Islay Energy Systems Options Appraisal

Final Report

Wood Group UK Limited – January 2021

Report for

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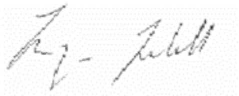

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Doc Ref. 43230-WOOD-ZZ-XX-RP-J-0004_S04_P01.4

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Document revisions

No.	Details	Date
1	Draft Report	02/10/20
2	Updated draft report	31/10/20
3	Updated draft report	16/12/20
4	Final report	18/01/21
5	Final report update	09/02/21

Executive summary

Purpose of this report

The Scottish Government, Highlands and Islands Enterprise (HIE) and Argyll and Bute Council (A&BC) are working with Local Energy Scotland (LES) to explore where a joint approach to the development of local energy systems on Islay can add value. Islay, as with other island communities, faces multiple challenges in meeting power, heat and transport energy needs for the benefit of all members of the community.

The report provides an overview of current energy requirements and explores opportunities for change. These opportunities are set out in four high-level scenarios that describe what is technically possible and identify many of the challenges and restrictions that may exist. Each scenario shows ways in which power, heat and transport energy needs could be met as part of a 'whole systems' approach. This approach can support delivery of sustainable (low carbon and affordable) energy for the whole community.

The four high-level scenarios do not seek to provide a single answer to Islay's future energy system, nor limit the list of options that can be explored. The scenarios simply provide ideas for what is possible and identify many of the actions that will be required. It is intended that the study will help inform individual, community, public and private stakeholders as they consider the future development of energy systems on Islay (and on surrounding islands) and inform future public and private investment. There is, for example, an energy project investment specifically for Islay within the proposed Argyll and Bute Rural Growth Deal (RGD).

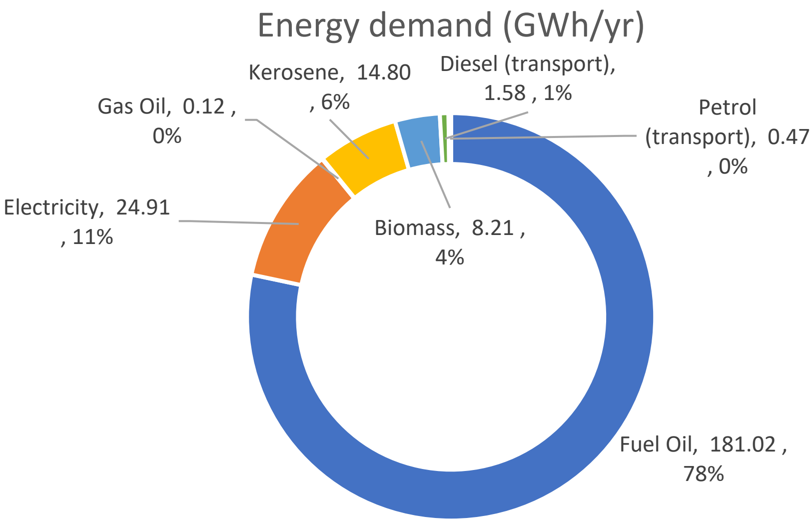
Why change the existing energy systems?

The majority of current energy is imported to the island – mainland generated electricity, fuel oil for steam production, heating oil for homes, petrol and diesel for vehicles. This means:

- Base costs of energy (for heat, power or transport) are higher than for mainland consumers
- Power supply is vulnerable to lengthy disruption due to damage to pylons, overhead lines or sub-sea cable failure. Back-up systems rely on diesel-fuelled generators (imported fuel)
- The existing electrical network cables and sub-stations on the island cannot accommodate larger amounts of local renewable generation without expensive upgrade works
- Poor sailing conditions directly affect the ability to bring heating and transport fuel on to the island. Importing fuel means berths on ferries are filled with tankers and lorries
- Current energy use is heavily reliant on fossil fuels (heating oil, petrol, diesel). These are likely to become harder to purchase and more expensive over time due to changes in the wider economy

Islay: Pathway to a sustainable energy system

Current energy demand across the island is dominated by heating fuels (fuel oil and kerosene account for around 80% of total energy demand). The GHG emissions associated with fuel oil use alone amount to around 48,000 tCO_{2e} per year. Argyll & Bute Council's total reported GHG emissions for their activities throughout their local authority area in 2018/19 were 34,738 tCO_{2e}. Given the Scottish Government's commitment to achieve net-zero emissions by 2045, this underlines the significant changes in how energy is generated, stored, and used, that will be required on Islay as well as nationally.



A whole system approach aligns with the Scottish Government Energy Strategy that underpins efforts to meet national greenhouse gas (GHG) reduction targets. By addressing the challenges set out in this study, a future energy system for Islay can use a range of technologies to meet the energy needs of homes and businesses. For Islay (and the surrounding islands) it is important that any changes to the energy system supports inclusive economic growth as an objective that all can benefit from. There are several challenges that this presents in terms of:

- Increasing security of supply by reducing reliance on imported power and fuels to the island. This includes smarter systems of delivery that more closely match local generation and demand
- Sustainable energy supply that maximises the use of natural resources to reduce reliance on high carbon fossil fuels (fuel oil, diesel and petrol for example) and their carbon intensive supply chains
- Reducing energy costs through developing affordable sources of low carbon energy that are suitable for power, heat and transport use
- Increasing the efficiency of energy use in residential and non-domestic buildings across Islay
- Use of alternative fuels for vehicles on Islay and supporting low carbon transport connections to the mainland (air and ferries)

High Level Scenarios

Each of the scenarios look at how to address the challenges set out in the previous section. With current energy demand for heat representing 80% of the total energy demand, the scenarios focus on how alternative sources of heat can be used. Changing the sources of energy used to provide heating, opens routes to change how power and transport energy needs are met. This means that while heat generation is the starting point, it leads into related changes that enhance the sustainability of the overall energy system on Islay.

Actions such as fuel switching are relatively fast to complete, where no significant change to boilers or other equipment is required. Developing offshore electricity generation, on the other hand, takes much longer due to the process of obtaining planning consent and time to build out equipment and cabling. Some technologies are readily available to buy now; others are less mature and are still developing. These factors influence how quickly changes can be made and the logical order in which they might occur. This also has a major impact on the financial costs of investment and the scale of funding required.

What can change?

At the core of the present energy system is imported energy – mainland generated electricity, fuel oil for steam production, heating oil for homes, petrol and diesel for vehicles.

Development of offshore electricity generation can provide a local source of energy that replaces the need for large volumes of imported fuel and heating oil. Tidal generated power, located in the Sound of Islay, can come into operation by the mid-2020s if action is taken now. This provides power for domestic oil users to switch to electric systems of heating and supports wider use of electric vehicles. Dependent on suitable market incentives being in place, this capacity could be increased again between 2025 – 2030. Offshore wind power, operational by early 2030s could provide the volume of power needed to help distilleries move to wider use of electric heating systems, supported with hydrogen generated via electrolysis locally. Hydrogen can also provide an alternative to diesel fuel for heavy goods vehicles (HGVs) and agricultural vehicles as these vehicles are replaced over time.

The heat required to raise steam for use in distilleries is the major source of heat demand on the island. Substitution of fuel oil by either hydrotreated vegetable oil (HVO) or compressed natural gas (CNG) offers a short-term reduction in GHG emissions, though does nothing to reduce reliance on fuel imports. No single system solutions can meet distillery requirements; however, a combination of anaerobic digestion and biomass can provide part of a solution in the medium term to late 2020s. Electric-led systems, either using high temperature heat pump systems or combined with hydrogen-fuelled boilers, become more feasible as a greater amount of offshore power generation becomes available.

By 2030 emerging fuelling needs for ferries and aircraft may require local fuelling stations at harbours (either battery storage capacity or hydrogen fuelling) and at the airport.

How would this look within the community?

Initial work among distilleries would see anaerobic digestion and biomass fuelled energy systems emerge by mid 2020s. Community engagement with potential tidal power developers would enable tidal power supply by mid-2020s. This would mean oil heating systems could be replaced with electric alternatives (this could be heat pumps, electric radiant heating or electric-led wet heating depending on the dwelling or building). Extending electric vehicle (EV) charging infrastructure would allow more electric vehicles to operate on the island (including visitors). Direct vehicle ownership could be supported (or replaced) by smart rental, vehicle share and other emerging operating models. Short term Government incentives may also apply.

Offshore wind generation, assisted by local community knowledge and relevant development skills, would provide the scale of power needed to support wider uptake of electric heating solutions across domestic and non-domestic users on the island. It would provide enough power to charge large battery storage capable of acting as primary system back-up instead of the existing diesel generators.

A reduction in the fuel oil required by distilleries, as well as reducing volumes of petrol and diesel used in transport, would mean far fewer fuel deliveries by late 2020s. This enhances supply security and increases capacity on ferries for local passengers and others (with fewer fuel vehicles required). It will also reduce fuel delivery vehicle movements to distilleries across the island.

Production of biobutanol and bioethanol from early 2020s would be a route to low carbon fuels for vehicles operating on the island. This would make it possible to run existing vehicles with little or no engine modifications required. Alternatively, fuel cell vehicles fuelled with hydrogen (produced using local electricity) could reduce vehicle exhaust GHG emissions across the island. Hydrogen is more likely to provide an alternative fuel for agricultural vehicles and HGVs (during existing cycles of vehicle replacement), with electric batteries used in passenger cars, taxis, vans and buses. A phased cycle of new vehicles could be achieved.

Balancing the power generated offshore with the demands for its use onshore (power and heat in buildings, power in charging vehicles and potentially in producing hydrogen) would become more important in reducing the reliance on power generated on the mainland. This would mean greater real time data showing all users the balance of generation and demand. It may also mean a change to more time of use charging, where users are encouraged to adjust their demand to suit the balance of supply.

Enabling actions

Community engagement – Community involvement is crucial in a number of roles:

- **Raising awareness** among the community regarding the challenges and opportunities that meeting energy needs on the island poses. If community members understand the challenges of maintaining secure, affordable and sustainable energy needs on the island then they can better engage with proposals for change. They will also better understand what might change and how this will impact the way they use and consume energy for power, heat and transport
- **Building local understanding of electric/hydrogen-based solutions** for heat and transport and developing skills to support future systems. This will enable Islay to play a wider role in supporting similar work across the Mid Argyll, Kintyre and the Islands (MAKI) region. This enhances the resilience of the energy system for Islay via its links with the mainland and supporting infrastructure both for residents and visitors to the island.
- **Engaging with developers**, commenting on proposed connections and supporting cost effective designs through sharing knowledge from previous proposed schemes and direct development work / studies (as applicable). Islay Energy Trust has engaged with developers looking at tidal and offshore wind development for several years and continues to do so. The local knowledge that this brings is important in helping to shape proposals for development. This includes promoting the benefit of using offshore generated power on Islay and local co-ordination of surveys and relevant studies supporting supply chain needs in build out.
- **Supporting discussions with developers** regarding power purchase agreements (PPAs) and agreement for use of generated power to support investor confidence in offshore schemes
- **Assisting use of funding routes** not directly open to commercial developers and exploring how local skills and expertise can be built into operation of generating schemes. Some funding routes are specifically linked to community engagement; other opportunities could exist in match funding private sector investment.

Energy efficiency – Effective decarbonisation of heat demand on the island needs a continued focus on efficiency of energy use across all sectors of the community. Continued investment support should be sought for all sectors via sources such as:

- Non-domestic – Industrial Energy Transformation Fund (IETF), Scottish Manufacturing Advisory Service (SMAS), HIE support for economic growth through investment in R&D and Innovation, Energy Efficient Business Support, future Scottish/UK Government funding streams
- Domestic – Social landlords (driven by targets set by Scottish Government), Home Energy Scotland (owner occupiers and private landlords) and future emerging funding streams

For non-domestic users this is driven, primarily, by cost savings associated with reduced energy use (and avoided related costs such as Climate Change Levy). An increase in locally generated energy will reduce supply risks associated with disruptions to imported fuel supplies to the island. While social landlord investment will continue across dwellings, driven by Scottish Government targets, these properties are only 20% of the total stock on the island. Support for owner occupiers and private landlords is therefore crucial in enabling a transition from oil to electric heating.

The Islay Energy Trust (IET) has previously supported energy efficiency programme of works for some households. A future role assisting sourcing of funding (potentially supplementing with community benefit funds) and helping administration of works could be beneficial. There is a role for Argyll & Bute Council as well as other public agencies in signposting and supporting householders and businesses in access to relevant funding streams available from Scottish and UK Government programmes.

Network management – Electricity grid management and control at present supports a limited number of small generators. If large scale (multi-MW) offshore generation becomes available to Islay this will need a suitable management system. This means some battery storage capacity and control system so that offshore generated power is prioritised for local use instead of mainland sources. It also needs to ensure that the local grid network across Islay, Jura and Colonsay remains stable. The recently developed Constraint Managed Zone (CMZ) provides an example of how local generation sources (in this case hydro) can be managed to prioritise their output and reduce reliance on diesel standby generation. While connection to the grid remains an integral part of the power system, smarter use of local generation via protocols used elsewhere in automated network management systems, is important in enhancing system resilience and encouraging development of further low carbon generation. The network operator (DNO) has an important role in collaborating with future renewable energy generation and bringing innovation from other parts of the UK electricity network to use productively on Islay. This role is becoming more important as regulations for how network operators work are updated.

Innovation investment – Innovation investment will be needed short term to support electric/hydrogen solutions for process heat and vehicle supply in particular. Use of funding streams such as the Green Distillery Fund, Low Carbon Infrastructure Transition Programme (LCITP) and future Energy Efficient Scotland programme funding could assist. Integrated heat/transport system solutions may be supported by advanced power purchase agreements and forward vehicle orders to develop local demand. All groups in the community can support access to these sources of investment and wider efforts to encourage inward investment to the island.

Scenarios 'at a glance'

Scenario 1 – Low Carbon Oil and Gas

- Distillery heating needs use electricity and hydrogen long term (2030+); medium term use is HVO (instead of fuel oil) and biogas (from AD)
- Increasing amount of offshore generation supports electrification of heating for non-domestic and domestic users (medium to long term)
- Reliance on mainland power sources is reduced by tidal/offshore generation; battery storage and hydro replace diesel generation as back-up
- Cars, taxis and vans become electric powered long term; hydrogen is the alternative fuel for buses, HGVs and agricultural vehicles

Scenario 2 – Low Carbon Gas

- Distillery heating needs use electricity and hydrogen long term (2030+); medium term use is CNG (instead of fuel oil) and biogas (from AD)
- Increasing amount of offshore generation supports electrification of heating for non-domestic and domestic users (medium to long term)
- Reliance on mainland power sources is reduced by tidal/offshore generation; battery storage and hydro replace diesel generation as back-up
- Cars, taxis and vans become electric powered long term; hydrogen is the alternative fuel for buses, HGVs and agricultural vehicles

Scenario 3 – Electric

- Distillery heating needs uses electricity long term (2030+); medium term use is HVO (instead of fuel oil) and electric
- Increasing amount of offshore generation supports electrification of heating for non-domestic and domestic users (medium to long term)
- Reliance on mainland power sources is reduced by tidal/offshore generation; battery storage and hydro replace diesel generation as back-up
- Cars, taxis and vans become electric powered long term; biodiesel is the alternative fuel for buses, HGVs and agricultural vehicles

Scenario 4 – Biomass and biogas

- Distillery heating needs uses electricity, hydrogen, biogas (from AD) and biomass long term (2030+); short term use is HVO (instead of fuel oil)
- Increasing amount of offshore generation supports electrification of heating for non-domestic and domestic users (medium to long term)
- Reliance on mainland power sources is reduced by tidal/offshore generation; battery storage and hydro replace diesel generation as back-up
- Cars, taxis and vans become electric powered long term; biodiesel is the alternative fuel for buses, HGVs and agricultural vehicles

Now			Short Term (2020 – 25)	Medium Term (2025 – 30)	Long Term (2030+)
Fuel Oil	S1	Heat (Distilleries)	HVO/Biogas	HVO /Biogas / Electric	Electric / Hydrogen
	S2		CNG / Biogas	CNG / Biogas / Electric	Electric / Hydrogen
	S3		HVO	HVO / Electric	Electric
	S4		HVO/Biogas	HVO /Biogas / Biomass / Electric	Electric / Hydrogen / Biomass
Oil / Electric / Biomass	S1-4	Heat (Non-domestic)	Limited switch to electric;	Electric heating; some heat pumps; biomass	Electric heating; some heat pumps; biomass
Oil / Electric		Heat (Domestic)	Fuel switch oil to electric	Extend use of heat pumps, electric heating	Mainly electric; small scale heat networks
Grid / Wind Diesel (standby)	S1-4	Power	Tidal / Grid / Wind CMZ (Diesel/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)
Diesel / Petrol	S1	Transport	EV / Diesel	EV / Diesel / Hydrogen	EV / Hydrogen
	S2		EV / Diesel	EV / Diesel / Hydrogen	EV / Hydrogen
	S3		EV / Diesel	EV / Diesel / Biodiesel	EV / Biodiesel
	S4		EV / Diesel	EV / Diesel / Biodiesel	EV / Biodiesel
100%		Carbon Emissions	50 – 70%	30 – 50%	10 – 30%
		Security of supply	Reliant on national grid On-island biogas & fuel import	Local generation eases reliance on national grid Low import of fuel (heat/transport)	Largely Self-sufficient generation Low fuel import

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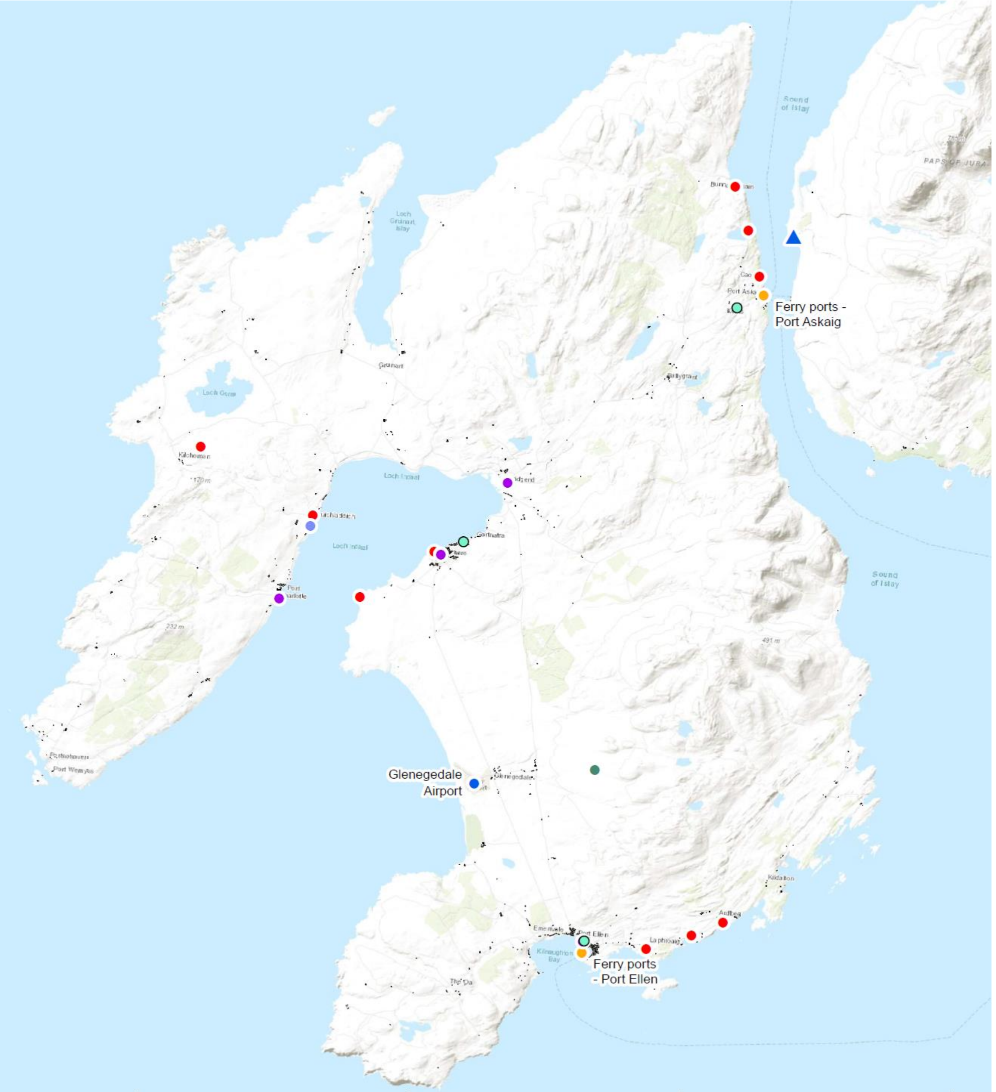


Key

- Primary substation
- Petrol stations
- Fuel Depot
- Airport
- Ferry Ports
- Distillery
- Community wind turbine
- Inver hydro scheme
- Buildings

1. Introduction

This section provides an overview of the current energy systems on Islay and the challenges associated with decarbonisation.

