DOI: 10.46793/CIGRE37.B1.07

B1.07

NOVI GREENLINK 500 MW INTERKONEKTOR

THE NEW GREENLINK 500 MW INTERCONNECTOR

Dorotea Damjanović, Teodora Mitrović, Bojan Poučković, Matthew Gibson*

Kratak sadržaj: Evropske zemlje su posvećene dekarbonizaciji proizvodnje električne energije sa jasno postavljenim ciljevima u narednim decenijama. Kao posledica toga, potreban je prelaz sa fosilnih goriva na obnovljive izvore energije. To će imati uticaja na električni prenosni sistem koji treba da se razvije i prilagodi promenama koje obnovljivi izvori energije donose. Elektroenergetski sistemi mogu lakše da podrže ove promene ako su povezani sa drugim sistemima i omogućavaju razmenu energije i podršku stabilnosti tokom rada. Elektroenergetski sistemi Velike Britanije i Irske klasifikovani su kao ostrvski elektroenergetski sistemi sa malim brojem interkonektora sa drugim elektroenergetskim sistemima.

Interkonektori su visokonaponski kablovi ili dalekovodi koji se koriste za povezivanje elektroenergetskih mreža različitih regiona ili zemalja. Interkonektori značajno doprinose povećanju energetske sigurnosti i pouzdanosti, stabilizaciji cene električne energije i integraciji obnovljivih izvora energije. Interkonektori se koriste za balansiranje ponude i potražnje putem prenosa viška obnovljive energije iz jedne zemlje u drugu. Irska je imala samo dva interkonektora u radu do početka 2025. godine: 1. Moyle interkonektor, između Škotske i Severne Irske, 2. East-West interkonektor, između Irske i Velike Britanije. Očekuje se da i će Celtic interkonektor, između južne obale Irske i severozapadne obale Francuske početi sa radom 2026. godine.

Greenlink interkonektor je novi podmorski i podzemni elektroenergetski interkonektorski kabl nominalnog kapaciteta 500 MW koji povezuje elektroenergetske mreže u Irskoj i Velikoj Britaniji. Ovaj HVDC interkonektor je ušao u komercijalni rad 2025. godine. Greenlink interkonektor se sastoji od dve konvertorske stanice - jedna se nalazi u blizini trafostanice Great Island u okrugu Wexford, a druga u blizini trafostanice Pembroke u Pembrokeshireu - povezane kablovima visokog napona jednosmerne struje (HVDC) ispod Irskog mora. Ukupna dužina kabla je 200 km, od čega se 160 km postavlja pod morem. HVDC veza je simetrične monopolarne konfiguracije sa jednosmernim naponom od ±320 kV. Greenlink interkonektor će obezbediti dvosmerno napajanje, u zavisnosti od ponude i potražnje u obe zemlje.

* Dorotea Damjanović, Mott MacDonald, dorotea.damjanovic@mottmac.com
Teodora Mitrović, Mott MacDonald, teodora.mitrovic@mottmac.com
Bojan Poučković, Mott MacDonald, bojan.pouckovic@mottmac.com
Matthew Gibson, Greenlink Interconnector Limited, matthew.gibson@greenlink.ie

Projekat Greenlink interkonektor će udvostručiti kapacitet interkonekcije između Irske i Velike Britanije i povećati sigurnost snabdevanja za potrošače, kao i dalju integraciju izvora energije sa niskom emisijom ugljenika. Greenlink interkonektor će u velikoj meri doprineti ekonomskom i ekološkom razvoju Irske i Velike Britanije. Ovaj rad opisuje metodologiju i tehnologije koje su korišćene za izradu projekta, kao i značaj samog projekta.

Ključne reči: *HVDC kablovi, Interkonektor, Održivost*

Abstract: European countries are committed to decarbonising power generation with clear goals over the coming decades. As a consequence, an energy transition from fossil fuel generation to renewable energy sources is required. This will influence electrical transmission systems which will need to develop and adapt to changes that new renewable energy sources bring. Electricity grids can accommodate these changes more easily if they are connected to other grids, thus allowing for power exchange and stability support during operation. The Great Britain and Ireland electricity grids are classed as islanded power systems with few interconnections.

Interconnectors are high-voltage cables or transmission lines used to connect the electricity grids of different regions or countries. They are an asset for increasing energy security and reliability, stabilizing the price of electricity and supporting integration of renewable energy sources. Interconnectors are used to balance supply and demand by transferring excess renewable energy from one country to another. Ireland had only two interconnectors in operations until beginning of 2025:

1. Moyle Interconnector, between Scotland and Northern Ireland,
2. East-West Interconnector, between England and Republic of Ireland.

