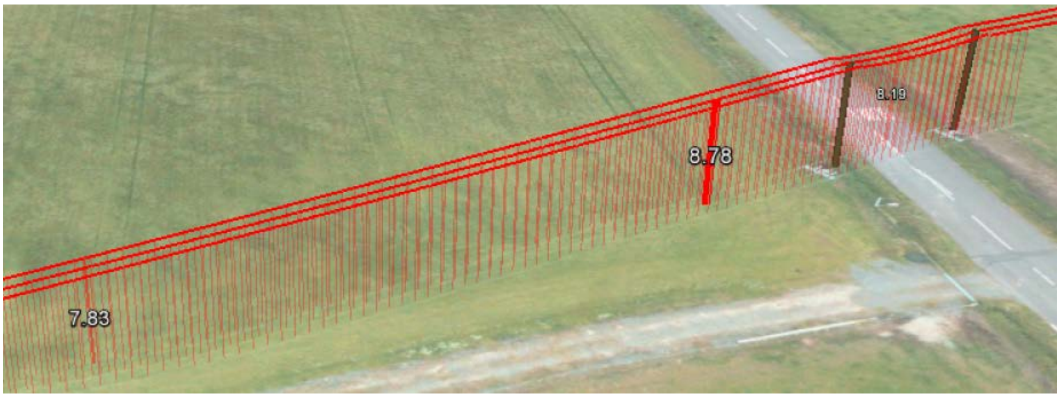


Figure 20 - Virtual World Showing Lowest Ground Clearance along Entire Span

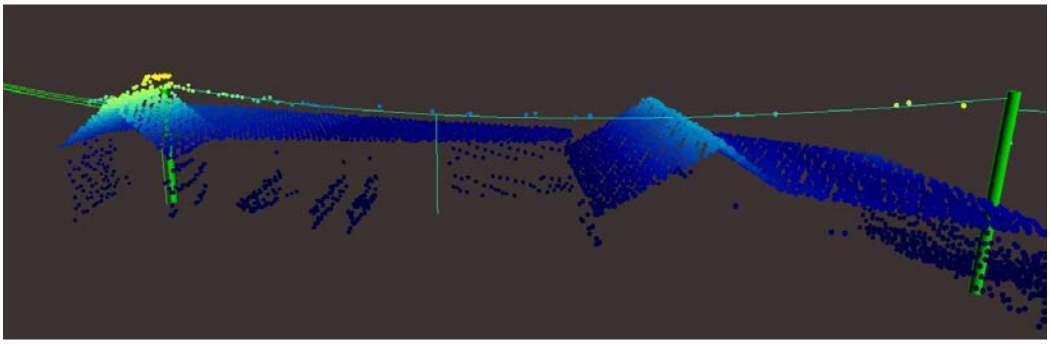


Figure 21 - Processed Point Cloud Data Showing Proximity of Structures to LV Conductor

Figure 22 - Virtual World vs Real World Representation of a Vegetation Intrusion

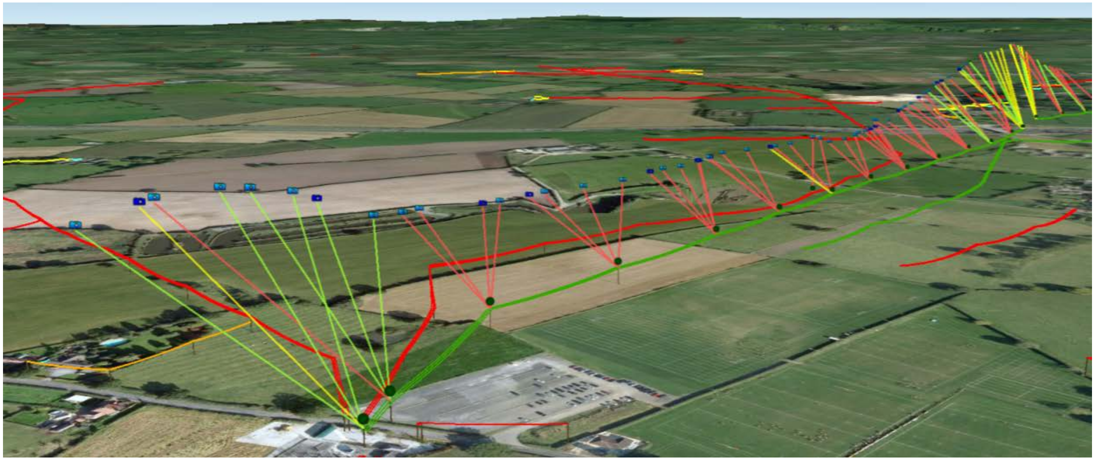


Figure 23 - Accessibility of HD Imagery Geospatially Tagged in the Virtual World

2.3.6.2 Analytics

Whilst the Virtual World model is impressive and contains a previously unimaginable amount of information on the OHL network, it cannot deliver any meaningful benefits without an integrated analytics solution. This is vital as it enables the core users to run queries to investigate network issues pertinent to the business or specific programmes. These queries can quickly identify sections of the network that are non-compliant and then provide the users with a direct link to each highlighted section of the network in the Virtual World where further investigation can take place if necessary.

Over the duration of the VWAM[4] project SPEN has built up first-hand experience of the value of the analytics, with the solution being used numerous times to:

- Identify low ground clearance issues at every voltage level as well as above infrastructure such as roadways.
- Quantify the number of OHL spans affected by vegetation within each Licence Area, Operation District and each individual circuit. In addition, the number of spans in each of the aforementioned which are non-compliant with vegetation management obligations and policy have been identified.
- Audit vegetation management contractors' performance.
- Assist Storm Resilience programmes by identifying spans of each circuit that have a tree within falling distance of the OHL.
- Quantify the angle each pole is at and identify those that are a cause for concern.

- Undertake Quality Assurance testing of the Virtual World model.
- Identify the variances in the length of Open Wire and ABC LV OHL in the Virtual World and SPEN's GIS.

SPEN also expects to be able to use Virtual World and Analytics to explore different risk thresholds, with the application of more granular risk factors being a key outcome of virtual world analytics. The list is far from exhaustive, and intends to highlight the range and capability of the Analytics software.

Figure 24 is a screenshot of the Roames Analytics provided by Fugro; this is a Microsoft Excel based solution that enables DNO users to quickly run queries in a package in which they are already familiar. This particular example shows the data filtered to the SPM Licence Area (Zone = South), the Merseyside District, the 132kV (Transmission) and 33kV (Sub-Transmission) circuits, with the corresponding results sorted to highlight priority circuits at the time of the capture.

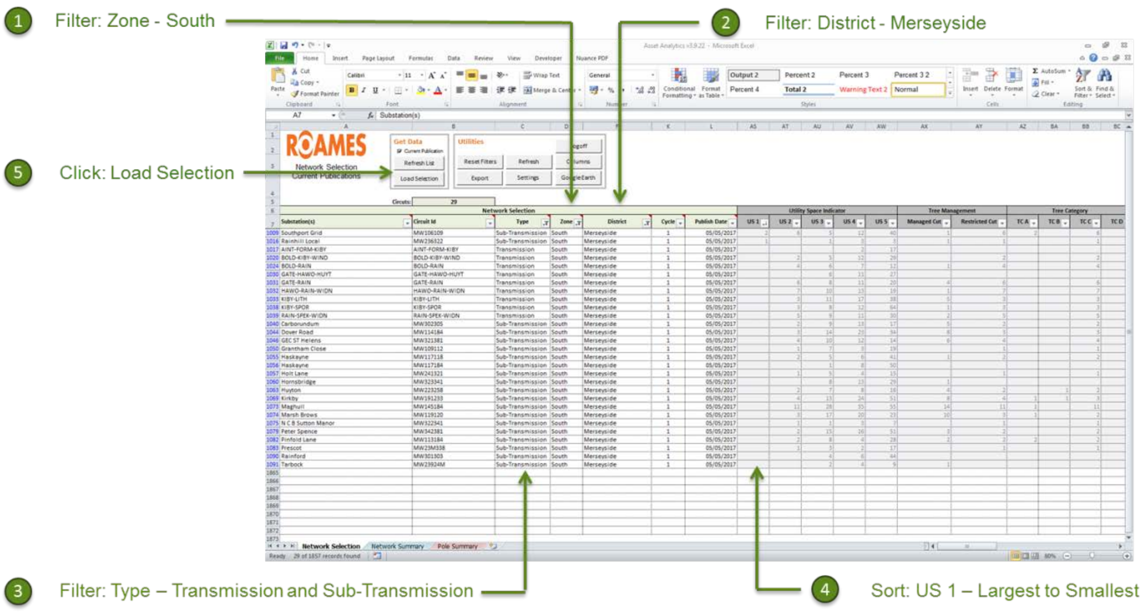


Figure 24 - Roames Analytics Utilised to Identify Spans of 132kV and 33kV network in the Merseyside District that have a US 1 Vegetation Issue at the time of capture

Analytics provides access to detailed network, span, pole and vegetation data which is categorised, risk ranked, and aggregated based on SPEN business rules. Further screen shots and examples are provided in Appendix a.

2.3.7 Vegetation Growth Model

The vegetation growth model is a key feature which will be incorporate into the Virtual World and Analytics platform. This will be done by analysing data collected from Fixed Wing Surveys gathered over the course of four consecutive growing seasons. This will coincide with the current vegetation management practice and ensure that data is collected at all stages, from the date vegetation is cut through to the next planned treatment date covering a 4 year period. This will enable SPEN to identify spans with slow growing vegetation and therefore avoid unnecessary cutting and also to identify fast growing vegetation. Where areas of fast growing vegetation are found, various mitigation measures may be considered, for example replacement of fast growing vegetation with slow growing vegetation types such as heathers, undergrounding or diverting a section of the line or modifying the cutting cycle.

The extended period of fixed wing LiDAR capture will also enable future development and refinements, for example incorporating other data sets such as seasonality, climatic variation, vegetation species etc. It is therefore envisaged that the growth model would be developed further in the future to provide more sophisticated analysis, business rules will be further refined, and this will continue to lead to efficiency improvements in vegetation management.

Figure 25 shows an abstract cell view of vegetation surface change detection in which red cells indicate newly detected vegetation, green cells indicate stable vegetation and magenta cells indicate vegetation that is no longer detected. Further vegetation visualisations are shown in Appendix c.

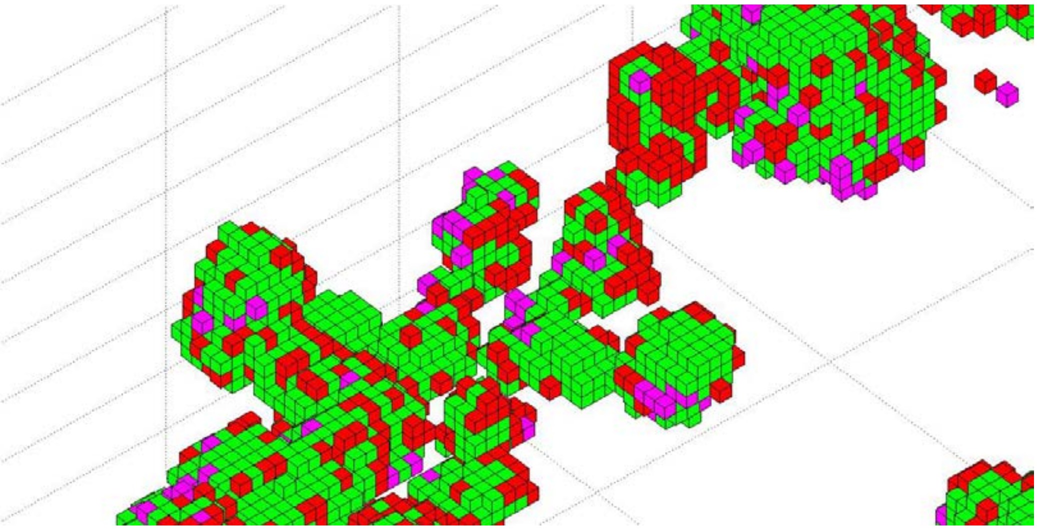


Figure 25 - Vegetation Surface Change Detection

The risk profile of vegetation approaching a conductor varies depending on the rate of growth, for example non-growing vegetation may indicate that a tree has fully matured and any further treatment (e.g. cutting) of this tree may actually result in the tree becoming more vigorous. Information gathered will be used to enable detailed classifications to be developed for each OHL span.

2.3.8 Circuit Capacity Model – Fugro Catan Case Study

LiDAR data enables OHL networks to be accurately modelled, providing a method to determine line sag, minimum ground clearance and network intrusion information which can therefore be used to provide a method of accurately determining circuit capacity. Line capacity is dependent on the conductor type, temperature and sag. Using these variables it is possible to calculate the maximum operating temperature the circuit can operate at without violating statutory clearance requirements, enabling circuits to accommodate additional low carbon generation and improving network flexibility. It will also be possible to establish a prioritised list of circuits based on investment required to increase the circuit rating.

The focus for circuit capacity will be on 33 kV and 132kV (SPM) circuits in the short term. LiDAR surveying integrated with overhead network design and analysis software such as Fugro’s Catan enables this analysis to be streamlined and completed network-wide. Traditionally, network-wide assessment of circuit capacity has been cost prohibitive as it required expensive and time consuming field based surveying to be completed. HOSS will greatly reduce the cost and time to implement, providing a viable solution utilising a rich source of data enabling circuits to be monitored and reappraised based on changing network and external factors.

SPEN has recently completed a pilot project with Fugro to demonstrate how the Roames Virtual World model integrated with Catan Overhead Line design software can be utilised to perform a capacity assessment on the 7km long XXXX. The LiDAR-derived 3D conductor geometry, conductor attachment points and terrain profile were extracted from the Roames Virtual World and utilised to build the model in Catan for the capacity assessment. SPEN provided input data into this assessment such as the conductor type, which was 7/4.30 HDBC.