1.1 At a glance

Electrical Power

The existing 33 kV circuit to Islay runs from Lochgilphead on the mainland to Carsaig Bay, before crossing under the Sound of Jura, down through Jura and across the Sound of Islay to the south of Port Askaig. There it tees into a single circuit which supplies Port Askaig, Bowmore and Port Ellen. These three sites then feed the 11 kV network serving the homes and businesses of Islay. This 11 kV system was upgraded in 2017; an additional overhead line circuit between Port Askaig and Port Ellen is proposed to further strengthen network resilience. There is a further 11kV link between Islay and Colonsay.

Transmission 33 kV network

An existing 6 MW diesel generation station located in Bowmore provides a source of back-up power in the event of loss of supply within the main circuit. The current Constraint Managed Zone (CMZ) enables hydro power from the Inver Hydro scheme on Jura to provide back-up power to reduce sole reliance on diesel generation. The largest single renewable energy generator on Islay is the community owned wind turbine (330 kW).

Heat

Fuel Oil Storage

Existing whisky sector heating fuel demand equates to around 15 million litres of fuel oil a year. Across the island oil is a significant primary fuel used in heating homes and businesses (around 40% of dwellings). Electricity provides the primary heating source for a further 40% of buildings on the island. The remaining heat demand is supplied via biomass and solid fuel.

All liquid heating fuel is imported on to the island either via direct shipping or transit vehicles via ferry. Fuel storage capacity amounts to the equivalent of a few weeks demand.

There are no existing gas distribution networks or district heating networks on the island. However, there are a number of examples of use of waste heat from the distilling process to support heating systems. This includes use of waste heat to heat individual buildings such as a visitor centre and bottling hall and integration of waste heat within the water supply system for the swimming pool in Bowmore.

Transport

The island is served by two Calmac-operated ferry routes – one operating into Port Askaig, the other operating into Port Ellen. The two vessels operating these routes are MV Finlaggan and MV Hebridean Isles. Demand over the past 5 years for these services has seen a steady increase. A ferry between Islay and Jura is operated by A&BC.

The HIAL operated airport provides capacity for flights to and from Glasgow, Oban and Colonsay. There are an average of two flights per day to/from Glasgow.

A local bus service operates on the island. This provides a service for general public and school children during term time.

Significant HGV journeys on the island are associated with movement of distillery sector raw materials and goods as well as other resources (e.g. timber and roadstone, agricultural goods and livestock).

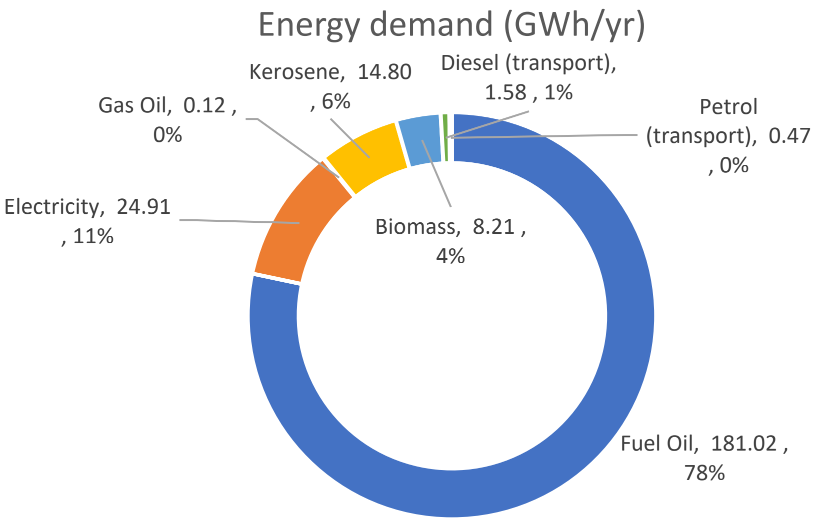
Islay Transport

A number of licenced taxis (around 25) also operate on the island.

Existing energy demand

A snapshot of current annual energy demand on Islay is provided here.

Figure 1.1 Overall annual energy demand (Islay)



The GHG emissions associated with fuel oil use alone amount to around 48,000 tCO_{2e} per year. Argyll & Bute Council's total reported GHG emissions under their Public Sector Climate Change Duties for the reporting period 2018/19 were 34,738 tCO_{2e}[1]. for the entire council area. The need to address energy needs (and associated carbon emissions) is therefore important for everyone on Islay.

Further details are provided in the Supporting Information at the back of this report.

1.2 Key challenges in a net zero world

Developing lower carbon supplies of energy for power, heat and transport is not only about a legally defined target; it provides an opportunity to enhance the 'whole system' energy needs of Islay in terms of:

- Sustainable energy supply maximising use of natural renewable resources
- Reduce energy costs particularly in respect of heat and transport
- Increased security of supply
- Robustness of energy supply to cater for increased demand

Each of these themes is discussed in turn here.

Sustainable Energy Supply

The majority of heating needs on the island are currently met via use of oil. This is an expensive resource that is wholly imported on to the island. From a GHG emissions perspective it is a carbon intensive fossil fuel. This means that current energy demand levels 'lock in' high GHG emissions.

- GHG emissions per person (Islay, Jura and Colonsay) 7.0 tCO_{2e}/yr; GHG emissions per person (Argyll & Bute) 6.3 tCO_{2e}/yr; 4.9 tCO_{2e}/yr (Scotland)[2]

The continued use of oil requires regular fuel deliveries both via vessel and trucks from the mainland (there is storage capacity on the island equivalent to a few weeks of supply). This means that the overall carbon impact of oil use is increased by the fossil fuels used in transporting the oil to Islay.

Decarbonisation of fuel use for heating on the island needs to look at a combination of lower carbon alternative fuels (short term) and increased use of natural resources (medium to long term) to deliver a meaningful reduction. This includes the sustainability of fuel sources and the carbon intensity of the supply chain in delivering these on the island.

Hydrogen is a resource that could become more important in the medium term (2025 onwards) as a means of reducing carbon emissions in heat, electricity and transport. Hydrogen can be used as a fuel source for heating, a fuel for transport (passenger vehicles, HGVs, ferries and aircraft) and as an energy store for later conversion to electricity. Crucially, when burnt as a fuel it does not result in any GHG emissions. Hydrogen production can be via processing of fossil fuel gas (so called blue hydrogen) or via electrolysis of water (green hydrogen). The net GHG impact is reduced further in the case of green hydrogen if the source of electricity used to power the electrolyser is itself renewable.

Limited existing renewable energy generation on the island means that the GHG emissions associated with electricity demand are not controlled by island users. Instead, it is external decisions by larger generators (off the island) regarding the mix of sources supplying the national grid that determine its carbon impacts. The removal of almost all coal-fired power generation from the UK grid has significantly reduced the carbon intensity of electricity production, reinforced by continued increase in the use of renewable generation. This

[1] https://sustainablescotlandnetwork.org/reports/argyll-and-bute-council (Accessed December 2020)
[2] https://www.gov.uk/government/collections/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics (Accessed September 2020)

uptake of renewable generation (including offshore wind) across Scotland (and the UK) is expected to further reduce the carbon intensity of grid electricity over the next decade and beyond.

This underlines the value of renewable electricity generation.

Reduced Energy Costs

The cost of imported oil and petrol/diesel for transport means that energy costs are high on the island.

Existing service charge models for the distribution of grid electricity also mean that typical electricity prices are higher than on the mainland. While the service charge model is designed to shield remote communities from the costs associated with more complex distribution the reality is that this results in a base cost that is reflected in electricity prices.

- Average price for UK grid electricity in 2019 was 18.75 p/kWh; average price of grid electricity for Scottish islands in 2019 was 19.82 p/kWh[3]

Transport fuel costs are high and exacerbated when costs of travel to and from the mainland (where any bulk items need moving by vehicle) are included.

- Price range for petrol on Islay 119.9 – 122.9 p/litre[4]; Scottish average price 114.3 p/litre[5]
- Price range for diesel on Islay 121.9 – 124.9 p/litre; Scottish average price 118.0 p/litre[6]

While no refuelling of ferries or aircraft take place on Islay these lifeline services are expensive to fuel; any opportunities to seek alternative fuels that reduce operating costs will benefit travellers.

Fuel for HGVs, buses and delivery vehicles operated on the island is expensive (relative to mainland prices); alternative fuelling options provide benefit both to operators (lower operation costs) and end consumers (potentially cheaper prices).

Increased security of supply

There are limited existing energy storage facilities on the island supporting power, heat and transport systems.

The diesel generation at Bowmore supports the island in the event of loss of supply via the mainland fed grid electricity supply.

Individual distilleries will typically have fuel storage for days of operation; residential oil tanks can provide a few weeks of supply in peak winter periods.

The energy systems on Islay are therefore vulnerable to relatively small perturbations relating to either loss of supply in the case of electricity or short-term difficulties in supply of other fuels due to ferry cancellations. Delivery of fuel requires movement by both marine vessel and articulated lorries and fuel tankers. In the latter case this adds to traffic flows on Islay.

Back up resilience is currently via high carbon intensity fuels.

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[3] https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics (Accessed September 2020)

[4] https://petrolmap.co.uk/petrol-stations/argyll-bute/isle-of-islay (Accessed September 2020)

[5] https://www.theaa.com/driving-advice/driving-costs/fuel-prices (Accessed September 2020)

[6] It is noted here that Rural Fuel Duty Relief for unleaded petrol and diesel currently applies on Islay. This provides a 5p/litre rebate on Excise Duty to retailers of these fuels

An increase in local capacity for energy generation therefore offers greater resilience for all consumers.

Meeting increased demand

Current projections for visitors to the island suggest sustained or increasing numbers across the whole year. There are also plans for expansion of both residential housing and distillery facilities in the near term.

Meeting future energy needs with existing energy systems will result in further pressure on generation and supply and little impact in terms of cost.

1.3 Natural Resources

Maximising use of natural resources provides an immediate route to decarbonising energy supply to any given area.

To date Islay has a limited scale of renewable energy generation:

- Community wind turbine (330 kW) – power output exported to grid. Currently in receipt of Feed-in tariff (FiT) for all generation. There are a number of small-scale single turbines also operating on the island (total capacity of around 80 kW)[7]
- Micro hydro scheme (50 kW) – systems feeding Estate buildings (35 kW) and off-grid supply (15 kW) to local quarry
- Solar PV (234 kW) – domestic installations and small number of non-domestic
- Biomass – A biomass boiler (465 kW) is installed in the energy centre that serves Islay High School and Bowmore Primary School. There are also a number of biomass boilers on the Dunlossit Estate serving heating needs of buildings

In terms of available resources:

- Wind – The existing wind turbine development shows the viability of wind resource on the island. In terms of a resource range mean average wind speeds are within a commercially developable range of 7.9 ms^{-1} - [8] 9.0 ms^{-1} within areas of the island. It is noted, however, that wider environmental designations and visual impact considerations potentially restrict locations for further onshore capacity.
- Solar – Available resource is around 2.8 $kWh/m^2/day$[9]. This offers potential annual cumulative generation of the order of 800 kWh/yr from a single kW of capacity
- Biomass – Estate management on the island includes areas of forestry[10] and associated felling licences for timber. A gross area of around 2,500 Ha of forestry is potentially available.
- Tidal[11] - Sound of Islay data suggests peak Springs flow of 4 ms^{-1} and peak Neaps flow of 3.5 ms^{-1} with an average power availability of 11.6 kW/m^2. There are existing consents for potential development both within the Sound of Islay and to the West of the island. Development of 10 MW capacity in the Sound of Islay is being actively explored

[7] Details based on Feed in tariff Installation report data published by Ofgem and cross-check with local sources
[8] NASA Power – Wind; https://www.rensmart.com/Maps
[9] PV GIS
[10] https://scottishforestry.maps.arcgis.com/apps/webappviewer/index.html?id=0d6125cfe892439ab0e5d0b74d9acc18
[11] https://www.renewables-atlas.info/explore-the-atlas/

- Offshore wind – There is sufficient resource to support offshore wind development. The current Scotwind leasing process managed by Crown Estate Scotland includes an area of seabed to the North-West of Islay (labelled W1 on the maps at the front of this report). Given the early stage in the development process there is no guarantee that any offshore wind power would be supplied to Islay (rather than being sent via cable to the mainland). The scale of development in this area can be up to 2 GW (further details in the Appendix).

1.4 Current System Constraints

- Electricity – grid capacity constrained for new generation. This means only small-scale generators (less than 50 kW capacity) can be installed without the need for additional (costly) work on the local network.
  - Vulnerability of supply in the event of planned maintenance or damage to the distribution system running from mainland. This means heavy reliance on the existing diesel generators and Constraint Managed Zone (CMZ) using the Inver hydro capacity on Jura
- Regulatory – Development of a micro-grid, operating independently of the national grid, is not presently achievable under supply regulations. The distributed network operator (DNO) holds a licence to operate that is regulated by Ofgem. These regulations set out the safe voltage and frequency range which must be maintained, universal rights of access for all consumers and generators and continuity of supply.
  - Consumer protection requirements mean that any supply agreements must include ability for consumers to select supply from another third party (unless the costs of these are entirely impractical for viability of the micro-grid).
- Heat – limited storage capacity and reliance on import of heating fuels. Fuel storage for heating oil offers, at most, a few weeks' worth of fuel requirements in winter months. This means reliance on fuel deliveries via shipping vessel (fuel oil) or tanker from the mainland (domestic heating oil)
- Building fabric – generally poor thermal performance of buildings means an in-built energy requirement that exacerbates issues of security of supply and associated running costs. Current estimates on the island are that 54% of households are likely to be in fuel poverty
- Transport – fuel use reliance on imported sources and little capacity to support wider transport infrastructure (bus, HGV, agricultural plant, ferries or aircraft). Few public EV charging points on the island at present (Bowmore and Port Ellen)

1.5 What can change?

Energy system changes

The following table provides a summary of the system changes that could be implemented and how these would influence current energy demands.

The use of these changes is explored in the Scenarios developed in the next section.

Table 1.1 Potential energy system interventions and broad target impacts

Intervention	Power	Heat	Transport
HVO Biodiesel (stationary equipment)	Less carbon intensive back up generation at Bowmore. This fuel switch could be achieved with little work required on generators	Less carbon intensive process heat for distilleries. This fuel switch could be achieved with little work required on boilers.	
CNG (boiler fuel)		Moderate retrofit work on existing boilers could enable use of CNG as a primary boiler fuel leaving fuel oil as a back-up source for distillery heat. Supporting storage tanks and pipelines required.	
Biomass		Lower carbon heat production for distilleries. Locally produced wood chip could provide the main fuel for new boilers. Lower carbon heat for larger residential properties could also be supplied using wood chip.	
Biogas from anaerobic digestion		Lower carbon heat for distilleries. Use of pot ale and spent lees from the distillation process can produce biogas that can be cleaned up and used as boiler fuel.	
Acetone-Butanol-Ethanol (ABE) fermentation			Butanol can be used as a lower carbon fuel replacing petrol in passenger cars
Hydrogen	Hydrogen produced via electrolysis can be stored and used to generate electricity. This can help in balancing grid supply.	Hydrogen can be produced via electrolysis using water as an input. Combustion of hydrogen does not result in any GHG emissions. Use of hydrogen would mean new boilers in distilleries and significant associated investment. Hydrogen can also be used in domestic boilers to provide heat and hot water.	Hydrogen can be used as a fuel in vehicles replacing petrol or diesel. This is an alternative to battery electric power, particularly for larger vehicles
Offshore electricity (Tidal)	Several different tidal turbine designs are available. The most advanced designs are developed to enable a phased build out so can be sized to meet existing and future needs. Lower carbon supply for homes and businesses (heat pumps or direct heating)	A renewable source of electricity provides support for changes in the way distillery process heat is supplied. Lower carbon process heat (electrical heating)	Zero emission vehicles in the form of battery electric (EV) vehicles can be supported. This is most useful for passenger and light goods vehicles moving away from petrol and diesel.
Offshore generation (wind)	Large scale wind generation would provide a means of supplying renewable electricity to the island. Network infrastructure is likely to be needed to support this sale of generation.	Electric heating for process heat could be supported via low carbon generation. Larger scale generation also supports domestic switch from oil to electric solutions (heat pumps or boilers)	Zero emission vehicles in the form of battery electric (EV) vehicles can be supported. This is most useful for passenger and light goods vehicles moving away from petrol and diesel.

Intervention	Power	Heat	Transport
			Charging infrastructure may also support potential new hybrid ferries at the island ports or electric/hybrid aircraft
Battery storage	Larger scale generation from wind and tidal power in particular can be used most efficiently by integrating some battery storage in the system design. This may be at the point of generation or at point of connection on the island. It also provides a means of moving from diesel back up supply for island	Supporting electrification of heat or availability of power to generate hydrogen	Zero emission vehicles Potential support for decarbonisation of ferries and aircraft
District heating		Efficient use of process heat in distilleries will include consideration of heat recovery. One direct use of such recovered heat is in supporting small scale communal (district) heating systems. These would need to be operated by third parties to support end consumers.	
Automatic network management (smart grid)	Change of operating scheme can prioritise use of local renewable generation. It can allow more exchange of local energy and reduce reliance on mainland generation for supply of local grid		
Electricity grid network reinforcement	Additional sub-sea cabling between Islay and Jura and further reinforcement of links from Colonsay to the mainland to develop a more resilient network capable of using increased mainland supply		

How the community experience might change

Changes to the systems that supply power, heat and transport on Islay will mean changes to the way in which the community uses and consumes this energy.

Examples of what these changes might mean are summarised here. These are supported with examples of change in other communities where relevant.

Power network management

The existing electricity grid is designed to enable large power generating units (multi-MW) to send electricity out to end users. It has had to adapt this design as more renewable generation (low MW or smaller) has been installed in local areas.

A smart grid system uses digital controls to prioritise how renewable electricity is used in a local network. This means that the network can balance overall electricity supply, while using as much of the renewable power in the local area where it is generated.

One example of matching local renewable electricity with local demand was the ACCESS project on Mull. In this case it developed a system so that electric heaters in homes could be matched with the local hydro scheme's electricity output. This did not change the ability of people in their homes being able to control when their heaters were operating. What it showed was the ability to look at power flows in a local area of the electricity network and match loads in a way that maintained the required set limits for network operation.

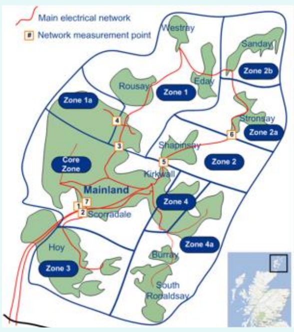
ACCESS Project, Isle of Mull

Domestic heaters were fitted with remote-control units so that a cloud-based 'brain' could switch them on or off in real-time to match the local hydro scheme's generation output. Controls at the hydro station communicated with the central 'brain' so that generator output was controlled remotely. The trial proved that electricity network power flows could be adjusted within the set limits for network operation.

An extension of this type of system enables active network management (ANM) of a section of the electricity network. In this case real time information is used to safely manage generation connections on the network.

Active Network Management, Orkney

The system measures the power flows at several measurement points on the network and controls multiple renewable generators that are part of the scheme. The network is divided into zones which represent constraint points in the network and the system receives real time information from the measurement points.



An example of the ANM approach is operating on Orkney. In this case the main electricity network on the islands has been divided into management zones. Within each zone is monitoring equipment that sends a signal to the central system if generation reaches the constraint limit on the zone. This then enables generation to be turned down (curtailed) or switched off (stopped).