An additional two interconnectors are being established. The Celtic Interconnector, between the southern coast of Republic of Ireland and the north-west coast of France, is expected to begin operation in 2026 and the Greenlink Interconnector, between the eastern coast of Republic of Ireland and south-west Wales, which went into operation in 2025.

The Greenlink Interconnector is a subsea and underground electricity interconnector cable with a nominal capacity of 500 MW that connects the electricity grids of Ireland and Great Britain. It consists of two converter stations - one located near Great Island substation in County Wexford and the other near Pembroke substation in Pembrokeshire - connected by the High Voltage Direct Current (HVDC) cables under the Irish Sea. The total length of the cable is 200 km, with 160 km being installed under the sea. The HVDC link is configured as a symmetrical monopole operating at a voltage of ±320 kV d.c. The Greenlink Interconnector will provide a bi-directional power supply, depending on the supply and demand in each country and will double the interconnection capacity between Ireland and Great Britain and increase the security of supply for consumers, as well as further the integration of low-carbon energy sources. Greenlink Interconnector will contribute to the economic and environmental development of both Ireland and Great Britain. This paper outlines the methodology and technologies used for project design, as well as the significance of the project.

Key words: *HVDC cables, Interconnector, Sustainability*

1 INTRODUCTION

Decarbonising power generation is a priority for European countries, with clear goals set for the coming decades. The shift from fossil fuels to renewable energy sources will impact the electrical transmission system, which must adapt to the new demands. Interconnected electricity grids can manage these changes by providing stability support during operation. However, the electricity systems of Great Britain and Ireland are largely isolated, with only a few interconnectors to other power networks.

Interconnectors are high-voltage cables or transmission lines that link the electricity grids of different regions or countries. By transferring surplus renewable energy from one country to another, they help balance supply and demand, ensuring a more stable and efficient energy grid. The first High Voltage Direct Current (HVDC) link to Ireland, the Moyle interconnector, which links Northern Ireland and Scotland, is mainly used for importing power during periods of high demand in Ireland. This Interconnector uses Line-Commutated Current-Sources converter (LCC) technology, which employs thyristor valves to convert AC to DC and vice versa. Recently, Ireland has authorised further HVDC interconnectors due to the increased proportion of renewable energy generation and supply security needs. This shift led to the development of the 500 MW East West Interconnector (EWIC) between Ireland and Wales. EWIC, which has been in operation since 2016, utilizes Hitachi HVDC Light® Generation 3 converters, based on Voltage-Sourced Converter (VSC) technology, using insulated gate bipolar transistor (IGBT) valves. To meet growing electricity demand and renewable energy generation, two new interconnectors are being developed: the 500 MW Greenlink between Ireland and Wales; and the 700 MW Celtic Interconnector between Ireland and France, expected to be completed by 2026. Both Greenlink and Celtic Interconnectors will use VSC technology, specifically HVDC PLUS® from Siemens Energy, with modular multilevel converters (MMC).

These projects will enhance Ireland's power supply security and facilitate access to the European power market. The impact of renewable energy on markets is a key factor in interconnection implementation. This paper provides an overview of the Greenlink project and the use of HVDC technology in Ireland.

2 HVDC TECHNOLOGY

2.1 Introduction to HVDC technology and the advantages over HVAC

Led by development in advanced power electronics and fully controlled semiconductors, HVDC technology has become a common solution for power transmission over long distances, especially in places where energy resources are located far from load centres.

Furthermore, it has provided an expansion in interconnection between transmission networks, thus giving more options for potential supplies and helping to balance out the issues of using renewable generation – mainly the intermittent nature of renewable sources. This aspect of HVDC technology is especially significant in assisting the transition to low-carbon generation.

Primary advantages of HVDC links over HVAC links are:

1. Elimination of reactive power compensation. When using long AC cable links, compensation for the reactive power generated is necessary and the economic length of cables is limited by the derating effect of the reactive component of the load current.

The requirement for compensation equipment is eliminated with HVDC technology and, as there is no reactive current, much longer cable lengths can be employed. With HVDC technology, power can thus be transmitted over longer distances than is practically achievable with HVAC.

2. Lower losses per km of route length than HVAC when using a similar cable system. However, HVDC converter stations must be included in losses calculations.

