This is an extract from the ***final report*** – please find the entire documents under the full documents section on the website.

Construction- Shetland

Firstly, the island will be surveyed, and the structural stability of the soil will be assessed. Areas of steep terrain will be levelled for the installation of roads and foundations; however, works will be kept to a minimum to preserve habitat. Each unit on the island will require carefully selected and constructed foundations that can withstand the determined load capacity.

Foundations

For the buildings, substations and hydrogen production infrastructure, a foundation will be required. The foundations will likely be concrete pad foundations unless suggested otherwise following ground investigations on the island. Ideally, all material will be sourced from mainland Scotland, with minimal transportation required from manufacturer to site. A low carbon concrete will be utilised and recycled materials will be used as far as possible.

Roads

It is assumed there are no access roads on the island and therefore the construction of roads will be essential for moving personnel and materials/equipment round the island. For this, a typical single carriageway road will be constructed using the generic construction as shown in Figure 56. This will require earth foundations, a gravel subbase, base course, surface course and asphalt road layer (Engineering Feed, 2024). An embankment will also be required alongside the road, so surface water runoff does not gather at the roadside; this will be constructed using reuse earth excavated for the road. The road length is expected to be 800m in length, spanning from one side of the island to the other, branching off to each of the components that make up the island.

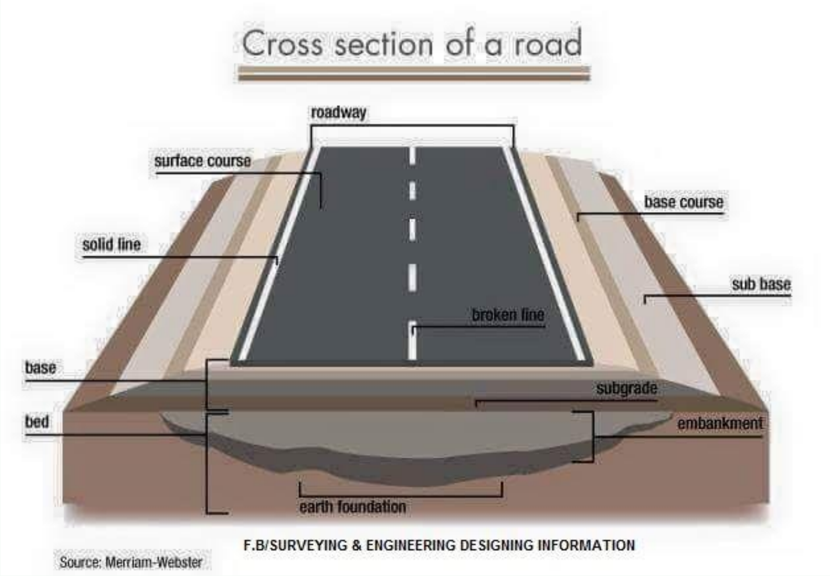


Figure 56- General Road Construction (Engineering Feed, 2024)

Welfare Facility

The island will home approximately 100m^2 of welfare facility that will be prefabricated off site. This facility will comprise of a bathroom(s), staff room area with sink, office room and small medical room. The offsite fabrication will further reduce the carbon by ensuring strong performance, quality, productivity, reduced risk and minimisation of buildability issues arising on site, which are more likely to occur on a remote island.

Wind Energy Infrastructure

The island will have a 2GW HVDC cable that connects onshore at Peterhead. Therefore, on the island it will be essential to have a transformer and convertor. Array cables connect the turbines to the island, where the voltage needs transformed, and the current needs converted from direct (DC) to alternating (AC).

The brand of this technology will depend on the leading design available at the time of construction. DC converter stations are considerably heavier than AC equipment however there are currently large developments being made in this sector. Figure 57 shows the HVDC substations that are being installed at dogger bank wind farm. They measure 65 x 36 x 39 metres and are 70% lighter in weight than previous designs. The number of substations required is dependent upon the number and size of wind farms connected.

Figure 57 - HVDC substations being installed at Dogger Bank (SSE Renewables, 2023)

Offshore Wind Farms

100 5MW wind turbines with a horizontal three-bladed design are proposed to be installed initially with a total capacity of 0.5GW. The turbines foundation is referenced from other wind farms nearby and are chosen to be floating. Inter-array cabling running between each turbine is installed with 20MW capacity, connecting four turbines. The power generated is then transmitted to one offshore substation platform on the island with an AC to DC converter.