This approach enables best use of renewable energy generation while avoiding generators having to contribute large amounts of extra investment in new network cables and switchgear.

Offshore generation (tidal)

There are a number of designs of tidal devices to generate electricity. Tidal turbines, that look a little like wind turbines, are one design that is being looked at for use in the Sound of Islay. The design is similar to turbines installed in Bluemull sound off Shetland. Each turbine has a capacity of 100 kW so can be installed in a phased manner that suits the level of demand in the local area. Larger turbine designs (1.0 – 2.0 MW each) are also available;

designs similar to these are deployed on the MeyGen project in the Pentland Firth off the North coast of Scotland. This will eventually have a generating capacity of nearly 400 MW if all phases of the project are completed.

It is estimated that up to 10 MW of capacity could be installed within the Sound of Islay with more opportunities of a similar scale in other areas further from shore. If this scale of generation were developed this would approximately double the local ability to meet electricity demand. Managed efficiently this would make the local network less prone to disruption due to issues with supply from the mainland. It would be easier to switch to electric heating from other fuels such as oil and solid fuel.

Offshore generation (wind)

Offshore wind turbines are much larger than the tidal turbines that might be installed in the Sound of Islay. The scale of difference is illustrated in the difference in rotor diameter. In the case of a tidal turbine the rotor diameter is around 8.5m; by contrast for an offshore wind turbine the rotor diameter is around 220 m (i.e. roughly 25 times larger). By way of comparison, the tallest building in Scotland (the Glasgow Tower) is 127 m in height.

The amount of electricity generation from offshore wind is therefore much larger than that from tidal devices (GW capacity rather than MW). Not all output from an offshore wind farm would be connected to Islay; however, even a small proportion of total output would be many times more than the tidal array output.

This would mean that the ability to meet electricity needs on the island would be hugely increased making use of electricity for heating and transport much easier.

Heat Pumps

Heat pumps use electricity to power the equipment needed to take heat from a primary source to where it can be used. The source of heat can be the air, ground or water.

Heat pumps can be used in individual buildings or can be sized to provide heat for a number of buildings using a shared connection.

There are examples of ground source heat pumps already used in Port Charlotte for a number of homes; there are also a number of air source heat pumps installed in individual buildings across the island. Argyll Community Housing Association (ACHA) plan to install air source heat pump systems in around 120 of their properties on Islay replacing wet electric systems in some homes and storage heaters in others.

Air Source Heat Pumps, West Highland Housing Association

A programme of retrofit work is ongoing with installation of 145 air source heat pumps and Sunamp heat batteries in WHHA properties.

2. Energy System Scenarios

This section provides outline scenarios that incorporate changes to the power, heat and transport supply on Islay

2.1 Scenario 1 – Low Carbon Oil and Gas

Sources of energy that can be used	Current	Short Term (2020 – 2025)	Medium Term (2025 – 2030)	Long Term (2030 onwards)
Heat	**Non-domestic**			
	Fuel oil Electric	HVO Biogas Electric	Biogas Electric	Biogas Electric Hydrogen
	Domestic			
	Oil Electric	Heat Pump Electric	Heat Pump Electric	Heat Pump Electric
Power	Grid Diesel stand-by Onshore renewables	Tidal Diesel stand-by Onshore renewables	Tidal Offshore Wind Onshore renewables Battery storage	Tidal Offshore wind Onshore renewables Battery storage
Transport	**Passenger Vehicles/Light Goods Vans**			
	Petrol / Diesel	EV Petrol / Diesel	EV	EV
	Buses, HGVs, Ferries, Aircraft, Other			
	Diesel / Gas Oil MFO Jet Fuel	Diesel / Gas Oil MFO Jet Fuel	Electric / Hydrogen MFO Jet Fuel	Electric / Hydrogen

System Changes	Commentary
Fuel switching	Initial decarbonisation of heat will be achieved via switch from fuel oil to HVO
Anaerobic digestion	Development of on island capacity for biogas generation provides contribution to further decarbonisation of heat at distilleries in South of island
Tidal generation	Tidal generation provides additional generation supporting electrification of residential heating (heat pumps and direct electric)
Additional phased tidal generation	As capacity is increased so electrification of distillery heat can be achieved Wider EV charging point network supports switch of cars and light goods vehicles to EV (including tourist traffic)
Offshore wind	Additional capacity provides ability to continue electrification of heat Power availability enables use of electrolysers to generate hydrogen
Hydrogen	Green hydrogen production supports further decarbonisation of process heat in distilleries and fuel switch for larger vehicles. Potential source of fuel for ferries and aircraft (hybrid and or electric)

Scenario 1	Now	Short Term (2020 – 25)	Medium Term (2025 – 30)	Long Term (2030+)
Heat (Distilleries)	Fuel Oil	HVO / Biogas	HVO / Biogas / Electric	Electric / Hydrogen
Heat (Non-domestic)	Oil / Electric / Biomass	Limited switch to electric; biomass	Electric heating; some heat pumps; biomass	Electric heating; some heat pumps; biomass
Heat (Domestic)	Oil / Electric	Fuel switch oil to electric	Extend use of heat pumps, electric boilers	Mainly electric; small scale heat networks
Power	Grid / Wind Diesel (standby)	Tidal / Grid / Wind CMZ (Diesel/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)
Transport	Diesel / Petrol	EV / Diesel	EV / Diesel / Hydrogen	EV / Hydrogen

Outline development actions

An outline of the development actions in this scenario is summarised here.

Timeframe	Stages of development	Changes to energy system	Development actions
2020 - 2025	Distilleries to convert boiler fuel from fuel oil to biofuel (HVO)	Reduced GHG emissions from process heat	Fuel specification agreement between all distilleries (2020) Fuel supplier to source new fuel and supply chain agreement 2021
2020 – 2025	Anaerobic digestion (AD) plant to be developed in South of the Island receiving co-products from local distilleries	Biogas source for further fuel switch in process heat	Development agreement between participating distilleries (2021) Feasibility and planning consent completed (2023) Build and commission complete (2024/25)
2020 – 2025	Offshore tidal development online	Associated grid capacity constraints alleviated Initial reduction in grid electricity import by non-domestic users	Tidal development design and planning consent completed (2021) First phase commission (2023) Initial non-domestic users sign power purchase agreement with tidal power operator (2024) Second phase commission (2025)
2020 – 2025	Electric vehicle infrastructure	Develop EV charging infrastructure to support passenger vehicles Charging infrastructure at ferry port to support future new vessel hybrid	A&BC / Business to seek Transport Scotland funding support to roll out further EV charging points Tidal developer / SSEN / Community determine CMAL infrastructure requirements to support new vessel
2020 - 2025	Electrification of residential heating	Energy efficiency measures supported to reduce heat demand Roll out of heat pumps and/or electric heating to replace oil	Social landlords to continue investment programme in line with Scottish Government targets Private owners to be supported via Scottish / UK Government access to funding (Third party agencies e.g. EST, IET). Potential support via A&BC Local Heat & Energy Efficiency Strategy
2025 – 2030	Electrification of heating for some distilleries	Switch from HVO to renewable electricity	Extended tidal power capacity offers greater supply vis power purchase agreements Electrification developed and commissioned (2028 – 2030)
2025 – 2030	Battery storage (linked with offshore capacity)	Electric battery storage replaces diesel generators as primary back up (along with Jura hydro)	SSEN invest in battery storage as part of asset renewal programme (2028 – 2030)
2025 – 2030	Electrolysers begin hydrogen production	Hydrogen fuel for distillery boilers Replacement of diesel fuel in HGVs, buses	Distillery investment supports initial electrolyser development (2028 – 2030) Community investment (A&BC, IET, others) supports hydrogen production for HGVs/buses (2028 – 2030)
2030 -	Hydrogen as potential fuel source for wider transport	Ferries, aircraft	Community, A&BC, HIAL and CMAL develop supply agreement for ferries and/or aircraft (2030)

Enabling Actions

There are a number of enabling actions that support this transition.

- Energy efficiency – Effective decarbonisation of heat demand on the island needs a continued focus on efficiency of energy use across all sectors of the community. Continued investment support should be sought for all sectors via sources such as:
  - Non-domestic – Industrial Energy Transformation Fund (IETF), Scottish Manufacturing Advisory Service (SMAS), HIE Sustainability Support, Energy Efficiency Business Support (EEBS), future Scottish/UK Government funding streams
  - Domestic – RSL (via EESSH2 targets), Home Energy Scotland (owner occupiers and private landlords) and future emerging funding streams
- Revision of fuel duty on HVO – A full HVO switch will mean higher fuel costs for distilleries due to existing duty payable on biofuels used in stationary sources. A revision of fuel duty would lower wholesale prices (potentially in same manner as current fuel duty relief on the island)
- Anaerobic digestion – There is no cost avoidance benefit to distilleries by using pot ale in AD rather than the current disposal route. No feed-in tariff is available for biogas production. Viability is enhanced by a pooled resource approach with third party development and operation on behalf of several distilleries
- Tidal development – Development costs at present would require a higher sale price than presently paid on the island for electricity (~ £150/MWh). Revised tariff position in respect of system use charges could make economics more favourable
- Distribution network management – Extending the generation capacity offshore (both tidal and wind) would be assisted by extension of the existing Constraint Managed Zone (CMZ) arrangements to an automated network management system or similar

Initial Benefit Analysis

While not providing a detailed technical assessment and associated financial model for each of the investment actions listed it is useful to consider broad-based benefits and limitations of each here.

Table 2.1 Overview of initial benefit analysis (Scenario 1)

	Benefit	Limitation
GHG Emissions	Fuel switch to HVO offers net GHG emissions reduction Domestic/Non-domestic switch from fuel/heating oil to electricity further reduces GHG emissions (heating) Switch from petrol/diesel to electric (small vehicles) reduces transport emissions Move to electric/hydrogen heating in distilleries further reduces GHG emissions Electric/hydrogen fuel for vehicles reduces GHG emissions associated with bus service and HGVs	Use of HVO retains fuel delivery vehicle runs across island Biogas production sufficient for only proportion of overall heating energy requirements Management system to minimise GHG emissions associated with vehicle replacement required
End user costs	Local AD production provides biogas at lower price than fuel oil	Currently limited sources of HVO production within Europe so potential competition for supply (associated price pressure

	Benefit	Limitation
	Initial phase of offshore generation lowers cost of electricity (power and heat) Further offshore generation lowers cost of electricity (power, heat and small vehicle transport) Reduced net operating costs of vehicles (electric/hydrogen)	Initial oil to electric switch in domestic heating cost neutral due to retained grid electricity prices Investment required to enable fuel switch to biogas, electric / hydrogen (distilleries); electric heating (other users)
Security of supply	Local AD facility reduces reliance on imported fuel oil Offshore generation increases local generation capacity reducing impact of maintenance/failure of distribution system from mainland Transport fuel switching to EV (small vehicles) reduces imported fuel requirements Switch to electric/hydrogen dominated system enable island to develop an energy system that is broadly self-sufficient Capacity to support local energy supply for ferry and aircraft operating to Islay	Use of HVO retains reliance on imported fuel supplies to Islay Some grid distribution network reinforcement work required to support additional capacity Investment in electric vehicle charging infrastructure required to support switch from petrol/diesel
Wider environment	Increased local air quality due to reduction in fuel oil and heating oil use Electrification of transport reduces particulate emissions (diesel/petrol) and impact of tourist traffic on local air quality	Electrolysers need water to produce hydrogen. This will mean higher demand for potable water or processing of sea water. Either route will need investment to avoid competition for existing water supply

Commentary

Non-domestic heat requirements are central to this scenario, enabling a shift from fuel oil as the primary fuel source to a mix of biogas, electricity and hydrogen across the distilling sector.

Initial fuel switching to HVO provides for a significant short-term GHG emission reduction with minimal investment requirements to adjust boiler configurations for heat supply. This would need a consensus regarding the specific fuel grade substitute to enable adjustment of supply shipments and storage of fuel on the island.

Development of an anaerobic digestion plant, pooling resource from a cluster of distilleries, provides a production route for biogas. While this requires investment in dual fuel burners it reduces the overall demand for HVO and therefore frequency of delivery requirements. If the pipework transporting the biogas is specified so as to be capable of transporting hydrogen as well then this provides some future proofing for further changes in energy use.

Availability of tidal power, initially at 1 MW, but increasing to 3 MW, provides generation capacity to support electrification of heating in residential properties. This includes direct electric heating, electric boilers and heat pump systems as suited to each property.

There is also potential to support electrification of heating systems in distilleries.

Underpinning ongoing system changes for supply for heat will be energy efficiency work in distilleries and the residential stock. Process efficiency may support heat recovery at distilleries where there are surrounding houses that could be fed via a small heat network. These synergies can be explored. Wider building fabric improvements will support efficient use of heat in residential and other non-domestic properties.

For transport, a wider network of EV charging points can be rolled out. This may include a battery storage facility at the ferry ports to support roll out of new hybrid vessels.

As offshore wind capacity becomes available this offers further capacity for electrification of heating across residential and non-domestic properties on the island. Integrated battery storage will provide scope for a combination of smart network management (managing local balancing of demand and supply) and low carbon backup (in preference to standby diesel generators).

At this stage green hydrogen production can also be sustained using offshore generation to supply electrolysers to generate hydrogen for local use by distilleries for heat, and more widely to fuel HGVs.

2.2 Scenario 2 – Low Carbon Gas

Sources of energy that can be used	Current	Short Term (2020 – 2025)	Medium Term (2025 – 2030)	Long Term (2030 onwards)
Heat	**Non-domestic**			
	Fuel oil Electric	CNG Biogas Electric	CNG Biogas Electric	Biogas Electric Hydrogen
	Domestic			
	Oil Electric	Heat Pump Electric	Heat Pump Electric	Heat Pump Electric
Power	Grid Diesel stand-by Onshore renewables	Tidal Diesel stand-by Onshore renewables	Tidal Offshore Wind Onshore renewables	Tidal Offshore wind Onshore renewables Battery storage
Transport	**Passenger Vehicles/Light Goods Vans**			
	Petrol / Diesel	EV Petrol / Diesel	EV	EV
	Buses, HGVs, Ferries, Aircraft, Other			
	Diesel / Gas Oil MFO Jet Fuel	Diesel / Gas Oil MFO Jet Fuel	Electric / Hydrogen MFO Jet Fuel	Hydrogen

System Overview	Commentary
Fuel switching	Initial decarbonisation of heat will be achieved via switch from fuel oil to CNG
Anaerobic digestion	Development of on island capacity for biogas generation provides contribution to further decarbonisation of heat at distilleries in South of island
Tidal generation	Tidal generation provides additional generation supporting electrification of residential heating (heat pumps and direct electric)
Additional phased tidal generation	As capacity is increased so electrification of distillery heat can be achieved Wider network of EV charging points supports switch of passenger cars and light goods vehicles to EV (including tourist traffic)
Offshore wind	Additional capacity provides ability to continue electrification of heat Power availability enables use of electrolysers to generate hydrogen
Hydrogen	Green hydrogen production supports further decarbonisation of process heat in distilleries and becomes available to support fuel switch for larger vehicles. Potential fuel options can support low carbon ferry and aircraft operation (hydrogen or electric)

Scenario 2	Now	Short Term (2020 – 25)	Medium Term (2025 – 30)	Long Term (2030+)
Heat (Distilleries)	Fuel Oil	CNG / Biogas	CNG / Biogas / Electric	Electric / Hydrogen
Heat (Non-domestic)	Oil / Electric / Biomass	Limited switch to electric; biomass	Electric heating; some heat pumps; biomass	Electric heating; some heat pumps; biomass
Heat (Domestic)	Oil / Electric	Fuel switch oil to electric	Extend use of heat pumps, electric heating	Mainly electric; small scale heat networks
Power	Grid / Wind Diesel (standby)	Tidal / Grid / Wind CMZ (Diesel/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)
Transport	Diesel / Petrol	EV / Diesel	EV / Diesel / Hydrogen	EV / Hydrogen

Outline development actions

An outline of the development actions in this scenario is summarised here.

Timeframe	Stages of development	Changes to energy system	Development actions
2020 - 2025	Distilleries to convert boiler fuel from fuel oil to CNG	Reduced GHG emissions from process heat	Fuel specification agreement between all distilleries (2020) Fuel supplier to source new fuel and supply chain agreement 2021
2020 – 2025	Anaerobic digestion (AD) plant to be developed in South of the Island receiving co-products from local distilleries	Biogas source for further fuel switch in process heat	Development agreement between participating distilleries (2021) Feasibility and planning consent completed (2023) Build and commission complete (2024/25)
2020 – 2025	Offshore tidal development online	Associated grid capacity constraints alleviated Initial reduction in grid electricity import by non-domestic users	Tidal development design and planning consent completed (2021) First phase commission (2023) Initial non-domestic users sign power purchase agreement with tidal power operator (2024) Second phase commission (2025)
2020 – 2025	Electric vehicle infrastructure	Develop EV charging infrastructure to support passenger vehicles Charging infrastructure at ferry port to support future new vessel hybrid	A&BC / Business to seek Transport Scotland funding support to roll out further EV charging points Tidal developer / SSEN / Community determine CMAL infrastructure requirements to support new vessel
2020 - 2025	Electrification of residential heating	Energy efficiency measures supported to reduce heat demand Roll out of heat pumps and/or electric heating to replace oil	Social landlords to continue investment programme in line with Scottish Government targets Private owners to be supported via Scottish / UK Government access to funding (Third party agencies e.g. EST, IET). Potential support via A&BC Local Heat & Energy Efficiency Strategy
2025 – 2030	Electrolysers begin hydrogen production	Hydrogen fuel for distillery boilers Replacement of diesel fuel in HGVs, buses	Distillery investment supports initial electrolyser development (2028 – 2030) Community investment (A&BC, IET, others) supports hydrogen production for HGVs/buses (2028 – 2030)
2025 – 2030	Offshore wind online	Adds to electricity capacity on the island	Extended capacity offers greater supply via power purchase agreements (2030) Electrification of heat developed and commissioned (2028 – 2030)
2025 – 2030	Battery storage (linked with offshore capacity)	Electric battery storage replaces diesel generators as primary back up (along with Jura hydro)	SSEN invest in battery storage as part of asset renewal programme (2028 – 2030)
2025 – 2030	Hydrogen as potential fuel source for wider transport	Ferries, aircraft	Community, A&BC, HIAL and CMAL develop supply agreement for ferries and/or aircraft (2030)

Enabling Actions

There are a number of enabling actions that support this transition.

- Energy efficiency – Effective decarbonisation of heat demand on the island needs a continued focus on efficiency of energy use across all sectors of the community. Continued investment support should be sought for all sectors via sources such as:

    - Non-domestic – Industrial Energy Transformation Fund (IETF), Scottish Manufacturing Advisory Service (SMAS), HIE Sustainability Support, Energy Efficient Business Support, future Scottish/UK Government funding streams
    - Domestic – RSL (via EESSH2 targets), Home Energy Scotland (owner occupiers and private landlords) and future emerging funding streams

- Anaerobic digestion – There is no cost avoidance benefit to distilleries by using pot ale in AD rather than the current disposal route. No feed-in tariff is available for biogas production. Viability is enhanced by a pooled resource approach with third party development and operation on behalf of several distilleries
- Tidal development – Development costs at present would require a higher sale price than presently paid on the island for electricity (~ £150/MWh). Revised tariff position in respect of system use charges could make economics more favourable
- Distribution network management – Extending the generation capacity offshore (both tidal and wind) would be assisted by extension of the existing Constraint Managed Zone (CMZ) arrangements to an automated network management system or similar

Initial Benefit Analysis

While not providing a detailed technical assessment and associated financial model for each of the investment actions listed it is useful to consider broad-based benefits and limitations of each here.

