# Welsh Government Independent Advisory Group on Future Electricity Grid for Wales

Request for Information Response

18th March 2025

GREEN GEN CYMRU

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**PRELIMINARY REMARKS**

PLEASE NOTE THAT THIS REPORT HAS BEEN PREPARED IN A VERY SHORT TIME FRAME TO MEET THE TIGHT TIME DEADLINES IMPOSED IN THE EMAIL RECEIVED ON 18 FEBRUARY 2025 FROM THE INDUSTRY ADVISORY GROUP ("IAG") SET UP IN JUNE 2024 BY THE WELSH GOVERNMENT. AS SUCH, IT IS VERY MUCH A WORK IN PROGRESS AND SHOULD BE READ SUBJECT TO FURTHER REFINEMENT AND POSSIBLE AMENDMENTS WHICH MAY FLOW FROM RECEIPT OF FINAL REPORTS FROM THE FOUR INDEPENDENT EXPERT BODIES REFERENCED AT SECTION A.4 BELOW AS WELL AS THROUGH FURTHER MODIFICATIONS RESULTING FROM CONTINUED RESEARCH AND ANALYSIS.

THE ABOVE NOTWITHSTANDING, WE TRUST THAT THE INITIAL RESULTS AND ANALYSIS CONTAINED WITHIN THIS REPORT WILL BE OF HELP TO THE IAG AS IT EXAMINES THE VERY IMPORTANT SUBJECT OF THE FUTURE ENERGY NEEDS OF WALES AND HOW BEST TO SATISFY SUCH NEEDS IN THE MOST COST EFFECTIVE, TIMELY AND ENVIRONMENTALLY SENSITIVE MANNER.

GIVEN THE ONGOING NATURE OF OUR STUDIES, WE WOULD ALSO WELCOME THE OPPORTUNITY TO DISCUSS THE CONTENTS OF THIS REPORT WITH THE IAG, TOGETHER WITH ANY FURTHER RESULTS ARISING FROM OUR CONTINUING WORK, AT A MUTUALLY CONVENIENT TIME AND PLACE.

# EXECUTIVE SUMMARY

Green GEN Cymru ('GGC') has been invited by the IAG to the Welsh Government to submit a report regarding the options and opportunities for developing a grid network in Wales to address the urgent (and clean) energy needs of the country (the 'Report'). We are pleased to present here our findings and conclusions derived not only from our own studies (including Section D: Notes 13 and 14 provided as attachments to this Report) and considerable experience but also from several independent and well recognised third parties with expertise in this field (each of whom are identified in Section A.4). The conclusions set out in the Report serve to reaffirm and corroborate numerous other studies and reports conducted into this area in recent years which are also referenced with links for completeness (see Section D: Notes 2-12).

The need for urgent and additional grid capacity in Wales - and in certain areas in particular - has already been well recognised by the Welsh Government and GGC is proposing a means to address this sorely needed capacity through a capital investment programme approaching £1billion with the associated jobs, skills and apprenticeships that come with such investment. We will also do so in an accelerated manner such as to deliver this programme by 2030 and in an environmentally and cost-efficient manner recognising the need to deliver this additional power to consumers at as attractive a price as possible in line with our statutory obligations as an Independent Distribution Network Operator ('IDNO').

GGC has conducted our work (and continues to do so) with a high regard for, and in very close collaboration with, those local communities most impacted by our projects as well as representatives of the Welsh Government and other industry bodies. The degree of GGC's involvement in recent years with local communities is highlighted within this Report and demonstrates where and how GGC has taken on board feedback from such communities - including undergrounding certain sections of the proposed grid network where clearly justified.

# Part A – CONTEXT OF REPORT

We refer to Eleanor Hoare's email of 18 February to Green GEN Cymru ("GGC") highlighting 3 technical areas of support on which the IAG would welcome our input and in respect of which we are pleased to have the opportunity to contribute. These will be addressed in detail in Section B of this Report. We'd also like to take the opportunity to comment on what we understand to be the Terms of Reference of the IAG (as forwarded to Green GEN Cymru in June 2024) and to place our Technical Report in the context of the overall energy needs of Wales. In so doing, we would like to highlight the following elements identified in such Terms of Reference:

***1.*** **Creating an accessible evidence base about the future needs of Wales including cost and benefit of different approaches to building grid infrastructure.** What might such needs be?

a) Economic growth:

Proudly based in Cardiff with a predominantly Welsh workforce, GGC will invest almost £1.0 billion establishing a new 132kV distribution network for Wales. This investment is creating jobs, supporting Welsh businesses, and developing a stronger more resilient electricity network to help boost economic growth, unlock Wales's energy potential and drive the transition to net zero. We explore each of these elements in greater detail below.

More generally in terms of the sector, GGC currently has connection agreements with 16 energy developments, and this is a number that will certainly grow. In terms of impact of these industries, Renewable UK's 2021 'Onshore wind industry prospectus' stated "Wales stands to see significant economic benefits as a result of onshore wind development, with an expected £4.4 billion in additional GVA and 3,000 jobs by 2030".

The Electricity Network Commissioner's Report (Companion Report Findings and Recommendations, June 2023) also identified that "the impacts of new infrastructure can also be positive. To support the decarbonisation of the electricity network a range of jobs and skills will be required. Skills range from construction, environmental science, planning to engineering. There is a need for more people to work in these areas across all organisations involved in planning and building electricity infrastructure. These jobs, and the economic and social benefits that arise from them, could provide opportunities for people in the local communities affected by infrastructure build".

The energy projects that rely on GGC will see over £3 billion invested by 2031, the majority of this before 2030. These are opportunities Wales can ill afford to miss and GGC will be a key player in delivering them.

b) Capital investment:

GGC has secured significant capital investment into Wales from our Windward Energy Group and Copenhagen Infrastructure Partners[1] (CIP) shareholders. On 25th February 2025 the Secretary of State for Wales announced a £600m investment by CIP in GGC and our sister company Bute Energy, which secures GGC's development phase expenditure to the end of 2027 and allows Bute Energy to commence construction on new renewable energy parks in Wales.

Based on our current project portfolio and programmes, GGC will invest almost £100m in development expenditure (DEVEX) and a minimum of £650m in capital expenditure (CAPEX) in Wales before we commence operation of the new 132kV network, presently expected to be in 2029. Operations will continue for a minimum of 40 years, requiring ongoing investment and working closely with local communities.

[1] www.cip.com

The connections we will provide for renewable energy generators will unlock a further c£3b of investment in Wales (e.g. investment in onshore wind, battery, and/or solar energy generation plants) and our ability to supply power to mid Wales will create opportunities for significant further business investment.

c) Electricity needs (see also Section A.2 below):

The constraints on grid capacity in Wales and associated economic and climate impacts, particularly in rural areas, are well established by both the Senedd's Climate Change, Environment, and Infrastructure Committee and the UK Government's Welsh Affairs Committee. In both the 2022 Senedd scrutiny report into Renewable Energy in Wales and the 2023 report on Electric Vehicle Charging, a lack of grid capacity was identified as a significant barrier to progress.

The report on Renewable Energy in particular highlights what Wales stands to miss out on if these constraints aren't addressed swiftly:

"A lack of grid capacity and a complex and slow consenting regime, amongst other things, are holding back the work of developing a more sustainable energy future. If left unaddressed, there is a real risk Wales will fail to meet its climate change commitments – losing out on the social and economic benefits the renewable energy revolution offers".

These concerns are echoed by the Welsh Affairs Committee who in 2022 considered grid capacity in Wales. Evidence they received highlighted concerns from the likes of Community Energy Wales and NFU Cymru with the NFU stating "We see rural connectivity and the development of electric grid networks as a key productivity growth enabler, and increased electrification as a key driver of new, more efficient technology in agriculture."

With the Future Energy Grids for Wales report emphasising that "Wales's electricity demand may almost triple by 2050", it is clear that expanding grid capacity at pace is essential to tackling the climate crisis, supporting renewable energy projects, helping businesses grow, and electrifying our heating and transport systems.