Tidal Energy Infrastructure

Wave turbines are assembled onshore before the installation offshore. Chains and cables are used to anchor the turbines onto the seabed to prevent drifting. The turbines are connected to a generator and all power is transmitted through underwater cables to one substation on the island where an AC to DC converter is located. The electricity generated is then transmitted to the grid for further usage.

Transport Routes

There are existing transport links near the energy island location including harbours and airports on mainland Shetland that link to major facilities. There are four airports (Figure 59), two harbours (Figure 58) and one port. All personnel will be brought in via these routes. On the island, a helipad will be required for health and safety purposes and a small dock would be essential for transporting materials and personnel for maintenance. The small dock will feature a 400m^2 concrete harbour wall.

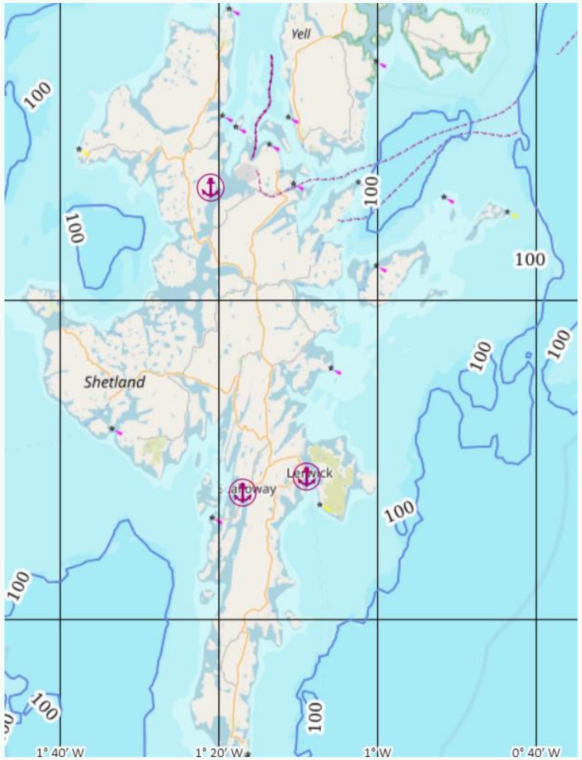


Figure 58- Shetland Harbours (Open Sea Map, 2023)