Table 2.2 Overview of initial benefit analysis (Scenario 2)

	Benefit	Limitation
GHG Emissions	Fuel switch to CNG offers net GHG emissions reduction Domestic/Non-domestic switch from fuel/heating oil to electricity further reduces GHG emissions (heating) Switch from petrol/diesel to electric (small vehicles) reduces transport emissions Move to electric/hydrogen heating in distilleries further reduces GHG emissions Electric/hydrogen fuel for vehicles reduces GHG emissions associated with bus service and HGVs	Use of CNG retains fuel delivery vehicle runs across island Biogas production sufficient for only proportion of overall heating energy requirements Management system to minimise GHG emissions associated with vehicle replacement required
End user costs	Local AD production provides biogas at lower price than fuel oil Initial phase of offshore generation lowers cost of electricity (power and heat) Further offshore generation lowers cost of electricity (power, heat and small vehicle transport) Reduced net operating costs of vehicles (electric/hydrogen)	Currently limited sources of CNG production within UK and Europe so potential competition for supply (associated price pressure Initial oil to electric switch in domestic heating cost neutral due to retained grid electricity prices Investment required to enable fuel switch to biogas, electric / hydrogen (distilleries); electric heating (other users)
Security of supply	Local AD facility reduces reliance on imported fuel oil	Use of CNG retains reliance on imported fuel supplies to Islay Some grid distribution network reinforcement work required to support additional capacity

	Benefit	Limitation
	Offshore generation increases local generation capacity reducing impact of maintenance/failure of distribution system from mainland Transport fuel switching to EV (small vehicles) reduces imported fuel requirements Switch to electric/hydrogen dominated system enable island to develop an energy system that is broadly self-sufficient Capacity to support local energy supply for ferry and aircraft operating to Islay	Investment in electric vehicle charging infrastructure required to support switch from petrol/diesel
Wider environment	Increased local air quality due to reduction in fuel oil and heating oil use Electrification of transport reduces particulate emissions (diesel/petrol) and impact of tourist traffic on local air quality	Increased water consumption associated with green hydrogen production needs to be managed to avoid water stress issues

Commentary

A fuel switch by distilleries from fuel oil to CNG as the primary fuel source for heat would require investment in dual burners and associated steam raising systems. However, this upfront investment offers a route to lower carbon gas fuels (either local biogas or hydrogen) as a future fuel switch with relatively modest additional capital costs. A fuel supply system similar to that already implemented at distilleries on the mainland is feasible, requiring a local gas handling facility to enable storage and distribution of gas on Islay.

Development of an Anaerobic Digestion facility in the South of the island would provide a shared resource for production of biogas, reducing the scale of imported CNG requirements for Islay as a whole.

Opportunities for supply of waste heat from distilleries into public buildings, or small-scale communal (district) heating systems can be explored. These would require third party management and operation.

A first phase of tidal power development in the Sound of Islay (~ 1 MW capacity) provides additional generation available for residential heating (fuel switch from existing oil-based systems).

There would also be scope to support development of an EV charging network on the island. This would support a shift to EVs among passenger vehicles and reduction in air emissions impact from tourist vehicles visiting the island.

Further phases of tidal power support the continued electrification of passenger and light goods vehicles on the island as well electrification of heat within residential properties.

The combination of additional tidal power generation and availability of hydro generation capacity from the Inver hydro facility on Jura can provide a backup supply via the ongoing Constraint Managed Zone (CMZ) to minimise need to use diesel generation at the Bowmore station.

The enhanced security of electricity supply achieved via availability of tidal power enables a further shift by some distilleries to electrification of heat. This is likely to require a combination of electrical and hydrogen based supply. Small scale hydrogen production (via electrolysis) could be feasible at this stage, supplemented with hydrogen produced elsewhere in the region. There are likely to be emerging hubs of production for hydrogen at this stage within the Oban or wider Kintyre peninsula given ongoing interest in decarbonisation of freight vehicles and ferries.

Offshore wind generation can provide an additional supply to Islay. This would facilitate increased hydrogen production supporting the shift to electrification and hydrogen within majority of distilleries.

Hydrogen fuelling infrastructure can then support full-scale shift from diesel within HGV fleet, as well as potential emerging requirements for ferries and/or aircraft.

Agricultural vehicles running either as electric battery powered or hybrid fuel cell solutions, may be available in the market at this point enabling decarbonisation of this sector of transport on the island.

2.3 Scenario 3 - Electric

Sources of energy that can be used	Current	Short Term (2020 – 2025)	Medium Term (2025 – 2030)	Long Term (2030 onwards)
Heat	**Non-domestic**			
	Fuel oil Electric	HVO Electric	HVO Electric	Electric
	Domestic			
	Oil Electric	Heat Pump Electric	Heat Pump Electric	Heat Pump Electric
Power	Grid Diesel stand-by Onshore renewables	Tidal Diesel stand-by Onshore renewables	Tidal Offshore Wind Onshore renewables Battery storage	Tidal Offshore wind Onshore renewables Battery storage
Transport	**Passenger Vehicles/Light Goods Vans**			
	Petrol / Diesel	EV Petrol / Diesel	EV	EV
	Buses, HGVs, Ferries, Aircraft, Other			
	Diesel / Gas Oil MFO Jet Fuel	Diesel / Gas Oil MFO Jet Fuel	Electric /Biodiesel MFO Jet Fuel	Biodiesel

System Overview	Commentary
Fuel switching	Initial decarbonisation of heat will be achieved via switch from fuel oil to HVO
Tidal generation	Tidal generation provides additional generation supporting electrification of residential heating (heat pumps and direct electric)
Additional phased tidal generation	As capacity is increased so electrification of distillery heat can be achieved Wider network of EV charging points supports switch of passenger cars and light goods vehicles to EV (including tourist traffic)
Offshore wind	Additional capacity provides ability to continue electrification of heat for non-domestic and domestic users
Biodiesel	On-island ABE production of biobutanol and bioethanol provides fuel for HGVs and agricultural vehicles. Potential support for aircraft.

Scenario 3	Now	Short Term (2020 – 25)	Medium Term (2025 – 30)	Long Term (2030+)
Heat (Distilleries)	Fuel Oil	HVO	HVO / Electric	Electric
Heat (Non-domestic)	Oil / Electric / Biomass	Limited switch to electric; biomass	Electric heating; some heat pumps; biomass	Electric heating; some heat pumps; biomass
Heat (Domestic)	Oil / Electric	Fuel switch oil to electric	Extend use of heat pumps, electric heating	Mainly electric; small scale heat networks
Power	Grid / Wind Diesel (standby)	Tidal / Grid / Wind CMZ (Diesel/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)
Transport	Diesel / Petrol	EV / Diesel	EV / Diesel / Biodiesel	EV / Biodiesel

Outline development actions

An outline of the development actions in this scenario is summarised here.

Timeframe	Stages of development	Changes to energy system	Development Actions
2020 - 2025	Distilleries to convert boiler fuel from fuel oil to biofuel (HVO)	Reduced GHG emissions from process heat	Fuel specification agreement between all distilleries (2020) Fuel supplier to source new fuel and supply chain agreement (2021)
2020 – 2025	Offshore tidal development online	Associated grid capacity constraints alleviated Initial reduction in grid electricity import by non-domestic users	Tidal development design and planning consent completed (2021) First phase commission (2023) Initial non-domestic users sign power purchase agreement with tidal power operator (2024) Second phase commission (2025)
2020 – 2025	Electric vehicle infrastructure	Develop EV charging infrastructure to support passenger vehicles Charging infrastructure at ferry port to support future new vessel hybrid	A&BC / Business to seek Transport Scotland funding support to roll out further EV charging points Tidal developer / SSEN / Community determine CMAL infrastructure requirements to support new vessel
2020 - 2025	Electrification of residential heating	Energy efficiency measures supported to reduce heat demand Roll out of heat pumps and/or electric heating to replace oil	Social landlords to continue investment programme in line with Scottish Government targets Private owners to be supported via Scottish / UK Government access to funding (Third party agencies e.g. EST, IET). Potential support via A&BC Local Heat & Energy Efficiency Strategy
2025 – 2030	Electrification of heating for some distilleries	Switch from HVO to renewable electricity	Extended capacity offers greater supply via power purchase agreements (2025) Electrification of heat developed and commissioned (2028 – 2030)
2025 – 2030	Offshore wind online	Adds to electricity capacity on the island	Extended capacity offers greater supply via power purchase agreements (2030) Electrification of heat developed and commissioned (2028 – 2030)
2025 – 2030	Battery storage (linked with offshore capacity)	Electric battery storage replaces diesel generators as primary back up (along with Jura hydro)	SSEN invest in battery storage as part of asset renewal programme (2028 – 2030)
2025 – 2030	Biodiesel production from ABE fermentation on island	Replacement of diesel fuel in HGVs, agricultural vehicles	Celtic Renewables invest in on-island facility and agree use of pot ale as feedstock (2027 – 2030) Supply agreement with local fuel retailers to sell biodiesel on island (2030)
2025 – 2030	Electricity for buses	Electric bus fleet	Community, A&BC, develop bus replacement plan with contractor (2025 - 27)

Enabling Actions

There are a number of enabling actions that support this transition.

- Energy efficiency – Effective decarbonisation of heat demand on the island needs a continued focus on efficiency of energy use across all sectors of the community. Continued investment support should be sought for all sectors via sources such as:

  - Non-domestic – Industrial Energy Transformation Fund (IETF), Scottish Manufacturing Advisory Service (SMAS), HIE Sustainability Support, Energy Efficient Business Support, future Scottish/UK Government funding streams
  - Domestic – RSL (via EESSH2 targets), Home Energy Scotland (owner occupiers and private landlords) and future emerging funding streams
- Tidal development – Development costs at present would require a higher sale price than presently paid on the island for electricity (~ £150/MWh). Revised tariff position in respect of system use charges could make economics more favourable
- Distribution network management – Extending the generation capacity offshore (both tidal and wind) would be assisted by extension of the existing Constraint Managed Zone (CMZ) arrangements to an automated network management system or similar

Initial Benefit Analysis

While not providing a detailed technical assessment and associated financial model for each of the investment actions listed it is useful to consider broad-based benefits and limitations of each here.

Table 2.3 Overview of initial benefit analysis (Scenario 3)

	Benefit	Limitation
GHG Emissions	Fuel switch to HVO offers net GHG emissions reduction Domestic/Non-domestic switch from fuel/heating oil to electricity further reduces GHG emissions (heating) Switch from petrol/diesel to electric (small vehicles) reduces transport emissions Move to electric heating in distilleries further reduces GHG emissions Electric/biodiesel fuel for vehicles reduces GHG emissions associated with bus service and HGVs	Use of HVO retains fuel delivery vehicle runs across island Biodiesel doesn't offer same scale of reduction as hydrogen fuel route for vehicles Management system to minimise GHG emissions associated with vehicle replacement required
End user costs	Initial phase of offshore generation lowers cost of electricity (power and heat) Further offshore generation lowers cost of electricity (power, heat and small vehicle transport) Reduced net operating costs of vehicles (electric/biodiesel)	Currently limited sources of HVO production within Europe so potential competition for supply (associated price pressure Initial oil to electric switch in domestic heating cost neutral due to retained grid electricity prices Investment required to enable fuel switch to biogas, electric (distilleries); electric heating (other users)
Security of supply	Offshore generation increases local generation capacity reducing impact of maintenance/failure of distribution system from mainland Transport fuel switching to EV (small vehicles) reduces imported fuel requirements Switch to electric/biodiesel dominated system enable island to develop an energy system that is broadly self-sufficient Capacity to support local energy supply for ferry and aircraft operating to Islay	Use of HVO retains reliance on imported fuel supplies to Islay Some grid distribution network reinforcement work required to support additional capacity Investment in electric vehicle charging infrastructure required to support switch from petrol/diesel Use of biodiesel relies on local production plant investment being delivered

	Benefit	Limitation
Wider environment	Increased local air quality due to reduction in fuel oil and heating oil use Electrification of transport reduces particulate emissions (diesel/petrol) and impact of tourist traffic on local air quality	Increased water consumption associated with green hydrogen production needs to be managed to avoid water stress issues

Commentary

Non-domestic heat requirements are central to this scenario, enabling a shift from fuel oil as the primary fuel source to electricity across the distilling sector.

Initial fuel switching to HVO provides for a significant short-term GHG emission reduction with minimal investment requirements to adjust boiler configurations for heat supply. This would need a consensus regarding the specific fuel grade substitute so as to enable adjustment of supply shipments and storage of fuel on the island.

Availability of tidal power, initially at 1 MW, but increasing to 3 MW, provides generation capacity to support electrification of heating within a small number of distillery sites.

Residential property currently using heating oil could begin to transition to electric heating systems. This includes direct electric heating, electric boilers and heat pump systems as suited to each property.

For transport, a wider network of EV charging points can be rolled out. This may include battery storage at the ferry ports to support roll out of new hybrid vessels.

As offshore wind capacity becomes available this offers further capacity for electrification of heating across residential and non-domestic properties on the island. Integrated battery storage will provide scope for a combination of smart network management (managing local balancing of demand and supply) and low carbon backup (in preference to standby diesel generators).

Opportunities for supply of waste heat from distilleries into public buildings, or small-scale communal (district) heating systems can be explored. These would require third party management and operation.

A local biodiesel production plant, using the ABE fermentation process, would provide a source of lower carbon fuel for buses, HGVs and agricultural vehicles. There is scope to extend this use to aircraft serving the island.

2.4 Scenario 4 – Biomass and biogas

Sources of energy that can be used		Current	Short Term (2020 – 2025)	Medium Term (2025 – 2030)	Long Term (2030 onwards)
Heat	**Non-domestic**				
		Fuel oil Electric	HVO Biogas Electric	HVO Biogas Biomass Electric	Biomass Electric Hydrogen
	Domestic				
		Oil Electric	Heat Pump Electric	Heat Pump Electric	Heat Pump Electric
Power		Grid Diesel stand-by Onshore renewables	Tidal Diesel stand-by Onshore renewables	Tidal Offshore Wind Onshore renewables Battery storage	Tidal Offshore wind Onshore renewables Battery storage
Transport	**Passenger Vehicles/Light Goods Vans**				
		Petrol / Diesel	EV Petrol / Diesel	EV	EV
	Buses, HGVs, Ferries, Aircraft, Other				
		Diesel / Gas Oil MFO Jet Fuel	Diesel / Gas Oil MFO Jet Fuel	Electric Hydrogen	Hydrogen

System Overview	Commentary
Fuel switching	Initial decarbonisation of heat will be achieved via switch from fuel oil to HVO
Biomass	Development of on island capacity for biomass provides contribution to further decarbonisation of heat at distilleries
Tidal generation	Tidal generation provides additional generation supporting electrification of residential heating (heat pumps and direct electric)
Additional phased tidal generation	As capacity is increased so electrification of distillery heat can be achieved Wider network of EV charging points supports switch of passenger cars and light goods vehicles to EV (including tourist traffic)
Offshore wind	Additional capacity provides ability to continue electrification of heat Power availability enables use of electrolysers to generate hydrogen
Hydrogen	Green hydrogen production supports further decarbonisation of process heat in distilleries and becomes available to support fuel switch for larger vehicles

Scenario 4	Now	Short Term (2020 – 25)	Medium Term (2025 – 30)	Long Term (2030+)
Heat (Distilleries)	Fuel Oil	HVO/Biogas	HVO /Biogas / Biomass / Electric	Electric / Hydrogen / Biomass
Heat (Non-domestic)	Oil / Electric / Biomass	Limited switch to electric; biomass	Electric heating; some heat pumps; biomass	Electric heating; some heat pumps; biomass
Heat (Domestic)	Oil / Electric	Fuel switch oil to electric	Extend use of heat pumps, electric heating	Mainly electric; small scale heat networks
Power	Grid / Wind Diesel (standby)	Tidal / Grid / Wind CMZ (Diesel/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)	Tidal / Offshore / Other CMZ (Battery/Hydro)
Transport	Diesel / Petrol	EV / Diesel	EV / Diesel / Biodiesel	EV / Biodiesel

Commentary

Timeframe	Stages of development	Changes to energy system	Development Actions
2020 - 2025	Distilleries to convert boiler fuel from fuel oil to biofuel (HVO)	Reduced GHG emissions from process heat	Fuel specification agreement between all distilleries (2020) Fuel supplier to source new fuel and supply chain agreement (2021)
2020 – 2025	Anaerobic digestion (AD) plant to be developed in South of the Island receiving co-products from local distilleries	Biogas source for further fuel switch in process heat	Development agreement between participating distilleries (2021) Feasibility and planning consent completed (2023) Build and commission complete (2024/25)
2020 – 2025	Biomass systems to provide heat to small number of distilleries	Biomass for process heat	Design and planning consent completed (2021 – 23) Wood fuel supply agreement in place (2023) Build and commission (2024 – 25)
2020 – 2025	Offshore tidal development online	Associated grid capacity constraints alleviated Initial reduction in grid electricity import by non-domestic users	Tidal development design and planning consent completed (2021) First phase commission (2023) Initial non-domestic users sign power purchase agreement with tidal power operator (2024) Second phase commission (2025)
2020 – 2025	Electric vehicle infrastructure	Develop EV charging infrastructure to support passenger vehicles Charging infrastructure at ferry port to support future new vessel hybrid	A&BC / Business to seek Transport Scotland funding support to roll out further EV charging points Tidal developer / SSEN / Community determine CMAL infrastructure requirements to support new vessel
2020 - 2025	Electrification of residential heating	Energy efficiency measures supported to reduce heat demand Roll out of heat pumps and/or electric heating to replace oil	Social landlords to continue investment programme in line with Scottish Government targets Private owners to be supported via Scottish / UK Government access to funding (Third party agencies e.g. EST, IET). Potential support via A&BC Local Heat & Energy Efficiency Strategy
2025 – 2030	Electrification of heating for some distilleries	Switch from HVO to renewable electricity	Extended capacity offers greater supply via power purchase agreements (2030) Electrification of heat developed and commissioned (2028 – 2030)

2025 – 2030	Battery storage (linked with offshore capacity)	Electric battery storage replaces diesel generators as primary back up (along with Jura hydro)	SSEN invest in battery storage as part of asset renewal programme (2028 – 2030)
2025 – 2030	Electrolysers begin hydrogen production	Hydrogen fuel for distillery boilers Replacement of diesel fuel in HGVs, buses	Distillery investment supports initial electrolyser development (2028 – 2030) Community investment (A&BC, IET, others) supports hydrogen production for HGVs/buses (2028 – 2030)
2025 – 2030	Hydrogen as potential fuel source for wider transport	Agricultural, Ferries, aircraft	Community, A&BC, HIAL and CMAL develop supply agreement for ferries and/or aircraft (2030)

Enabling Actions

There are a number of enabling actions that support this transition.

- Energy efficiency – Effective decarbonisation of heat demand on the island needs a continued focus on efficiency of energy use across all sectors of the community. Continued investment support should be sought for all sectors via sources such as:
    - Non-domestic – Industrial Energy Transformation Fund (IETF), Scottish Manufacturing Advisory Service (SMAS), HIE Sustainability Support, Energy Efficient Business Support, future Scottish/UK Government funding streams
    - Domestic – RSL (via EESSH2 targets), Home Energy Scotland (owner occupiers and private landlords) and future emerging funding streams
- Anaerobic digestion – There is no cost avoidance benefit to distilleries by using pot ale in AD rather than the current disposal route. No feed-in tariff is available for biogas production. Viability is enhanced by a pooled resource approach with third party development and operation on behalf of several distilleries
- Tidal development – Development costs at present would require a higher sale price than presently paid on the island for electricity (~ £150/MWh). Revised tariff position in respect of system use charges could make economics more favourable
- Distribution network management – Extending the generation capacity offshore (both tidal and wind) would be assisted by extension of the existing Constraint Managed Zone (CMZ) arrangements to an automated network management system or similar

Initial Benefit Analysis

While not providing a detailed technical assessment and associated financial model for each of the investment actions listed it is useful to consider broad-based benefits and limitations of each here.