The screenshot from Catan given in Figure 26 shows an example of the line profile for the 33kV circuit between poles 12801266 and 12801322. The top curve (blue) is the conductor geometry from the time of survey, the red curve represents the conductor's position at 50°C operating temperature and the purple curve represents the conductor's position at 60°C operating temperature. The green line represents the terrain profile that has been extracted from Roames Virtual World.

The bottom curves represent the conductor clearance curves, the yellow curve being the 50°C clearance curve (offset from conductor) and the orange curve the 60°C clearance curve (offset from conductor). These clearance curves are set at ESQCR specification of 5.2 metres minimum ground clearance for 33kV (for normal ground).

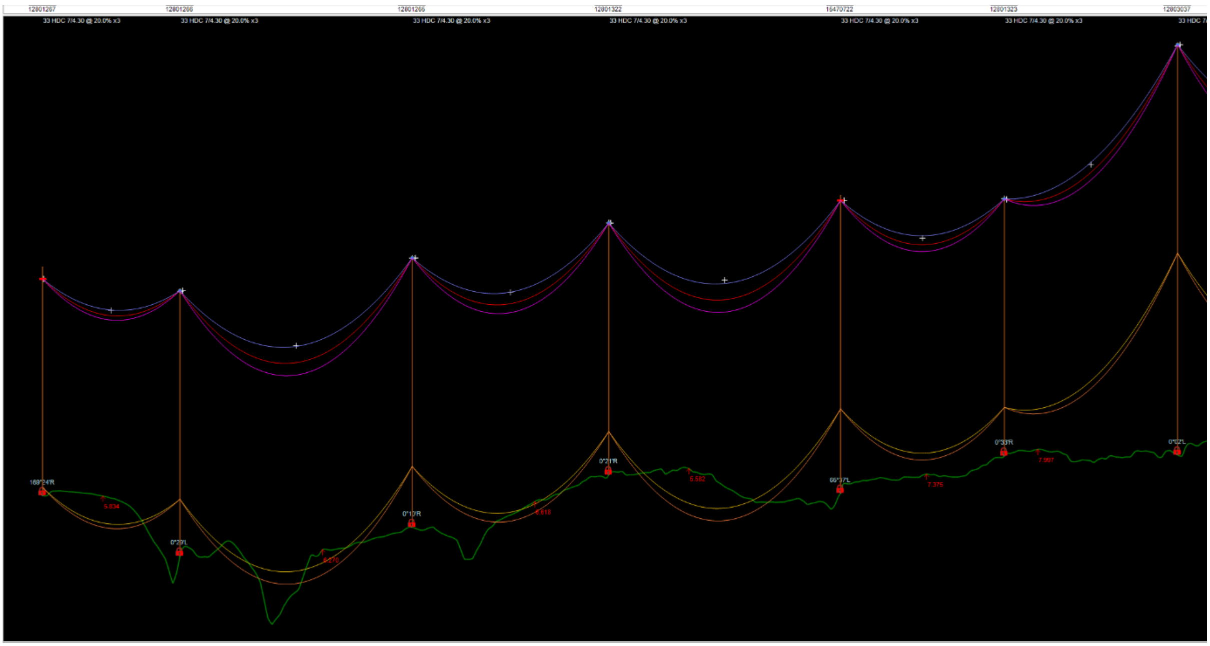


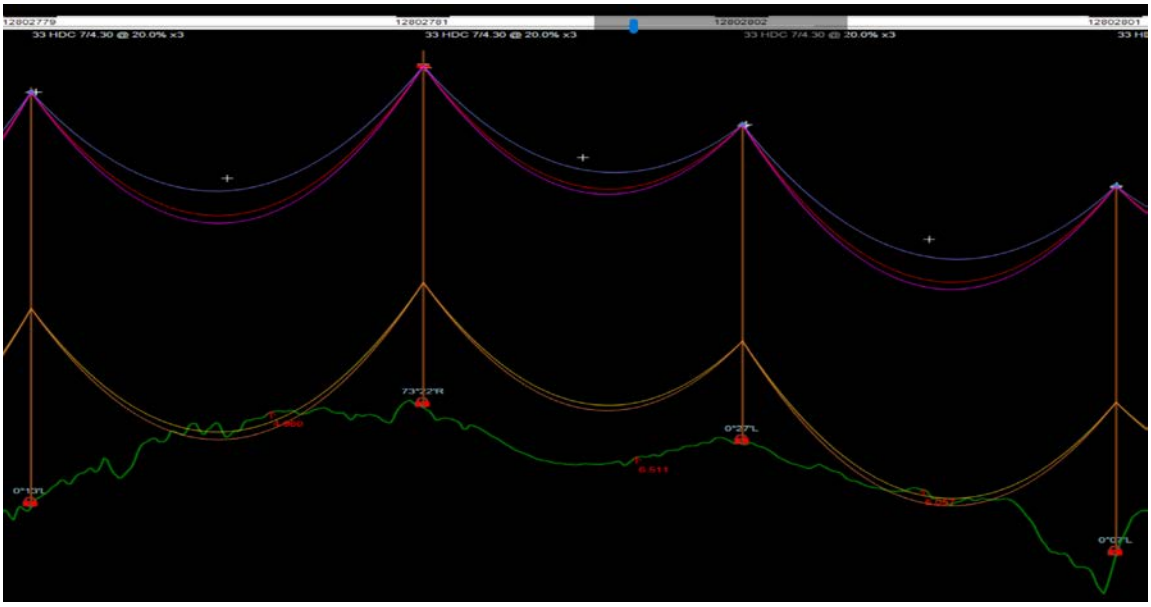
Figure 26 – Example line profile between poles 12801266 and 12801322 from Catan with conductor curves and clearance curves at 50oC and 60oC operating temperature.

All 71 spans for the 33kV circuit have been analysed using Catan against 50°C and 60°C operating temperatures. The findings are that at 50°C operating temperature there are 6 spans that do not achieve the minimum ground clearance of 5.2 metres. These are given in Table 3.

Table 3 – Spans that do not achieve minimum ground clearance

Start Pole	End Pole	Ground Clearance (metres) @ 50°C operating temperature
12803016	12803015	5.16
12802779	12802781	4.96
12802802	12892801	5.06
12802835	12802833	5
12802833	12802832	5.08
12802557	12802552	4.91

The screenshot below is from the spans between poles 12802779 and 12892801. At span 12802779 to 12802781 the 50°C clearance curve (yellow) intersects the terrain curve (green) which indicates that at 50°C this span would not meet the minimum statutory clearance requirement of 5.2 metres. The minimum conductor ground clearance for this span at 50°C is 4.96 metres. Similarly span 12802802 to 12892801 would not meet the minimum statutory clearance requirement at 50°C with a minimum conductor ground clearance of 5.06 metres.



Example line profile between poles 12802779 and 12892801 showing that the minimum statutory clearance requirements is not achieved for two of the three spans at 50oC operating temperature.

The findings are that at 60°C operating temperature there is an additional 1 span that would not achieve the minimum ground clearance of 5.2 metres.

This trial capacity assessment case study indicates that for XXXX circuit to enable the circuit to be re-rated at, 60°C operating temperature, 7 spans would require remedial work to meet the minimum statutory clearance requirements.

This is a positive outcome in that it shows that when SPEN performs asset replacement work, that only one additional span would need to be uprated in order to achieve an overhead line operating temperature of 60°C rather than 50°C, i.e.. Increasing the overhead line operating temperature from 50°C to 60°C results in an increase in rating by approximately 2MVA, hence potentially an additional 2MW of low carbon generation could be accommodated onto the network.

2.4 Summary of Benefits

At a high level, the benefits associated with a holistic overhead line surveys approach are summarised in Figure 27. The benefits denoted in green have been quantified and feed into the business case for the bid (see Section 3), whilst the benefits denoted in blue have been described qualitatively. The ultimate impact of the roll-out of HOSS for customers will be reduced use of system costs; they are also likely to see improved speed and accuracy of obtaining a connection and long term improvements in Customer Interruptions (CI) and Customer Minutes Lost (CMLs). HOSS will also deliver Carbon and environmental benefits for customers, these outlined in Section 4.

Figure 27 – Benefits of HOSS. Green denotes those benefits that have been quantified in the bid and blue denotes qualitative benefits

2.4.1 Statutory Inspections

There are various benefits associated with the move from foot patrols to technology for statutory inspections as below:

- There is much less likelihood of human error. For example, it can be difficult to see whether an insulator has cracked or whether a line is superficial. Technology will be able to determine this with accuracy based on LiDAR imagery and analytics.

- Technology will enable the real condition of assets to be determined and recorded automatically within the systems; therefore improve resource utilisation and mitigating potential problems arising from poor condition assessment data.
- Inspections can be subjective based on the competence and perspective of the inspector. Technology (LiDAR and pole testing equipment) will enable the true values to be obtained. This can provide cost benefits due to remedial work not being required, for example in reducing overhead line sag or pole replacement.
- There are potential health and safety benefits due to asset issues being identified with greater accuracy and reliability (e.g. ground clearance issues) and reduced number of foot patrols resulting in reduced risk of loss time accidents.

2.4.2 Vegetation Management

Vegetation management is currently carried out via a three-year contract as follows:

- Tender issued for vegetation management on a consent and cut basis;
- Contractors walk the line in order to carry out inspections. Every km of line is walked and marked up every 3 years;
- The spans with vegetation that require cutting are identified, consent obtained from land owners, and treated;
- Contractors report back on the cut; providing a guarantee for the 3 year period.

LiDAR information together with the growth model will enable an integrated vegetation management plan to be developed and will provide the following benefits:

- Reduction in line lengths inspected by patrols: It will no longer be necessary to walk the full spans of the lines as lines where vegetation is not an issue will be identified though LiDAR.
- Deferment of cycle cut and extension: There is the potential to re-priorities the circuits once the growth rate on each circuit is understood. Less problematic circuits would be identified and the cut cycle could be extended. On the more problematic circuits potential mitigations such as replacement of vegetation with other species or undergrounding could be considered.
- Reduction in planned outages required to manage vegetation: Many of these outages will be avoided through proactive management of vegetation.
- Improved navigation and routing: Direct identification of sites using aerial imaging and accurate mapping will allow contractors to avoid navigating around features such as rivers and contours which will save time in navigation and routing.
- Streamlined auditing: Network-wide auditing can be completed from the desktop. The effectiveness of current vegetation strategy and plan can also be continually monitored by comparing actual vegetation condition with predicted condition.

2.4.3 Increased OHL Capacity

By identifying the sag of the overhead line through LiDAR, it is possible to re-evaluate the capacity of individual spans and circuits and ultimately identify additional capacity or network constraints to be alleviated. SPEN can utilise this information to implement the most cost-effective design solution for customers and enable increased overhead line capacity, facilitating low carbon technologies to connect before conventional reinforcement is required.

2.4.4 Regulatory Reporting

RIIO funding for vegetation management is currently primarily related to the length of OHL that the DNO has to manage. However, this does not take into account vegetation growth rate or vegetation intrusions, and both of these parameters are found to affect the level of vegetation growth management required. For example, in the South of England where vegetation growth rates are highest, a risk-based approach tends to prioritise management practice, whereas in Scotland a managed cycle is generally achieved.

With a vegetation growth model that takes into account the specific characteristics of the network, it would be possible to provide the regulator with detailed information regarding the actions and therefore funding required to maintain vegetation within allowable limits. This would be a significant benefit as it would enable funding to be targeted and provide confidence that statutory limits could be achieved within a defined level of funding.

Reporting of the health of network assets as required by RIIO would also become highly accurate for overhead line equipment. For example, RIIO requires that the health of OHL poles, fittings and conductors are all reported. Currently, there are examples of instances where remediation work has been carried out but where this work has not been recorded in SPEN's systems, leading to inefficiencies. Use of technology to understand asset health also mitigates the risk of inaccurate asset inspections due to human error.

2.4.5 Condition Based Asset Assessment

The proposed LiDAR technology, together with the pole measurement device, enables the condition of existing assets to be assessed more accurately and consistently compared with human inspections and minimise human error:

- Low ground clearance for overhead lines and clearance for other fittings can be determined very accurately using LiDAR, whereas there is human error associated with these measurements if LiDAR technology is not used;
- Asset condition such as the presence of cracks in insulators can often be determined with more accuracy and more efficiency with LiDAR technology compared with visual inspection;
- The strength of a pole can be measured with significantly more accuracy with a pole testing device than with a hammer test. A hammer test tends to lead to many more poles being replaced than would be necessary using a pole testing device.

Three issues that were identified following Fixed Wing flights in 2016 as part of SPEN's IFI project are listed below and were reported as emergencies:

- An 11kV middle conductor detached from the insulator and moved 1.5m up from the cross arm;
- An 11kV conductor detached from its insulator and hanging 2.2m below the cross-arm; and
- A service wire found lying on the ground in the garden of a house.

Adoption of the wood pole testing device is predicted to save the replacement of a number of wood poles per annum. As there is a carbon cost associated with each wood pole, this therefore leads to a carbon benefit due to the wood pole saving. In addition, there is a benefit due to the reduction in the amount of creosote required. Creosote is a potential carcinogen and therefore minimising its use is beneficial.

2.4.6 New Connections

Processing connection offers for new connections is a labour intensive process, and requires a significant amount of knowledge and experience. Field visits may also be required to perform asset and environment reconnaissance. Enabling accurate network data to be available in one place, with visualisation tools incorporated, will significantly improve the toolkit available to engineers to enable them to process connections as quickly and accurately as possible.

There have been instances in which data inaccuracy (for example inaccurate pole location) has led to an inaccurate quote for a new connection (for example incorrect cable length or misunderstanding of crossing location) and these instances would be mitigated through the availability of accurate data. In addition, the ability to process connections applications more quickly and easily is likely to free up skilled personnel to concentrate on other tasks and projects, such as improving DNO ways of work, implementing innovation projects etc.