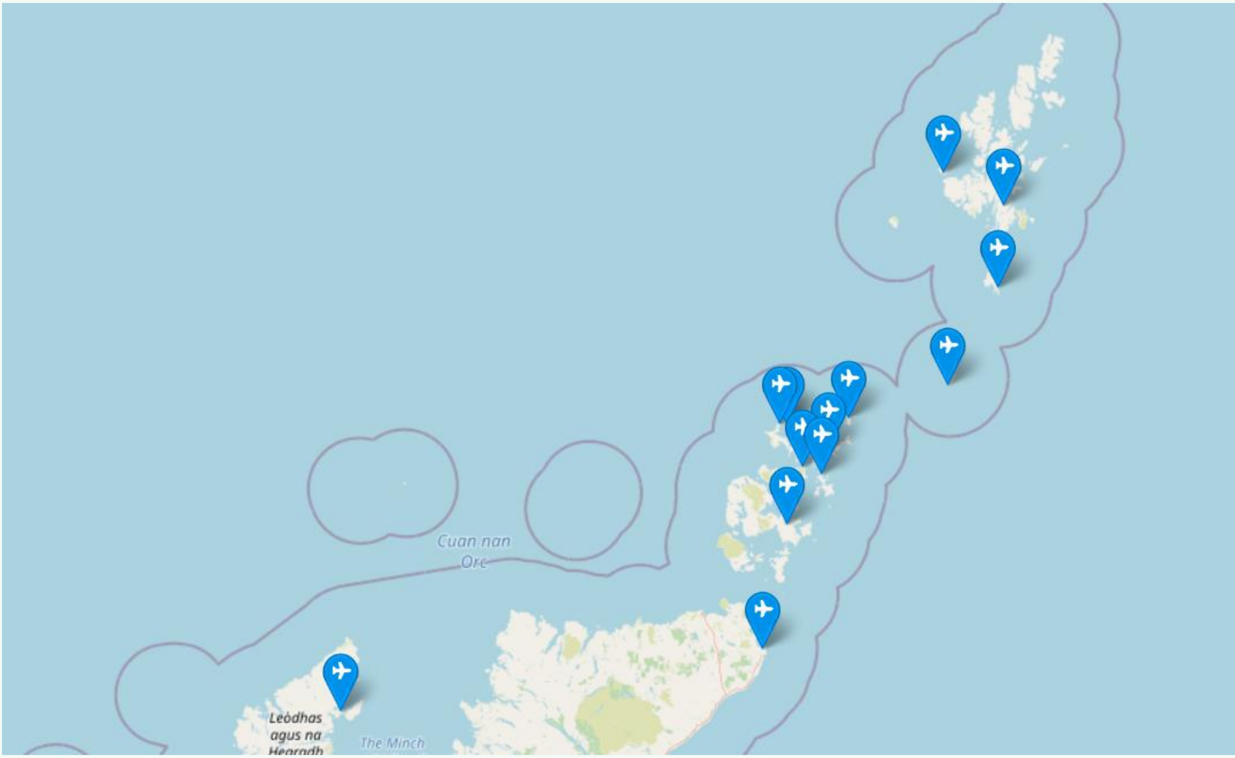


Figure 59- Shetland airports (Aiports DK, 2023)

Hydrogen

To construct the hydrogen production and storage facility on Shetland, necessary utilities should be installed such as power supply connections and salt cavern pipeline connectors (if possible) and storage tanks if the utilisation of underground salt cavern or rock cavern storage is not possible. Figure 60 shows a simplified version of an onshore hydrogen production station that utilises offshore wind energy. Similar to the offshore hydrogen platform, the Shetland energy island will include the following: PEM Electrolyser; transformer systems; heat exchanger systems; desalination system and a hydrogen compression system.

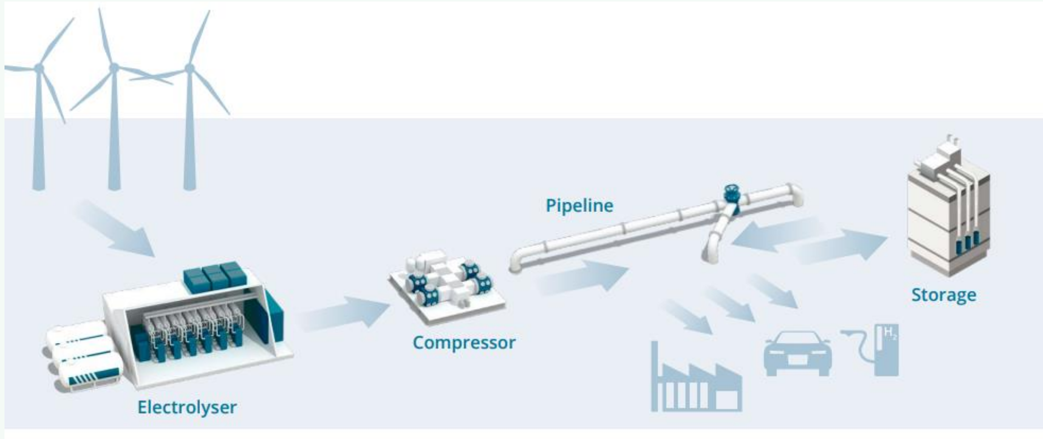


Figure 60- simplified version of an onshore hydrogen production station (Peter Adam et al., 2020)

The construction of a salt cavern storage facility on the Shetland Island will involve a variety of key stages where firstly the site must include a substantial deep salt layer that will allow cavern creation. The salt layer shouldn't have any geological faults or fractures so that the cavern integrity is upheld (Department for Energy Security and Net Zero, 2024). Mineral impurities within the cavern should be minimal to ensure that the hydrogen molecules do not react with other substances. Solution mining should then be undertaken when a well is drilled into the salt layer before injecting water. The water will dissolve the salt, create brine and then be pumped back to the surface (Department for Energy Security and Net Zero, 2024). The process is carried out until the desired size and shape is created before the brine is then treated and disposed of safely unless repurposed for use in other industrial processes. Once the cavern has been formed, infrastructure for creating, retrieving and storing the hydrogen is installed including compressors, piping and safety systems.