Table 2.4 Overview of initial benefit analysis (Scenario 4)

	Benefit	Limitation
GHG Emissions	Fuel switch to HVO offers net GHG emissions reduction Domestic/Non-domestic switch from fuel/heating oil to electricity further reduces GHG emissions (heating) Switch from petrol/diesel to electric (small vehicles) reduces transport emissions Move to electric/hydrogen heating in distilleries further reduces GHG emissions Electric/hydrogen fuel for vehicles reduces GHG emissions associated with bus service and HGVs	Use of HVO retains fuel delivery vehicle runs across island Biogas production sufficient for only proportion of overall heating energy requirements Management system to minimise GHG emissions associated with vehicle replacement required
End user costs	Use of locally produced biomass (and draff) reduces costs of fuel oil and transport of draff Initial phase of offshore generation lowers cost of electricity (power and heat) Further offshore generation lowers cost of electricity (power, heat and small vehicle transport) Reduced net operating costs of vehicles (electric/hydrogen)	Currently limited sources of HVO production within Europe so potential competition for supply (associated price pressure Initial oil to electric switch in domestic heating cost neutral due to retained grid electricity prices Investment required to enable fuel switch to biogas, electric / hydrogen (distilleries); electric heating (other users)
Security of supply	Local biomass use reduces reliance on imported fuel oil Offshore generation increases local generation capacity reducing impact of maintenance/failure of distribution system from mainland Transport fuel switching to EV (small vehicles) reduces imported fuel requirements Switch to electric/hydrogen dominated system enable island to develop an energy system that is broadly self-sufficient Capacity to support local energy supply for ferry and aircraft operating to Islay	Use of HVO retains reliance on imported fuel supplies to Islay Some grid distribution network reinforcement work required to support additional capacity Investment in electric vehicle charging infrastructure required to support switch from petrol/diesel
Wider environment	Increased local air quality due to reduction in fuel oil and heating oil use Electrification of transport reduces particulate emissions (diesel/petrol) and impact of tourist traffic on local air quality	Increased water consumption associated with green hydrogen production needs to be managed to avoid water stress issues

Commentary

Non-domestic heat requirements are central to this scenario, enabling a shift from fuel oil as the primary fuel source to a mix of biomass, electricity and hydrogen across the distilling sector.

Initial fuel switching to HVO provides for a significant short-term GHG emission reduction with minimal investment requirements to adjust boiler configurations for heat supply. This would need a consensus regarding the specific fuel grade substitute to enable adjustment of supply shipments and storage of fuel on the island.

Locally harvested biomass provides an opportunity for a further fuel switch for a small number of distilleries. This would require processing, drying and storage facilities for the biomass. Recovery of process heat to enable drying of wood chip would be one potential solution.

Development of an Anaerobic Digestion facility in the South of the island would provide a shared resource for production of biogas, reducing the scale of imported CNG requirements for Islay as a whole.

Opportunities for supply of waste heat from distilleries into public buildings, or small-scale communal (district) heating systems can be explored. These would require third party management and operation.

Availability of tidal power, initially at 1 MW, but increasing to 3 MW, provides generation capacity to support electrification of heating within a further number of distillery sites.

Residential property currently using heating oil could begin to transition to electric heating systems. This includes direct electric heating, electric boilers and heat pump systems as suited to each property.

Opportunities for supply of waste heat from distilleries into public buildings, or small-scale communal (district) heating systems can be explored. These would require third party management and operation.

For transport, a wider network of EV charging points can be rolled out. This may include battery storage infrastructure at the ferry ports to support roll out of new hybrid vessels.

As offshore wind capacity becomes available this offers further capacity for electrification of heating across residential and non-domestic properties on the island. Integrated battery storage will provide scope for a combination of smart network management (managing local balancing of demand and supply) and low carbon backup (in preference to standby diesel generators).

At this stage green hydrogen production can also be sustained using offshore generation to supply electrolysers to generate hydrogen for local use by distilleries for heat, and more widely to fuel HGVs. Fuel for aircraft and ferries may be supported via locally produced hydrogen or battery storage.

3. Whole System Approach

This section provides a summary of how the whole system approach can deliver benefits for the whole community.

3.1 Security of supply

The current system of heat supply to meet the combined needs of industry and householders on the island relies on fossil fuels and an associated delivery network. This currently locks in, not only, the GHG emissions associated with burning fuel, but the related transport (and further GHG emissions) of fuels to and around the island.

There is also a vulnerability to power supplies due to any extended maintenance or unplanned outages along the length of the transmission and distribution system from Lochgilphead and Port Ann. Damage to sub-sea cabling in particular is costly and time-consuming to complete. Work to replace the submarine cable between Jura and the mainland in 2019/20, for example, took five months to complete. Safe working practices mean that any maintenance work on the system between the mainland and Islay results in the power being switched off and reliance on diesel back up (supported by the CMZ).

Transport fuels are also entirely imported.

While fuel switching by distilleries to either HVO (biodiesel) or CNG provides short term benefits in respect of reduced GHG emissions, it does not significantly alter the fuel movements and storage requirements in the current system.

Nor does it reduce vulnerability to limited or loss of primary fuel supplies due to processing capacity or shipping/ferry cancellations due to poor weather or vessel breakdown.

Development of significant additional power generation, via offshore wind and tidal power, is a route to greater security of supply. It enables a shift away from oil by distilleries and residents that reduces the fuel import needs and regular fuel transport to the island. It can be supported by other supplies that in isolation don't provide the scale of energy needed to support the island's needs (biogas via anaerobic digestion or locally produced biomass, for example).

A greater availability of electricity also means that larger scale battery storage can be developed. This offers a means of reducing reliance on existing diesel generators. It also supports greater use of renewable generation on the island through a smart grid approach. This would mean use of systems already deployed on Mull and Orkney where there is greater visibility to end users of the real time balance of supply and demand. This could 'prioritise' renewable generation and minimise import from mainland generation. It also enables the integration of electric vehicles and electric heating in homes.

The additional available generation also enables local production of hydrogen. This has multiple potential benefits, offering scope for energy storage (regenerating electricity to support grid balancing), transport fuel for larger vehicles (buses, agricultural vehicles and HGVs) and heating (likely in the distilleries predominantly).

3.2 Local generation

At the heart of Scotland's Energy Strategy is a recognition of the benefit of local systems developed to meet local needs. All of the scenarios outlined here develop a decarbonisation approach that uses local generation efficiently in meeting the whole system needs across power, heat and transport.

Using offshore power generation as a means of reducing fuel oil and heating oil requirements on the island reduces the associated transport burden that the distribution of these fuels requires.

Linked with further work on thermal performance of buildings, it also provides a means of directly addressing issues of fuel poverty and affordability of sustainable energy.

It provides a direct route to decarbonisation of transport, offering a local system of hydrogen production that can underpin any future wider hydrogen distribution networks across the Mid Argyll, Kintyre and Islands region.

3.3 Developing and enhancing expertise

The community has successfully implemented numerous examples of sustainable energy good practice to date, including development of the community wind turbine and recovery of waste heat for use in buildings and local swimming pool.

The intersection of power, heat and transport needs means that the emerging local energy system needs to be able to cross-link energy supply. At its best this needs collaboration between energy users and consumers to recognise how innovation can most effectively delivering change. This includes seeking and security sources of investment as well as building on existing on-island expertise to support delivery of energy projects.

As communities across Scotland continue to look at low carbon heat and transport it is important that the community on Islay can maintain a role in shaping the changing infrastructure and energy systems that this will develop.

As the changing energy system becomes more integrated it means that sources of investment are increasingly diverse since their primary target may be general innovation or aspects of heat, power of transport. The value of collaboration between community members is therefore higher in recognising where opportunities are available to secure funding for new systems or generation.

Appendix A
Supporting Information

Grid Electricity System

The primary substation feeding Islay is located at Lochgilphead.

Parameter	Unit of Measure	Value
Minimum Load	MW	0.61
Maximum Load	MW	9.57
Contracted Generation	MVA	33.89
Upstream Status		Constrained
Downstream Status		Constrained
Corresponding GSP		Port Ann
Transformer Nameplate Rating	MVA	8.0
Reverse Powerflow Capacity	%	50
Break Fault Level vs Rating	kA	7.36 / 13.1

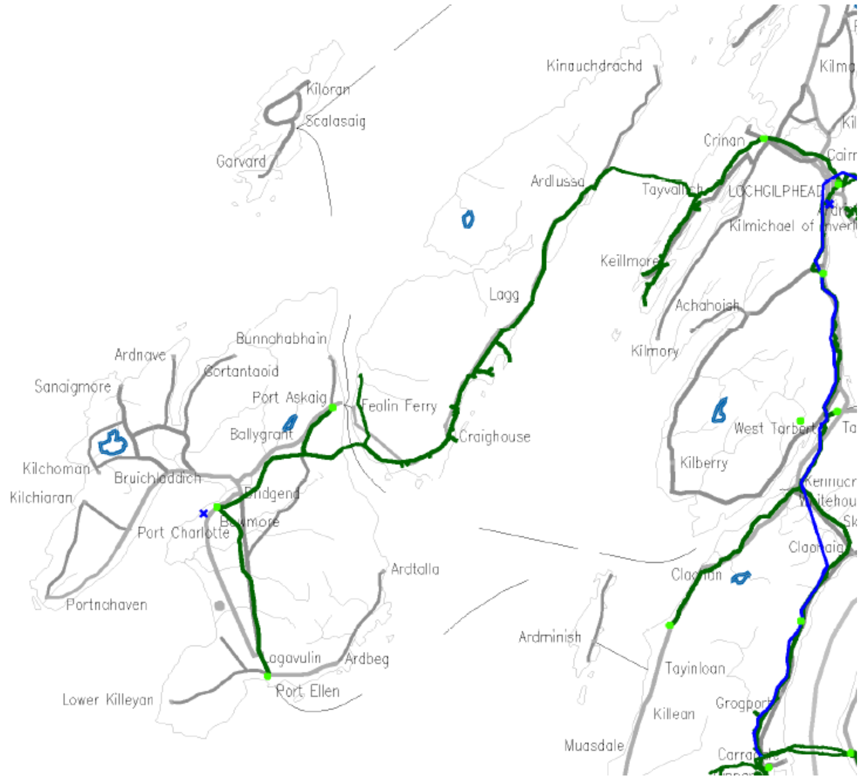
Source: https://www.ssen.co.uk/GenerationAvailabilityMap/?mapareaid=2 (Accessed September 2020)

The grid supply point is at Port Ann.

Parameter	Unit of Measure	Value
Transformer Nameplate Rating	MVA	30.0
Maximum Load	MW	26.24
Minimum Load	MW	5.80
Transmission Status		Unconstrained
Distribution Status		Unconstrained
Voltage	kV	132 / 33

The route of the 33 kV network serving Islay (Jura and Colonsay) includes two sections of sub-sea cable. The first links from the mainland at Tayvallich across to Jura; the second links Islay and Jura South of Port Askaig. A 11kV subsea cable runs from Islay to Colonsay. The extent of the 33 kV network is shown in the diagram here.

Figure A.1 Electricity network serving Islay (33 kV line)



Note: Bold dark green line represents route of 33 kV network; grey lines represent low voltage distribution system to homes and businesses; light green dots represent sub-stations

Whole system modelling works looking at the electricity supply system on Islay has estimated current electricity consumption at 18 GWh/yr with a maximum demand of 7.6 MW. There is currently around 30 MVA of capacity available at the GSP (Port Ann).[12]

Existing capacity on Islay to connect additional renewable energy generation is limited to small scale systems of 50 kW or less.

To allow larger scale generation to be connected requires investment on the mainland high voltage system to enable reinforcement of the GSP at Port Ann. Current commitments made by SSEN see work on the North Argyll 275/132 kV Substation, 275 kV double circuit tower line to Dalmally Substation and reinforcement of the existing Inveraray-Taynuilt 132 kV towerline circuit, with associated reinforcement works at Port Ann completed in late 2023 at the earliest[13]. The capacity of the subsea link between Jura and the mainland would then become the main constraint to further capacity on the Islay and Jura network.

Grid Electricity profile of demand

Electricity demand for different end users will follow typical patterns across days, weeks and months. For larger users of electricity half hourly meters record data every 30 minutes. This means that it is relatively easy to develop a profile of demand across days in the year.

Although domestic users typically only record electricity demand daily, it is possible to look at typical demand profiles created by the National Grid using aggregated information from individual users.

[12] Whole System Growth Scenario Modelling, Summary report (February 2019), Mott MacDonald on behalf of SSEN
[13] https://www.ssen.co.uk/GenerationAvailabilityMap/?mapareaid=2 (Accessed October 2020)

The shape of these profiles helps an understanding of how difficult it could be to match the changes in demand with the output from any local power generation. For example, in summer months a building will use less power for lighting than in winter months (when daylight is available for shorter periods and direct sunshine more limited). If this building is supplied via solar PV generation then the output from the solar panels is likely to be at its highest in summer months and lowest in winter months (when lighting demand in the building is at its highest). Matching the supply and demand in this case needs to consider how best to use the peak solar production in the summer and meet the shortfall in demand during winter.

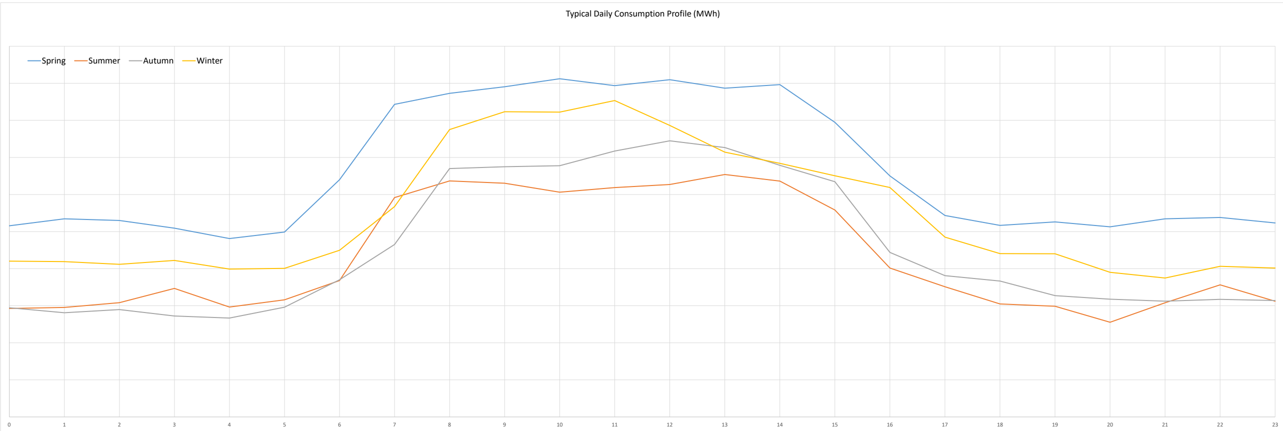
In the case of an office building electricity demand will rise in the morning as people arrive for work, peak in the middle of the day and drop relatively rapidly at the end of the working day as people leave the office.

If there is a process that requires power (e.g. a pump that moves water all day long) then this demand will remain constant over a given period. This would be reflected in a 'flat' profile since external changes don't heavily influence the demand required to support the process.

From the data provided for this study it is possible to look at simulations of demand that have been modelled by SSEN and a hybrid of data provided by individual users.

In the case of distilleries, a typical daily demand profile, based on existing demand data, for each season is shown here.

Figure A.2 Distillery – typical daily electricity demand profile



For domestic users there are representative meter profiles for two types of consumer.

- Class 1 meters are installed in homes which don't use Economy 7 (or similar), i.e. have primary heating that is not electric
- Class 2 meters are installed in homes that use Economy 7 (or similar), i.e. have primary heating that is electric

The representative daily profiles for each consumer set, for different seasons, are shown here.

In the case of Class 1 meters there are two clear spikes in demand – one in the morning (06:30 – 09:00) as people get ready and leave for work, school etc. and one in the evening when people return home (17:00 – 19:00). Peaks in demand are sharper in Autumn and Winter, and flatter in the case of Spring and Summer. This shows the impact of lighting needs and lower periods of time spent at home in later evening.

In the case of Class 2 meters a similar pattern for day-time usage is seen. However, in this case there is a higher night-time demand profile (most pronounced in winter) as storage heaters are charged while the lowest electricity cost applies.

Figure A.3 Representative meter profile (domestic user without electric heating)

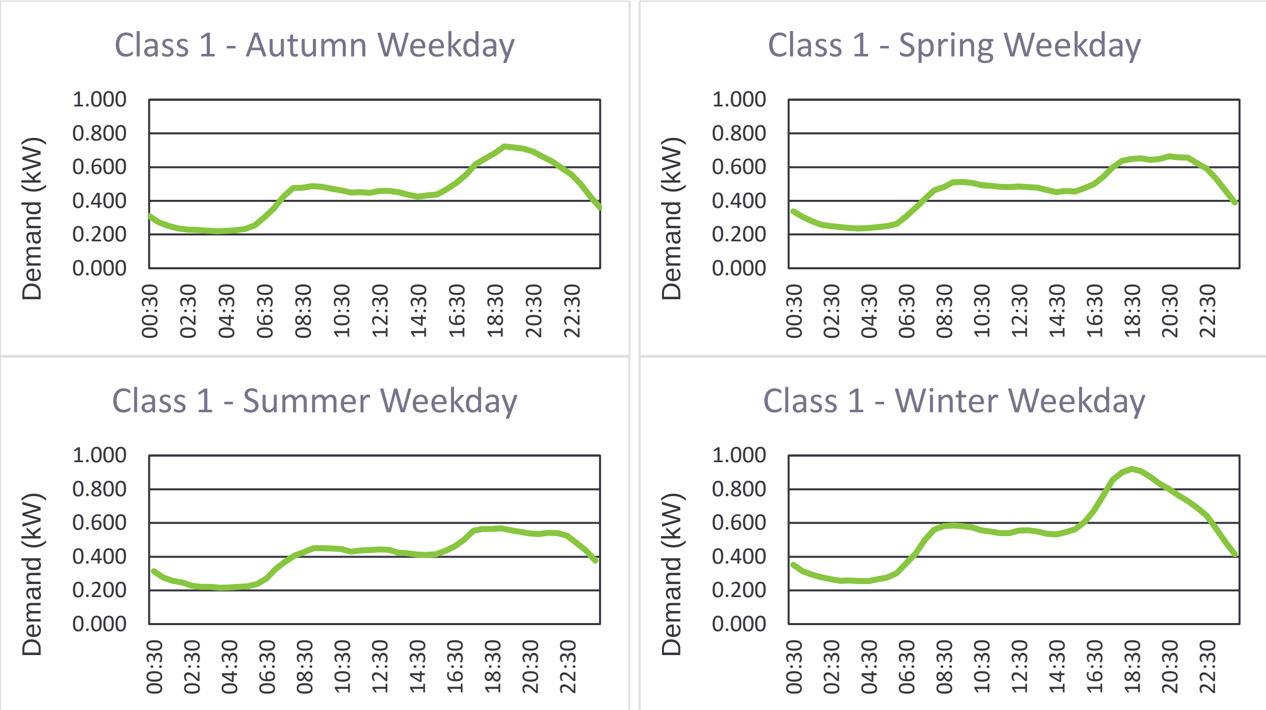
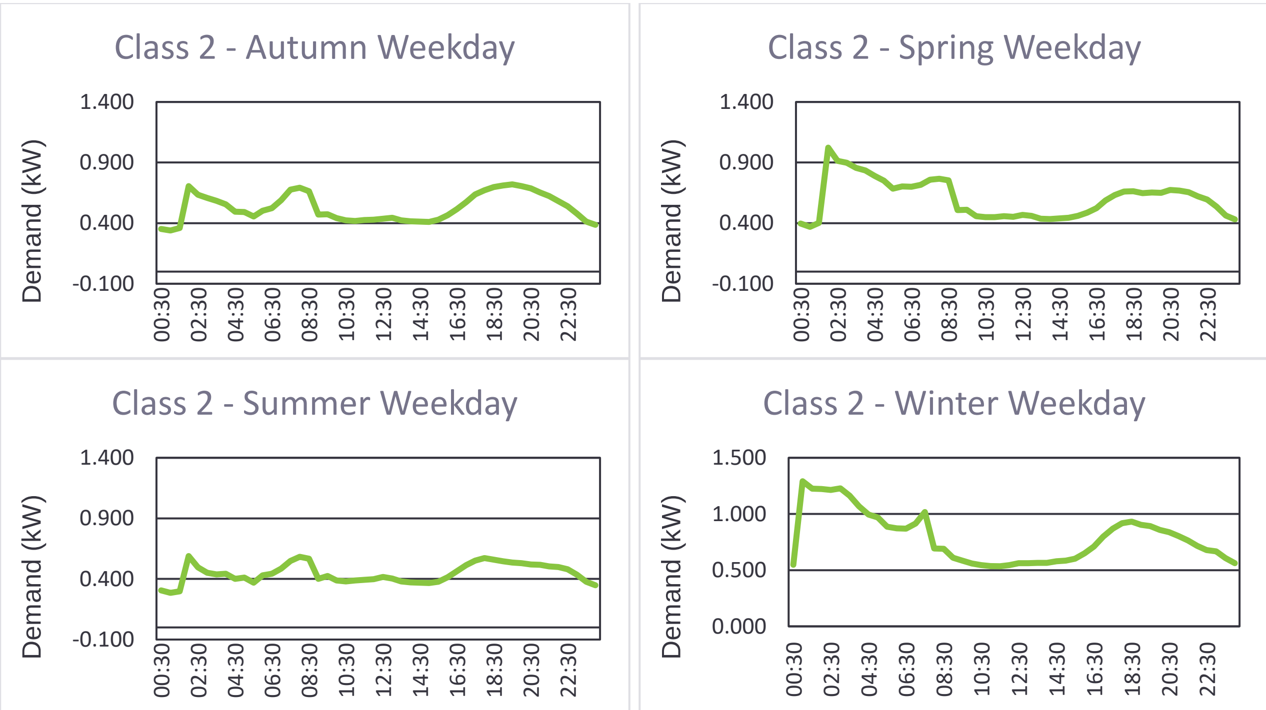


Figure A.4 Representative meter profile (domestic user with electric heating)



Fuel Supply System

There is a single existing fuel depot on Islay servicing both Islay and Jura.