Customer service is also likely to improve due to the increased speed and accuracy of obtaining a connection.

2.4.7 Customer Service

More efficient and targeted vegetation management will enable the problematic circuits to be identified and mitigation methods to be implemented, such as replacement of fast-growing vegetation with slower growing vegetation, undergrounding the section of line or modifying the cutting cycle. This will therefore lead to long term improvements in Customer Interruptions (CI) and Customer Minutes Lost (CMLs) due to reduced interruptions caused by vegetation.

3 Application Business Case

This section sets out the information required by Ofgem's 'Electricity Distribution Innovation Roll-out Mechanism submission guidance'[6]. The required information required can be summarised as:

1. Why the innovation roll-out was not considered when SPD was developing its ED1 business plan.
2. Why IRM funding is required.
3. A clear business case justifying the merits of undertaking the roll-out and how it links to long term business changes/direction that the licensee wants to make.
4. Analysis of how the total costs have been estimated and potential inaccuracies.
5. How the licensee will recover any granted funding through Use of System charges.
6. How the licensee will ensure that the timing of apportioning these costs will be appropriately reflected in UoS charges and that only costs incurred during the ED1 will be recovered.

These requirements are covered in Sections 3.1 – 3.6 respectively.

3.1 Why the Innovation Roll-out was not considered in SPEN's ED1 Plan

The roll-out was not considered in SPEN's ED1 plan because at this time there was insufficient evidence and understanding of the technologies to build this into the plan. For example, the IFI LiDAR project[3] was started after SPEN had made their ED1 submission, starting in October 2014. Similarly, NIA VWAM[4] was registered at the start of ED1.

Perhaps most importantly, this project represents a completely new strategy for surveys and way of working for SPEN. It is proposed in this project that existing foot patrol surveys will continue throughout ED1, and that surveys utilising new technology will be added from 2018 onwards. Data and analysis from these surveys will be used to inform SPEN's new processes.

3.2 Why IRM Funding is Required

IRM funding is required because, as described above, it is necessary for the two types of surveys (foot patrols and new technology) to run in parallel within ED1, partly as knowledge is built up of the new surveys and business processes are devised, but also importantly, to ensure that the safety and security of the network can be maintained. SPEN has carried out surveys via foot patrols for many years, and the outputs and processes around these surveys are well known. New technology has only been trialled on parts of the network to date; therefore devising a new strategy around new technology requires a significant shift for SPEN in terms of a new way of working. Therefore, the five years remaining years in ED1 will be used to make sure that new processes are robust and to mitigate risk. Furthermore continuing with conventional foot patrol surveys in these years will enable a comparison of data outputs to be made and learning to be disseminated to the wider industry.

The consequences of not receiving the funding are that technology would be introduced piecemeal and over a longer time period, therefore there would not be a wholesale change in the current strategy. HOSS would come in through the ED2 plans, but benefits would only be realised at the end of ED2. Implementing the technology now

[6] Electricity Distribution Innovation Roll-Out Mechanism submission guidance, Ofgem, 17/02/2016

moves the benefits forward and therefore provides better value for customers. IRM funding would also demonstrate an industry-leading approach that other DNOs could follow into ED2. Without the IRM project, other DNOs might not follow into ED2, potentially pushing back UK-wide benefits into ED3.

3.3 Summary of Business Case justifying Merits of Roll-Out

The Cost Benefit Analysis (CBA) model proposed by Ofgem has been adopted to illustrate the overall benefit of the new survey strategy proposed by SPEN. The following benefits have been quantified and are outlined further in this section:

- Wood pole testing device costs and benefits;
- Vegetation management; and
- Condition Based Asset Assessment.

The output of the CBA is summarised in Table 4 below. It should be noted that two scenarios have been included in the CBA mid (mid case and worst case) but there is also an upper case that could give even great NPV values.

Table 4 – Summary of CBA outputs

		Calculated NPV Values		
Option	**Comment**	8 years (ED1)	16 years (ED2)	24 years (ED3)
Baseline	**Business as usual – LiDAR and related technologies not adopted**	0	0	0
Scenario 1 (Mid)	**Mid case benefits assumptions applied**	-5.12	7.75	29.92
Scenario 2 (Worst)	**Worst case benefits assumptions applied**	-5.12	4.15	21.17

It should also be noted that there are a number of benefits that have not been quantified at this stage, but in reality are likely to lead to significant improvements for SPEN and Ofgem. These are described in Section 2. HOSS implements a whole new strategy for surveys, providing a wealth of new data and information. It is likely that as the project progresses, significant benefits will be seen across the business in many areas due to the increased data and analytics available, but it has been difficult to quantify all of these potential benefits at this point.

3.3.1 Long Term Business Changes

As set out within Section 1, HOSS introduces a completely new strategy for surveys, replacing foot patrol surveys with technology as far as possible. Some foot patrol surveys will still be required initially in order to provide complete coverage of the network, particularly at LV. However, going forward due to the new strategy, it will be possible to incorporate new survey technologies readily as business processes will have changed to reflect new technologies. The ultimate aim of SPEN is to replace virtually all foot patrol inspections with technology-based inspections. The exception to this will be the requirement for people to visit areas in order to gain consents for vegetation cutting.

3.4 Analysis of Costs

This proposal represents a significant shift in strategy for surveys and inspections. The existing and new strategies are described in the following section and provide additional understanding and guidance for the estimated cost and assumptions.

The final cost of the HOSS solution will be based on the coverage obtained by each of the technologies and associated unit costs, following a tendering exercise. The network coverage figures built into this proposal have been generated through experiences to date as well consultation with several technology vendors. The inspection costs have been based on our current market understanding, with built in economies of scale and reductions based on a competitive tender process.

3.4.1 Survey Costs

In the existing strategy the following surveys are undertaken with the frequencies described:

- Statutory inspections inspect all OHL assets on the network.
  1/6 of the network is surveyed every year (i.e. each network asset, other than high risk assets, is surveyed once every 6 years).
- High risk statutory inspections inspect high risk OHL assets.
  Specific sites have been classified as High Risk and are inspected at an increased 1 in 3 year frequency (i.e. each high risk asset is surveyed once every three years). The percentage of the network required to be surveyed for high risk statutory inspections varies depending on the voltage level, but is in the order of ~0.05% of the network. These inspections are carried out by foot patrols.
- Modernisation Programme Inspection.
  This is carried out on a 1/12 year frequency a year ahead of the modernisation programme. This is a comprehensive inspection that includes all of the elements of the statutory inspection as well as condition assessments.
- For vegetation inspections, 1/2 of the network is surveyed every year at 132 kV and EHV voltages (i.e. the entire network is surveyed once every two years). At HV and LV, 1/3 of the network is surveyed every year (i.e. the entire network is surveyed once every three years).

It is accepted that each technology in isolation will not provide the level of detail or coverage to enable the removal of all manual inspections however as a collective solution HOSS will provide complete coverage of the OHL network and provide the level of details and clarity required to extend the current level of manual inspections to 1 in every 12 years to coincide with the current modernisation programme inspection policy.

For each technology, the foot surveys that can be replaced and the likely coverage have been assessed to understand how much of the network can be captured effectively and to determine the level of foot patrol surveys which will likely need to be retained once the new technology is implemented. These parameters are summarised in Table 5 and Table 6 below and they have been used within the CBA. However in reality, as experience increases and technology advances, the coverage that will be achieved using LiDAR technology will increase, hence leading to even greater benefits.

Table 5 – Summary of Inspection Coverage

Technology	Voltage	Coverage	Justification
Fixed Wing	132kV, EHV and HV	XXXX	Vast majority of network covered via LiDAR Identifies sag and vegetation but not all asset details, such as pole lean or geospatial corrections.
	LV Main	XXXX	
	LV Services	XXXX	Coverage estimates from manufacturers (with European experience) and experience from VWAM project
Helicopter	132kV & EHV	XXXX	100% coverage is not achievable due to Civil Aviation Authority limitations Captures all asset detail (as per foot patrols) Coverage estimates from manufacturers (with European experience)
	HV	XXXX	
	LV Main & Services	XXXX	
Ground Based	132 kV	XXXX	Combine with helicopter LiDAR to increase total coverage Captures all asset detail (as per foot patrols) Coverage has been assessed by SP from a consideration of proximity of roads with assets
	EHV	XXXX	
	HV	XXXX	
	LV Main & Services	XXXX	

**Coverage will be greater than zero, but is not cost effective to collect due to the low coverage that could be achieved. Coverage could increase in time with the use of Unmanned Aerial Vehicles (UAVs)*

Table 6 – Summary of HOSS Frequency

Estimated level of Foot Patrols Required			
Inspection	**Voltage**	**Coverage Required**	**Justification**
High Risk Statutory Inspections	All	XXXX	Continue to assess via foot patrol due to high risk nature Small proportion of network
Statutory Inspections	132kV & 33kV	XXXX	XXXX foot patrol combined with XXXX helicopter provides full 132kV and EHV coverage
	HV	XXXX	XXXX foot patrol combined with XXXX helicopter provides full HV coverage
	LV Main & Service	XXXX	XXXX foot patrol combined with XXXX ground based LiDAR provides full LV coverage

Modernisation Programme Inspections	All	XXXX	Enhanced Pole condition assessment tool to be used during Modernisation Programme
Vegetation Inspections	All	XXXX	Initially continue to assess 100% via foot patrol for vegetation inspections. May reduce inspection time (not currently taken into account in CBA) and in future may reduce foot coverage depending on project findings.

Within the CBA model, these percentage coverage values have been combined with the inspection frequencies and network lengths in order to obtain an annual inspection cost, and thereby compare the baseline scenario (foot patrols only) with the option proposed, which is the combination of new technology with minimal foot patrols.

In terms of frequency of surveying for the new technologies, the following assumptions have been made. Survey frequency for the foot patrol surveys will remain unchanged in ED2, but the coverage required will be vastly reduced.

- **Fixed Wing LiDAR:**
  The entire network will be surveyed for four consecutive years from 2019 – 2022. The reason for this is to enable a growth model to be achieved. Four years of data are required to achieve accuracy and because in some years vegetation will be cut back on the three-year cycle. The growth model is a major contributor to providing the cost-benefit associated with vegetation management (cutting). From 2023 onwards, 1/3 of the network will be surveyed each year.
- **Helicopter LiDAR:**
  The entire network will be surveyed in 2020 and again in 2023. 2020 has been selected as it follows the Fixed Wing surveys which will enable geospatial OHL corrections to be made and the creation of a more efficient and effective flight programme to be generated. The second year has been selected to provide sufficient time between the surveys to analyse the data however still enabling the data to be reconciled. Following these two surveys, it is proposed to carry out a full Helicopter survey every 6 years, which is the same frequency as the existing statutory foot patrols.
- **Ground Based LiDAR:**
  The purpose of ground based LiDAR is to gather similar data compared with helicopter surveys, but to increase the coverage and capture areas of the network that cannot be reached by helicopter. Therefore, the ground based LiDAR surveys will take place at the same time and with the same frequency as the Helicopter surveys.

Figure 28 and Figure 29 below illustrate the proposed frequencies and network coverage for the various surveys that will be used throughout ED1 and ED2 for the proposed solution. Note that the baseline scenario (i.e. continue as usual with no LiDAR technology) would have the foot patrol survey coverage and frequency shown in ED1, which would continue going forward with no LiDAR surveys. In Figure 28 it can be seen that it has been assumed that the statutory inspection coverage required can be ramped down in the last two years of ED1 as part of the transition from the existing to the new strategy. This results in some benefits realised in ED1.

[redacted]

Figure 28 – Change in statutory inspection coverage by network level between RIIO ED1 and RIIO ED2

[redacted]

Figure 29 – Proposed LiDAR inspection frequency and coverage in RIIO ED1 and RIIO ED2

The following unit cost assumptions given in Figure 7 have been used to calculate the total inspection costs. For fixed wing, costs are predicted to be significantly lower than those at which SPEN is currently contracting as it is assumed that following a competitive tendering exercise and due to economics of scale that costs will fall.

Table 7 – Input Costs for Inspections and Surveys

Survey Type	Network Voltage	Cost / km (2012/13 Prices)	Comment
Fixed Wing	All voltage levels	XXXX	Well known cost from IRM project and confirmed with suppliers
Helicopter	All voltage levels	XXXX	Assumed that competitive rates will be obtained through tendering process. Supplier estimates taken into account
Ground Based	All voltage levels	XXXX	
Statutory Foot Inspections (SPD)	132kV	XXXX	Extrapolated from SPEN ED1 settlement
	EHV	XXXX	
	HV	XXXX	
	LV	XXXX	
Vegetation Inspections (SPD)	132kV	XXXX	Extrapolated from SPEN ED1 settlement
	EHV	XXXX	
	HV	XXXX	
	LV	XXXX	
Statutory Foot Inspections (SPM)	132kV	XXXX	Extrapolated from SPEN ED1 settlement
	EHV	XXXX	
	HV	XXXX	
	LV	XXXX	
Vegetation Inspections (SPM)	132kV	XXXX	Extrapolated from SPEN ED1 settlement
	EHV	XXXX	
	HV	XXXX	
	LV	XXXX	

Table 8 - Summary of Survey Costs

	ED1 (£m)	ED2 (£m)
Baseline Scenario		
Foot Inspection Costs	XXXX	XXXX
Vegetation Inspection Costs	XXXX	XXXX
Total Inspection Costs	XXXX	XXXX
With Technology		
Foot Inspection Costs	XXXX	XXXX
Vegetation Inspection Costs	XXXX	XXXX
LiDAR Costs	XXXX	XXXX
IT	XXXX	XXXX
Pole Testing Costs	XXXX	XXXX
SPEN FTE Costs	XXXX	XXXX
Total Inspection + Technology Costs	XXXX	XXXX
Cost Difference	***£20.04m cost increase***	***£0.05m cost reduction***

It can be seen from Table 8 - Summary of Survey Costs that there is a significant investment in new technology in ED1 whilst the existing foot inspection continue as usual, but in ED2 and going forward the new strategy has virtually the same costs as the existing survey strategy.