The cavern should then be tested to ensure its integrity, where the cavern is filled with a test gas like nitrogen and the pressure is monitored over time. if the pressure remains stable than the salt cavern should be acceptable for operation. The cavern will then be filled with a cushion gas and a working gas (hydrogen) under pressure that can be altered depending on supply and demand fluctuations (Department for Energy Security and Net Zero, 2024).

The construction of the hydrogen pipelines will require the "pigging technique" to enable the pipe wall to be inspected for any anomalies that might be present. The pipes will also be cleaned through pigging to remove any residual gas traces in the pipeline. Then, if no anomalies are found, the pipelines can be used for hydrogen. From Shetland, a minimum of 800m long additional pipeline will be welded to the existing pipeline for it to connect to the island.

Flood Defence

- **Flood Risk Assessment**
  An assessment should be carried out during the design phase to determine the risk of flooding events and its consequences throughout the design life of the energy island. Data such as flood maps, flood zones, storage area historic flood events and hydrology reports are needed to provide detailed information for the computer models. Areas with high flood risks should be avoided during the construction, and emergency preventions or defences should be prioritised on these areas in the event of a flood.

- **Stormwater Management**
  Stormwater management is to reduce excess stormwater runoff to prevent sudden runoff causing flooding and infrastructure damage. It can be done through nature with soil which can absorb and filter the stormwater, which then will be released back into the ocean. Additionally, infrastructure such as culverts, gutters, retention ponds and drainage pipes can help to channel and restore the stormwater for treatment to be further used in other aspects such as toilet flushing on energy island.

- **Pumping System**
  Flood control pumps should be installed around the energy island to drain away large volumes of water during flooding. These pumps can be activated manually or automatically during areas with severe flooding to prevent water from accumulating on the site and causing damage to the infrastructure on the island.

- **Monitoring Sensors and Early Warning System**
  Monitoring sensors are used to detect real-time data and give insight into water levels, velocity, rainfall, or weather. Analysis of this data allows early warning of flood risk allowing for immediate action in emergency response plans.

- **Sea Walls/Flood Barriers**
  Seawalls and flood barriers are flood defence which can be installed around the flood-prone areas on the energy island. They are typically made of concrete, masonry or steel and are designed to withstand the forces exerted by waves and currents to prevent high tides and storm surges reaching the infrastructure on the island (The Flood Hub, 2024).

- **Breakwaters/Groynes**
  Breakwater and groynes are both structures designed to dissipate wave energy before they reach the shore. Breakwaters are vertical walls made from rock, stone or concrete that runs parallel to the shoreline whereas groynes are low-lying structures made from wood or concrete set out into the ocean (The Flood Hub, 2024) This helps to reduce the coastal erosion and create a calmer water around the shore (The Flood Hub, 2024).

Connecting Multiple Countries

Connecting an energy island off the coast of Shetland to multiple countries would require careful planning and consideration of various factors including geographical location, construction and operation of undersea cables, connection points, seabed conditions, depth, marine life considerations, maintenance requirements, technical and economic feasibility, regulatory frameworks, and international cooperation.

One of the most common methods of connecting offshore energy infrastructure to multiple countries is through undersea cables. High-voltage direct current (HVDC) cables would be the likely choice for transmitting electricity over long distances with minimal losses. To connect the energy island to onshore grids in different countries, the most suitable routes would be chosen. It is essential that the selected routes avoid marine protected zones and any obstructions. The HVDC cables would then be laid on or under seabed with shallow gradient and soft sediment (Scottish Government, 2019b) There are currently no HVDC cables that run between different countries, however, there are plans for a 260km subsea HVDC (High Voltage Direct Current) cable between Shetland and mainland Scotland, known as the Shetland HVDC Connection (Figure 61). This cable aims to connect the renewable energy resources of the Shetland Islands, particularly wind power, to the mainland grid. This was part of broader efforts to enhance the connectivity of renewable energy sources in the UK. Once this project is complete it will allow an additional 443MW wind farm to be connected to the Great Britain grid (Scottish and Southern Electricity Networks, 2024).