Fuel oil is supplied to the island by shipping vessel with holding tanks at the fuel depot.

Deliveries to individual customers are then made by tankers on the island. In the case of Jura this is via ferry from Port Askaig.

Supplies of diesel and petrol are transported from the mainland using rigid articulated vehicles tailored to the needs of maritime safety and agreement with the ferry operator.

Supplies of gas oil and kerosene for heating are also transported from the mainland.

Small amounts of lubricant oils are supplied from the mainland (palletised and pre-packaged).

Bunded fuel supply for use by local authority vehicles is held separately to the main fuel depot.

There are no existing fuelling requirements for aircraft or ferries on the island.

There are four transport fuelling stations operating on Islay all of which are privately owned and operated; there is one other fuelling station that is community-owned.

Transport System

Islay is served by both ferry and air services.

Table A.1 Ferry carrying capacity (2019)

Route	Total Passengers	Total Cars	Total Coaches	Total Commercial Vehicles	Total Vehicles
Kennacraig – Islay (2019)	231,477	81,630	484	12,531	94,645
% Change vs 2018	+3.41%	+2.72%	+8.28%	+3.79%	
Kennacraig – Islay/Colonsay/Oban	21,488	7,161	17	569	7,747
% Change vs 2019	+4.69%	+5.71%	0%	-5.64%	
Islay - Jura	68,000				28,500

Note: https://www.calmac.co.uk/article/7226/Carrying-Statistics-2019---text-version (Accessed September 2020) and https://www.argyll-bute.gov.uk/moderngov/documents/s138872/Council%20Operated%20Ferries%2016052019%20Policy%20and%20Resources%20Committee.pdf (Accessed September 2020)

CalMac operate the ferries from the mainland, while Argyll & Bute Council operate the Islay-Jura ferry. It is noted that there is a potential replacement of the existing Islay-Jura ferry projected in 2028/29.

HGV traffic on the island is significant, both for the movement of fuel as well as inputs and products from distilleries on the island.

A local bus service operates on Islay.

There is also a van delivery service and local taxi services.

Road vehicle movements statistics are available for several count points on the island.

Details of three of these are provided here.

Table A.2 Road Transport (Annual Average Daily Flow, 2019)

	CP 10941	CP 10942	CP 50930
Description	A846. Start junction A847; End junction Port Askaig Ferry. Link length 12.4 km	A847. Start junction end of road, Portnahaven; End junction B8018. Link length 16.6 km	A846. Start junction Ardbeg pier; end junction B8016. Link length 7.4 km
Pedal cycles	9	14	10
2-wheeled motor vehicles	168	266	173
Cars & taxis	689	953	604
Buses & coaches	14	14	12
Light goods vehicles	9	8	4
Heavy goods vehicles	201	59	34
All motor vehicles	1,082	1,298	827

Note: Annual Average Daily Flow is number of vehicles that travel past the count point (in both directions) on an average day of the year

Distillery Sector

There are currently 9 operational distilleries on Islay; additional sites may come on-stream in the near future. Future expansion plans relating to maltings and support facilities (warehouses, visitor facilities and general accommodation) are also under consideration at sites on the island.

There is a further distillery operating on Jura.

The sector as a whole requires significant volumes of heat to support the distillation process. This is significantly greater than the electricity demand associated with operation of equipment and ancillary services (lighting, pumps etc.) within operating sites.

A high-level estimate of current energy demand is provided here.

Table A.3 Distillery annual energy demand

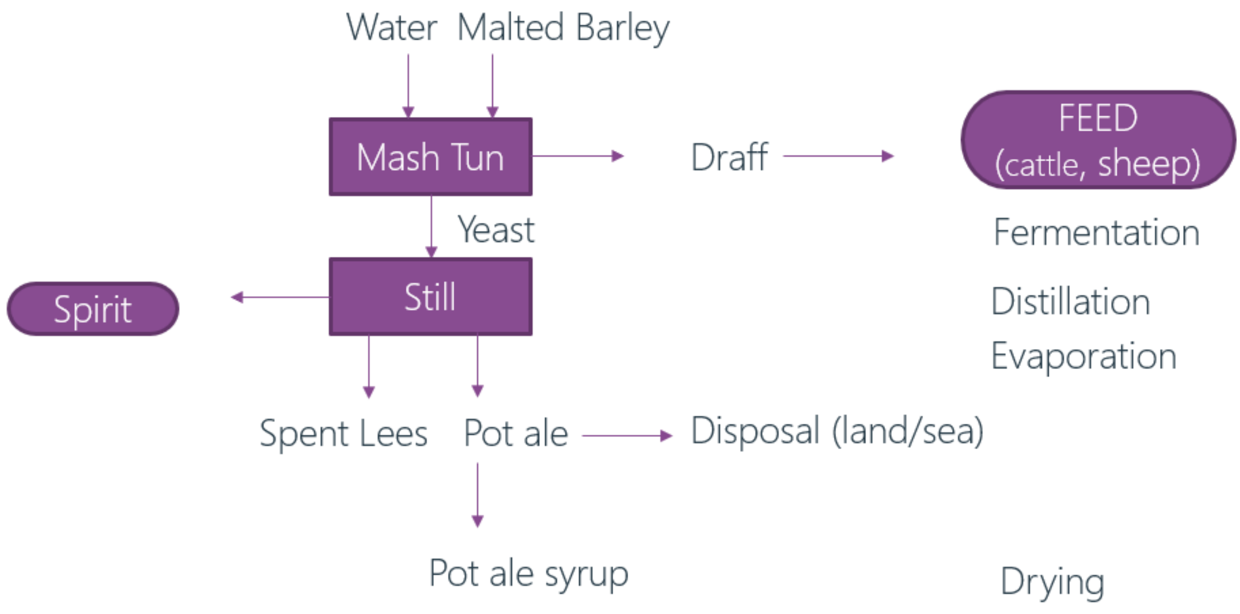
Energy Source	GWh/yr	Comments
Fuel Oil	181.0	Based on combination of data supplied by distilleries [80% of total] and estimates [20% of total] (where data has not been made available)
Of which:		
North West	39.4	
North East (inc Jura)	63.9	
South	77.7	

Energy Source	GWh/yr	Comments
Electricity	9.0	Based on combination of data supplied by distilleries [80% of total] and estimates [20% of total] (where data has not been made available)
Of which:		
North West	1.8	
North East (inc Jura)	2.3	
South	4.9	
Other	0.8	Gas oil, kerosene

Note: Details supplied by distilleries and supplemented with estimation (where data was unavailable)

A typical malt distilling process generates several by-products that can be used either in further energy production or by other third parties. A simplified view of the process by-products is provided here.

Figure A.5 Typical by-products of a malt distillation process



At present draff is sold on for use as animal feed. Around a third of total draff production is used on the island with the rest exported to the mainland.

At least 30% of pot ale generated on the island is discharged into the Sound of Islay, having been tankered to the mainland point of discharge at Caol Ila. This has associated local environmental impacts in terms of both the fuel used in tankering pot ale around the island and in associated wear and tear on local roads.

Public Bodies

Local Authority

Argyll & Bute Council operate a number of facilities and assets on Islay.

- Schools (Bowmore Primary School, Port Ellen Primary School, Port Charlotte Primary School [including nursery facilities], Keills Primary School and Islay High School in Bowmore)
- Offices (Bowmore Area Office and Service Point, Lifeboat Office at Port Askaig, Pier Office at Port Askaig and Kilarrow House in Bowmore)
- Depots and facilities (Bowmore Roads Depot, Bowmore Amenity Depot, Gartbreck Landfill)
- Gortonvogie Home for the Elderly (Bowmore)
- Ramsay Memorial Hall (Port Ellen)
- Ferry Terminal Waiting Room and ferry ramp (Port Askaig)
- Public amenities (public toilets at Port Ellen and Portnahaven and lighting at Bruichladdich Pier)

Energy use is predominantly electricity, with gas oil and biomass for heating used in a number of school buildings.

Table A.4 Local authority annual energy demand

Energy Source	GWh/yr	Comments
Gas Oil	0.2	Heating of schools
Electricity	0.8	Power and heat for buildings and assets on island
Biomass	1.6	Heating
Diesel (Transport)	0.2	Split bunded tank storage capacity 12,000 litres
Petrol (Transport)	0.03	
Gas Oil (transport)	0.01	Split bunded tank storage capacity 3,000 litres

Note: Details supplied by A&BC

Healthcare

NHS Highland (operating via the Argyll & Bute Health and Social Care Partnership) are responsible for the Islay Hospital in Bowmore. This is a community hospital providing a Community Casualty Unit, GP acute ward, Maternity, Radiography, AHPs and Community Nursing services.

There are GP practices operating within Bowmore, Port Charlotte and Port Ellen.

Annual electricity consumption is estimated to be of the order of 250 MWh/yr.

Scottish Water

There are a number of water treatment works on the island and associated pumping infrastructure supporting distribution of drinking water. The main water treatment works are located at:

- Torra (Port Charlotte) – operating capacity ~ 0.9 ML/day
- Ballygrant
- Bowmore

Wastewater treatment works are at Port Charlotte.

Annual electricity consumption across all assets is in the order of 850 MWh/yr.

Domestic Energy

Current estimates of fuel poverty across the MAKI (Mid Argyll, Kintyre and Islands) region and associated areas are summarised here. This includes a comparison of figures for the Argyll & Bute local authority area and Scotland as a whole. Due to the small dataset for Colonsay an official figure is not published for residents on the island.

Table A.5 Fuel Poverty Summary

Area	Likelihood of households in fuel poverty
Islay	54%
Jura	46%
Mid Argyll	46%
Kintyre	63%
Mid Argyll, Kintyre & Islands (total)	53%
Argyll & Bute	43%
Scotland	27%

Note: Details from https://www.argyll-bute.gov.uk/moderngov/documents/s143034/Housing%20Services%20Activity%20Report%20SHIP%20Annual%20Update.pdf (Accessed September 2020)

The figure for Islay is higher than that for the Argyll & Bute area as a whole and residents are twice as likely than mainland households in Scotland to be in fuel poverty.

Table A.6 Total Dwellings by Property Type (Islay, Jura and Colonsay)

Property Type	Number of dwellings (Islay)	Number of dwellings (Jura)	Number of dwellings (Colonsay)
Detached	599	99	82
Semi-detached	463	33	21
Terraced	596	8	1
Flats	251	28	2

Note: Details from Home Analytics dataset. Excludes 7 dwellings listed as unknown on Islay

Table A.7 Total Dwellings by Property Age and Dwelling Type (Islay) [% of whole stock]

Property Age	Detached	Semi-Detached	Terraced	Flats	Total
Pre-1919	14%	5%	11%	6%	**35%**
1919 – 1949	1%	3%	1%	1%	**6%**
1950 – 1983	9%	14%	18%	2%	**43%**

Property Age	Detached	Semi-Detached	Terraced	Flats	Total
1984 – 1991	2%	1%	1%	2%	**6%**
1992 – 2002	3%	0%	0%	2%	**6%**
Post-2002	2%	2%	1%	0%	**5%**
Total	**31%**	**24%**	**31%**	**13%**	**100%**

Note: Details from Home Analytics dataset. Excludes 7 dwellings listed as unknown

Table A.8 Total Dwellings by Property Age and Dwelling Type (Scotland) [% of whole stock]

Property Age	Detached	Semi-Detached	Terraced	Flats	Total
Pre-1919	4%	2%	3%	9%	**19%**
1919 – 1944	1%	3%	1%	6%	**11%**
1945 – 1964	2%	6%	7%	7%	**21%**
1965 – 1982	4%	5%	7%	5%	**21%**
Post-1982	11%	5%	3%	9%	**27%**
Total	**22%**	**20%**	**21%**	**46%**	**100%**

Note: Details from https://www.gov.scot/publications/scottish-house-condition-survey-2018-key-findings/pages/4/ (Accessed September 2020)

Table A.9 Estimated energy demand (by primary fuel)

GWh/yr	Islay	Jura	Colonsay
Biomass/solid fuel	6.5	0.7	0.5
Electricity	12.9	1.4	1.2
Oil	14.4	1.1	0.3
Other	0.16	0.0	0.0

Note: Based on Home Analytics data

Table A.10 Estimated transport fuel demand (Islay)

	Diesel	Petrol	Gas Oil
Transport fuel (GWh/yr)	1.6	0.5	0.1

Note: Based on data received from Argyll & Bute Council and other public datasets

Demographics

Latest Census data provides for a population of c. 3,300 inhabitants on Islay. The corresponding numbers in Jura and Colonsay are c. 200 and c. 120 respectively.

HVO (Biodiesel)

Hydrotreated vegetable oil (HVO) is produced via hydroprocessing of oils and fats. This is an alternative process to esterification in order to produce diesel from biomass requiring input of hydrogen as a feedstock.

The resulting fuel is free from esters or other contaminants meaning that it doesn't react with water or oxygen nor forms any sludge when in storage. It also means significant reduction in NOx and hydrocarbon emissions in comparison to conventional diesel.

A comparison of fuel characteristics between HVO and conventional diesel is provided here. This shows that fuel substitution can be achieved with minimal adjustment to existing plant equipment.

Table A.11 Comparison of fuel properties (diesel and HVO)

	Diesel	HVO
Biogenic content	5%	100%
Oxygen level	0	0
Sulphur content	<10	<1
Specific gravity	0.84	0.78
Distillation level (°C)	200 – 350	200 – 320
Cetane level	51	70 -90
Stability from oxidation	Average	Excellent
GHG Emissions (gCO_{2e}/MJ)	70 -75	30 -60

Source: Adapted from https://www.crownoil.co.uk/faq/hvo-fuel/ (Accessed September 2020)

At present there are few production facilities for HVO in Europe and none that are operational in the UK. European HVO production figures for 2019 are summarised here.

Table A.12 European HVO production (million litres) - 2019

Country	Netherlands	Finland	Spain	Italy	Sweden	France	Portugal	All
Production Volume	1,218	545	490	387	200	128	40	3,010

Source: https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_The%20Hague_EU-28_7-15-2019.pdf (Accessed October 2020)

HVO production is small in comparison with total EU production of biodiesel (using soya bean, rapeseed and palm oils) which reached 11,140 million litres with a further 3,370 million litres imported from outside of Europe (Argentina, Indonesia, Malaysia and China).

Current EU policy for renewable energy is set in the EU Energy and Climate Change Package (CCP) and the Fuel Quality Directive (FQD). In the Renewable Energy Directive (RED), which is part of the CCP, specific sustainability requirements are defined for conventional liquid biofuels. The successor to the RED, is the RED II which will come into operation in 2021 and operate for the period to 2030. It sets a new overall renewable energy target of 32 % by 2030 and a 14 % target for the transport sector. Importantly, it sets out targets for the use of advanced, non-food based biofuels (not derived from fats and oils) to 3.5 % by 2030, and a blending cap of 1.7 % for advanced biofuels produced with waste fats and oils.

HVO is considered an advanced biofuel. It is therefore likely that there will be increased demand for HVO across the EU and associated production capacity increases.

This presents a risk to using HVO in the UK given the need to import fuel from outside the UK and pressure on prices due to high demand elsewhere in Europe.

Biomass from forestry

Indicative survey volumes from estate managed forestry on Islay suggest:

- Managed area of 2,500 Ha
- Five-year tonnage (2020 – 2024) – 24,450 tonnes
- Five-year tonnage (2025 – 2029) – 22,900 tonnes
- Five-year tonnage (2030 – 2034) – 44,362 tonnes

Similar figures for Jura were not available to the current study.

Estimated roundwood yield available for bioenergy is 50% of tonnage figures.

Estimated calorific value of wood chips (30% moisture content) is 14.76 GJ/tonne (gross CV) or 4.10 kWh/kg.

Fuel oil has a calorific value of 43.31 GJ/tonne (gross CV) or 12.03 kWh/kg.

Raising an equivalent amount of heat therefore requires 3 kg of wood chips for every 1 kg of fuel oil currently in use.

Heat output from a biomass boiler varies more slowly than an equivalent fuel oil boiler. This makes it less responsive to steam demand. To account for this, it may be necessary to oversize the boiler to provide a greater thermal mass, or use a larger steam main (therefore increasing thermal mass transfer). A further design option is to use a steam accumulator. Steam is condensed in a cylinder at higher pressure than required. Flash steam generation can then be carried out to meet short term fluctuations in demand.

Proposed steam raising systems in distilleries may use solely biomass in the form of wood chips, or a mix of wood chips and draff.

Previous estimates of draff volumes on the island suggest total arising in the range of 35,000 – 47,000 tonnes/year[14].

Individual distilleries will size system requirements to meet projected energy needs as suits their production capacity.

[14] Sustainable Energy using Anaerobic Digestion of By-Products: Islay Whisky Industry Case Study (L. Duguid, 2016, University of Strathclyde)

As an example of estimated resource requirements, a fuel oil replacement scheme for existing boiler capacity of 6 MW is considered.

Assumed existing operation:

Operating hours – 7,000 hrs/yr (allowing for maintenance schedules)

Boiler efficiency – 85%

Estimated annual fuel energy input = 14,000 MWh/yr

Equivalent fuel oil consumption (litres) = 1.2 million litres per year

Assumed alternative fuel regime:

Biomass – wood chips (~ 30% moisture content) accounting for 60% of fuel input

Draff – air dried (~ 75% moisture content) accounting for 40% of fuel input

Given the same operating hours and boiler efficiency then the equivalent fuel input equates to around 3,000 – 3,500 tonnes/yr of wood chip and 2,500 – 3,000 tonnes/yr of draff.

This assumes that some of the steam raised in the new system will be used to dry the wood chips.

If on-island wood supplies are to be used then there would need to be space on site for chipping equipment to process the wood deliveries.

From a GHG emissions perspective combustion of 1.2 million litres of fuel oil generates approximately 3,750 tCO_{2e} per year. The GHG emissions associated with the biomass/draff system would be approximately 230 tCO_{2e} per year – a net reduction of 95%.

In terms of feedstock, the timber management figures for Islay suggest that this scale of demand for biomass could be sustained at a single site (c. 50% of total survey volumes amount to around 12,000 tonnes of wood over a 5-yr period in comparison with around 15,000 tonnes requirement here). Given the degree of estimation in available wood and the ability to adjust the balance of biomass and draff fuel input this looks achievable.

This clearly presents a limitation on widespread use of biomass at distilleries across the island.

In terms of delivery of fuel there would be limited difference between current fuel deliveries of fuel oil and equivalent cycle of delivery of biomass (averaging a similar number of deliveries per week).

From an operations and maintenance perspective there will be similar requirements to those for the existing boilers. Given the fuel mix used in the biomass/draff system (rather than a homogenous single input in the case of fuel oil) this may mean more maintenance time is required.

Hydrogen and Battery Tractors

Integration of battery packs into tractors is challenging. A John Deere electric tractor[15], SESAM, has a 150 kWh battery with a weight of around 1.15 tonnes. The vehicle can run at full power for 1 hour and needs around 3 hours to recharge the battery.