It has been assumed that in the last two years of ED1, both the foot inspection costs and the vegetation inspection costs start to fall as the transition between the existing strategy and the new strategy is made.

The following additional assumptions around survey costs have also been made:

- In ED2, the cost of LiDAR surveys will fall by XXXX due to increased economies of scale and increased competition;

- Vegetation inspection costs have been reduced by XXXX in ED2. This is because LiDAR data will show where vegetation inspections are required – i.e. inspections will not be required on the whole network – and data will also be used to inform contractors' of cutting requirements. However, there will still need to be visits in person to sites, in particular to enable consents to be gained for vegetation cutting.

3.4.2 Wood Pole Testing Device Costs

A unit cost estimate for a single wood pole testing device was obtained from one of the suppliers. Given the number of wood pole testing devices estimated to be required (132), it was assumed that a lower unit price of approximately XXXX would be achievable. It was also assumed that the devices would need to be periodically recalibrated and reconditioned after XXXX at a cost of approximately XXXX per unit but that devices would not need to be fully replaced.

3.4.3 Vegetation Management Costs

SPEN, like all network operators, is required to maintain a safe clearance distance from overhead lines. Managing vegetation to maintain these clearance levels represents a significant part of the DNO costs. The rate at which vegetation grows influences the cutting cycle of the vegetation and therefore has a significant influence on costs.

At present, the allowance for vegetation management is primarily based on the length of the DNO network, with less dependency on growth rate. However, evidence shows that vegetation management costs are in fact significantly influenced by the growth rate, and if growth rate is not taken into account and funding remains the same, this can have an impact on the clearance distances that are being achieved by network operators.

Figure 30 below provides a visual representation of the distances that are required for vegetation management.

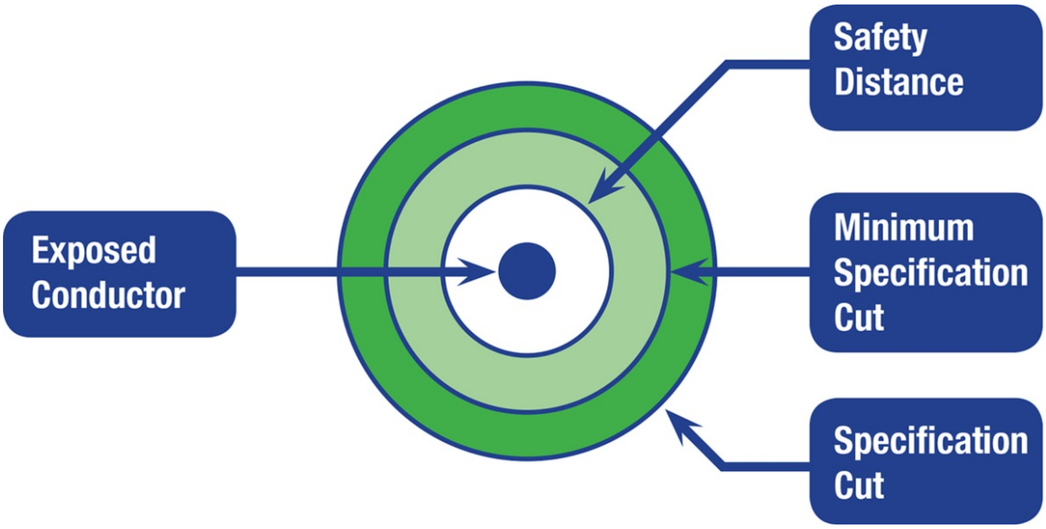


Figure 30 – Visual Representation of Vegetation Management

The NIA VWAM project[4] currently shows that XXXX of vegetation in SPD and XXXX of vegetation in SPM is currently within the minimum specification. As growth rates increase, and if the same strategy is pursued with the same funding, these percentages will increase. There is also a risk of vegetation encroaching on the safety distance, which presents a health and safety risk and also an increase in CIs and CMLs.

The IFI vegetation management project[2] introduced the concept of Utility Space Degradation (USD) and estimated average rates of USD in 2011 and derived rates for 2020 by modelling the change in the extent and location of the bioclimatic zones as a result of the predicted climate change. In Table 9, growth rates for 2028 have also been found by extrapolation. Further evidence around growth rate increases is described in Section 2.

Table 9 – Vegetation Space Degradation Predictions

	USD 2011	USD 2020	USD 2028
SPD (Scotland)	0.57	0.79	0.99
SPM	0.80	1.01	1.20
ENW	0.59	0.86	1.10
UKPN (East)	1.05	1.09	1.13
UKPN (South)	1.31	1.31	1.31
WPD (East)	1.05	1.17	1.28
WPD (West)	1.08	1.22	1.34

Figure 31 illustrates the issue if growth rates increase but the cutting cycle is not changed. In order to keep within the limits, either the cutting cycle would need to be increased or more vegetation would need to be cut back to ensure that vegetation does not encroach on the overhead line within the growing period. Either way, this represents an increase in cost.

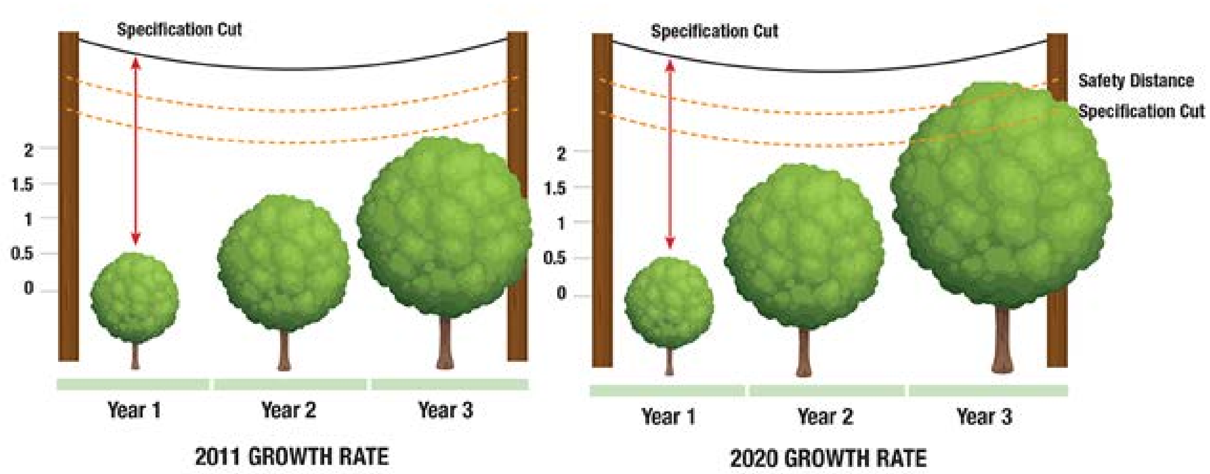


Figure 31 – Impact on change in growth rates on vegetation management

By considering the increase in vegetation growth rate and therefore the increase in depth of cutting or frequency that would be required to maintain the spans within limits, and a consideration of the specification limits, the following increases in vegetation management costs have been estimated. It should be noted that this represents a pragmatic increase in costs, i.e. costs have not been assumed to increase in direct proportion to vegetation growth rates.

Table 10 – Vegetation Cost Increases

	% Increase 2011 - 2020	**% Increase 2011 - 2028**
SPD		
LV	15	31
11 kV	12	24
33 kV	11	22
132 kV	9	18
SPM		
LV	20	42
11 kV	15	31
33 kV	13	27

In addition, costs gathered directly from contractors provide evidence that vegetation management costs for those spans with vegetation growth infringing on the clearance distances are significantly more expensive. Costs are provided in Table 11.

Table 11 - Contractor Costs for Vegetation Management

	132 kV Wood Pole Span (£)		
Contractor	**Light**	**Medium**	**Heavy**
1	XXXX	XXXX	XXXX
2	XXXX	XXXX	XXXX
3	XXXX	XXXX	XXXX

Where:

> ***Light*** *is the likelihood of less than 20% of the affected span having vegetation infringing upon the specified clearance distance within the cutting cycle;*
>
> ***Medium*** *is the likelihood of between 20% and 50% of the affected span having vegetation infringing upon the specified clearance distance within the cutting cycle;*
>
> ***Heavy*** *is the likelihood of at least 51% of the affected span having vegetation infringing upon the specified clearance distance within the cutting cycle.*

These uplifts given in Table 12 have then been applied to the ED2 and ED3 periods to understand the level of funding likely to be required to maintain the network within current limits, without introducing any other changes to the vegetation management strategy (i.e. without LiDAR and the vegetation growth model).

The predicted vegetation management increases due to increasing growth rates are therefore given in the table below:

Table 12 – Predicted Increase in Vegetation Management Costs due to Vegetation Growth, assuming LiDAR and growth model are not implemented

	ED1	**ED2**	**ED3**
SPD			
ENATS	XXXX	XXXX	XXXX
ETR	XXXX	XXXX	XXXX
TOTAL	XXXX	XXXX	XXXX
SPM			
ENATS	XXXX	XXXX	XXXX
ETR	XXXX	XXXX	XXXX
TOTAL	XXXX	XXXX	XXXX

3.4.4 SPEN Internal FTE Costs

The assumptions given in Table 13 have been made regarding the internal staff requirement in order to implement HOSS. The project transition period will be resource intensive due to the level of data and project management required however it is envisaged that the current level of internal resources for all inspections will be redeployed during ED2 resulting in no new additional resource requirement for this period.

These figures are based on 208 working days per annum and a day rate of £444/day.

Table 13 – SPEN Internal Cost Estimate

Role	Year				
	2018	**2019**	**2020**	**2021**	**2022**
Manager	208	208	208	208	208
Project Coordinator (SPD)	104	208	208	208	208
Project Coordinator (SPM)	104	208	208	208	208
GIS & Data Analyst	104	416	416	208	208
IT Systems Integration	0	208	104	104	0
Policy & Regulation	0	0	52	52	52
Communications & Training	0	0	52	52	104
Procurement	208	52	0	0	52
Total	***728***	***1300***	***1248***	***1040***	***1040***
# FTE	***3.50***	***6.25***	***6.00***	***5.00***	***5.00***
Cost (£m)	***£0.323***	***£0.578***	***£0.555***	***£0.462***	***£0.462***
Total Cost (£m)					***£2.38***

3.5 Recovery of IRM Funding through UoS Charges

SPEN will ensure our IRM expenditure presented in Table 14, Table 15 and Table 16 will be appropriately reflected in network charges by including the IRM expenditure in the Price Control Financial Model (PCFM). The PCFM is a Financial Instrument governed by the ED1 Licence.

Our IRM forecast expenditure will increase our allowed costs in the PCFM model. The model compares our allowed costs with actual expenditure and determines the appropriate revenues we should seek to collect each year. Therefore this model adjusts our network charges for any variance in our IRM expenditure between forecast and actual expenditure.

Table 14 – Proposed IRM Expenditure (SPD)

SPD	**ED1**							
Year:	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
LiDAR Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Software Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Pole Testing Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SPEN FTE Costs	-	-	-	0.15	0.27	0.26	0.22	0.22
Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.38
Total Costs	0.00	0.00	0.01	1.28	3.77	1.39	1.34	2.29
Total Costs	**£10.08m**							
TOTAL IRM figure requested	**£9.51m**							

Table 15 – Proposed IRM Expenditure (SPM)

SPM	**ED1**							
Year:	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
LiDAR Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Software Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Pole Testing Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SPEN FTE Costs	-	-	-	0.17	0.30	0.29	0.24	0.24
Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.43
Total Costs	0.00	0.00	0.01	1.42	4.18	1.54	1.49	2.55
Total Costs	**£11.18m**							
TOTAL IRM figure requested	**£9.89m**							

Table 16 – Total Proposed IRM Expenditure

Total	**ED1**							
Year:	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
LiDAR Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Software Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Pole Testing Costs	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SPEN FTE Costs	-	-	-	0.15	0.27	0.26	0.22	0.22
Benefits	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.38
Total Costs	0.00	0.00	0.01	1.28	3.77	1.39	1.34	2.29
Total Costs	**£21.26m**							
TOTAL IRM figure requested	**£20.04m**							

3.6 Recovering Costs within ED1 Period

This bid only seeks to request funding for costs during RIIO-ED1. SPEN's charging policy ensures that use of system charges for a given year recover costs incurred that year, and therefore we will only recover costs during ED1 hat have been incurred during ED1.

Capital Costs beyond ED1 and ongoing operational costs are excluded from the funding request.

4 Evaluation Criteria

The IRM guidance sets out the following items that will be considered by Ofgem when assessing the bid:

a) Will deliver additional carbon, environmental or any other wider benefits;
b) Will provide long-term value for money for energy customers;
c) Will not enable the licensee to receive additional commercial benefits which are greater or equal to the cost of implementing the Proven Innovation;
d) Will not be used to fund any of the ordinary business arrangements of the licensee
    a. It is noted that Ofgem encourages applicants to address how the innovation will enhance competition within the market
e) Involves Proven Innovation and warrants limited funding support
f) Is ready to be rolled-out with any funding provided being used in the price control period

In this section we set out our response to each of the criteria a) to f) and provide supporting information to demonstrate how the proposed scope will fulfil these criteria.

4.1 Deliver Carbon, Environmental or Other Wider Benefits

HOSS will deliver additional carbon, environmental and wider societal benefits. The roll-out will make a contribution to the Governments carbon reduction strategy through the ability to inspect existing asset more effectively; such as improved pole condition assessments leading to a reduction in pole replacements and improved carbon benefits from efficient vegetation management. Moreover the proposal will facilitate the Government's plan to transition to a low carbon economy by realising additional OHL capacity, enabling increase levels of Low Carbon Technologies (LCT) to connect.