Figure 61: Shetland HVDC Connection (Wikipedia, 2024)

In Scottish waters, there are currently 88 operational cables, covering approximately 3,500km of international cables and 1,100km of inshore cables. These cables form part of an international network that passes both the North and South of Shetland, linking Europe to North America, the Faroe Islands, Iceland, and Greenland (Figure 62) (Scottish Government, 2019a). Therefore, there are also possibilities to introduce more HDVC cables between Shetland and surrounding countries in the same alignment as already existing telecom cables.

Additionally, there's a plan for the Maali power interconnector, which aims to connect Shetland with Norway. This interconnector will establish an electricity transmission link between the two countries, facilitating the exchange of power and promoting the utilisation of renewable energy. Its purpose is to enable the transfer of energy from windfarms near/on Shetland to Norway during periods of high production, and from Norway during periods of low wind (Scottish Government, 2019a).

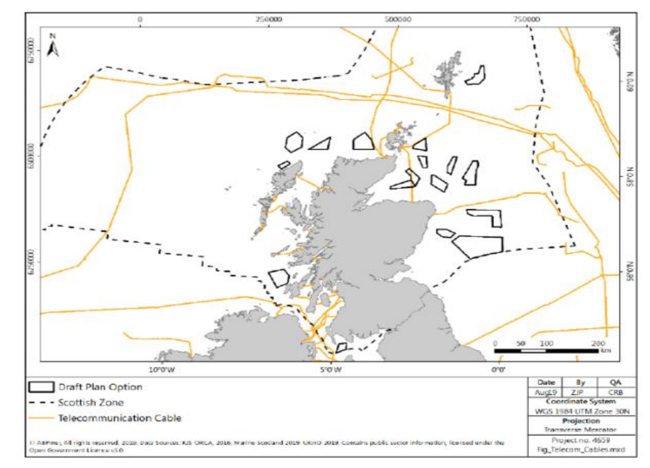


Figure 62: International telecom cable routes (Scottish Government, 2019a)

A document from the Shetland Islands Council provides a report on the feasibility of establishing a North Atlantic Energy Network (NAEN) centred around the Shetland Islands. The report provides a comprehensive analysis of the potential for developing an energy network in the North Atlantic region with Shetland as a key hub, highlighting both opportunities and challenges associated with such a venture. The NAEN aims to harness renewable energy resources, particularly wind and marine energy, to meet local energy needs and export surplus energy to neighbouring regions (North Atlantic Energy Network, 2016). Members from relevant parties from Greenland, Iceland, Faroe Islands, Shetland, and Norway met in Copenhagen in February 2015 to discuss this idea. Each country reported on their energy production status and renewable energy potential, with thorough investigation into the technological aspects of each.

The report outlines key infrastructure requirements such as interconnection cables, renewable energy generation facilities, and energy storage solutions. The importance of collaboration between stakeholders including governments, energy companies, and local communities is also detailed, as well as potential challenges such as environmental impacts, regulatory barriers, and financing issues that need to be addressed for the successful implementation of the NAEN (North Atlantic Energy Network, 2016).

By addressing these considerations and working closely with the relevant stakeholders, it has been confirmed it would be possible to connect an energy island off the coast of Shetland to multiple countries and facilitate the transmission of renewable energy across borders. With the increasing focus on decarbonisation and the transition to renewable energy across Europe and beyond, this cross-border energy integration project is increasingly feasible and attractive. With evolving and emerging technologies, energy islands will be easily integrated into the electricity network through the expansion of projects similar to the ones detailed above and are a natural next step in connecting multiple countries to the UK utilising undersea cables.