A New Holland prototype hydrogen fuelled tractor was able to run for around 3 hours on an 8.2 kg Hydrogen tank pressurised to 350 bar. Refuelling was of similar duration to conventional diesel fuel.[16]

[15] https://www.agriland.ie/farming-news/electric-john-deere-tractor-runs-for-4-hours-on-a-charge/ (Accessed December 2020)
[16] https://ives-technicalreviews.eu/article/view/4381# (Accessed September 2020)

Hydrogen Buses

A number of cities across the world are currently running fleets of hydrogen fuelled buses including Aberdeen and London.

In the case of Aberdeen there is a fleet of 10 buses operating. Production of hydrogen is from a 1 MW electrolyser incorporated within a hydrogen refuelling station.

Hydrogen Ferries

Design work looking at hydrogen fuelled ferries is ongoing around the world. Designs for hybrid ferries (either using a mix of hydrogen and electric power or fossil fuel and hydrogen) are at an advanced stage. For example, the Norwegian ferry operator Norled will bring into service a hydrogen fuelled ferry during 2021[17]. This will use hydrogen to provide at least 50% of its propulsion power. A separate consortium is designing a ferry capable of carrying 1,800 passengers and up to 380 cars which would be powered using hydrogen as the single fuel source. This is proposed to be in operation in 2027[18].

In Scotland, design work in Orkney is looking at the use of hydrogen in a hybrid ferry design, replacing existing use of marine fuel oil[19]. The HySeasIII project is developing hydrogen fuelled propulsion systems on land with a view to then using them in a roll-on roll-off passenger ferry design[20]. The SWIFTH2 project worked with the Point & Sandwick Trust to determine the feasibility of local renewable energy generation providing the electricity required to operate electrolysers to generate hydrogen as fuel for a ferry[21].

These developments show that hydrogen fuelled ferries could come into service in the period 2025 onwards. This would potentially mean a need for battery charging facilities and/or hydrogen fuelling stations at the ferry terminals.

Low Carbon aircraft

Ongoing research and development work seeks alternatives to existing jet fuel in powering aircraft. ZeroAvia completed a world first in late 2020 when a test flight of a six-seater plane powered by hydrogen was completed[22]. Its HyFlyer II project will develop a powertrain capable of powering aircraft with up to 19 passengers (fuelled using hydrogen). It proposes that the 19-seater aircraft will be capable of a successful flight during 2023.

Electric planes continue to be worked on; the largest all electric powered plane to date was a six-seater plane in the United States[23].

Work looking at biofuels as an alternative for jet fuel also continues. A number of suppliers presently offer blended fuel, which mixes jet fuel with oil derived from waste oils. Work is continuing to expand the number

[17] https://ferryshippingnews.com/tag/hydrogen-powered-ferry/#:~:text=Norled%20won%20the%20competition%20to,%2DSkipavik%20in%20Rogaland%2C%20Norway.&text=Today%2C%20no%20comparable%20hydrogen%20powered,2021%20to%2028%20February%202031 (Accessed December 2020)

[18] https://www.h2-view.com/story/consortium-to-develop-hydrogen-powered-ferry-for-norway/ (Accessed December 2020)

[19] https://hydime.co.uk/ (Accessed December 2020)

[20] https://www.hyseas3.eu/the-project/ (Accessed December 2020)

[21] http://www.pointandsandwick.co.uk/wp-content/uploads/2019/07/Scottish-Western-Isles-Ferry-Transport-using-Hydrogen-Feasibility-Report.pdf (Accessed December 2020)

[22] https://www.zeroavia.com/press-release-25-09-2020 (Accessed December 2020)

[23] https://www.nbcnews.com/science/science-news/largest-electric-plane-yet-completed-its-first-flight-it-s-n1221401 (Accessed December 2020)

of airlines using sustainable aircraft fuel[24]. Fuels can be produced via the ABE fermentation route, for example (see below for further details).

While large commercial aircraft fuelled with hydrogen or batteries are not close to commercial development there is clearly potential for smaller aircraft, such as those connecting Islay to the mainland, to come into operation in the late 2020s. This would potentially open requirements for Islay Airport to install battery charging and hydrogen fuelling stations. This would also be a source of demand for supply from renewable energy generation (or local hydrogen production).

Tidal Power

Proposed development in Sound of Islay would use an array built from 100 kW rated turbines. Each turbine is capable of producing at least 450,000 kWh of electricity per year. A typical specification for each turbine is reproduced here.

- Rated capacity: 100 kW
- Design life: 20 years
- Rotor diameter: 8.5 metres
- Rotor speed: 10 to 27 rpm
- Mounting: gravity seabed base
- Starting tidal speed: 0.5 m/s
- Tidal speed for rated power: 2.0 m/s

Development of an initial 10 turbines (1 MW capacity) could be achievable by 2023 with a full 3 MW capacity operating by 2025. Depending upon optimisation of turbine output achieving the 3 MW capacity may not require a full array of 30 turbines.

Offshore Wind

Crown Estate Scotland is managing the process of leasing areas of seabed within Scottish waters for the purpose of renewable energy development. The primary purpose of the first round of the ScotWind leasing process is to grant property rights for seabed for new commercial scale offshore wind project development. The Scotwind Leasing launch summary document[25] notes that a cap of 10 GW of total offshore capacity has been proposed for wind development. This has been re-affirmed in the recently published Sectoral Marine Plan for Offshore Wind Energy[26]. A typical development density of 5MW/km^2 is assumed, with a minimum size of development deemed as 100 MW.

The leasing process provides a transparent means of identifying areas of seabed made available for development, selecting developers and setting out appropriate terms under which any development will use the seabed. It also includes a requirement on developers to provide a Supply Chain Development Statement (SCDS) setting out the anticipated requirements of the project and the geographic impact this might have. This seeks to support one of the objectives of the Sectoral Marine Plan in developing local supply chains and skills.

[24] https://www.iata.org/en/programs/environment/sustainable-aviation-fuels/ (Accessed December 2020)
[25] https://www.crownestatescotland.com/maps-and-publications (Accessed October 2020)
[26] https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2020/10/sectoral-marine-plan-offshore-wind-energy/documents/sectoral-marine-plan-offshore-wind-energy/sectoral-marine-plan-offshore-wind-energy/govscot%3Adocument/sectoral-marine-plan-offshore-wind-energy.pdf (Accessed October 2020)

There is one Draft Plan Option (DPO) area identified within the West region, labelled as W1. The total available area is 754 km^2 within which development of up to 2 GW may be feasible.

Given ongoing dialogue via Crown Estate Scotland it is not currently known what preferred design option may be taken forward for development of the W1 allocation to the North West of Islay. The scale of generation is likely to mean that a connection point could be made to the 33 kV network on Islay as well as to the mainland transmission network. This would potentially mean connection at the Bowmore sub-station. Battery storage (either at the generation or connection point) is also likely to be designed in to support efficient use of generation and associated intermittency. In practice, battery storage could be incorporated both at sea and on land.

It is estimated that generation capacity could be available based on commissioning in 2030.

The proposed scale of generation is much larger than current maximum load on Islay – even a minimum scale development of 100 MW is more than 10 times greater than the current maximum load. As an indicative figure, a single 2.5 – 3 MW offshore wind turbine can generate 6,000 MWh in a year, which is around two-thirds of current power demand for all the distilleries on the island.

There are two ways in which power generated by offshore wind turbines could be landed on Islay. The first would be to connect into a sub-station (most likely at Bowmore) and supply power to the local grid across the island. Alternatively, a private wire supply could be connected to a selected number of high demand users, such as water treatment works or distilleries (for example).

Anaerobic Digestion

Initial estimates of available energy output suggest that use of both pot ale and draff is important in maximising biogas yields. Indicative figures using estimates of available pot ale and draff on the island are provided here.

Table A.13 Indicative energy yields available via anaerobic digestion

Parameter	Unit of Measure	Lower Estimate	Mid Estimate	Upper Estimate
Mass of Pot Ale	tonnes/yr	100,500	119,000	136,000
Mass of Draff	tonnes/yr	35,000	41,000	47,000
Pot Ale				
Biogas Yield	Nm^3/yr	2,600,000	3,000,000	3,500,000
Methane Yield	Nm^3/yr	1,440,000	1,700,000	1,950,000
Available Energy	MWh/yr	14,400	17,000	19,500
Net GHG Saving (vs. Fuel Oil)	tCO_{2e}/yr	-30%	-30%	-30%
Draff				
Biogas Yield	Nm^3/yr	4,000,000	4,700,000	5,400,000
Methane Yield	Nm^3/yr	2,230,000	2,600,000	3,000,000
Available Energy	MWh/yr	22,000	26,000	30,000
Net GHG Saving (vs. Fuel Oil)	tCO_{2e}/yr	-30%	-30%	-30%

Note: Assumes 55% methane content in biogas; GHG emission conversion factors from UK Government GHG Conversion Factors for Company Reporting (BEIS, 2020)

Current annual fuel oil use across the existing distilleries on Islay and Jura is estimated to be in the order of 181,000 MWh/yr. On that basis, the estimates here equate to somewhere in the region of 30 – 40% of total energy requirements. In practice this is an upper limit since it relies on use of all pot ale and draff arisings on the island. While pot ale is readily available (since it is discharged at low cost), draff is more difficult.

Significant draff volumes are used currently as animal feed not only on Islay, but also in the wider Kintyre peninsula. It is a cost-effective feed for livestock farmers to use. Replacing the nutritional value of the draff with any other suitable alternative means a doubling of costs for farmers.

Removing a substantial volume of draff from the animal feed market is likely to have significant economic impacts on the viability of livestock farming on the island and more widely in Kintyre and Mid Argyll.[27]

In terms of practical implementation, dual fuel burners are an option. This provides the flexibility for a site to operate using both methane (when available) and fuel oil (otherwise). This also potentially opens opportunity to use other gas streams (e.g. hydrogen) as well as lower carbon oils (e.g. HVO).

While this option provides a means of significant GHG reduction (in comparison to current use of fuel oil) it offers limited additional security of supply due to the retained use of fuel oil. It would reduce the number of weekly deliveries to site of fuel oil.

AD Proposal – Southern Islay

Three Global Distillers have engaged with a French Inward investor Gas company to supply a proposed compressed gas pipeline and supply infrastructure across a section of southern Islay[28]. This pipeline will be "greened" with Biomethane and Syngas initially, with a view to hydrogen injection over time.

This is an inward investment project for Scotland leading to an additional German inward investment project to inject green gas Biomethane from the same Distillery sites. Gas is derived entirely from the whisky process of these sites.

There is room to expand this process and it is replicable across the Island and further across Scotland and beyond.

The Carbon impact is very considerable indeed and will make the Distilleries more competitive and will "future proof" the product carbon footprint for the consumer. This project will unlock ferry slots and reduce traffic movements on the Island.

Heat Pump solutions for distilleries

The roadmap to net zero developed by the Scotch Whisky Association (SWA) recognises that there a number of technologies that are likely to be used in order to support efforts by distilleries to achieve net zero targets by 2030.

One potential solution to meeting heating needs instead of raising steam is to use a heat pump system. While no such systems are currently in operation in the UK, there is a design proposed by a working consortium of STAR Renewable Energy, Pale Blue Dot Energy and Allen Associates dubbed GreenStills. The system design uses enhanced heat recovery (in conventional processes heat input for distillation is nearly all wasted via condenser cooling water) to assist in a heating system that uses mineral oil as a heat transfer fluid. This enables a high temperature heat pump solution that can be supported by a range of renewable energy generation (e.g. wind, solar, tidal etc.) as suits local conditions. A heat store provides a means of capturing energy even if the source is variable (e.g. wind energy output).

[27] Distillery by-products, livestock feed and bio-energy use: report, Scottish Government 2019 (Accessed September 2020)
[28] Private correspondence, Peter Murphy, Director – UK Water Ltd (December 2020)

This system, or similar designs, may become more viable for use in late 2020s onwards. This presumes some success in implementing it in similar operations (wider distillation processes and brewing). It is most suited to new distilleries rather than retrofitting to existing facilities.

Celtic Renewables – ABE Fermentation

The Acetone-Butanol-Ethanol (ABE) fermentation process uses bacteria to ferment carbohydrates (e.g. starch and glucose) to produce the three chemicals Acetone, Butanol and Ethanol. This process is well established having operated at industrial scale until the mid 1950s when petrochemical processes became more cost efficient.

Celtic Renewables, a Scottish based company, has revived the process and modified it to enable production based on inexpensive feedstocks – potatoes, draff and pot ale. Their first industrial scale production plant is currently being built at Grangemouth and will be operational in 2021. The outputs of the process are all useful feedstocks for other industrial processes and as a vehicle fuel:

- Butanol – Paints/coatings and biofuel
- Ethanol – Medicinal uses, plastics production, biofuel
- Acetone – plastics production and cosmetics
- Animal feed – a solid residue from the fermentation process can be supplied as animal feed

The company sees future expansion in all global markets, via a mixture of Build-Own-Operate, Joint Ventures and Third Party Licence.

Initial targets for expansion potentially include a production facility in Ireland, a larger scale production facility in North East Scotland and a production facility on Islay.

No timeframe or confirmed investment in a project on Islay is in place at present.

Production of butanol on the island would offer a low carbon fuel that could be used directly in existing conventional petrol cars. This would offer around an 80 – 85% reduction in GHG emissions compared to current conventional fuel.

It would also be possible to consider use of butanol as a low carbon aviation fuel, though this would not work as a 'drop in' fuel as in the case of cars.

While a proposed production facility on Islay could use pot ale as a feedstock there would not be the internal demand for fuel to avoid export of products back to the mainland.

The benefit of any production facility would be to provide a locally produced fuel for vehicles. This would minimise GHG emissions, but not completely remove them as is the case for electric vehicles or hydrogen fuelled vehicles.

There would be vehicle movements from the island to the mainland in transporting products from the fermentation process to wider markets.

Glossary

A table of abbreviations used throughout this report is provided here for ease of reference.

Table of abbreviations

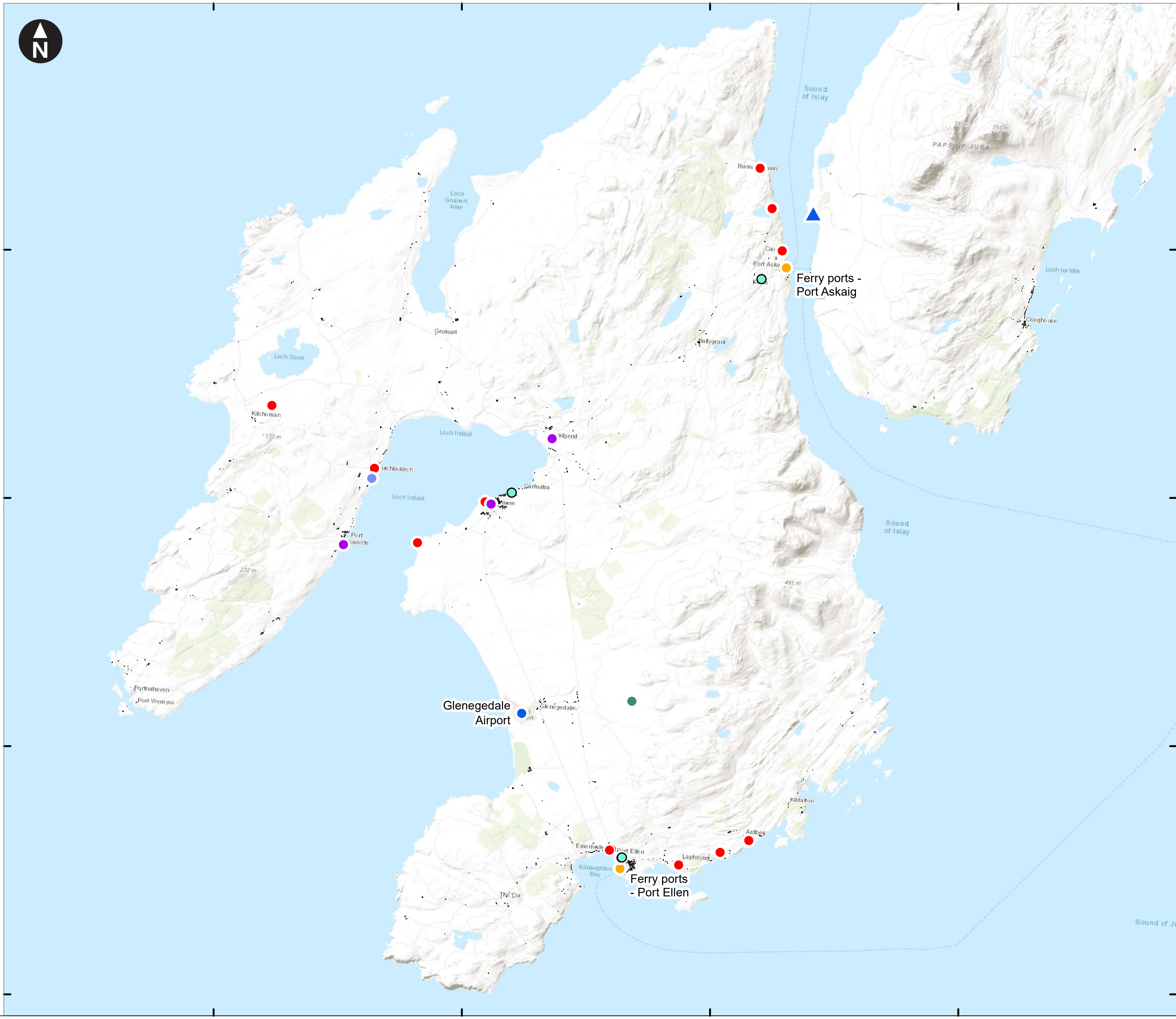
Abbreviation	Full Details	Comment
A&BC	Argyll & Bute Council	Local authority area within which Islay, Jura & Colonsay sit
AD	Anaerobic digestion	Process that breaks down bio-materials without oxygen being present. The output is a biogas as well as a solid by-product that can be used as a soil improver
CCC	Committee on Climate Change	Independent group that provides analysis and advice to the UK and Scottish Governments about climate change
CMZ	Constraint Managed Zones	A geographic region on the grid electricity network where local renewables, battery storage or stand-by generators are used to support the balance of supply
CNG	Compressed natural gas	Compressed gas that can be used as a heating fuel
Draff	Draff	Residue left from processing of barley after mashing with hot water. This is often used as an animal feed
EEBS	Energy Efficient Business Support	Support programme operated by Scottish Government providing advice to businesses as to how to manage their use of resources
EESSH2	Energy Efficiency Standard for Social Housing post-2020	Standard for energy efficiency that applies to social housing operated by registered social landlords
EV	Electric vehicle	Low emission vehicle powered by an electric battery rather than liquid or gas fuels
FiT	Feed-in tariff	Tariff payment received for each unit (kWh) of energy generated from renewable sources that are eligible for the scheme.
GHG	Greenhouse gases	Term used to describe a group of gases (Carbon Dioxide, Methane, Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons, Sulphur Hexafluoride and Nitrogen Trifluoride) that contribute to global warming effects and associated climate change impacts
GSP	Grid supply point	The connection between the transmission and distribution systems that form the national electricity grid
HGV	Heavy goods vehicle	Large goods vehicle with a net weight of 3.5 tonnes or more
HIAL	Highlands & Islands Airports Limited	Company that operates Islay Airport as well as 10 other regional airports in Scotland
HIE	Highlands & Islands Enterprise	The economic and community development agency for the north and west of Scotland
HVO	Hydrotreated vegetable oil	A renewable fuel that can be used in place of diesel
IETF	Industrial Energy Transformation Fund	Scottish Government funding to support low carbon operation in industry

Abbreviation	Full Details	Comment
IET	Islay Energy Trust	A community owned organisation that aims to develop renewable energy projects for the benefit of the community whilst reducing Islay's carbon footprint
LCITP	Low Carbon Infrastructure Transition Programme	Source of funding available from Scottish Government used in developing low carbon projects
LES	Local Energy Scotland	Organisation that supports development of renewable energy systems within communities
MAKI	Mid-Argyll, Kintyre & The Islands	Geographic region managed by Argyll & Bute Council. Islay sits within this region.
MVA	Mega Volt Ampere	Measure of the load on the electricity network
MW	Mega Watt	Measure of the electrical power of a generator or electrical device
Pot Ale	Pot Ale	Watery waste product from the distillation process
RSL	Registered Social Landlord	An organisation that own or manage social housing
SMAS	Scottish Manufacturing Advisory Service	Organisation offering support to small and medium sized enterprises on best practice in manufacturing
Solar PV	Solar photovoltaics	Renewable energy device that uses solar energy to generate electricity
W1	W1 development area	Potential development area for offshore wind generation

Table of symbols used in report

Symbol	Full Details	Comment
	Fuel oil	Fossil fuel used primarily as a fuel for boilers on the island
	Existing grid electricity	Mix of sources used to supply the existing national grid electricity network
	HVO	Hydrotreated vegetable oil. Alternative to fuel oil made from vegetable oil sources
	Biogas	Methane gas produced from anaerobic digestion that can be used like fossil fuel natural gas
	Green electricity	General symbol for electricity produced from renewable energy sources
	Tidal energy	Electricity produced from tidal devices such as tidal turbines
	Onshore wind	Renewable electricity produced by onshore wind turbines
	Offshore wind	Renewable electricity produced by offshore wind turbines

Symbol	Full Details	Comment
	Hydro electricity	Renewable electricity produced by hydropower systems
	Battery storage	Battery used to store generated electricity
H_2	Hydrogen gas	Hydrogen gas used as an alternative fuel for heating or transport.
	Heat pump	Device that uses electricity along with natural resources (air, ground or water) to generate heat
	CNG	Compressed natural gas that can be used a heating fuel
	Biomass	Wood fuel (either chips, pellets or logs) used to generate heat
	District heating	System where a number of buildings are supplied heat from a single central source
	Renewable electricity (solar PV)	Renewable electricity generated via solar PV
	Conventional passenger cars and light goods vehicles (LGVs)	Existing cars and small vans that use diesel or petrol as fuel
	Heavy goods vehicles (HGVs)	Existing HGVs that use diesel as fuel
	Buses and coaches	Existing buses and coaches that use diesel as a fuel
	Agricultural vehicles	Existing agricultural vehicles that are fuelled with diesel
	Low carbon buses and coaches	Buses and coaches that are powered either using batteries (electric vehicles) or fuel cells (using hydrogen as a fuel)
	Low carbon agricultural vehicles	Agricultural vehicles that are powered either using batteries (electric vehicles) or fuel cells (using hydrogen as a fuel)
	Electric passenger vehicles and LGVs	Cars and light goods vehicles that are powered using batteries (electric vehicles)
	Low carbon heavy goods vehicles	HGVs that are powered either using batteries (electric vehicles) or fuel cells (using hydrogen as a fuel)



Key

- Primary substation
- Petrol stations
- Fuel Depot
- Airport
- Ferry Ports
- Distillery/Maltings
- Community wind turbine
- Inver hydro scheme
- Buildings

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000 m

Scale at A3: 1:150,000

Islay Energy Systems Options Appraisal

Figure 1.1
Islay Energy Infrastructure

February 2021

wood.