Whilst it is accepted the proposed methods of LiDAR data collection will have an adverse carbon impact, HOSS will deliver a net carbon benefit which has been further described and quantified in the following section.

- Sustainability
- Carbon impact due to LiDAR technology;
- Carbon benefit due to savings in wood poles;
- The increase in low carbon generation required to offset the carbon impact;
- The carbon benefit due to more efficient vegetation management; and
- Other environmental benefits.

4.1.1 Alignment with SPEN Sustainability Strategy

SPEN has recently developed a new Sustainability Strategy which set out a series of Goals and Objectives and identified a revised suite of seven Sustainability Drivers. These are shown in Figure 32. The Sustainability Drivers are used to guide and prioritise the activities and projects that SPEN takes forward in the drive towards becoming a Sustainable Networks Business. As shown in Table 17, each of the seven Sustainability Drivers would represented by the successful application of the LiDAR IRM Project, with the extent of the impact identified in column three on balance of whether the impacts are generally positive or negative.

Section 4: Evaluation Criteria continued

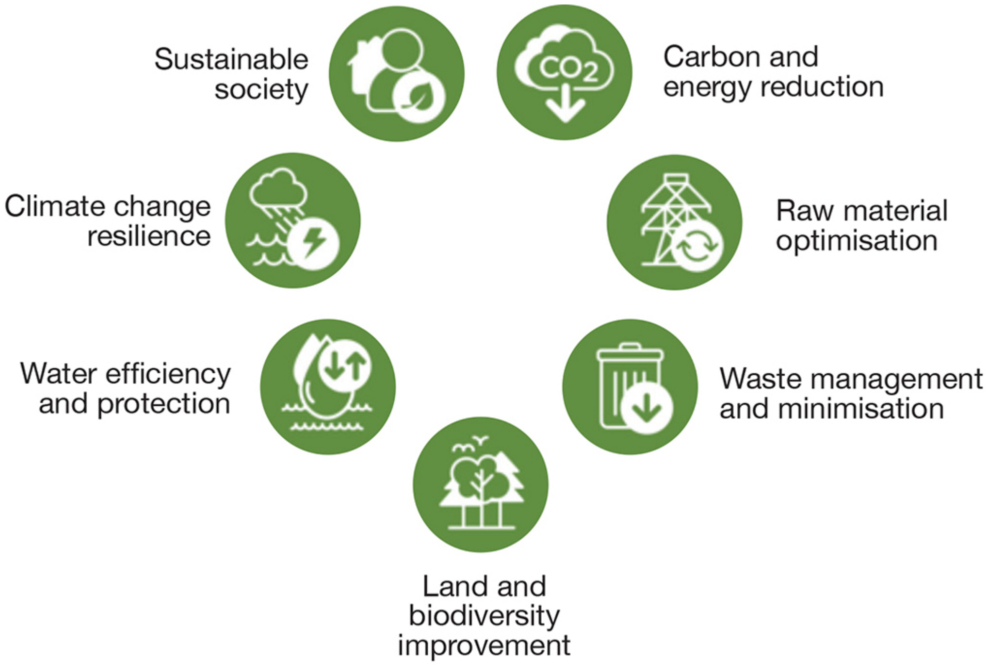


Figure 32 – Visual Representation of SPEN's Sustainability Drivers

Table 17 – Relevance of LiDAR IRM Project to SPEN's Sustainability Drivers

Sustainability Driver	HOSS	Impact High / Medium / Low
Carbon and Energy Reduction	• Carbon reduction from reduced pole replacement and increased renewable generation • Carbon impact from LiDAR flights	Medium impact (positive)
Raw Material Optimisation	• Reduction in number of new wood poles required per annum	High Impact (positive)
Waste Management and Minimisation	• Reduction in wood pole wastage	High impact (positive)
Land and Biodiversity Improvement	• Improvement in vegetation management	High impact (positive)
Water Efficiency and Protection	• No impact	Low impact (positive)
Climate Change Resilience	• Increased resilience of network due to optimised vegetation management	High impact (positive)
Sustainable Society	• No additional impact	Low impact (positive)

Section 4: Evaluation Criteria continued

4.1.2 Carbon Impact due to LiDAR

Conversion factors enabling aviation fuel and fuel used in vehicles to be converted to tCO_2e have been taken from spreadsheets published by the Department for Business, Energy & Industrial Strategy (BEIS)[7]. The values calculated for a single flight of the entire network for Fixed Wing and Helicopter LiDAR, and the value for ground based surveys (based on network coverage that will be achieved) are given in Table 18. The relevant network coverage percentages, on which these carbon impact calculations are based, are given in Section 3.4.1.

Table 18 – Carbon Impact from LiDAR

Technology	tCO2e
Fixed Wing	342
Helicopter	1,117
Ground Based	2
Total Carbon Impact	***1,461***

4.1.3 Carbon Benefit from Wood Pole Savings

Wood pole carbon savings have been quantified based on the estimated number of wood poles that no longer need to be replaced with a new wood pole, i.e. continuing to use the existing in-situ wood pole.

A literature review has identified data that outlines the greenhouse gas impact of utility wood poles, and also the toxic releases due to the use of creosote per wood pole[8]. For a wood pole of average height 13.7m, the values for Greenhouse Gases in tCO_2e and Toxic Releases (kg) were 0.20 and 0.18 respectively. A second study study[9] identified the "anthropogenic" greenhouse gas emission for a wood pole to be 228 lb-CO2-eq (converted to 0.10 tCO2e).

Taking 0.10, 0.15 and 0.20 tCO2e as worst, mid and best case values respectively gives the following carbon savings presented in Table 19 for the three scenarios previously developed.

Table 19 – Estimated Carbon Savings for Wood Poles

Scenario	Best	Mid	Worst
# Poles Saved	XXXX	XXXX	XXXX
Carbon Saving tCO_2e	XXXX	XXXX	XXXX

[7] Government emission conversion factors for greenhouse gas company reporting, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting
[8] The Environmental Impact of Utility Poles, 28/5/08, A. Wood, D. Reddy and R. Koganti, Dartmouth School of Engineering
[9] Conclusions and Summary Report on an Environmental Life Cycle Assessment f Utility Poles, prepared by AquAeTer, Treeted Wood Council, 2012

Section 4: Evaluation Criteria continued

4.1.4 Carbon Benefit from Increasing OHL Capacity

The low carbon generation required to offset all of the LiDAR carbon impact has been calculated using offset values provided by Ofgem. The calculation for three sample years is show below – note that these are the years in which a complete survey of the network is proposed to be carried out by helicopter (i.e. worst case). It can be seen that only a small amount of additional low carbon generation needs to be connected in order to mitigate the impact of the LiDAR technology. It is assumed that this level of additional low carbon generation will be readily realisable in order to offset LiDAR carbon emissions. In reality, the additional capacity that will be made available through the overhead line capacity modelling is likely to be significantly greater, but it has not been possible to fully quantify this benefit at this point.

Table 20 – Low carbon generation required to offset LiDAR carbon

Year	**2020**	**2029**	**2035**
t CO2e per kWh (conversion factor)	1,461	1,233	1,233
MWh Offset Needed	3,284	3,921	6,039
MW needed	0.375	0.448	0.689
MW needed assuming 27.3% capacity factor	***1.37***	***1.64***	***2.53***

4.1.5 Carbon Benefit from Efficient Vegetation Management

4.1.5.1 Air Quality Improvement

It is widely accepted that vegetation contributes to the removal of some pollutants from air as a result of deposition and absorption on the leaves and porous surface of plants, although the extent to which this occurs is still subject to debate. The regulation of air quality is important because air pollution can cause health problems in affected populations. The value is estimated through the avoided costs of healthcare that would otherwise be required to treat health problems induced by a higher density of air pollutants.

AECOM has carried out some work for SPEN to estimate air quality improvement values due to the vegetation currently managed by SPEN on the networks[10]. This report and the details behind the calculations can be provided. The NPV over a 15 year period (2017-2032) for air quality improvement due to SPEN vegetation was found to be £16.7m, showing that vegetation on the SPEN network has a significant air quality benefit.

4.1.5.2 Value of Carbon Sequestration

AEOM has also calculated the value of carbon sequestration due to trees and other plants on SPEN's network. Trees and other vegetation act as "carbon sinks", i.e. they store carbon used in photosynthesis as biomass. Increasing the amount of carbon that is locked away in biomass slows the accumulation of carbon in the atmosphere in the form of CO_2 and other greenhouse gases. For further information on the calculation methodology, please refer to the AECOM report[10]. The total value of carbon sequestration for SPEN's networks has been calculated to have a 15 year NPV of approximately £34m, showing again that SPEN's vegetation has significant natural capital.

[10] SPEN Network vegetation: Preliminary natural capital assessment briefing note, AECOM, May 2017

4.1.6 Other Environmental Benefits

4.1.6.1 Creosote in Wood Poles

Coal-tar creosote was a commonly used wood preservative, produced by the high temperature carbonisation of coal and consists primarily of aromatic hydrocarbons with some tar and acid bases. Creosote has been identified as a potential carcinogen and as a result its use has been limited to specific industries. SPEN is participating in efforts to identify alternatives to creosote as a result of its potential dangers to human health.

A reduced need for precautionary wood pole replacement will limit the requirement for newly creosote-treated wood poles to be replaced on the network.

4.1.6.2 Reduction in Spread of Disease

LiDAR surveys enable greater coverage compared with pole surveys. Foot patrol walkovers may miss tree health seven trees away (for example) if the person is only walking beneath the line, but the unhealthy tree may rapidly cause disease spread in the nearby trees. In addition, the strategy and process behind LiDAR surveys can be optimised in order to detect tree health.

LiDAR is therefore a clear benefit especially given the emerging threats to vegetation such as sudden oak death, ash dieback, the current disease affecting Japanese Larch and the outbreaks of Dutch Elm Disease in the 1980s.

4.1.6.3 Data Availability to Not for Profit Organisations

SPEN would potentially look to make data available free of charge to selected non-for-profit environmental stakeholders and government regulators, for example RSPB and Natural Resources Wales, to help to plan for and enhance the area and interests that they represent. This would provide societal benefits by enabling these bodies to better meet national, regional and local targets and objectives for environmental protection and enhancement.

4.2 Provide Long-Term Value for Money for Customers

4.2.1 Additional Benefits Expected from the Innovation

The HOSS will provide long term value for money for energy customer through the additional benefits delivered by;

- Wood Pole Testing Device
- Vegetation Management
- Reduction in CIs and CMLs
- Asset management benefits
- Health & Safety benefits

The following sections will outline, describe and where possible quantify these benefits.

4.2.1.1 Wood Pole Testing Device Benefits

As part of the survey strategy, it is proposed to implement a wood pole testing device which will give a consistent and fixed value for the strength of the pole. This would be carried out during the modernisation programme inspections. The strategy behind implementing the pole strength testing device is to test all poles in the ED1 period and from ED2 onwards to test poles once every 12 years, or 1/12 of the poles in the network every year.

Compared with the traditional hammer test, the advantages are:

- Obtaining a numerical value for pole strength allows the pole replacement dates to be forecast;
- The numerical value enables asset managers to make more robust judgements;
- Unlike the hammer test, the result is not open to interpretation.

Two readings from the pole strength testing device are required to make a decision on pole replacement, as the first value gives the absolute strength and the second value enables the rate of change of strength to be determined. Therefore, it is not envisaged that different decisions compared with those from the hammer test would be made in ED1, but once a second reading has been obtained in ED2 it will be possible to determine the life expectancy of the pole and therefore schedule its replacement.

DNO poles are categorised by Health Index (HI). Poles with a Health Index of 5 (HI5) are the worst performing poles, followed by those with HI4. These poles would be schedules for replacement. HI3 poles would not be replaced. An investigation carried out by Exact Projects Limited[11] showed that after testing poles using a pole testing device, 30% of poles previously categorised as HI5 did not need to be replaced and were re-categorised as HI3, and 60% of poles previously categorised as HI4 did not need to be replace and were re-categorised as HI3. This data has been used to calculate a likely percentage of poles saved due to use of the electronic testing device.

The volume of wood poles replaced per annum by SPEN is given in Table 21.

Table 21 – SPEN existing pole replacement

	Average No Poles Replaced/ Annum	**Average No Poles Replaced/ Annum due to being Rotten**
SPM		
LV Poles	XXXX	XXXX
6.6/11kV Poles	XXXX	XXXX
33kV Poles	XXXX	XXXX
SPD		
LV Poles	XXXX	XXXX
6.6/11kV Poles	XXXX	XXXX
33kV Poles	XXXX	XXXX
Annual Pole Replacement due to Rot		XXXX

The potential savings are given in Table 22 below. These numbers have been used within the CBA tool, taking the mid case as “Option Proposed” and the worst case as “Option Proposed 2”.

[11] Exact Projects Wood Pole Testing Procedure & Cost Benefit Analysis, April 2017

Section 4: Evaluation Criteria continued

Table 22 - Potential Cost Reduction due to Pole Replacement

	Best Case	Mid Case	Worst Case
Existing Pole Replacement/ Annum due to Rot	XXXX	XXXX	XXXX
Reduction in % Poles being Replaced	XXXX	XXXX	XXXX
No. Poles Saved	XXXX	XXXX	XXXX
Cost Saving due to Poles Saved	XXXX	XXXX	XXXX
Cost Saving due to Reduced Disposal Costs	XXXX	XXXX	XXXX
Total Cost Reduction	XXXX	XXXX	XXXX

4.2.1.2 Vegetation Management Benefits

The following benefits which are predicted to be achieved using the new technology have been quantified below. Three potential scenarios were investigated.