GGC has completed analysis on the energy demand for electrification targets in mid-Wales, reviewing Welsh Government Net Zero targets and Powys' 2035 Energy Strategy. Further information is provided at Note 13 in Section D of this Report, with the outcomes summarised as:

- Current peak demand across the proposed GGC network area amounts to 275 MW, which under Powys' 2035 Energy Strategy scenarios is estimated to range 380-500 MW, double the carrying capacity of the existing network.
- In order to achieve Net Zero by 2045, this peak demand – assuming full electrification – is estimated to range 640–750 MW, a 130–270% increase in network carrying capacity.
- Current network infrastructure in this area is already constrained, with both National Grid Electricity Distribution and SP Energy Networks (SPEN) unable to add any additional generation or provide a local connection to the network without reinforcement in the required timescales.

As an IDNO, GGC will help address these challenges by developing over 300km of new grid infrastructure through Powys, Ceredigion and Carmarthenshire, adding over 2.5GW of new capacity in rural communities which currently suffer some of the largest grid constraints. As a distribution network, this will not only open up generation opportunities for Wales but add resilience and demand connections for new energy users such as businesses and housing developments. We are acting at the pace that the climate emergency and Welsh Government's Net Zero targets demands and are looking at innovative technologies to maximise capacity on the smallest infrastructure possible. We are proposing to combine new conductors that can carry additional capacity on L7 towers which are just over half the height of standard transmission (L3) towers.

In addressing such critical needs, no longer should buses need to be sent from Ceredigion to Carmarthen to recharge their batteries overnight and local companies will have the opportunity to expand their businesses which they have been hitherto constrained from doing because of a lack of grid capacity.

d) Job creation:

In terms of economic impact, we have created highly skilled and highly paid jobs at our new headquarters in Cardiff and are looking to double our workforce headcount to almost 50 full time staff by the end of this year. We have engaged contractors who have expanded and created Welsh offices due to our projects and we are already in discussion with Welsh companies across the country to ensure they are ready for the construction phase which will create opportunities expected to number close to 1,000 new roles. Combine these opportunities with the associated generation companies with whom we already have connection agreements, and the opportunities for additional employment opportunities can be expected to increase significantly. GGC will conduct an Economic Impact Assessment following sufficient development of project plans and as a demonstration of the potential opportunities unlocked by new distribution lines, RUK's onshore wind prospectus stated, "Wales stands to see significant economic benefits as a result of onshore wind development, with an expected £4.4 billion in additional GVA and 3,000 jobs by 2030".

To place these opportunities in a concrete context, companies from as far afield as Jones Brothers in Ruthin have expressly said to us that they would rather send their workforce down the A483 to mid Wales rather than up the M6 to Scotland. Similarly, Davies Cranes in Carmarthen are eagerly looking forward to the opportunity to deploy their own workforce close to home. We do not want to disappoint them nor their workforce - both existing and potential. Allied to this of course will be the opportunities to develop apprenticeships and related skill sets. These projects will require ongoing operation and maintenance so the jobs will not only be local but for the medium/longer term and not purely transient in nature.

e) Improved and reliable IT availability (including 5G):

Innovation is also a major push for the company, and we are looking at ways to combine technologies to help address the connectivity issues that the communities around our projects also experience. For example, pylons can be used to provide 5G coverage by mounting cellular antennas on them. These antennas transmit and receive 5G signals, just like traditional mobile phone masts. This is feasible, is being done elsewhere in the UK and Is something we are passionately pursuing as using existing pylons avoids the costs and environmental impact of building new cell towers. It works by connecting the antennas to the core network, typically through the earth wire laid along the very top of the pylon or by microwave dishes that link wirelessly to nearby base stations.

This aspect s further detailed under Part B of this response where we note our Community Change ambitions.

f) The cost and benefit of different approaches to building grid infrastructure are addressed in detail in Section B below.

It will be noted in this context that as a holder of an IDNO License we have certain legal obligations arising under the terms of that License including being cost effective and ensuring efficiencies in the network. This to protect consumer rights and ensure fair and affordable pricing. Further analysis of what such legal obligations include are set out in greater detail in Note 1 below.

***2.*** **What approaches might be acceptable in meeting the current and future energy needs of Wales**

This overlaps to a degree section A.1 above but it is we think worth highlighting in particular:

a) Ensuring a robust grid network delivering reliable energy in much deprived areas:

The extent (and resilience) of GGC's new grid network would deliver an additional c.2.5GW of capacity across those areas in Wales most in need where the anticipated energy needs are estimated at present to be approximately 15TWHrs [DESNZ, 2024: Sub-national electricity consumption data]. This would be provided through the construction of three main grid lines with numerous spur connections to generation sites in mid and north Wales. Two of the main grid lines connect to the 400kV National Grid at Llandyfaelog in Carmarthenshire and the third connects at Lower Frankton in Shropshire. The main grid lines need to operate at a higher capacity than the spurs and are a mix of overhead line and underground cable. The spurs are normally a mix of different types of wood pole and underground cable arrangements.

Delivery of such a network should be addressed in the most viable and cost-effective manner possible to provide value and efficiencies in protecting and minimising consumer cost. This is of course at the heart of much of what is covered in section B below and addressed in the various expert reports referenced at A.4 below and at Notes 2-1[2] in section D. The cost comparison of overhead lines against underground cables is one very important element and, in recognition of this we have commissioned not only the four independent third party reports in section A.4 but also drawn upon and researched other analyses referenced in Section D at Notes 2-12. These include, for example, the Renewables UK (RUK) report dated 27 February 2025 and analysis of overhead line against underground cable costs carried out in other countries (Germany being the country here referenced). A recent House of Lords report (2024) supports similar conclusion to those drawn by other parties, namely that the ***cost of burying cables underground is typically anything from at least 5-7 times the cost of constructing overhead lines.***

Section B below and in particular paragraphs (i), (ii), (iv), and (x) strongly reinforce the above points as do the Tables referenced therein.

Published comparisons on the costs and impacts of overhead line against underground cables are generally based on transmission level operating voltages (above 132kV in England and Wales) and most documents presented in Section D of this Report consider 400kV. The conclusions drawn regarding increased costs for underground cables are just as applicable to distribution level voltages (132kV and below) due to:

- Common asset technology (network design and hardware components) used at both transmission and distribution operating voltages and the requirement to meet common UK legislation regarding safety and performance.
- Capacity drivers for cost – underground cable is the most expensive item to be procured in a network and this drives higher cost differences for high-capacity networks as more cables per phase as needed to accommodate the power requirement (up to three cables per phase instead of one or two).

Combining the points above, the high-capacity proposals for GGC's network to meet our contracted generation customers' needs and unlock up to 2.5GW of new renewable energy generation means the publicly available reports are very appropriate context even when presented at a different operating voltage.

b) Operational and Maintenance requirements:

Operation and maintenance of infrastructure is a key consideration for any network, both in terms of meeting connected customer requirements and in meeting UK Government legislation requirements, overseen by Ofgem. Outage periods must be minimised whether they are for planned maintenance or in reaction to damage caused by storm events and the design of the network is key to this. Operations are planned years in advance in conjunction with National Grid and routine maintenance of assets is an ongoing process depending on the type; further details are provided in Section B(v) below.

c) Protecting the environment:

As a responsible infrastructure developer, GGC must deliver an electricity grid that balances technological progress with environmental stewardship. Whilst the construction and operation of grid infrastructure has some impacts, proactive mitigation measures ensure these are minimised. By employing careful routeing and micro-siting of assets and working to environmental management plans approved under the planning consent process, GGC can minimise impacts on communities, landscapes, biodiversity, and heritage assets. Further details on how GGC deliver specific aspects of mitigating impacts to communities and the environment is provided in Section B(iii) below.

d) Accelerated delivery

The UK Government has set a target for delivery of Clean Power by 2030 focussed on boosting energy independence and lowering bills. Both Transmission and Distribution networks holistically working together are key to this ambitious plan and GGC's distribution network will play an important part with completion planned for 2029. Furter detail is provided at Section A3 below.

e) Full, regular and transparent engagement with local communities.

GGC engages comprehensively with local communities impacted by our projects. For all our proposals, we consult early in the development phase to give communities and stakeholders the opportunity to review plans in their formative stages. Our team provides a consistent, informed and considerate approach to engagement, allowing communities to provide meaningful feedback at key stages, influencing outcomes and helping shape the projects.

As an example, for the proposed Towy Usk and Towy Teifi grid projects, GGC is holding three stages of public consultation: two informal non-statutory stages, and one formal statutory. This phased approach allows for focused engagement, ensuring that sufficient time and attention are given to each stage, from early discussions, through to statutory consultation and the submission of the planning consent application.