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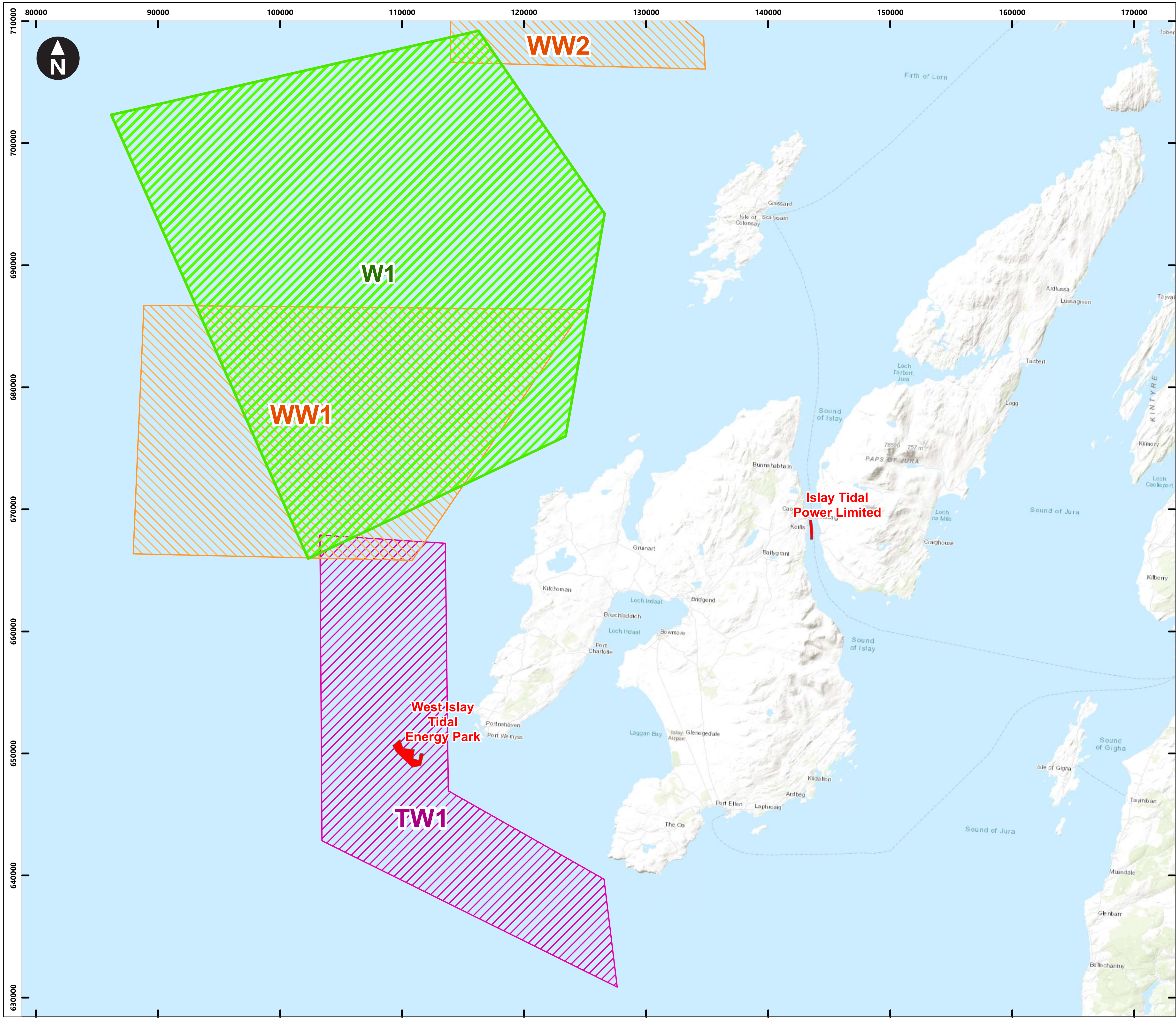

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Key

- Energy infrastructure agreements
- Wave draft plan options
- Tidal draft plan options
- Scotwind option

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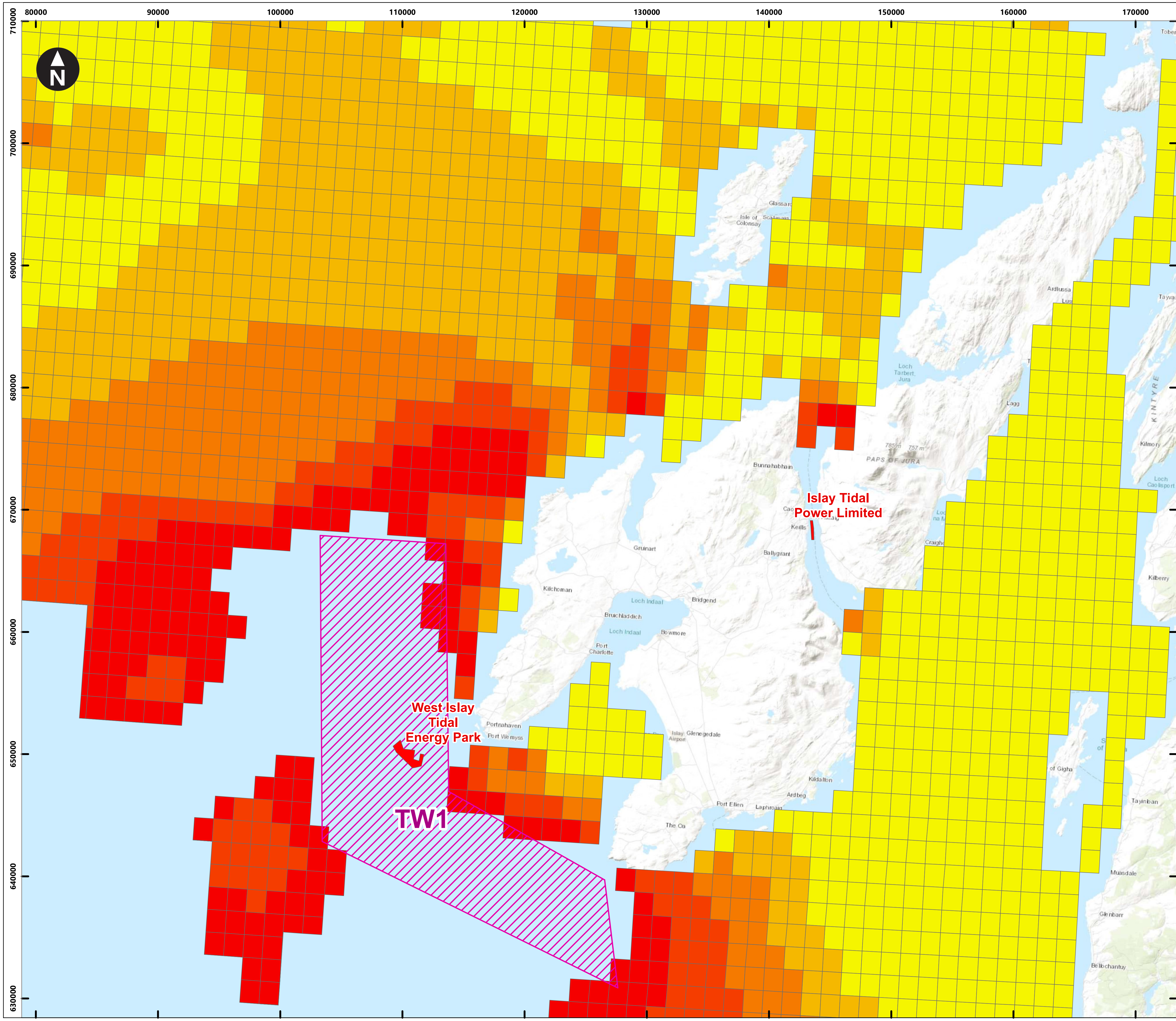
Scale at A3: 1:300,000

Islay Energy Systems Options Appraisal

Figure 1.2
Islay Offshore Renewables

October 2020

wood.



Key

Energy infrastructure agreements

Tidal draft plan options (2013)

Average power obtainable per square metre (vertical cross section) over a complete annual tidal cycle and for the complete tidal curve (not just the peak current speeds): Kilowatts per square metre (kW/m2) of vertical water column*

0.00 - 0.01

0.01 - 0.04

0.04 - 0.11

0.11 - 0.22

0.22 - 0.55

*Atlas of UK Marine Renewable Energy Resources. 2008. ABPmer. Date of access (22, October, 2020)

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Scale at A3: 1:300,000

Islay Energy Systems Options Appraisal

Figure 1.3
Islay Tidal Resource

October 2020

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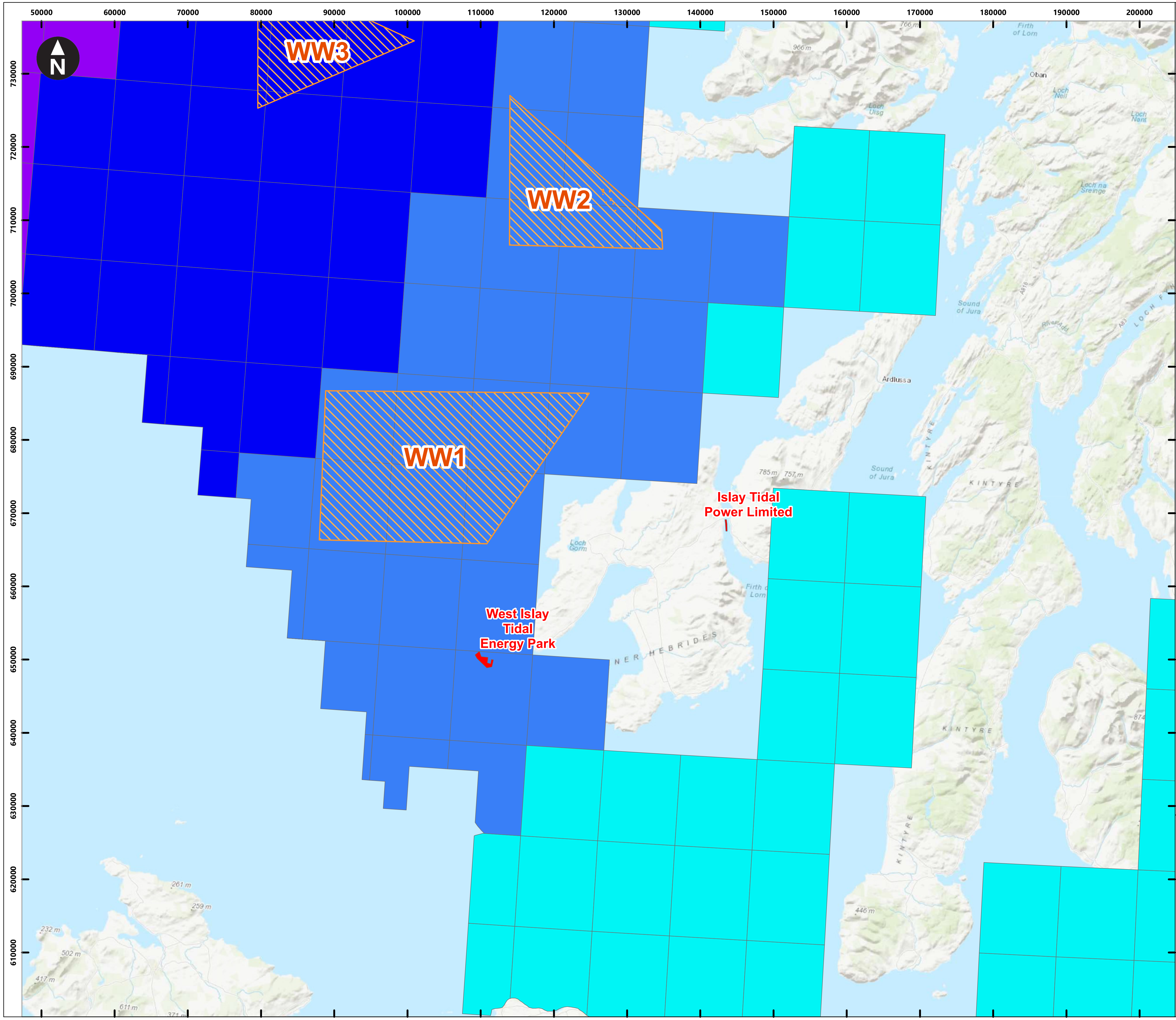
43230 edi003a Islay tide resource



Key

Energy infrastructure agreements

Wave draft plan options (2013)

Annual Mean Wave Power (Full Wave Field) calculated in kilowatts per metre (kW/m) per horizontal metre of wave crest using the energy period calculation (TE)*

0.00 - 14.17

14.17 - 26.12

26.12 - 38.77

38.77 - 51.96

51.96 - 74.64

*Atlas of UK Marine Renewable Energy Resources. 2008. ABPmer. Date of access (22, October, 2020)

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Scale at A3: 1:500,000

Islay Energy Systems Options Appraisal

Figure 1.4
Islay Wave Resource

October 2020

wood.

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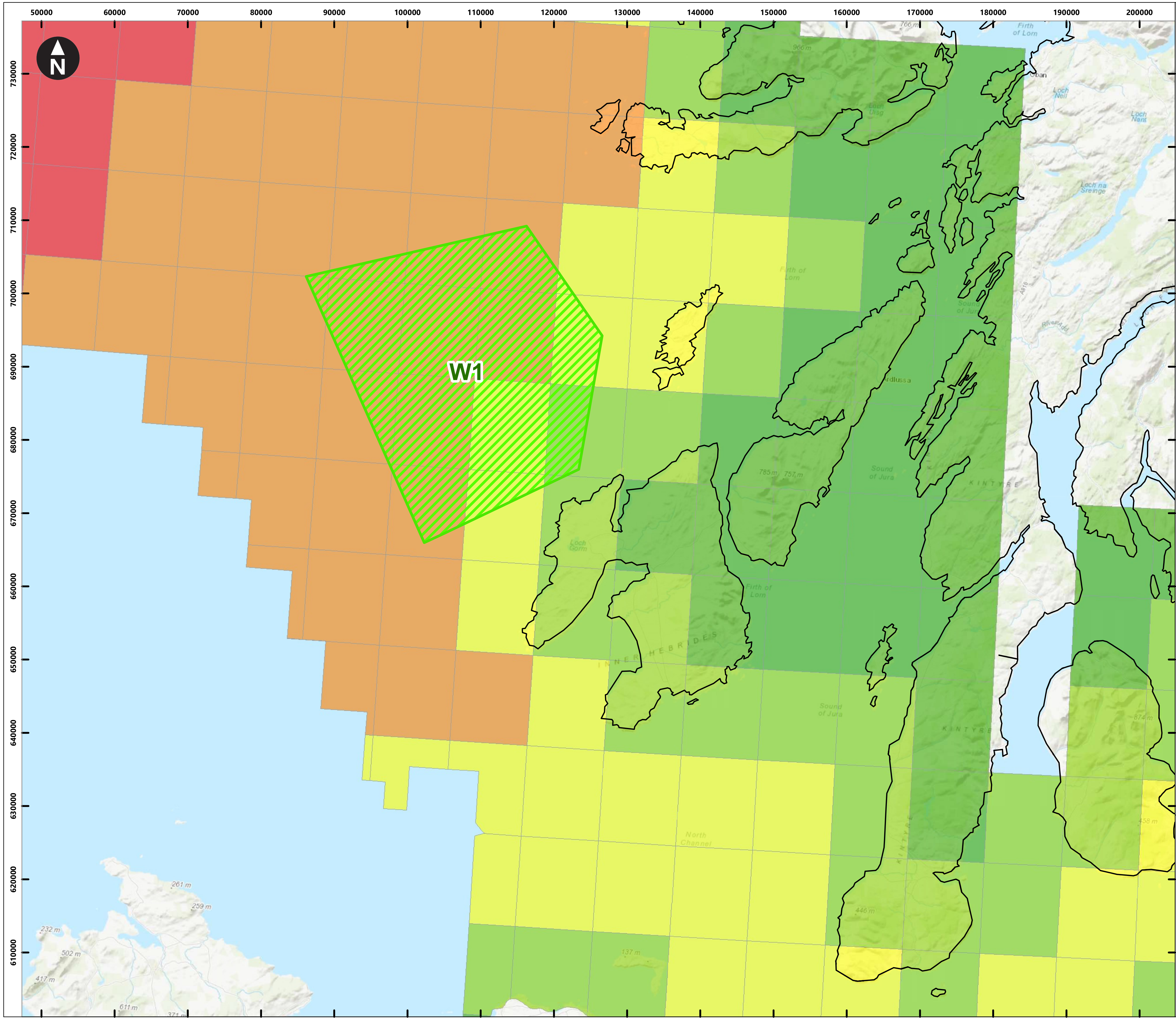

Key

Scotwind option area

Annual Mean Wind Speed recorded in metres per second (m/s) 100 metres above sea surface*

4.48 - 6.73
6.73 - 8.59
8.59 - 9.88
9.88 - 10.80
10.80 - 12.3

*Atlas of UK Marine Renewable Energy Resources. 2008. ABPmer. Date of access (22, October, 2020)

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Scale at A3: 1:500,000

Islay Energy Systems Options Appraisal

Figure 1.5
Islay Wind Resource

January 2021

wood.

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43230 edi005b Islay wind resource