1. Reduction in Line Length inspected by Patrols

It will no longer be necessary to walk the full spans of the lines. In Manweb, it is estimated that XXXX of the lines would not need to be patrolled and in Scotland XXXX of the spans would not need to be looked at. Instead, these patrols would be replaced by scanning and analysis. However, it may not be possible to realise the full benefit depending on the location of these spans and therefore three scenarios have been considered as follows:

- Best case: XXXX reduction for SPD; XXXX reduction for SPM
- Mid case: XXXX reduction for SPD; XXXX reduction for SPM
- Worst case: XXXX reduction for SPD; XXXX reduction for SPM

2. Deferment of Cut and Cycle Extension

There is the potential to re-prioritise circuits once the growth rate on each circuit is understood. Problematic circuits could be identified and the cut cycle could be extended on less problematic circuits to 4, 4.5 or 5 years from 3 years. Three potential scenarios have been considered:

- Best case: XXXX of circuits can have a deferred cut; move to 5 year cycle
- Mid case: XXXX of circuits can have a deferred cut; move to 4.5 year cycle
- Worst case: XXXX of circuits can have a deferred cut; move to 4 year cycle

3. Improved Navigation and Routing

Direct identification of sites using aerial imaging and accurate mapping will allow contractors to avoid navigating around features such a rivers and inaccessible contours. Navigational confusions are avoided due to improved data. Anecdotal evidence has suggested that half a day per week of rural network activity is lost in navigational activity including ineffectually crossing rivers, rerouting around terrain, finding sites etc (i.e. around 10%). Similarly, urban navigation inefficiencies equate to around XXXX of programme cost[12].

Three potential scenarios have therefore been considered:

- Best case: XXXX improvement in efficiency
- Mid case: XXXX improvement in efficiency
- Worst case: XXXX improvement in efficiency

The input assumptions for scenario modelling are summarised in Table 23 and Table 24 below.

Table 23 – Summary Input Assumptions for Scenario Modelling

	Best Case		Mid Case		Worst Case	
	SPD	**SPM**	**SPD**	**SPM**	**SPD**	**SPM**
Reduction in line length inspected by patrols (%)	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
% of lines where cut can be extended - Cycle extension (%)	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Extension Timeframe (years)	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Reduced hours per task - improved navigation and routing (%)	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Table 24 – Summarised Input Assumptions for Scenario Modelling

	Best Case		Mid Case		Worst Case	
	SPD	**SPM**	**SPD**	**SPM**	**SPD**	**SPM**
Reduction in line length inspected by patrols (%)	SPEN estimates that XXXX of spans in Manweb do not need to be looked at and XXXX in Scotland. May not be possible to realise full reduction depending on location of spans.					
% of lines where cut can be extended - Cycle extension (%)	Supplier Estimate				Lower percentages in case upper estimate is not realisable.	
Extension Timeframe (years)	Supplier estimates 4.5 – 5 years				More pessimistic assumption	
Reduced hours per task - improved navigation and routing (%)	Supplier estimates XXXX reduction					

Efficient vegetation management will enable both areas of low growth to be identified, where cutting cycles can therefore be lengthened, and problematic areas to be identified where there is significant vegetation volume and where growth rates are high and increasing. Identifying the problematic areas would then enable mitigations to be identified, costed and implemented. Mitigation could include undergrounding a length of

[12] Fugro Roames – Business Benefits Framework

overhead line, replacing vegetation with slower growing species or re-routing an overhead line.

The ADAS report on vegetation growth shows that different areas have vastly different vegetation growth rates depending on the characteristics of the bioclimatic zone, and therefore LiDAR combined with a vegetation growth model is extremely important in defining an efficient vegetation management strategy. The table below shows the percentage area of the SPD region covered by some examples of bioclimatic zones with associated growth rates. This shows that areas of higher growth rates are increasing, whereas areas of lower growth rates are reducing. In addition there are significant differences between the growth rates of the various areas.

Table 25 – Percentage area of the SPD regions covered by selected bioclimatic zones in the periods 1981 – 2010 and a prediction for 2020 with a medium emission scenario

Bioclimatic Zone		**% SPD area covered by bioclimatic zone**	
Description	**Mean USD**	**1981-201**	**2020 Medium Emission Scenario**
Slightly cold, slightly moist, medium soil	0.73	4.6	0.1
Moderately cool, slightly dry, medium soil	0.64	7.6	1.5
Slightly cool, slightly dry, medium soil	1.22	2.9	13.2
Slightly cool, slightly moist, medium soil	1.07	7.6	18.0

Table 26 shows the savings predicted to be made through more efficient vegetation management in the mid-case and worst-case scenarios.

Table 26 - Benefits due to Efficient Vegetation Management

	ED1 (£m)	**ED2 (£m)**	**ED3 (£m)**
Baseline Scenario			
Tree Cutting Costs	XXXX	XXXX	XXXX
Scenario 1 – Mid Case Assumptions			
Tree Cutting Costs	XXXX	XXXX	XXXX
% Saving compared with Baseline	XXXX	XXXX	XXXX
Scenario 2 – Worst Case Assumptions			
Tree Cutting Costs	XXXX	XXXX	XXXX
% Saving compared with Baseline	XXXX	XXXX	XXXX

Section 4: Evaluation Criteria continued

4.2.1.3 Reduction in CIs and CMLs

Improved vegetation management is predicted to reduce the number of planned outages associated with tree cutting, because vegetation management will be more proactive and efficient. The growth model in particular will enable SPEN to identify and expedite the cutting of spans prior to them exceeding the 'Specification Cut' boundary. It is therefore predicted that fewer planned outages will be required, and a rolling reduction of 2.5% per annum has been applied to the number of outages for the last two years of RIIO ED1 up until year 5 of ED2, i.e. 2022 – 2028. The existing data for SPM and SPD has been used as a baseline, and is given in Table 27 below.

Table 27 – Planned outages due to Tree Cutting (average 2012 – 2016 data)

	SPD	SPM	Total
# Planned Outages	235	1301	1,536
CI (Interruptions)	2785	18776	21,561[13]
CML (Minutes Lost)	66,1430	5,855,371	6,516,801[14]

4.2.1.4 Condition Based Asset Assessment

The quantifiable benefits relating to condition based asset assessment are due to improvements in health and safety. There are two key areas in which LiDAR and related survey techniques will assist in improving health and safety:

- Reduction in non-fatal incidents associated with personnel walking in rural areas;
- Identification and therefore resolution of OHLs with low ground clearance for which incidents often result in fatalities.

Reduction in Non-Fatal Incidents

For the last three consecutive years one health and safety non-fatal incident per year has been reported in SPENs (SP) license areas relating to overhead line (OHL) inspections[15]. The incidents are consistent with those expected for personnel walking in rural areas i.e. slips, trips and falls.

The cost per major injury assumed by Ofgem is £27.5k. The technology described in this proposal will reduce the amount of time spent walking in rural areas by approximately 50%. Therefore, the likely annual H&S saving associated with a reduction in these incidents is relatively modest at approximately £13.7k/ annum.

Reduction in Fatal Incidents

Low overhead line clearance is one of the key risks in terms of overhead line safety. Minimum clearances are referenced in the HSE guidance document "Avoiding danger from overhead power lines"[16] and published by the Energy Networks Association (ENA Technical Specification 43-8 Overhead Line Clearances). Clearances are specified both for the distance from the ground and for clearance between the wires and structures such as buildings and lamp posts.

[13] CI Penalty halved in CBA due to being pre-planned
[14] CML Penalty halved in CBA due to being pre-planned
[15] Line Patrol Incidents spreadsheet, SPEN
[16] Avoiding danger from overhead power lines, HSE, http://www.hse.gov.uk/pubns/gs6.pdf

Section 4: Evaluation Criteria continued

There was a fatality associated with the low ground clearance of an 11kV overhead line within the UKPN region in 2016, when a member of the public was killed after colliding with the overhead line. There have been other fatalities and serious injuries associated with collisions of equipment and vehicles with overhead lines, but no evidence that these incidents were associated with low ground clearance.

Statistics presented by the Health & Safety Executive (HSE) for Standard Industrial Classification (SIC) 35 'Electricity, Gas, Steam and air conditioning supply[17] show that for the past five consecutive years there have been five employee and two third party fatalities. Additionally there have been 910 non-fatal reported injuries within the industry. It is not possible to isolate these figures for the electricity supply industry alone or separate them out by activity e.g. OHL inspections.

According to the HSE, an average of two people are killed each year when they come into contact with OHLs during agricultural work, with many more injured[18]. At least one of these incidents was associated with low overhead line clearance (UKPN fatality). The technology described in this submission will enable SPEN to identify any overhead lines with low ground clearance and potentially identify unsafe activities being undertaken in close proximity to their assets. Whilst this is highly dependent on the timing of surveys, it clearly provides increased information, including on clearances between wires and structures, which will lead to an overall safety improvement.

The cost per fatality assumed by Ofgem is £1.79m. Whilst it is difficult to directly associate LiDAR and associated techniques with a reduction in fatalities, these techniques will clearly provide enhanced information on network clearances and land usage, which will improve network health and safety and reduce the risk of fatalities. For example, if the low ground clearance of the UKPN OHL had been known in advance, it is likely that this accident could have been avoided. A reduction in fatalities of 1 in 20 years has therefore been assumed as an upper scenario, i.e. £1.79m in a 20 year period (i.e. "Option Proposed" in the CBA tool). For Option Proposed 2 it has been assumed that there is no saving due to reduced fatality.

4.2.2 Timeline for Additional Benefits

For the mid-case assumptions, benefits will start to be realised in Year 13, i.e. 2028. For the worst-case scenario, benefits will be realised from year 15, i.e. 2030.

It should be noted that many of the potential benefits have not been quantified, and therefore it is likely that overall benefits will be higher and will be realised more quickly.

4.2.3 Explanation of Costs, Benchmarks and Pricing Assumptions

The costs and their underlying assumptions are explained in detail within Section 3.4.

4.2.4 Justification that Scale of Roll-Out is Appropriate related to Benefits

The NPV is predicted to be between £4.15m and £7.75m up until the end of ED2. This is partly because a significant investment cost is required in order to introduce the new technologies, devise the growth model and change SPEN's procedures. Also, foot patrols will run in parallel throughout ED1 in order to mitigate risk in what are quite significant changes in ways of working.

---

[17] RIDIND: RIDDOR reported injuries by detailed industry, HSE
http://www.hse.gov.uk/statisitics/tables/index.htm

[18] http://www.hse.gov.uk/agriculture/experience/electricity.htm

However, going forward into ED3, the NPV can be seen to increase to between £19m and £27m, showing that this new technology is laying a foundation for significant consumer benefits looking into the future.

4.2.5 Evidence of Expected Additional Benefits

Evidence for the expected benefits is provided in detail in Section 4.2.1.

4.2.6 IRM as a source for Funding

IRM funding is specifically targeted at proven innovation that is not within the ordinary business arrangements of the licensee, i.e. the rollout should be novel but the innovation should be proven. However, NIC and NIA are competitions to fund the development and demonstration of new technologies, operating and commercial arrangements. NIA projects are generally smaller than NIC projects, and may be used to develop NIC submissions.

This bid is looking to take individual innovations that have been proven in different sectors or geographies, and combine them into an integrated strategy. Whilst the individual technologies are therefore proven elsewhere, the combined strategy is novel, is not business as usual and has not been trialled or implemented by any DNO in the world. This therefore meets the criteria for IRM funding but not for NIC or NIA funding.

4.3 Additional Commercial Benefits

The key potential additional benefit in implementing this technology is the opportunity of selling data to other data providers, such as organisations such as RSPB, forestry commission, the Environment Agency, Ordnance Survey etc. However, the revenue from this will be significantly lower than the cost of implementing the innovation. The cost to implement the innovation in the RIIO ED1 period is XXXX, and revenue from data provision would be significantly lower. This is because the data is very geospatially specialised and therefore only parts of the available LiDAR data are likely to be of interest to third parties. SPEN will endeavour to seek opportunities to sell data to third parties and reduce ED1, ED2 allowance claims accordingly through RRP to take into account this income.

4.4 Ordinary Business Arrangements

None of the technology developments suggested are part of business as usual, and there is no allowance within the ED1 budget to fund any of these developments. Business as usual for inspection and survey activities for SP Energy Networks comprises a range of different surveys being carried out via foot patrols, along with a hammer test to test for wood pole strength. The current inspection strategy is described in detail in Section 2.2 of the bid document.

The aim of this project is to replace as much of the foot patrol surveying as possible with a combination of LiDAR technologies and a pole testing device. It has been shown through SP Energy Networks' analysis that the existing tests can be replaced by new technologies, and that this leads to other benefits (described in Section 2) such as more accurate data, reduced risk of error and improved regulatory reporting.

In terms of enhancing competition within the market, take up of these technologies will help to grow the UK market for LiDAR, analysis and pole testing equipment. It is likely that more network companies will take up more of these technologies, especially as success is demonstrated through this project. LiDAR providers have already indicated that LiDAR costs/ km may fall as LiDAR becomes "business as usual", and whilst this has not been included within the CBA model, increased take up of LiDAR will make it increasingly cost effective.

4.5 Proven Innovation

This technology is all available and has been applied and proven to some extent within the electricity networks sector and within other sectors and countries. Examples are summarised in Table 28 below. What sets HOSS apart is the novel integration of all of the technologies to deliver greater value than they would separately and placing the resulting virtual world and analytics at the heart of SPEN core business.