Since the launch of these projects, GGC has received more than 5,000 pieces of feedback. Thanks to this input - alongside further environmental and technical assessments - we have refined our proposals including committing to underground sections in key heritage and landscape settings (Merlin's Hill and Llanarthne) and considering the cumulative impacts of our and other grid projects by undergrounding near the National Grid 400kV Llandyfaelog substation.

Our goal is to work to create engagement with stakeholders, to encourage open and constructive dialogue and consultation. Anticipating potential concerns early and addressing them proactively will ensure stakeholders feel heard, and that their feedback is understood and valued. As of 1st March 2025, 37,247 leaflets have been issued to properties near our projects and 6994 people have attended our consultation events. We have received 5372 individual pieces of feedback that have been categorised and fed into our change control process and have been present for 195 hours at 39 in-person public consultation events[2].

37,247 leaflets | 6,994 attendees | 5,372 pieces of feedback | 39 in-person consultation events | Lasting 195 hours

Effective community consultation relies on clear, accessible communication in both English and Welsh. We develop key messages that place our portfolio and projects in a broader context, highlighting the benefits of green energy networks in meeting the future needs of Wales's people, communities, and businesses.

These critical elements and our engagement with the local communities are explained in more detail in section B (iii), (vi), (vii), (viii) and (ix) below.

[2] Further consultations in March 2025 have increased these figures to 45,554 leaflets, 214 hours and 45 in-person events as at the date of submission of the Report.

3. **Enabling electricity grid infrastructure to be delivered at the pace required to achieve Welsh Government net zero targets**

a) In designing our network and our project timelines we are very conscious of the Welsh Government's targets for Net Zero 2050 alongside the ambitions of the historic Cooperation Agreement with Plaid Cymru to rapidly accelerate Wales's approach to achieving net zero by 2035. We are also aware that the Welsh Government has set a target for renewable electricity generation to be equivalent to 100% of annual electricity consumption by 2035. The recently published Energy Generation in Wales 2023 report flags that due to the anticipated increase in electricity consumption "Welsh renewable electricity generation needs to increase nearly fourfold by 2035."

2035 is only ten years away, Wales needs to see a significant increase in renewable generation connected to the grid and be able to export to consumers – GGC's network will provide 25% of this[3]. Without transmission **and** distribution networks being ready, it will not be possible to achieve the degree of decarbonised electrification anticipated or deliver low carbon electricity to consumers in a much more decentralised system.

b) GGC's present programme seeks to achieve relevant planning consents and Final Investment Decision (FID) for each of the three main grid lines in 2027 and Commercial Operation Date (COD) by 2030 as shown in the summary table below:

| **Project** | **Consenting process** | **Consent submission** | **Consent received** | **FID** | **COD** |
|---|---|---|---|---|---|
| **Towy Usk** | Welsh Gov – DNS | June 2026 | June 2027 | October 2027 | June 2029 |
| **Towy Teifi** | Welsh Gov – DNS | July 2026 | July 2027 | October 2027 | June 2029 |
| **Vyrnwy Frankton** | UK Gov - NSIP | March 2026 | April 2027 | October 2027 | October 2029 |

c) GGC's projects and planned grid programme we believe to be the only realistic means of enabling the Welsh Government to achieve its Clean Energy Targets target given the lengthy consultations and detailed planning already undertaken. Other potential grid projects are deliverable in a much later timescale. The much-referenced NGET North-South 400kV transmission line for example would to our mind not be deliverable nor electricity supply available to answer the urgent needs of businesses and communities in Wales until realistically at least 2036. We therefore see our grid system as complementary to, rather than in competition with, transmission operators and other DNOs in that we are well placed to help deliver 2030 targets as part of longer-term net zero ambitions.

Of further note is that creation or expansion of an electricity network requires whole system planning and GGC is reliant on connection points to the National 400kV Transmission Grid being delivered as planned to meet 2030 targets, ensuring a joined-up and collaborative approach with the TO and other DNOs where required.

[3] Based on a fourfold increase of requirement (currently 3,663MW), Wales requires an additional 10,989MW, of which GGC's network can provide up to 3,000MW depending on final design parameters.

*4.* **Engaging technical experts to present relevant information**

The technical information requested by the IAG is provided in Part B of this report and GGC has also commissioned the following reports which are nearing completion for release in May 2025:

a) **Turner & Townsend**: cost review providing a per km rate for overhead line, trenched underground cable and ploughed underground cable. Please note that both GGC and ATP Plough have provided input to this report, and it will confirm the following outputs on a model of 1150MVA capacity as per GGC network requirements for our Towy Usk grid line:

   L7 towers - **£1.269m/km** (simple route) to **£1.636m/km** (complex route)
   Underground cable (trench installation, 3 x 2000mm$^2$ Aluminium cables per phase) - **£6.97m/km**
   Underground cable (plough installation, 3 x 2500mm$^2$ Aluminium cables per phase) - **£7.83m/km**
   Underground cable (trench installation, 2 x 2500mm$^2$ Copper cables per phase) - **£8.07m/km**
   Underground cable (plough installation, 2 x 2500mm$^2$ Copper cables per phase) - **not feasible** due to inability to control cable temperature through imported selected backfill.

   Full breakdown of the underground cable costs is provided in the Turner and Townsend source document at Note 14 (see below in this Section for the overhead line cost breakdown). All figures include a common application of 20% contingency for all options and are based on current system design. Whilst factors such as ground investigation results may influence design changes the effect on all options would be the same and therefore the ratio of costs can be expected to remain as presented in the Turner & Townsend costings.

   The higher cost for installation of underground cables with a plough over open-cut trenching is due to the increased cable size needed to maintain performance levels of the network when using the plough, shown by the need to increase from 2000mm$^2$ to 25000mm$^2$ diameters in the aluminium cable examples above. The cost of cable is the most expensive component of any underground network and increasing the diameter has a large effect on overall option cost but is required to offset heat dissipation issues when cables are installed without selected imported backfill (i.e. mole plough installation).

   Copper cables can accommodate higher capacities than aluminium, hence the option to install at two cables per phase instead of three as shown in the example for a 1150MVA cable system above. Their higher running capacity means heat dissipation must be supported by introduction of selected backfill, making installation unviable by any technique other than open trenching. Copper cables are more expensive than aluminium due to higher material costs in manufacture.

   Further details on use and suitability of cable ploughing are provided at Section B (iv) below.

   The comparative cost breakdown for an overhead line option from Turner and Townsend is provided below. Their final report with commentary on all costings will collate the overhead line and underground cable results together under one document.

Forecast costs of a simple, average, and complex installation, considering factors above are shown below:

| | | | Simple Overhead Line - 100km direct line | | Average Overhead Line - 100km direct line | | Complex Overhead Line - 100km direct line | |
|---|---|---|---|---|---|---|---|---|
| | | | Assume 5% for route divergence = 105km | | Assume 15% for route divergence = 115km | | Assume 25% for route divergence = 125km | |
| **Units** | **Unit Rate** | **Unit** | **Qty** | **Total Cost (£k)** | **Qty** | **Total Cost (£k)** | **Qty** | **Total Cost (£k)** |
| L7 Suspension towers | 115,000 | nr | 280 | 32,200 | 246 | 28,290 | 250 | 28,750 |
| L7 Tension towers | 170,000 | nr | 70 | 11,900 | 164 | 27,880 | 250 | 42,500 |
| L7 Terminal towers | 170,000 | nr | 2 | 340 | 2 | 340 | 2 | 340 |
| EO for Piled Foundations | 90,000 | nr | 88 | 7,920 | 103 | 9,270 | 125 | 11,250 |
| L7 suspension insulators | 1,500 | nr | 1680 | 2,520 | 1476 | 2,214 | 1500 | 2,250 |
| L7 tension insulators | 2,000 | nr | 840 | 1,680 | 1968 | 3,936 | 3000 | 6,000 |
| L7 terminal insulators | 2,000 | nr | 12 | 24 | 12 | 24 | 12 | 24 |
| UPAS Conductor | 175,000 | km | 105 | 18,375 | 115 | 20,125 | 125 | 21,875 |
| Earth cable | 30,000 | km | 105 | 3,150 | 115 | 3,450 | 125 | 3,750 |
| Access | 120,000 | km | 105 | 12,600 | 115 | 13,800 | 125 | 15,000 |
| EO for access in remote areas | | % | | | 20 | 2,760 | 50 | 7,500 |
| Miscellaneous | 2 | % | | 1,814 | | 2,242 | | 2,785 |
| Prelims | 20 | % | | 18,505 | | 22,866 | | 28,405 |
| **Sub Total** | | | | **111,028** | | **137,197** | | **170,429** |
| Risk and Contingency | 20% | | | 22,206 | | 27,439 | | 34,086 |
| **Total cost** | | | | **133,233** | | **164,636** | | **204,514** |
| **Cost per km (direct line)** | | | | **1,332** | | **1,646** | | **2,045** |
| **Cost per km (route)** | | | | **1,269** | | **1,432** | | **1,636** |

b) **Cable Consulting International (CCI)**: cable system design for GGC capacities with commentary on installation techniques (open-cut trenching and ploughing). This review forms the basis of cable system design where GGC plans to deploy it over overhead line for technical or visual impact reasons. It provides the basis for underground cable options costing in the Turner & Townsend analysis above and recommends a **minimum of two cables per phase installed by open cut trenching** to ensure imported backfill can be introduced to control cable temperature and meet performance requirements.