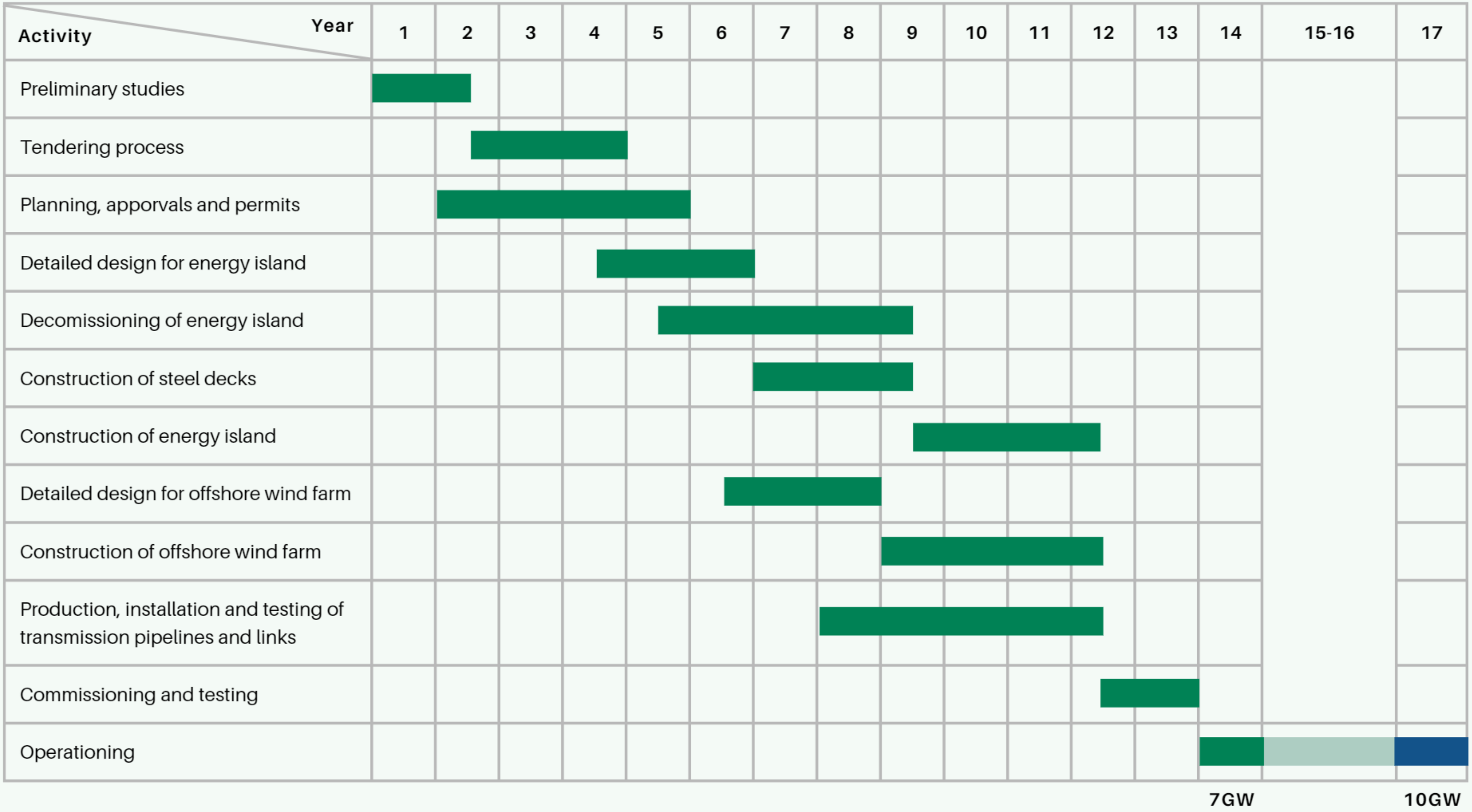
1. Timescales

The timescale from the planning to the operation of an energy island is typically 10 to 15 years. The general steps are as follow:

- Preliminary studies (1-2 years): to assess the feasibility of the energy island by analysing the site location, conducting environmental impact assessments, exploring potential renewable energy recourse, and analysing economic viability of the project.
- Planning, approval and permitting (3-4 years): to plan out the timescales and secure funding for the project and to obtain permits and approvals from relevant authorities.
- Detailed design (2 years): to develop detailed engineering designs for the energy island including its structure and infrastructure such as hydrogen storage, together with the connections within renewables, substations, national grid, and with other neighbouring countries.
- Construction (3-5 years): the construction of energy island's infrastructure which was included in the detailed design.
- Construction of offshore wind farm (5-8 years): to design and construct the offshore wind farms to be connected to the energy island (Wind Cycle Energy, 2024)
- Construction of pipelines (5 years): to design, produce and install interconnecting pipelines for power transmission (Energistyrelsen, 2022)
- Commissioning and testing (1 year): to test the power generation and transmission throughout the energy island, ensuring its effectiveness and safety performance (Energistyrelsen, 2022)
- Operational: energy islands have a typical design life of 80 years; it is proposed that a smaller amount of power will be generated in the first three years after construction with a goal to expand to 10GW (Energistyrelsen, 2022)