3. Higher power transfer with same size and insulation level of DC lines. Skin effect causes AC resistance to be higher than DC resistance, which leads to higher losses due to resistance. Lower resistance in HVDC cables consequentially allows for smaller cable sizes in DC systems, reducing the required ground area.

4. HVDC links allow for asynchronous AC grids to be connected.

5. Beyond a certain distance, the investment costs of HVDC links are lower than the investment costs for HVAC links [4].

2.2 Typical application of HVDC links

HVDC links are commonly used for interconnecting two asynchronous AC systems or two AC systems with different frequencies, subsea power transmission and long-distance bulk power delivery.

2.3 HVDC Configuration

HVDC transmission systems can be configured as monopolar or bipolar.

2.3.1 Bipolar HVDC system

Bipolar configurations consist of two converters (poles), one operating between positive line and earth, the other between negative line and earth. In a rigid bipole configuration there is no return current path through earth and the load in each pole must therefore be be balanced. If an earth return is provided then the poles can operate independently such that, if a fault occurs on one line, the system can continue to operate as monopolar using earth as a return path. This path can be through ground electrodes installed at each end of the line, however as ground returns can cause corrosion of third party assets, metallic return paths are becoming more common, albeit they add to the cost. [4]

2.3.2 Monopolar HVDC system

Monopolar configurations can be symmetrical (two high voltage lines) or asymmetrical (a high voltage conductor and an earth/metallic return).

Asymmetrical monopolar systems use a single high-voltage conductor, while the earth/sea or a metallic low-voltage conductor is used as a return conductor. However, earth returns are becoming less common due to the impact on the environment and other buried services.

Symmetrical monopolar systems do not require an earth return path and circulate current through the line conductors.

The Greenlink HVDC link is configured as a symmetrical monopole with DC voltages of ±320 kV presented in Figure 2.1. It uses a HVDC VSC converter module in half-bridge topology based on the IGBT technology. [3]

Main reasons for using symmetrical monopole configuration instead of bipolar configuration are the simplicity of construction and maintenance, as well as requiring less land.

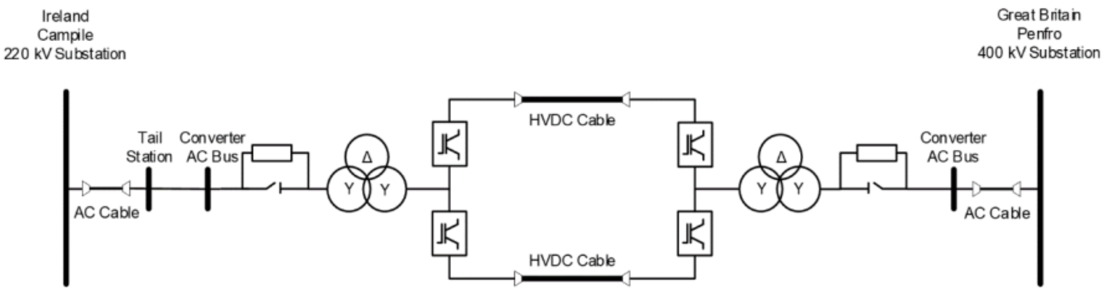

Figure 2.1: Symmetrical Monopole Diagram

3 GREENLINK INTERCONNECTOR

Development of the Greenlink project began in 2017 and achieved final onshore and marine planning consents in 2021. Greenlink is a subsea and underground electricity interconnector cable, complete with converter stations. With a nominal capacity of 500 MW, Greenlink establishes a new grid connection between EirGrid's Great Island substation in County Wexford, Ireland, and National Grid's Pembroke substation in Pembrokeshire, Wales – connected by two HVDC cables under the Irish Sea. Power can flow in either direction based on supply and demand in each country.

Greenlink holds strategic importance by significantly enhancing interconnection between Ireland and Great Britain. Its construction and development is expected to boost energy security, attract regional investment, provide value for consumers and facilitate the integration of low-carbon renewable energy sources. Developers believe that interconnectors can also help prevent curtailment of wind and solar energy by enabling the export of surplus output during periods when supply exceeds demand.

During the development process, a variety of detailed technical and environmental surveys have been conducted to ensure the final design effectively addresses the local environment's challenges and opportunities. These studies include bird studies, ecological assessments, construction and access studies, landscape and visual impact assessments, noise assessments, traffic and transport assessments, cultural heritage assessments, geological assessments and site hydrology assessments.