c) **LSTC:** a desk top feasibility study to understand the difference between the routing of a project that is either fully overhead line or fully underground cable. LTSC have used a GGC development project to provide a comparison between an underground cable route and the overhead line route. The feasibility study focusses on comparing the engineering and constructability aspects of both a cable and overhead line route, demonstrating that undergrounding a network is far more complex than simply a matter of additional costs.

d) **DNV**: UK industry-wide review of overhead line and cable technologies including assessment of the advantages and disadvantages between technologies with both technologies present on the same circuit/network. The assessment will consider archetype designs for long and short distance overhead lines, long and short cable sections, cable and overhead line transitions and methods of crossing obstacles such as water courses and roads. These designs will be compared considering costs, deliverability and operability, environment and community impacts of the technologies.

We will be making all reports available to the Welsh Government and other stakeholders upon completion. They will provide information to help stakeholders' understanding of GGC's position on the application of overhead line and underground cable, and proposed installation methodologies.

# Part B - TECHNICAL REPORT

We here address the specific requests in your email of 18 February:

1. Technical data relating to network topology archetypes comparing overhead and underground distribution voltage lines.
2. Request for additional resources (as identified at paragraphs i - xi together with access to case studies where available)

**i) How is our network designed?**

An electricity network is designed through meeting the need of customers for electricity connection and power transfer, this can be for demand (supply of power to a consumer) or generation developers. A customer request for connection requires capacity of the connection to be assessed, understanding the location of the customer and the point of connection to the existing or planned network. Power system studies are then undertaken to understand the impact to the existing or planned network and how it interacts with connected networks (in GGC's case the NGET 400kV transmission system). Outputs from power system studies may drive changes to network design or confirm the requirement of additional equipment such as reactive compensation to support the voltage profile across the network.

A network design is standardised to existing UK practices to enable common operational and maintenance procedures to be implemented; any non-standard proposals are assessed as part of a cost benefit analysis with the connection applicant to ensure they are aware of additional operating costs. All aspects of our network are designed and operated in accordance with the UK's legislation, implemented in Wales through compliance the UK network policies and procedures.

GGC's network is currently in the design development stage; we are consulting on preferred overhead line and underground cable routes and sites for supporting control infrastructure having designed the network electrically based on our power system studies. Any new connection requests from this point onwards are analysed as noted above and accommodated to the customer's requirements as far as reasonably practicable whilst not creating detriment to existing customers or the overall network design.

**ii) What does electricity grid infrastructure consist of and what are the variables?**

Linear infrastructure consists of towers (pylons), wood poles, underground cables and cable sealing end compounds, which provide transfer from overhead line to underground cable or vice-versa. Substations and switching stations are used to connect or isolate circuits or change voltage via a transformer. Substations can be housed within buildings or have equipment outside and generally consist of switchgear, control equipment, transformers and reactors.

Converter stations are associated with High Voltage Direct Current (HVDC) networks, converting Alternating Current (AC) power to Direct Current (DC) for transmission over longer distances. GGC does not use HVDC technology on our network and it requires a Transmission Operator (TO) license to implement (operating above 132kV in England and Wales).

Towers are typically of a steel lattice structure and classed as suspension, tension or terminal according to their placement and function within the overhead line system. A standard suite of towers is available in the UK with larger towers being used at higher operating voltages or capacities to meet electrical safety distance requirements (distances between live circuits and earth connections).

Wood poles can be used to carry power where a lower capacity than towers is needed. As they hold conductors closer to the ground the span length between poles is less than towers therefore more poles are required.

Underground cables are used to cross major obstacles where overhead line is not suitable for safety or network stability reasons, for example major watercourses, difficult terrain or 3rd party infrastructure constraints such as roads or airports. Underground cables can also be used to meet visual and landscape requirements associated with areas of designated natural beauty.

Variables across the infrastructure types noted above are informed by network design requirements, mainly the capacity of the system that is being designed. For example, a higher capacity transfer via underground cables may create the need for three cables per electrical phase instead of two, which increases the total number of cables in the ground up from six to nine (based on standard 3-phase AC electricity). This same capacity requirement could vary the type of overhead line towers or wood poles used on other sections of the network, and the protection and control equipment at substations and switching stations would also have to be scaled up accordingly.

### iii) What are the processes associated with creating new grid?

Creating a new electricity distribution grid involves multiple processes including technical study, planning consent, stakeholder engagement, design and engineering, environmental assessment, procurement and finally construction and commissioning. The technical study and design and engineering aspects have been covered under item Bi) *How is our network designed* above.

**Planning Consent** – GGC's projects will each be applying for planning consent under the Welsh Government's Developments of National Significance (DNS) process apart from our Vyrnwy to Frankton project as it crosses into England and is submitting application under the UK Government's Nationally Significant Infrastructure Project (NSIP) process. The main difference is the wrapping up of all secondary consents under NSIP through the creation of a Development Consent Order (DCO) in UK law, whereas a DNS consent requires the applicant to gain separate secondary consents with relevant authorities. Both consent processes require extensive environmental surveying of proposed network routes and demonstration of sufficient stakeholder engagement to inform the proposed design. This is a process that takes a minimum of two years to complete, often longer for complex linear infrastructure such as electricity networks.

**Stakeholder Engagement** – as noted above, any planning consent application must include evidence of sufficient engagement with stakeholders (including local communities) and demonstration that concerns or preferences have been considered in presentation of the proposed solution. GGC goes above and beyond the minimum single statutory engagement criteria for all our projects, providing a minimum of two engagement opportunities (three for larger projects) so continued input and review of our designs is enabled with stakeholders. The engagement periods typically last three to four weeks and consist of a series of consultations with relevant stakeholders including open drop-in public events in locations affected by our proposals. We also visit all landowners to engage directly on our plans and discuss any changes that they would like to see.

**Environmental Assessment** – as noted in Item 2c) above, electricity networks must be planned and constructed in accordance with strict environmental management legislation which GGC and our supply chain implement robustly. A major component of any planning consent submission is the Environmental Impact Assessment (EIA) and this must be fully detailed by the applicant through at least one full year of environmental surveys, often more if access to land is restricted in parts of the year for agricultural or other reasons. Currently, GGC is surveying proposed project routes and sites to ascertain what habitats or species are present, this informs plans for construction management measures or the decision to choose one route/site option over another.

**Procurement** – competitive tendering of all development and construction works is completed with consideration of Welsh businesses and supply chain wherever possible. Social value contribution proposed by suppliers in the procurement phase is assessed alongside health and safety performance, completion of similar projects, financial stability, delivery proposal plans and cost of services. Completion of procurement activities usually takes around 12 months depending on scale and complexity of scope.

**Construction and Commissioning** – with all consents and suppliers in place, GGC will ask our investors for the funds to commence construction activities and execute the works in their approved final format. Construction can take up to 24 months for projects of the scale of GGC's larger proposals, including a period of electrical commissioning of the installed assets to our customers (generators and demand centres) and through our connection points to the UK's 400kV transmission network. All activities under this part of the process are delivered in accordance with approved management plans and any associated planning consent discharge conditions. These might include, for example, creation of biodiversity net gain (BNG) in an area where a new substation is established to ensure the network's environmental impact is positive overall.