Table 28 – Summary of innovation examples for proposed technologies in other regions and sectors

Technology	Examples/ Track Record	SPEN Application
Fixed Wing Surveys	• Small-scale proof of concept trials undertaken by both SPEN and UKPN under separate IFI projects • ~66% of SPEN OHL network captured under NIA Pilot project • Initial large scale surveys being undertaken by both UKPN and SSE as of late 2016 • Deployed widespread over the last 3-4 years in several Australian DNOs (includes Ergon and Essential Energy)	• SPENs application and utilisation of these surveys goes far beyond what has been trialled / adopted in the UK to date. SPEN intend the Virtual World and Analytics delivered from these surveys to serve as the foundation of the HOSS • SPENs level of adoption is on a par with that in Australia where the technology was initially developed • The surveys will be undertaken on all OHL circuits from 132kV (SPM only) down to LV • Multiple consecutive captures utilised to establish Vegetation Growth model for every span of OHL captured
Helicopter Surveys	• Helicopter LiDAR corridor surveys common place in UK at Transmission and sporadically at 132kV, likewise photographic (and thermal imagery) surveys, but to date surveys that do both are not common practice • <132kV Helicopter surveys are used strategically by most UK DNOs with the exception of WPD • WPD extensively undertake Helicopter Visual / Photographic OHL surveys,	• Through this proposal SPEN would be the first UK DNO to adopt this technology widespread • The technology would be integral to the HOSS as it will enable SPEN to replace existing manual Statutory Inspections for 132kV (SPM only), 33kV and 11kV circuits

Section 4: Evaluation Criteria continued

	through *'NIA_WPD_0007 Airborne Inspection Phase 1'*[19] they are looking to enhance these surveys through the addition of LiDAR remote sensors • SSE have undertaken trials of Pole Top Condition Assessments through Helicopter surveys • In Australia, Essential Energy has undertaken pole top condition assessments on all rural network <66kV for the last 4 years, assessing on average 300,000 poles per year • In Europe (in particular Finland, Sweden, France and Italy) there are multiple examples of where Helicopter surveys combining LiDAR and HD photography has used down to 11kV	• The adoption of these surveys will ultimately provide a readymade application that could be targeted by UAV technologies
Ground Based Surveys	• Two successful small-scale proof of concept trials undertaken in the village of Ruthin, North Wales • Widespread utilisation of Ground Based LiDAR / HD Photographic surveys within Highways and Railway industry	• SPEN intend to be the first DNO to adopt this type of survey in any capacity, through doing so we expect to have the most comprehensive LV Virtual World model and Analytics of any DNO
Non-Destructive Pole Strength Testing Device	• Several devices currently being investigated by UK DNOs but not implemented as business as usual to date • There are multiple examples in Europe and Australasia where this technology has been successfully deployed, in Italy the VONAQ NDPT has been proven to reduce pole wastage significantly in the Telecoms Industry	• SPEN intend to be the first DNO to commit adopt NDPT devices to identify the condition of every pole on the OHL network • Subsequently integrating the results obtained with CBRM and Modernisation programmes

Table 28 shows that the proposed technologies have been implemented in other locations and sectors, but that implementation in the UK has been very limited to date. Therefore it can be seen that the innovations are proven, but innovative from a UK networks perspective.

4.6 Ready to be Rolled Out

From the table above it can be seen that all of the innovative survey technologies have been trialled in the UK to some extent by other DNOs or in other countries or sectors, and are therefore ready to be rolled out.

[19] https://www.westernpowerinnovation.co.uk/Document-library/2016/Registration-Forms/Airborne-Inspection-Project-Registration-Form.aspx

SPEN has however to some extent trialled all of the technologies or has worked closely with technology providers who have elsewhere to identify the full capability of each survey. Through the activities listed below SPEN has gained the necessary confidence to pursue the HOSS and substantially reduce the need for OHL foot patrols:

- ~66% of the SPEN OHL network has been surveyed using fixed wing LiDAR over the course of 2015 and 2016.
- The corresponding Virtual World and Analytics software has been extensively trialled by SPEN over the last 2 years. The capability to match LiDAR detected assets with those contained within existing corporate systems has been extensively developed and tested for accuracy.
- The accuracy of the aforementioned has been extensively investigated and robust quality assurance measures have been identified and introduced.
- Helicopter HD Photographic surveys have been trailed by SPEN to confirm they provide sufficiently detailed images to enable visual checks to be undertaken from a desktop.
- SPEN has assessed the granularity of Helicopter LiDAR surveys undertaken on UK Transmission networks and European Distribution networks. The returned point cloud data is clearly sufficient enough to model the key OHL components required.
- Ground Based LiDAR and HD Photographic surveys have been trialled by SPEN, the level of detailed captured by both sensors has been assessed.
- SPEN has undertaken the trial of several NDPTs that have recently been introduced to the UK, these trials have sufficiently highlighted the capabilities of each device and the quality and range of data returned.

In ED1, the required funding to cover LiDAR technology and pole testing devices is a total of XXXX. Within this period, it is proposed to continue with foot patrols as per business as usual, to ensure that data gathered from the LiDAR can be used to replace foot patrols within the ED2 period. A huge amount of data from technology will be gathered in ED1 and time will need to be taken to understand, rationalise, analyse and build this into SP Energy Networks' business processes. In ED2, it is envisaged that the foot patrols will be replaced by technology, other than for the areas that cannot be reached by LiDAR (i.e. to provide full network coverage).

4.6.1 Project Plan and Resources

A project plan has been developed and is presented in Appendix d.

The resources required to deliver the roll-out have been identified based on SPENs experiences under the NIA project. These assumptions are given in Table 29 and are based on 208 working days per annum and a day rate of £444/day.

Table 29 – SPEN Internal Cost Estimate

Role	**Year**				
	2018	**2019**	**2020**	**2021**	**2022**
Manager	208	208	208	208	208
Project Coordinator (SPD)	104	208	208	208	208
Project Coordinator (SPM)	104	208	208	208	208

GIS & Data Analyst	104	416	416	208	208
IT Systems Integration	0	208	104	104	0
Policy & Regulation	0	0	52	52	52
Communications & Training	0	0	52	52	104
Procurement	208	52	0	0	52
Total	***728***	***1300***	***1248***	***1040***	***1040***
# FTE	***3.50***	***6.25***	***6.00***	***5.00***	***5.00***
Cost (£m)	***£0.323***	***£0.578***	***£0.555***	***£0.462***	***£0.462***
Total Cost (£m)					***£2.38***

4.6.2 Risk

A risk register has been developed and this is presented in Table 30.

Table 30 – Risk Register for HOSS

Risk	Comments	Mitigation
Integration Risk	A significant amount of different types of data (three types of LiDAR data and pole testing data) will need to be integrated into the analytics software in order to provide a cohesive solution. Whilst existing technology can achieve this, it is unknown whether other network operators have attempted this on the same scale and with the same range of inputs.	Part of the purpose of this IRM project is to resolve any of these teething issues. In addition, patrol based surveys will continue throughout the ED1 period and therefore there is no risk that required data will not be collected within this period. The ED1 period should provide sufficient time for any integration issues to be resolved.
LV Coverage	Whilst fixed wing LiDAR coverage is well understood, there is uncertainty around the coverage that will be achieved for helicopter LiDAR and ground-based LiDAR.	A lower estimate (i.e. 0%) has been assumed for LV coverage for helicopter LiDAR, whereas it is possible that in the future it may be cost effective to achieve some LV coverage using helicopter LiDAR. Coverage for ground based LiDAR has been estimated from SPEN analysis, but it will only be verified during the project. However, the preliminary analysis implies that the coverage values included are achievable.
Price Escalation	Risk of price increases compared with those included in the submission.	Prices are well understood for fixed wing LiDAR as this has been implemented in a previous IFI project. Prices for other LiDAR technologies have been obtained directly from suppliers and it is believed that these may be pessimistic estimates,

Section 4: Evaluation Criteria continued

		particularly if economies of scale are obtained as the technologies progress in the future. An upper estimate has been included for the pole testing device, as there are a number of potential devices on the market which will need to be assessed and selected as part of this project.
Change in Way of Working	This new holistic strategy represents a complete change in the way people within SP currently work, i.e. replacing foot patrols with technology. A huge amount of additional information will also be available, which will change the way that staff approach activities such as new connection design, in addition to the surveys themselves.	There has already been significant engagement across SPEN to communicate and explain the proposed new technologies. In general, the business has been very receptive to the idea of introducing these technologies, especially when the types of imagery and analysis that can be achieved has been demonstrated. Mitigation will therefore include an extension of this engagement and briefing sessions, training for staff in the new technologies and introduction of new processes where required.
Programme Risk	Procurement process becomes protracted as HOSS requires multiple contracts to be awarded within the first XXXX	Significant time has been allocated in the programme to enable the procurement process to be conducted effectively. Prior to the IRM decision SPEN will generate draft technical specifications for each of the HOSS components to enable the procurement process to start at the earliest opportunity.
Data Quality	The quality of the returned inspection data is not high enough for the purposes identified.	SPEN will reduce this risk through a robust procurement process that will seek evidence from each vendor of the quality of data returned. It will also stipulate that the chosen vendor(s) implement a thorough Quality Assurance process prior to issuing data. The awarded contracts will also relate payments to the data quality.

5 Regulatory Issues

This proposal does not raise any issues requiring any change in regulatory rules and does not require any form of derogation. This proposal does require an adjustment to the regulatory settlement as set out in Section 1.

The proposed rollout of the HOSS does not raise any potential negative impacts on customers, or any financial or logistical implications on generators and suppliers.

6 Appendices

a. IFI 1416 ROAMES LiDAR Llyn Peninsula Project Data

Table A1 – Llyn Peninsula Growth Rates by Circuit

Circuit Name	Length of network captured (m)	Average of growth rate (m)
MW82502	148	0.48
MW82504	108	1.47
MW825836	1680	0.60
MW83601	12475	0.61
MW83602	7751	0.92
MW83603	17014	0.78
MW83604	28055	0.72
MW83605	8456	0.59
MW83606	5937	0.64
MW836841	4268	0.37
MW8368A1	3799	2.04
MW84003	45	0.29
MW84101	6265	0.45
MW84102	6792	0.62
MW84103	7108	0.75
MW84104	49	0.61
MW8A101	1136	0.70
MW8A102	899	1.11
MW8A103	261	0.81
Grand Total	112247	**0.72**

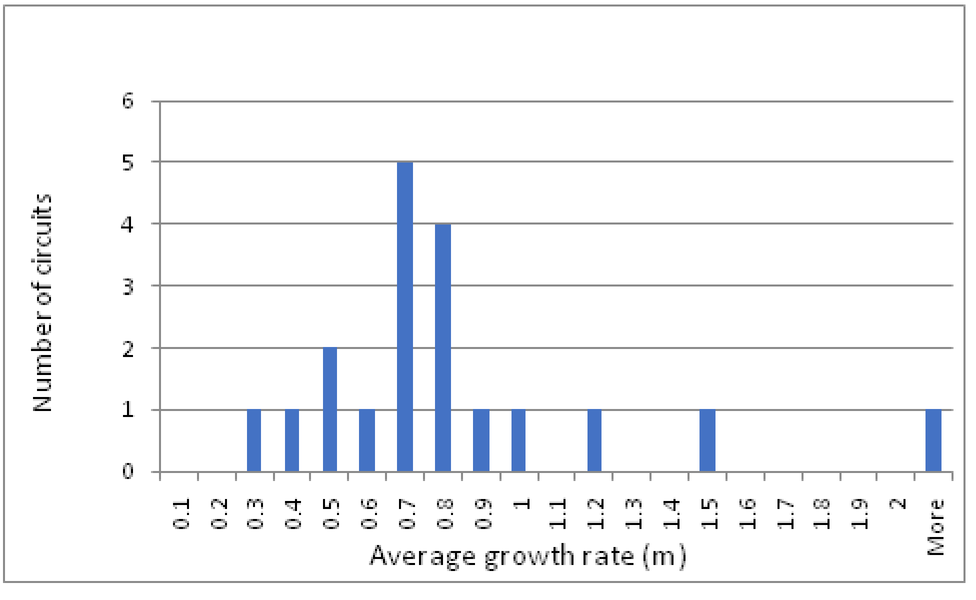


Figure A2 – Llyn Peninsula Growth Rate Variation

b. Further Roames Analytics Screen Shots

Network					Intrusions		Utility Space Indicator			
Span Length	Span Voltage	Depot	Pole A ENID	Pole B ENID	Intrusion Volume	Minimun Distance to Conductor	US 1	US 2	US 3	US 4
13.47	Service	Lanarkshire		10668504	0.06	4.77				
27.74	LV ABC	Lanarkshire	81099526	10668504	171.46	0.57	1		1	2
19.2	Service	Lanarkshire	10667975		34.5	2.48				3
28.07	LV ABC	Lanarkshire	10667974	10667975	138.5	0.75	1		1	2
31.34	LV ABC	Lanarkshire	10668506	10667974	227.78	0.84		1	2	1

Figure B1 – Example of span summary sheet from Fugro Roames Analytics solution for circuit SP16922

Pole Data						Matched Pole Details				
Captured Date	Pole Height (m)	Pole Lean	Pole Lean Confidence	Pole Voltages	Pole Confidence	Depot	Pole ENID	Match Confidence	Match Distance (m)	Material
6/06/2016	9.27	3.05	1	LV ABC	1	Lanarkshire	10668504	0.943	2.5	Wood
6/06/2016	7.63			LV ABC	1	Lanarkshire	10667975	0.886	7.85	Wood
6/06/2016	7.63			LV ABC	1	Lanarkshire	10667974	0.975	5.32	Wood
6/06/2016	7.3	0.75	0.81	LV ABC	1	Lanarkshire	10668506	0.967	4.54	Wood

Figure B2 – Example of pole summary sheet from Fugro Roames Analytics solution for circuit SP16922