4 CABLE SYSTEM

The Greenlink Interconnector includes two HVDC cables and a fibre optic cable system for communication with a total circuit length of approximately 190 km, comprised of 160 km of subsea cable and 30 km of land cable (in Ireland and Wales). Special designs were implemented for utility crossings, watercourses and other areas where standard depth cannot be maintained.

The cable uses cross-linked polyethylene (XLPE) insulation with a lead sheath and steel wire armour to protect the cable.

The armouring is made from round or flat steel wire wound in a helical form. Over the armour wires a polyethylene sheath was applied to make the cable easier to handle and ensure the armour wires remained in place during bending. In Figure 4.1 is represented cable cross-section. The cable route is shown in Figure 4.2.

- Approximately 29 km of DC onshore cable installed in Ireland and Wales
- 21 joints were made on the Irish land Cable
- 5 joints were made on the Welsh land cable.
- Land cable: Aluminium XLPE with a cross section of 1200mm²
- Subsea cable: Aluminium XLPE with a cross section of 1100mm^2

Figure 4.1: Cable cross-section

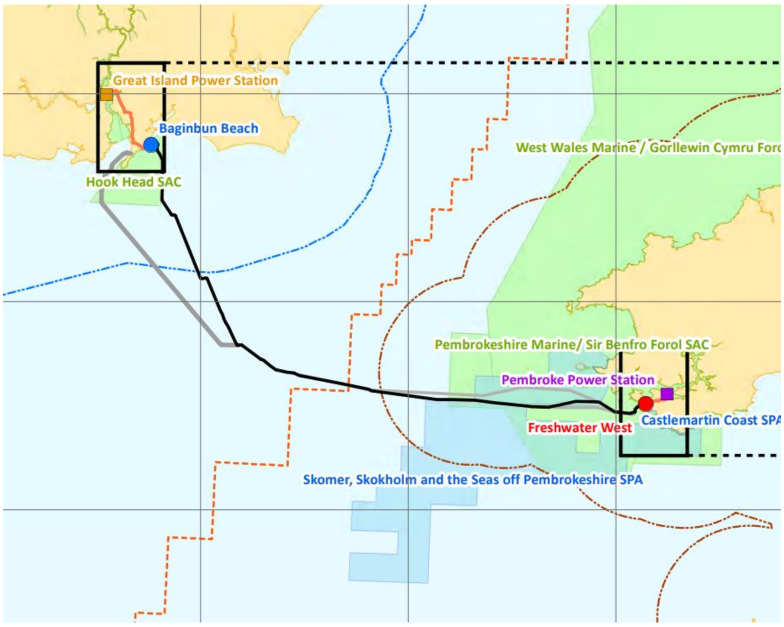

Figure 4.2: Greenlink Interconnector route overview

4.1 Onshore Cables

HVDC cables have a smaller footprint than HVAC cables, making them suitable for underground installation in road networks or agricultural land. The onshore cables were buried in a single trench, generally at 850 mm depth to top of the duct, with plastic ducts. To simplify the construction, the plastic cable ducts were installed first, with a protective cover and warning tape, where the underground cables were then subsequently pulled through.

In agricultural areas, the depth to top of the duct could increase to around 1050 mm. The trench width could vary with the depth of cover. Typically, the two ducts were placed close together, about 300 mm apart, alongside the fibre optic cable duct, and within a bedding of thermally suitable compactable granulated material such as cement-bound sand (CBS). The remainder of the trench was reinstated with a bedding of indigenous sub-soil, overlain by topsoil and any extant turf.

This setup is illustrated in Figure 4.3.

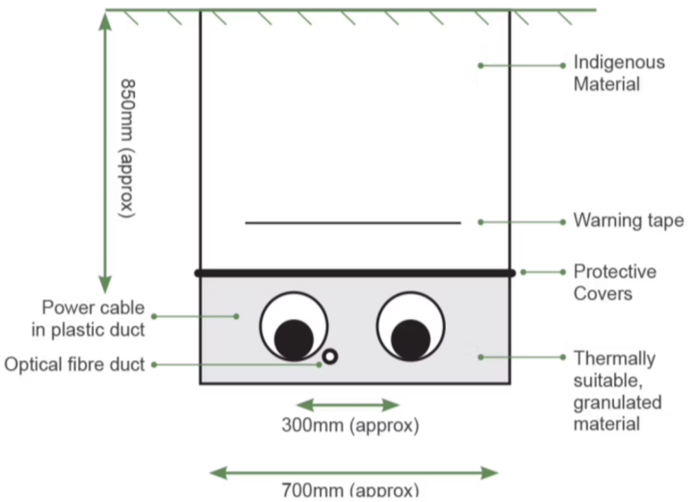

Figure 4.3: Indicative underground cable arrangement

Protective covers and yellow warning tape were used above the ducts to reduce the risk of accidental excavation. Cables were installed at depths that avoid interference with common land activities such as ploughing, and the land was restored post-installation. Marker posts indicate cable locations at key points.