**iv) Have you used cable ploughing at all? If so, where did you use it, why did you choose it for this work, and what advantages/drawbacks did it present?**

Given the pre-construction status of GGC's projects we have not installed any underground cables to date, however several members of our team have experience of cable ploughing from earlier in their careers. Two members of our construction management team have previously worked for a Welsh company providing cable plough services.

The mole plough has been used for cable installation at distribution voltages in the UK - most prominently 11kV, 33kV and 66kV - for many years and has proven to be an effective solution at these lower capacity requirements where controlled backfill to the cable and ducts is not required to mitigate heat dissipation issues associated with higher capacities. If heat is allowed to build up in a cable (or conductor) it suffers significant electrical loses and quickly becomes inefficient to operate. For this reason, higher capacity cable systems are designed to be installed in an open-cut trench so **the soil around the cables can be removed and replaced with selected sands or cement-bonded sand** (CBS) which are far more efficient at dissipating heat away from the cables, ensuring efficient operation with reduced risk of failure. The alternative using a plough is to install (if possible) far larger ducts and cables to cope with the losses, creating significant additional costs as the most expensive element of any cable system is the copper or aluminium cable and not the installation technique applied.

Additionally, the topography of terrain across longer, higher-capacity networks tend to challenge the capability of ploughing machines with other installation methods still required for crossing roads and areas of vegetation.

It is important to note that the mole plough only installs ducts for non-direct buried cables[4] – both ploughing and open trenching techniques place the ducts in the ground and then pull the electricity cables through afterwards so haul roads, jointing areas and construction compounds are still needed for both.

GGC is in dialogue with ATP Plough in Wales as part of our potential supply chain and will continue to assess if plough installation technology can be deployed on the projects subject to the points noted above.

**v) How are faults found, and maintenance / repair carried out?**

This varies significantly between overhead line and underground cable systems:

[4] Due to the size and weight in handling operations, cables above 66kV rating are pulled through pre-installed ducts.

**Overhead lines** - visual inspection (ground patrols) annually, vegetation management around the conductors every 3-5 years, painting and corrosion protection every 15 years, insulator replacement approximately every 20 years and conductor replacement around the 40-year mark. Overhead lines are more exposed to storm events but designed to cope with all but the most severe circumstances; if damage is sustained the fault can be found quickly through visual inspection (drones are often used) and repaired easily without the need to dig up infrastructure.

**Underground cable systems** - require less frequent maintenance due to their protection from the elements, however they are harder to inspect and repair when faults do occur. Routine inspection and monitoring are completed annually at manhole and joint bay locations with in-depth joint inspections every 1-2 years, cable and insulation resistance testing every 3-5years, sheath integrity testing every 5-10 years and cable replacement at around 40 years assuming no significant heat issues before then.

Both types of network asset can be monitored for "hotspots" (signalling excessive heat build-up and inefficient operation or damage to assets) with installation of Distributed Temperature Monitoring (DTM) systems and, for overhead lines, infra-red drone or helicopter-mounted cameras can also catch hotspots before they develop into a fault.

<u>Communities and Compensation:</u>

**vi) What can or should communities expect when it comes to remediation works following installation or maintenance of infrastructure?**

Communities can expect various remediation works to restore areas affected by construction activities. Roadways and footpaths will be restored to the same or usually better condition following local authority regulations, any landscaped areas are typically re- seeded, re turfed, or replanted. There is also the option for communities or landowners to retain paths or roads for their own use subject to planning consents.

**vii) What is the expected lifespan of the different parts of the infrastructure and can or should communities expect when it comes to the end of infrastructure lifespans?**

When network infrastructure is decommissioned or replaced after a – typically – 40-year design life, restoration work may be necessary to return the site to a usable natural state. Proper disposal or recycling decommissioned equipment, including hazardous materials must be done in compliance with environmental regulations.

The removal of overhead lines is relatively straightforward with towers or wood poles being cut at ground level after the conductors have been removed, broken up for transport and then removed for recycling where possible. Foundations are then removed to at least 1m below ground level to allow the ground to be used for other purposes.

Removal of underground cables is less simple, with the cables pulled back out of their ducts and then the ducts being dug out of the ground along the length of the route. Joint bays are also removed with concrete surrounds being taken down to at least 1m below ground level. These activities disturb the ground and take a lot longer than overhead line removal to complete.

**viii) What evidence do you hold as to the impacts of networks on health, both mental and physical?**

As a new Independent Distribution Network Operator currently developing a 132kV network GGC refers to industry guidance to ensure best practice for considering the impact on both mental and physical health. This includes design and construction of all network assets in accordance with UK law and National Energy System Operator and Energy Networks Association policies and codes of practice, all of which are informed by appropriate health and wellbeing studies and updated accordingly.

**ix) What schemes or structures do you have or use for community benefits or for compensation payments to landowners?**

Compensation is dependent on several factors and assessment must be applied to the specific impact of the scheme on an individual property or community group. The right to claim compensation is governed by a framework of legislation, case law and established practice dependant on the circumstances, which can obviously vary significantly between cases. For GGC (at the development stage of network creation) details of compensation applicable to individual landowners or affected persons will become clearer once we progress designs.

**Landowners** - in accordance with National Grid guidelines and IDNO license requirements, GGC has published a document setting out the standard payments for voluntary agreements for new infrastructure, land agent and legal fees: Green_Gen_CYMRU_Landowner_Payments.pdf. This document provides a consistent methodology for acquiring land rights for GGC projects as we work with landowner to host our grid infrastructure. GGC pays costs for landowners engaging professional representation in dealing with our projects.

All affected landowners are offered Option Agreements in line with the above strategy to enable GGC to acquire land, rights over land or to obtain temporary land rights, before planning consent is granted. In parallel with seeking voluntary agreements, GGC may (under IDNO licensee status) apply for compulsory acquisition rights should there be any issue with implementation of voluntary agreements (e.g. insolvency, death etc). In the event rights are acquired through compulsory acquisition, the provisions of the compensation code will be relied upon during negotiations. GGC's preference will always be to secure land rights on a voluntary basis.

**Communities** - as a licensed IDNO organisation, all costs, expenditure and profit created by GGC is subject to Ofgem scrutiny and approval. As such, IDNOs (and other licensed network operators) are not able to offer the same scale of cash community benefit funds that a renewable generator is able to. GGC's approach in this area instead aims to maximise our assets to create community improvement and our focus – in addition to providing grid access to mid Wales for the first time, see below - is on the feasibility of introducing a 5G communications network to mid Wales through the placement of optical fibres and mobile phone masts on our towers and through the ducts that house our underground cables. Whilst this ambition is still in early feasibility review, we hope to progress it in line with developing our network designs over the next 12-18 months to include as part of our planning consent submissions.

GGC will also enable community change through access to grid connections in areas of Wales that are currently chronically short of power, enabling businesses to develop and providing much needed power for electric vehicle charging and other net zero initiatives. We are, for example, currently working with Powys County Council to identify their future electricity use needs and how the provision of a new distribution network could best support them.

As noted under the Procurement section above, GGC requires our engaged contractors to provide social value to the areas and communities they will be working in and this forms part of the tender assessment process. Through these commitments (often expressed as an agreed % equivalent value of the overall contract) we can offer the skills of our supply chain to local communities to complete projects for the lasting benefit of that area. For example, a civil contractor can be paired up with local sports clubs to improve drainage on low-lying playing pitches or upgrade spectator facilities.

Finally, one of GGC's generation customers, Bute Energy, has opened its community fund to communities in proximity to our grid projects in recognition of the wider impact of their energy parks. Worth millions of pounds per year, this money will be available to provide financial support for initiatives that improve the quality of life for community members, help secure clean energy independence, foster engagement, and address social and economic concerns. Further details are available at www.bute.energy/community-investment/

Generally, GGC acknowledges major infrastructure developments can impact homeowners, landowners and communities and we are committed to ensuring that any impacts are mitigated as much as possible whilst delivering the assets Wales needs to meet net zero targets and secure energy supply for future generations. We are supportive of the UK Government's Planning and Infrastructure Bill[5] published in March 2025 with a minded-to position to offer £2,500 discount over 10 years for those living up to 500m from new and significantly upgraded electricity transmission infrastructure and look forward to further details of the scheme including proposals for distribution networks.