Shetland

The below Gantt chart shows the timescale for the energy island designed in Shetland. The design and construction of tidal turbines are also included which will take around five years in total. The preliminary studies will include surveys to assess the feasibility of salt cavern hydrogen storage options and EIA's. It is proposed that the energy island will have an approximate capacity of 3.3GW, connecting other renewables such as the proposed wind farms and developing tidal arrays, which can be expanded to reach a capacity of 10GW in 10 years of operational life.


Activity
Year
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15-16
17
Preliminary studies
Tendering process
Planning, apporvals and permits
Detailed design for energy island
Decomissioning of energy island
Construction of steel decks
Construction of energy island
Detailed design for offshore wind farm
Construction of offshore wind farm
Production, installation and testing of transmission pipelines and links
Commissioning and testing
Operationing
7GW
10GW

2. Meeting Legislation Requirements

National Legislation and Policies

The UK set out policies responding to the climate emergency with the *Climate Change Act 2008***,** introducing legally binding 2050 targets to reduce greenhouse gas emissions by at least 80% relative to 1990 levels. In Scotland, there are objectives to meet the *Paris Agreement* by 2045. Due to these commitments, there is a need to action the energy transition more than ever and there is the vast opinion that hydrogen will play a critical role in this shift.

Key Legislation

The Oil and Gas Authority (OGA) has a role to boost the economic recovery of the UK's oil and gas resources whilst also helping the UK achieve Net Zero goals. OGA are empowered by:

- *The Petroleum Act 1998*
- *The Energy Act 2016*
- *Energy Act 2011*

In 2021, the OGA strategy was revised to place an obligation on the oil and gas industry to support the Secretary of State in meeting the target of net zero carbon by 2050. By repurposing existing rigs and pipelines to accommodate renewable energy production, the oil and gas industry can successfully undertake these commitments whilst also having a monetary incentive of producing and exporting energy.

The Offshore Safety Directive Regulator (OSDR) is the Authority responsible for overseeing industry compliance of the safety of offshore oil and gas operations in conjunction with the EU Directive. Directive 2013/30/EU ('the Directive') is implemented in the UK by various regulations including:

- *Offshore Installations (Offshore Safety Directive) Regulations 2015*

Acting in conjunction with HSE (the Health and Safety Executive), the OSDR helps to regulate any activity undertaken offshore, ensuring that appropriate measures have been taken to prevent, mitigate and control any major safety and environmental hazards that may present as well as the consequences of these hazards. OPRED and HSE are regulatory bodies that also have responsibilities to apply health and safety and environmental provisions made for the directive. These include activities that involve offshore: pipelines; decommissioning; reacting to incidents and emergencies; development of regulatory policy and technical matters; sharing regulatory information; and legal issues.

Other Regulations and Regulatory Bodies and Policies

- Marine Scotland
- Crown Estate Scotland
- Statutory Consultancies including Scottish National Heritage, Local and National Planning Authorities, Maritime and Coastguard Agency, Northern Lighthouse Board, Marine Planning Partnerships, Marine Renewables Facilitators Group and the Scottish Environment Protection Agency (SEPA)

- *Health and Safety at Work Act 1974*
- *Environmental Protection Act 1990*
- *Supply of Machinery (safety) Regulations 2008*
- *CDM 2015 Regulations*
- *MCA obligations (use of vessel for host of hydrogen generation or service provider)*
- *The Energy Act 2008*
- *The Carbon Dioxide Regulations 2010.*

It is also important to engage with local communities, governmental agencies, and stakeholders to address concerns, obtain necessary permits, and obtain support for the project before any work is undertaken.