In highways, cables were installed in 700 mm wide trenches, at 750 mm depth to top of the duct, with ducts embedded in concrete at road crossings. Temporary road closures ensure safe installation.

The onshore cable route in Ireland is approximately 22 km long and is mostly run beneath roads to avoid agricultural or private land. The cable route under the road is approximately 19.5 km long [12]. Traffic management measures in the form of lane closures and road closures were required, which were approved by local authorities. All roads were reinstated by license conditions from the local authority after cable works were completed. This included full road-width reinstatement [13].

The onshore cable route in Wales is approximately 7 km long. Land cables were laid under a local road (as shown in Figure 4.4), agricultural and private land between Freshwater West Beach and the Penfro Converter Station. Most of the route is within agricultural land, where temporary plastic mat roads were used to protect the fields [11].

Figure 4.4: Cable installation in Wales

4.2 Subsea Cables

Approximately 160 km of the Greenlink cable route is offshore. The bundled cable arrangement was used offshore and was laid in two campaigns: the Welsh Campaign and the Irish Campaign.

Two offshore cables were tied in a bundle with a fibre optic cable (used for control and communication purposed) and laid in a single trench. This is represented in Figure 4.5. The cables were buried at sea using a combination of jetting and trenching. For protection, concrete mattresses and rock placement were utilized. The subsea cables were laid at a maximum depth of 125 m.

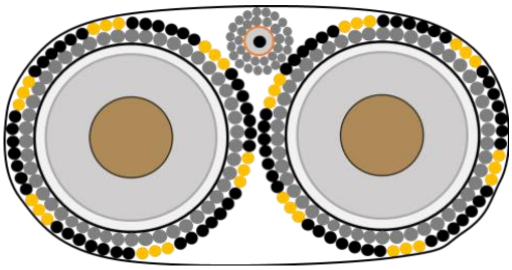

Figure 4.5: Bundled cable arrangement [8]

The Welsh campaign was completed first in 2023, and the Irish campaign followed in 2024. After these campaigns, the offshore joint described as an “Omega” joint was completed between the two cables. The two ends of the cable were pulled onto a vessel for jointing and after completion, were lowered to the seabed [10].

The routes were chosen after a thorough assessment of the marine environment and technical challenges. The cables were mostly buried in the seabed, but where this was not feasible, they were laid on the seabed with protective measures (concrete mattresses or rock dumping). To bury the cable in the seabed, the trenching machine Swordfish was used. This specialized equipment creates underwater trenches where cables are laid and buried to protect them against erosion. The machine was launched from the vessel Symphony and controlled remotely by the crew. The Simon Stevin fall pipe vessel was used to bury the cable with rock. Two types of rock load were used: 1-5” filter rock and 5-40 kg armour rock. This is represented in Figure 4.6.

Approximately 16 km of the subsea cable route in Welsh waters required external cable protection due to ground conditions. External cable protection was also used where Greenlink crossed existing subsea telecommunication cables in both Irish and Welsh waters.

Figure 4.6: Deploying cable burying vessel

4.3 Installation of Cables at Landfalls

Horizontal Directional Drilling (HDD) was used to install the cables at Baginbun Beach (Ireland) and Freshwater West (Wales). An illustration of how it works is illustrated in Figure 4.7. The HDD length was about 960 m in Ireland and about 1270 m in Wales [10].

HDD is a modern technique used to install underground cables while avoiding open trenching. After extensive studies, a cable route is determined and drilled. The bores are then lined with an inert pipe and the cables are pulled into this duct. The subsea HVDC cable will connect to the land HVDC cable in an underground transition jointing pit (TJP) within a temporary landfall compound, set back from the beach above MHWS. In Ireland and Wales, the TJP was on agricultural land. The HDD works in Ireland location are shown in Figure 4.8.

HDD ducts were installed from the TJP to emerge below the low water mark, passing approximately 10 m beneath the beach. The subsea cables were pulled through these ducts from the cable lay vessel to be joined with the land HVDC cables. All cabling and jointing infrastructure is underground.