As noted above, GGC is still in a development stage and no final decisions have been made on where overhead lines or underground cables will go within the preferred routes corridors. It is very important that people engage in the planning process and respond to consultations to tell us their concerns so we can work to reduce the effects on communities and individual properties. Once we have refined our proposals, we will work with landowners affected to discuss how we can support them.

### x) Innovative approaches to grid infrastructure

As noted above, grid infrastructure is subject to strict UK Government and National Grid legislation and policies to ensure safe and efficient provision and operation of these nationally significant assets. This can often leave little room for innovation, however GGC will be using new conductor system technology on smaller overhead line towers to provide far greater network capacity (usually associated with 275kV – 400kV systems) without introducing transmission-level towers.

To achieve this, we must type-register the new conductor for use on L7 towers in the UK and design our underground cable systems, control and protection measures and overall power flow model accordingly. The greater capacity being offered on L7 towers (27m in height) compared to L3 towers (54m) means we can offer more connections to more renewable generators and local businesses and communities without increasing our visual landscape impact. It also means there is less risk of our network becoming oversubscribed too early and additional, potentially larger, infrastructure being required in the future.

### xi) Technical data comparisons for overhead line and underground cable

The following pages contain tables comparing overhead line and underground cable archetypes at 132kV and 33kV as per the IAG's specific requests for technical information.

[5] Guide to the Planning and Infrastructure Bill - GOV.UK

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# 132kV Circuit Archetypes Comparison

| Characteristic | AC Overhead Line (OHL) | AC Underground Cable | DC Overhead Line |
|---|---|---|---|
| **Archetype Description** | | | |
| **Maximum Continuous Distribution Capacity (MVA)** | In the Uk Distribution Network operators typically operate at various ratings dependant on the number of conductors per phase and number of circuits on the tower. lower capacity systems are single circuit ACSR single conductor per phase operating at 150mva.To the top end of the scale where ACCC high capacity twin bundle conductors are used across 2 circuits capacities of 1600mva can be achieved. All OHL lines systems are susceptible to capacity losses dependant on linear lengths and operating temperatures. | The MVA rating of 132kv cable systems depends on the conductor size, insulation type, installation method (direct buried, in ducts, or in tunnels) and thermal resistivity of surrounding soil. Lower end of the scale is 630mm2 Aluminium (1 cable per phase) 140-150MVA per CCT. To the top end of the scales are 2500mm2 copper with imported backfill surround (forced cooling) 3 cables per phase 1600mva can be achieved. Similar to OHL systems capacity losses will occur when long linear lengths of cable systems are attempted. Copper is significantly more expensive than aluminium per tonne. Aluminium is lighter but requires a larger cross section to carry the same current. Typical cost as of March 25 is copper £7000 £9000 per tonne and aluminium is £1800-£2500 per tonne. Several factors need to be considered when choosing the most suitable material for bespoke cable systems. | However, for voltage source converter (VSC) schemes, power transfer can be a few MW to 330 MW for DC voltages up to +/- 150 kV 2 |
| **Maximum Technically Feasible Route Length (km)** | Unrestricted however, line losses may cause very long lines to be uneconomical over the lifetime of the asset | The maximum cable length for a 132kV cable route depends on several factors such as voltage drop, cable impedance and capacitance, the maximum is approximately 20km. | Unrestricted |
| **Life-span (years)** | Design life 40 years Typically, in operation > 40 years with appropriate inspection and maintenance being undertaken. Can be up to 80 years if major refurbishment is performed at an appropriate interval | Design life up to 40yrs, with components like joints and cable sealing ends, typically replaced after 40 years | Design life 40 years Replacement of significant system components of converter system<br>required after 20 years |
| **Infrastructure Operational Footprint** | 30 – 100 sqm land take per tower, approx. 4 spans per km.<br>Vegetation management required.<br>Temporary and permanent infrastructure beneath OHL is discouraged.<br>Agricultural activities can continue beneath OHL.<br>to ensure safe clearance and mitigate against possible flashovers and faults | Building and excavations are prohibited within swathe path. The Swathe path width is dependent on cable/duct installation depth, Cable/duct phase group axial separation and trench excavation method.<br>Tree and hedge planting is also restricted above the cables or within 3m of the cable trench to avoid vegetation encroachment. Ground agricultural and rural activities can still take place. | Smaller than HV AC as only one phase and earth wire is needed, for VSC converter station, footprint can be in the range of 120m x 60m x 22m 4 |
| **Future scalability for long-term planning** | Future Point-of Connections (PoC) possible<br>Route diversions<br>Can be uprated or real time monitored for additional capacity or congestion relief respectively | The uprating can only be achieved at significant cost, if undertaken post installation. This would include re-excavation, installing larger or additional cables. Generally, this procedure is not recommended. | With advancement of power electronics and key components such as the converter bridge (thyristor), voltage and current ratings may increase<br>Allows for power transmission in both directions – advantageous where energy trading is considered. HVDC technology allows for more power transfer per conductor – potential for high power transfer for long lines at higher voltages. Technically difficult to tap off power at intermediate locations, converter station required at every location for generation/demand addition. |
| **Deliverability and operability** | | | |

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|---|---|---|---|
| **Planning and consents** | Planning consent required under Development of National Significance.5 For OHLs less than 2 km in length, development consent may be applied for under the provisions of section 37 of the Electricity Act 1989. | Classed as permitted development under the Town and Country Planning (General Permitted Development) (Scotland) Order 1992 (as amended), (England) Order 2015, (Wales) Order 2014. Suitable rights over land (such as wayleaves and easements) must be obtained from every owner or party with a relevant interest in the land crossed by an underground cable. Wayleaves and easements are usually granted voluntarily through negotiation, but if not, utility owner can apply to the relevant authority (Government Office) for approval. | Planning consent required under Development of National Significance. For OHLs less than 2 km in length, development consent may be applied for under the provisions of section 37 of the Electricity Act 1989. |
| **Reliability, availability and maintainability** | OHLs designed reliability levels linked to strategic importance within a network<br>Designed to withstand appropriate return period of prevailing weather conditions (e.g., 1 in 150- year return period etc.).<br>Prone to lightning strikes<br>Double circuit OHL allows for live line maintenance on one circuit and operation of the other<br>Repair and maintenance can be performed at short notice and completed within hours or days depending on the condition of the structure. Repair to conductor system or foundations may require longer periods (weeks) | - Less Susceptible to disruption caused by the environment factors (storms /high winds). In the case of double circuits, if one cable experiences a fault or requires maintenance the other circuit can continue to supply power, minimising the risk of service interruptions. Most cable faults are caused by faulty joints, improper earthing, sheath issues and third-party damage. Faults may take between two to six weeks to locate and repair, often requiring excavations that can lead to road closures and traffic disruptions. Tests are undertaken of the cable joint sheaths | Provision for redundancy for greater reliability is expensive to achieve<br>Similar maintenance requirements for AC OHL lines (Specialist skillset for maintenance of converter stations)<br>Prone to lightning strikes |
| **Flexible circuit rating** | Real time monitoring may allow for higher current rating under favourable weather conditions | In emergency situations, the 132kV cable will be subjected to temporary overload conditions for a short duration. This overload condition needs to be carefully monitored in real-time to ensure safe operation and prevent any potential damage | Real time monitoring may allow for higher current rating under favourable weather conditions |
| **Provision of restoration services**<br><br>**(All require an intact source of energy at one end)** | Immediately available for system restoration – able to transfer power from one restoration energy source to another | Continuous monitoring of the cable's performance will be carried out using a fibre optic cable, which will provide precise, real- time data on temperature, current, and other relevant parameters to ensure that the overload does not exceed safe limits. The restoration of a 132kV cable circuit requires ensuring a reliable and intact energy source at one end of the circuit. This intact source, combined with advanced fault detection, repair capabilities, and protective devices, enables the system to recover from faults quickly. Fiber optic monitoring systems and effective switching strategies play a critical role in ensuring that the restoration process is smooth, efficient, and safe for the overall grid stability. | Immediately available for system restoration – able to transfer power from one restoration energy source to another |
| **Environmental Impacts** | | | |
| **Construction** | Vegetation removal for access and construction activities (stringing, laydown areas, construction offices, welfare)<br>Compaction of soil – can be corrected by deep sub- soiling once line is constructed<br>Litter and waste<br>Temporary noise<br>Temporary coppicing of hedgerows and trees along servitude<br>Temporary soil storage<br>Possible disturbance to wildlife and livestock. For the latter, proper arrangements should be made with the landowners.<br>Potential damage to crops, roads, fences, irrigation systems<br>Erosion control may be required at tower/pole site or on permanent OHL maintenance access routes | Construction activities can generate noise levels, potentially affecting nearby communities.<br>- Dust generation from excavation or construction machinery can contribute to air pollution.<br>- Underground cable installations require materials such as cables, conduits, and backfill, which can occasionally lead to excess waste.<br>- Construction activities can disturb the soil, potentially harming plant species and disrupting soil-dwelling organisms.<br>- Clearing vegetation along the typically few- meter-wide cable route can result in the permanent loss of plant species, including trees and understory vegetation.<br>- Construction activities and underground cables can disrupt wildlife movement, isolating populations and limiting access to essential resources and breeding grounds. | May be similar to HVAC OHL however, HVDC construction is simpler and less expensive than HVAC |