Network					Intrusion								
Capture Status	Closest Pole ENID	Distance to Closest Pole	Span Length	Span Voltage	Intrusion Id	Intrusion Voltage	Captured Date	Intrusion Distance to Conductor	Vertical Distance	Horizontal Distance	Distance From Centreline	Intrusion Maximum Height
Good	10668504	0.41	13.47	Service	270868272	Service	6/06/2016	4.78	-4.4	2.4	2.5	4.6
Good	81099526	5.27	27.74	LV ABC	270872611	LV ABC	6/06/2016	5.42	-5	2.3	2.6	1.99
Good	81099526	0.43	27.74	LV ABC	270872619	LV ABC	6/06/2016	11.25	-6.1	9.5	9.6	1.94
Good	81099526	11.69	27.74	LV ABC	270872623	LV ABC	6/06/2016	1.18	-0.3	1.1	1.2	12.01
Good	10668504	3.01	27.74	LV ABC	270872639	LV ABC	6/06/2016	3.26	-3.4	0.2	0.7	4.6
Good	81099526	2.5	27.74	LV ABC	270872649	LV ABC	6/06/2016	5.66	0.3	5.6	5.3	14.59
Good	10668504	6.73	27.74	LV ABC	270872659	LV ABC	6/06/2016	6.59	-0.7	6.5	6.2	10.84
Good	81099526	6.57	27.74	LV ABC	270872673	LV ABC	6/06/2016	5.81	5.2	2.7	2.9	21.87
Good	81099526	0.42	27.74	LV ABC	270872681	LV ABC	6/06/2016	5.8	0.8	5.7	5.3	16.22
Good	81099526	10.69	27.74	LV ABC	270872690	LV ABC	6/06/2016	2.19	2.2	0.2	0.2	21.12
Good	81099526	0.43	27.74	LV ABC	270872697	LV ABC	6/06/2016	2.95	-2.7	1.2	1.1	9.77
Good	81099526	1.63	27.74	LV ABC	270872713	LV ABC	6/06/2016	4.83	2.1	4.4	4.8	15.7
Good	81099526	4.58	27.74	LV ABC	270872722	LV ABC	6/06/2016	0.58	-0.5	0.2	0.5	12.81
Good		3.66	19.2	Service	270868634	Service	6/06/2016	4.89	-2.6	4.2	4.2	2.27

Figure B3 – Example of intrusion summary sheet from Fugro Roames Analytics solution for circuit SP16922

Other						
Utility Space Indicator	Data Issue	Tree Management	Y	Proximity Zone	X	Tree Category
US 3		Managed Cut	674482.115	1	262477.605	D
US 1		Restricted Cut	674479.514	1	262470.906	C
US 3		Managed Cut	674379.753	1	261989.961	D
US 1		Restricted Cut	674378.402	1	261992.614	C
US 3		Managed Cut	674353.913	1	262003.806	D
US 3		Managed Cut	674363.438	1	261997.391	D
US 2		Restricted Cut	674366.264	1	261996.512	A

Figure B4 – Example of intrusion data aligned to SPEN vegetation management specification from Fugro Roames Analytics solution for circuit SP16922

Roames Analytics can also be directly integrated with advanced business intelligence software such as Tableau and PowerBI.

Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma

Section 6: Appendices continued

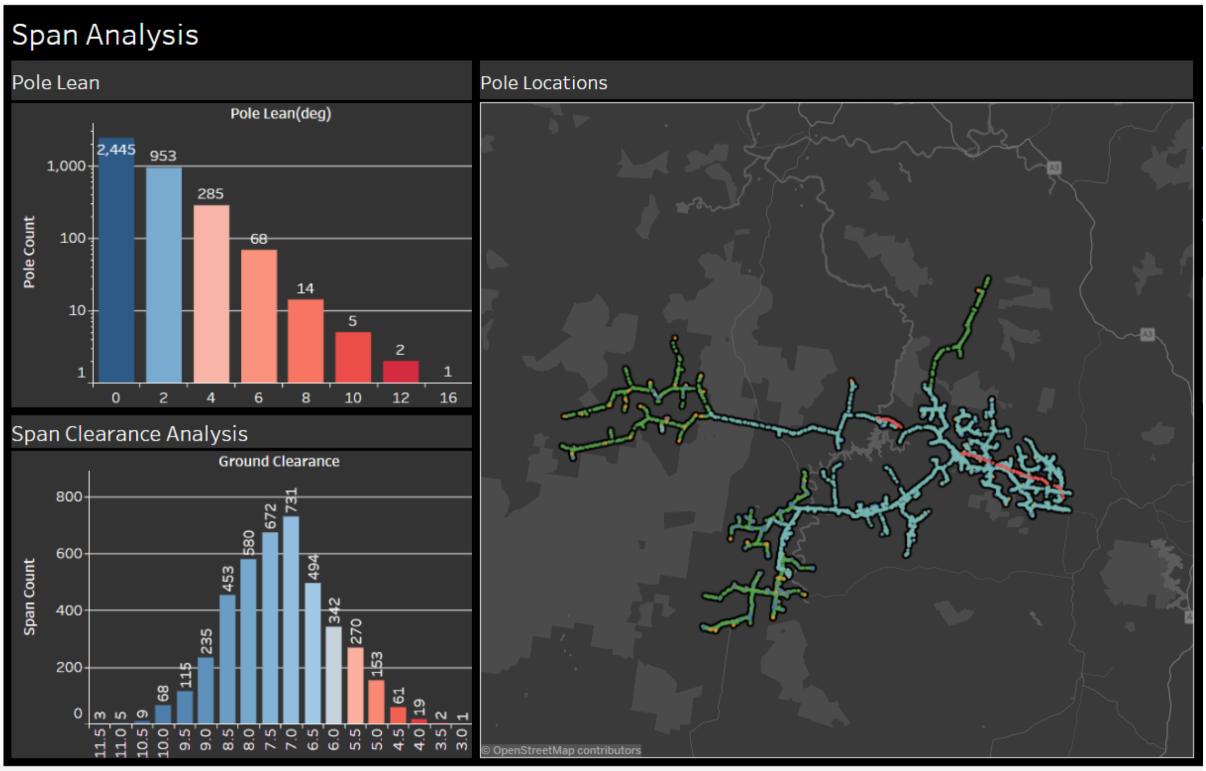


Figure B5 – Example of span clearance and pole lean data integrated with Tableau business intelligence software

c. Further Vegetation Screen Shots

Network					Intrusion								
Bay Id	Closest Site Label	Intrusion Label	Intrusion Rating	Intrusion Voltage	Intrusion Distance to CC	Vertical Distance	Horizontal Distance	Distance From Centreline	Intrusion Maximum Height	Intrusion Volume	Growth (Cycle 3-2)	Growth Classification	Growth (Avg)
698853	2155988	LLCL	31.87	HV	0.53	-0.4	0.3	1.5	9.5	59.78	-0.74	Normal	0.56
700282	2068854	LLACL	31.86	HV	0.24	-0.4	0.4	1.7	14.31	135.55	0.56	Normal	0.44
674512	2155627	CL	31.8	HV	0.47	-0.5	0.1	0.7	8.48	86.02	0.81	Normal	0.54
693664	2110929	CL	31.35	HV	0.86	-0.8	0.4	1	7.92	55.68	-0.88	Normal	0.9
698853	2155396	LLACL	31.25	HV	0.55	0.3	0.5	1.4	7.62	45.44	-1.15	Fast	1.31
698267	2118881	LLACL	31.12	HV	0.69	0.1	0.7	1.9	13.35	40.7	-0.54	Normal	1.07
700333	2029424	LLACL	31.07	HV	0.57	-0.5	0.2	0.6	13.71	36.22	0.68	Mature	0.84
674512	2155627	LLCL	30.9	HV	0.48	-0.3	0.3	0.9	7.87	54.59	0.87	Normal	0.8
699342	5064740	LLACL	30.71	HV	0.75	0.6	0.5	0.3	19.71	49.79	0.8	Mature	0.42
700341	2021776	LLCL	30.53	HV	0.24	-0.2	0.4	1.4	7.74	32.32	0.01	Fast	0.78
698925	2153739	CL	30.44	HV	0.8	0.4	0.7	1.6	14.68	46.34	-0.12	Normal	1.15
670275		CL	30.27	HV	1.18	-0.3	1.1	2.5	9.92	30.02	-0.18	Normal	1.55
698672	2068953	CL	30.12	HV	0.71	-0.7	0	1.4	8.05	29.7	-0.8	Fast	1.2
700333	2029424	LLCL	30.05	HV	0.55	-0.2	0.5	1.4	12.21	24.96	0.92	Normal	0.73
698582	2069015	CL	30.03	HV	0.86	-0.5	0.7	1.6	11.07	40.51	-0.41	Normal	1.01
697734	5093206	CL	30	HV	0.93	-0.5	0.8	1.9	8.2	23.42	-0.25	Mature	0.38
670263	5064727	CL	29.94	HV	1.23	-0.3	1.2	2.2	5.26	16.77	0.43	Normal	0.41
649104	2094581	CL	29.79	HV	0.79	0.3	0.7	1.4	13.75	27.58	-1.11	Fast	1.82
673979	2064260	CL	29.57	HV	0.92	-0.4	0.8	2	10.34	22.46	0.68	Fast	0.96
698672	2068953	CL	29.46	HV	0.84	-0.8	0.1	1.5	7.95	22.08	-0.64	Normal	1.21
699470	2156239	CL	29.43	HV	1.01	0.3	1	2.2	13.23	20.16	0.28	Mature	0.24
700279	5255890	LLACL	29.13	HV	1.58	0.5	1.5	2.3	14.64	33.02	0.21	Normal	0.45
698672	2068953	CL	28.84	HV	0.97	-0.9	0.4	0.4	7.69	34.18	-0.95	Normal	1.4
692730	2118880	CL	28.35	HV	0.97	-0.7	0.7	1.9	11.34	42.69	-0.97	Normal	0.7
698857		CL	28.32	HV	0.94	-0.9	0.2	1.1	7.11	40.51	0.41	Normal	0.39
692877	2052950	CL	28.29	HV	1.81	0.1	1.8	2.7	7.66	8.96	0.73	Normal	0.59
692930	2029673	CL	28.03	HV	1.03	-0.9	0.5	0.6	7.46	25.98	-0.27	Normal	1.53
685305	2156062	CL	27.77	HV	1.66	-0.4	1.6	2.8	11.33	36.35	-0.59	Normal	1.1
699502	2155430	CL	27.77	HV	1.62	0.2	1.6	2.6	9.45	28.48	-1.19	Normal	0.99

Figure C1: Example of Excel report showing growth rate of individual vegetation encroachment reported against client metadata (e.g. span id)

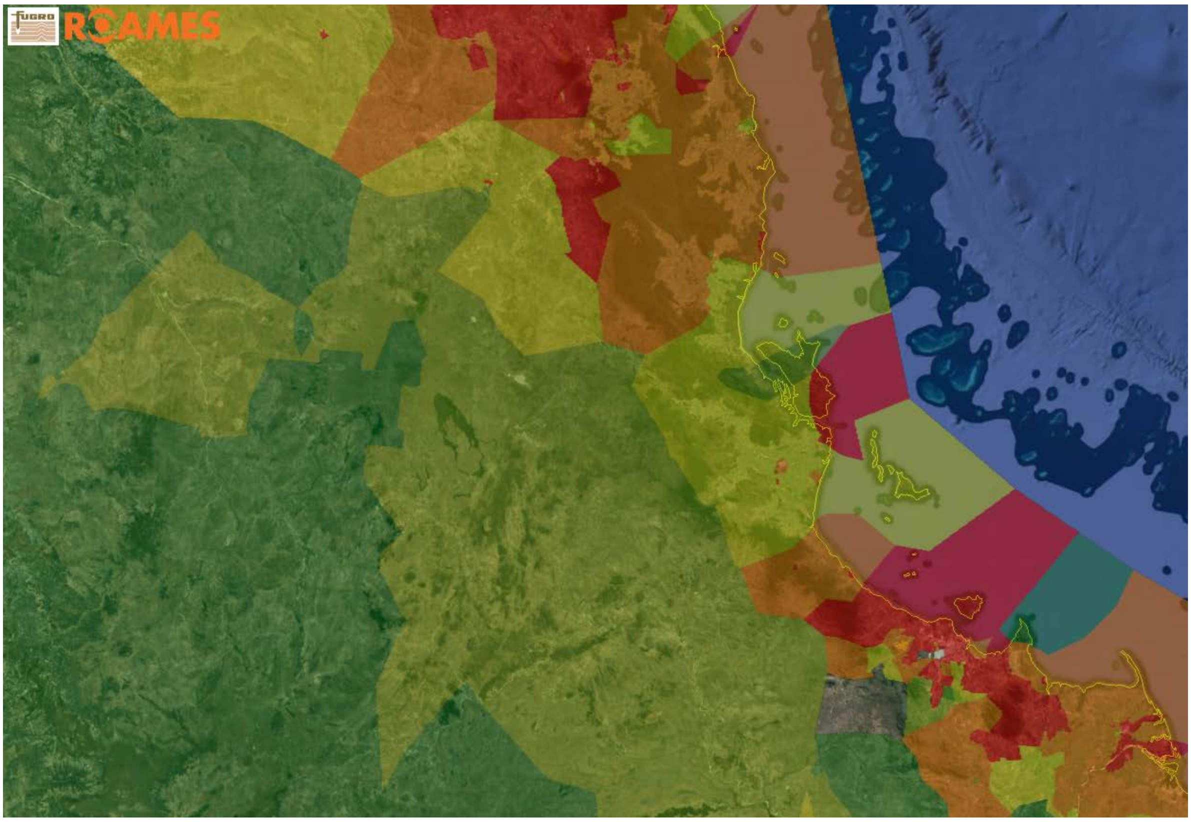


Figure C2: Example visualisation of heat-map showing vegetation growth rate at Vegetation Area level - red indicates area of high growth rate (based on client defined thresholds) transitioning to green indicating areas of low growth rate

Figure C3: Example visualisation of heat-map showing vegetation growth rate at span level - red indicates area of high growth rate (based on client defined thresholds) transitioning to green indicating areas of low growth rate

Distribution Network Operator Innovation Roll-Out Mechanism (IRM) Submission Pro Forma

Section 6: Appendices continued

d. Project Plan