After completing the HDD and jointing activities, the landfall compound was reinstated and returned to arable use. This method ensures that the installation process does not impact the beaches or the dune system at Freshwater West. The cables emerge below the low water mark, avoiding any work on the beaches themselves.

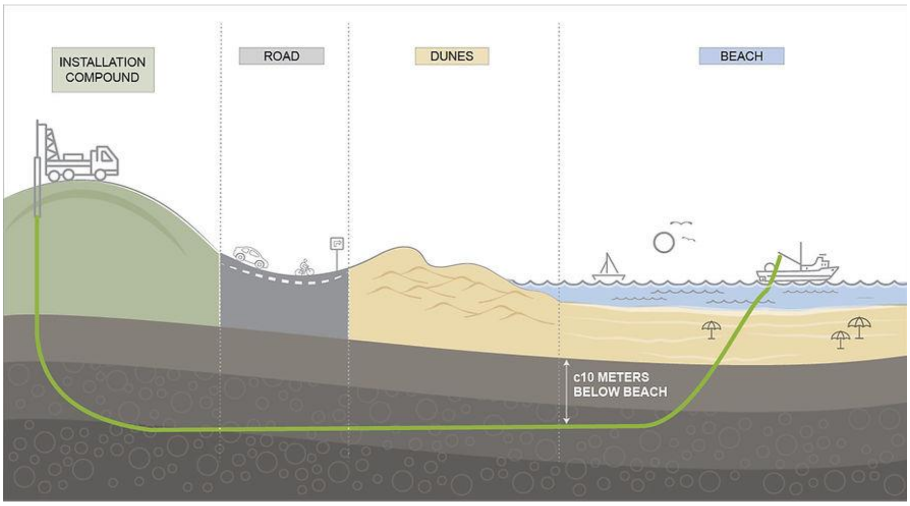

Figure 4.7: HDD installation illustration

Figure 4.8: HDD at Ireland location

5 CONCLUSION

This paper has provided an overview of the 500 MW HVDC Greenlink Interconnector, a project of great significance for Ireland and Great Britain. It contributes to energy security, integrates low-carbon sources, attracts regional investments, and provides value for customers.

Outlined in the paper are the basics of HVDC technology used for the Greenlink Interconnector, as well as the cable installation procedure on the project. The 320 kV HVDC cable project has been presented, which included onshore and offshore cable routes including landfall locations both in Wales and Ireland. The subsea cables were laid in two campaigns with a mid-route field joint.

The subsea cables were mostly buried in the seabed, but where this was not feasible, they were laid on the seabed and protective measures (concrete mattresses or rock dumping) were used.

Horizontal direction drilling has been used at landfall locations. The length of HDD is considerable at both landfalls. The landfall transition joint areas were reinstated and returned to arable use.

The onshore cable route in Wales and Ireland is 30 km long. While the land cable was mostly installed under roads and avoids agricultural or private land in Ireland, a different approach has been used in Wales where the cable was mostly laid under agricultural land.

6 BIBLIOGRAPHY

[1] Miro Cengic, prof. dr. sc. Denis Pelin, “High Voltage Direct Current (HVDC) Systems in Ireland”, CIGRE Hrtvatska B4-05 Webinar, 2023

[2] Available at the link: https://www.greenlink.ie

[3] Jonathan Ruddy, Technology Manager, Greenlink Interconnector Ltd.: “Greenlink Interconnector Project”, CIGRE Ireland B4 Webinar, 8th October 2021

[4] ENTSOE, European Network of Transmission System Operators for Electricity, HVDC Links in System Operations, Technical Paper, 2nd December 2019

[5] Available at the link: Greenlink subsea cable, Irish Sea | Jan De Nul

[6] Available at the link: PowerPoint Presentation

[7] Available at the link: GREENLINK Completion

[8] Greenlink Summary of Onshore and Offshore Enviromental Effects, September 2019

[9] Available at the link: Sumitomo Electric Successfully Completes Greenlink Interconnector Project | Sumitomo Electric

[10] Available at the link: Podcast: Interconnectors - The Green Link to Ireland | WSP

[11] Available at the link: Community NEWSLETTER MAY 2023 - WALES

[12] Available at the link: Community NEWSLETTER Issue 4 April 2023 – Ireland

[13] Available at the link: Community NEWSLETTER Issue 3 August 2022 – Ireland

[14] Available at the link: https://www.independent.ie/regionals/wexford/new-ross-news/2m-spend-on-16kms-of-south-wexford-roads-being-reinstated-is-welcomed/a1276356336.html