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| **Operational** | Livestock may become entangled with the base steelwork of the tower (for poorly designed towers)<br>Potential bird collisions – can be mitigated through appropriate installation of bird flight diverters or warning devices<br>Birds may use the structures for nesting, perching or roosting. Can lead to line performance issues due to polluting of insulators, bird excreta streamers or untidy nests. Flash overs can be fatal to birds (electrocution).<br>Possible mitigation through anti-bird perching or anti-nesting devices or suspended tension sets<br>Wildlife may become frightened during helicopter visual inspection patrols | Vegetation clearance around access points may be necessary for proper access and maintenance | May be similar to HV AC OHL |
| **Community Impacts** | | | |
| **Construction** | Construction impacts may be more prevalent in urban areas than rural areas<br>Traffic accommodation may be required for delivery of materials and any earth moving plant<br>Land access on private land is likely in rural areas together with provision for access routes (temporary or permanent)<br>Depending on crop type/ vegetation beneath the line, unmanaged vegetation can be fire hazards. Any line faults can start grassfires which can cause loss of grazing land<br>Disturbances to unrecorded archaeological or heritage sites | The installation of underground cables can disrupt local communities through noise, dust, traffic congestion, and restricted access during construction. Potential land use disruption due to cable trenching activities (dependent on the cable route selected) and less impact in rural areas, higher impact in urban. urban. | Similar to AC overhead line |
| **Operational** | Potential visual impact from towers, poles and conductor system; especially where there are corridors of OHLs<br>Potential influence on property values<br>Where tower citing is not optimal, towers can be a hinderance to farming activities.<br>Impact damage to towers or poles from farming equipment can be a consequence.<br>Where not addressed appropriately in the design of the overhead line – capacitive and inductive coupling between the OHL and other objects (e.g., telephone lines, fences, pipelines) can be a safety issue | Periodic vegetation management, such as sapling removal and clearing around access points, is required to maintain the integrity and accessibility of underground cables.<br>Access may be needed for maintenance, inspections, or repairs on the underground cable system, potentially causing temporary disruptions or restricted access to certain areas.<br>Provide information to the community regarding potential EMF impacts from underground cables With proper planning, these impacts can be minimized as EMF levels decrease with distance. | May be similar to HVAC OHL<br>Generally, radio and audible noise design limits are less than HVAC<br>Can cause induced severe harmonic interference into adjacent telephone systems. Mitigated through special filtering.<br>No induced currents into the bodies or people or animals as DC currents are not time-varying |
| **Cost Magnitude Comparison factors for [circuit technical definition TBC]** | | | |
| **Lifetime archetype costs** | Operational maintenance costs are considered as lifetime maintenance expenses. Typical activities are Routine inspections every 3-5 years £5000 per km. vegetation management 5-7 years £5000 per km, Insulator replacement 20 years £5000 per tower, conductor replacement 40 years £125,000 per km. | Cable Supply and installation upwards of 5x AC Overhead line and install for 132kV operation.<br>- Installation (Ducted/Buried)<br>- Jointing & Terminations<br>- Civil Works (Trenching, Backfilling, etc.)<br>- Operational & Maintenance (Lifetime 40 Years)<br>- Energy Losses (Lifetime, Depending on Load)<br>- Decommissioning & End-of-Life | Initial capital costs are higher than HV AC due to needed converter stations.<br>Converter stations with overload capabilities may be even more expensive.<br>Maintenance costs can also be more than HVAC given the technical complexity of the system and specialist skillsets required to maintain equipment |
| **Life time losses costs** | Lifetime losses in OHL systems occur due to losses in the conductors at high voltages. This depends on the conductor type and loading levels. The total energy loss of 40-year lifespan depends on annual hours of operation and current electricity cost. At 132kV line losses are moderate but still a cost factor for DNOS. | Compared to OHL U/G cables have higher lifetime losses due to higher conductor resistance and losses from insulation. it has been suggested that underground systems will have higher losses. | HVDC systems up to 800kV, lifetime losses not known |

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# 33kV Circuit Archetypes Comparison

| Characteristic | AC Overhead Line | AC Underground Cable |
|---|---|---|
| **Archetype Description** | | |
| Maximum Continuous Distribution Capacity (MVA) | Typical Single Circuit values are 10 -50MVA, double circuit range from 20-100MVA | Typical ratings single circuit 1 cable per phase 95sqmm direct buried 20MVA up to 630sqmm 90-100MVA |
| Maximum Technically Feasible Route Length (km) | Unrestricted however, at distribution level (low voltage), line lengths are typically not very long as line losses start to make power transfer at this voltage level uneconomical.<br>Suggested:<br>0 > 33 kV line < 80 km | Approx. 15km cable length for a 33kV cable route depends on several factors, including the cable type, voltage drop, and the capacity of the associated electrical system. Anything beyond the determined length based on power system studies that may require voltage boosting equipment or intermediate substations to maintain the system's stability and efficiency. |
| Life-span (years) | Design life span ~ 20 years.<br>With appropriate visual inspection and maintenance, this can be more than 30 years | Design life up to 40 years, with components like joints and cable sealing ends typically replaced after 40 years. |
| Infrastructure Operational Footprint | 5 – 15 sqm (excl. stays) | Building and excavations prohibited within, cable swathe path (swathe path dependent on cable/duct installation depth, Cable/duct phase group axial separation and trench excavation method). Tree and hedge planting is also restricted above the cables or within 3m of the cable trench to avoid vegetation encroachment and various above- ground agricultural and rural activities may still take place. |
| Future scalability for long-term planning | May allow for bi- directional load flow however, voltage drop, and thermal constraints together with other technical issues (e.g., harmonics) may limit uptake of distributed energy resources (DER)s. May be possible to uprate or real time monitor for dynamic line rating. | The uprating can only be achieved at significant cost, such as through re- excavation, installing larger or additional cables. Generally, this procedure is not recommended. |
| **Deliverability and operability** | | |
| Planning and consents | As the voltage level is less than 132 kV, development consent is required under the provisions of section 37 of the Electricity Act 1989. | Classed as 'permitted development' under the Town and Country Planning (General Permitted Development) (Scotland) Order 1992 (as amended), (England) Order 2015, (Wales) Order 2014.<br>- Suitable rights over land (such as wayleaves and easements) must be obtained from every owner or party with a relevant interest in the land crossed by an underground cable.<br>- Wayleaves and easements are usually granted voluntarily through negotiation, but if not, utility owner can apply to the relevant authority (e.g., Government Office) for approval.<br>- Sealing end compounds may require planning permission. |
| Reliability, availability and maintainability | Designed to deterministic principles. Reliability is inherently built into the OHL through provision of load and safety factors.<br>Standard (low) maintenance requirements – periodic visual inspection and maintenance<br>Vegetation management required to maintain clearances and mitigate against possible flash overs and faults | Less susceptible to disruptions caused by environmental factors (storm, high winds etc.)<br>Most cable faults are caused by faulty joints, sheath issues and third-party damage. Faults may take between two to six weeks to locate and repair, often requiring excavations that can lead to road closures and traffic disruptions. Test of cable sheath joints |
| Flexible circuit rating | Possible candidate for uprating or real time monitoring | In emergency situations, the 33kV cable will be subjected to temporary overload conditions for a short duration. This overload condition needs to be carefully monitored in real-time to ensure safe operation and prevent any potential damage to the system. Continuous monitoring of the cable's performance will be carried out using a fibre optic cable, which will provide precise, real-time data on temperature, current, and other relevant parameters to ensure that the overload does not exceed safe limits.<br>- The fibre optic cable will enable efficient, continuous surveillance of the cable's status, facilitating quick action if necessary to mitigate any risks associated with the overload. |

| | | |
|---|---|---|
| **Provision of restoration services**<br><br>**(All require an intact source of energy at one end)** | Immediately available for system restoration – able to transfer power from one restoration energy source to another – however, may only be applicable within smaller microgrids/ low voltage distribution grids | The restoration of a 33kV cable circuit requires ensuring a reliable and intact energy source at one end of the circuit. This intact source, combined with advanced fault detection, repair capabilities, and protective devices, enables the system to recover from faults quickly.<br>- Fiber optic monitoring systems and effective switching strategies play a critical role in ensuring that the restoration process is smooth, efficient, and safe for the overall grid stability. |
| **Environmental Impacts** | | |
| **Construction** | Similar to 132 kV | Construction activities can generate high noise levels, potentially affecting nearby communities.<br>- Dust generation from excavation or construction machinery can contribute to air pollution.<br>- Underground cable installations require materials such as cables, conduits, and backfill, which can occasionally lead to excess waste.<br>- Construction activities can disturb the soil, potentially harming plant species and disrupting soil- dwelling organisms.<br>- Clearing vegetation along the typically few-meter-wide cable route can result in the loss of plant species, including trees and understory vegetation.<br>- Construction activities and underground cables can disrupt wildlife movement, isolating populations and limiting access to essential resources and breeding grounds. |
| **Operational** | Similar to 132 kV with exception of disturbance of wildlife during helicopter visual inspection – method not likely used at 33 kV; inspection would likely be via ground-vehicle/drones or by foot patrol | Vegetation clearance around access points may be necessary for proper access and maintenance. |
| **Community Impacts** | | |
| **Construction** | Similar to 132 kV | Periodic vegetation management, such as sapling removal and clearing around access points, is required to maintain the integrity and accessibility of underground cables.<br>Access may be needed for maintenance, inspections, or repairs on the underground cable system, potentially causing temporary disruptions or restricted access to certain areas.<br>Provide information to the community regarding potential EMF impacts from underground cables. With proper planning, these impacts can be minimized as EMF levels decrease with distance. |
| **Operational** | Similar to 132 kV | Vegetation clearance around access points may be necessary for proper access and maintenance. |
| **Cost Magnitude Comparison factors for [circuit technical definition TBC]** | | |
| **Lifetime archetype costs** | Operational maintenance costs are considered as lifetime maintenance expenses and are estimated to be similar at 33kV and 132kV. Typical activities are routine inspections every 3-5 years £5000 per km, vegetation management 5-7 years £5000 per km, Insulator replacement 20 years £5000 per tower , conductor replacement 40 years. | Cable Supply<br>- Installation (Ducted/Buried)<br>- Jointing & Terminations<br>- Civil Works (Trenching, Backfilling, etc.)<br>- Operational & Maintenance (Lifetime 40 Years)<br>- Energy Losses (Lifetime, Depending on Load)<br>- Decommissioning & End-of-Life |
| **Life time losses costs** | Lifetime losses in OHL systems occur due to losses in the conductors at high voltages. This depends on the conductor type and loading levels. The total energy loss of 40 year lifespan depends on annual hours of operation and current electricity cost. | No information |

## Part C - CONCLUSIONS

We trust that the IAG will find this Report helpful in its determination of the most efficient, speedy and cost-effective means of addressing the urgent energy needs of Wales in as environmentally sensitive a manner as possible and in so doing delivering significant job opportunities within the country both in the short and longer term. It is an opportunity which Wales cannot afford to let slip and GGC is ready to do all it can to help achieve it. To that end, we welcome continued discussion with the IAG and to answering any questions or clarifying any points arising from this Report at the IAG's convenience.

# Part D – NOTES & REFERENCES

**Note 1:** IDNOs, whether combined or not with accredited Independent Connection Providers, offer one approach to building grid infrastructure, which is an alternative to the regional DNO.
IDNOs have traditionally been associated with building grid infrastructure for new demand customers at new residential and commercial developments, offering more flexible funding arrangements for developers and with business models focused on developers rather than responding to the widespread needs of large regional networks. IDNOs can, however, also provide competition to DNOs in relation to generation connection infrastructure. As a holder of an IDNO License, our business model is focused on providing new distribution grid infrastructure to respond to the needs of new renewable energy projects. We are subject to nearly all of the same licence obligations as a DNO to protect consumers and facilitate competition including:

- An obligation to offer terms of connection (Condition 12);
- An obligation to charge for connections and use of infrastructure in accordance with a charging methodology approved by the industry regulator, Ofgem (Conditions 13, 13A, 13B, 13C and 14); and
- An obligation to treat customers fairly and make special provision for vulnerable customers (Condition 10 and 10AA).

However, as we do not have responsibility for maintaining a large regional network, we can focus our resources on building new infrastructure. We cannot resolve delays in the transmission system, but we consider we provide a viable and valuable option for the construction of new grid infrastructure.

**Note 2:** Electricity Transmission Study, an independent report endorsed by the IET, Parsons Brinkerhoff in association with Cable Consulting International Ltd, February 2012
**Note 3:** Network Topology Assessment, The electricity System Operator, March 2024
**Note 4:** House of Lords, Undergrounding Electrical Transmission Cables, February 2024
**Note 5:** National Grid, 'Everything you ever wanted to know about electricity pylons', webpage
**Note 6:** National Grid, 'Undergrounding high-voltage electricity transmission lines: The technical issues', Jan 2015
**Note 7:** Underground cables vs Overhead lines: quasi experimental evidence for the effects of public perception and evidence
**Note 8:** ENA Environment Briefing, Transporting Electricity, Overhead Lines or Underground Cables, September 2017
**Note 9:** ENA Electric and Magnetic Fields, the facts, September 2017
**Note 10:** Renewable UK, A closer look at Undergrounding Overhead lines, February 2025
**Note 11:** SSEN, The challenges of Undergrounding at 400kV
**Note 12:** German underground cost comparisons: Netzentwicklungsplan Strom 2037/2045, Version 2023
**Note 13:** 22052023_GGC Network Contribution to Mid-Wales
**Note 14**: Turner & Townsend: Open cut v mole ploughing cost comparison – Green GEN Towy Usk dated 17th March 2025

**<u>Overhead line and underground cable comparison references</u>**

Numbering aligned with notes above:


2) Electricity Transmission Study, an Independent report endorsed by the IET, Parsons Brinkerhoff in association with Cable Consulting International Ltd, February 2012, Electricity Transmission Costing Study
3) Network Topology Assessment, The electricity System Operator, March 2024, www.neso.energy/document/download/pdf
4) House of Lords, Undergrounding Electrical Transmission Cables, February 2024, 'Undergrounding' electrical transmission cables - House of Lords Library

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5) National Grid, 'Everything you ever wanted to know about electricity pylons', webpage, Facts about electricity pylons | National Grid Group
6) National Grid, 'Undergrounding high-voltage electricity transmission lines: The technical issues', Jan 2015, National Grid, 'Undergrounding high-voltage electricity transmission lines: The technical issues', Jan 2015 - Search
7) ENA Environment Briefing, Transporting Electricity, Overhead Lines or Underground Cables, September 2017, 7) ENA Environment Briefing, Transporting Electricity, Overhead Lines or Underground Cables, September 2017 - Search
8) ENA Electric and Magnetic Fields, the facts, September 2017, 8) ENA Electric and Magnetic Fields, the facts, September 2017 - Search
9) Renewable UK, A closer look at Undergrounding Overhead lines, February 2025, A closer look at undergrounding electricity lines
10) SSEN, The challenges of Undergrounding at 400kV, the-challenges-with-undergrounding-at-400kv.pdf
11) Lifetime Costs Report, Brechfa Forest, Feb 2014 Lifetime-Costs-Report.pdf
12) German undergrounding and overhead line costs in kilometres,230321 NEP_Kostenschaetzung_NEP2037_2045_v2023_1.Entwurfen.pdf,231_NEP_Kostenschaetzung_NEP2037_2045_V2023_1.Entwurf.pdf
13) 22052023_GGC Network Contribution to Mid-Wales.pdf (provided as an attachment to the Report)
14) 20250317 T&T GGC TOWY USK - Open Cut Vs Ploughing costings.pdf (provided as an attachment to the Report)