European Commission

Clean energy for EU islands:

Technology solutions booklet

The Clean energy for EU islands secretariat is managed by the European Commission Directorate-General for Energy

ENERGY

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The Clean energy for EU islands secretariat introduction

The Clean energy for EU islands Initiative was launched in May 2017, underlining the European Union's intent to accelerate the clean energy transition on Europe's more than 2,400 inhabited islands. The initiative aims to **reduce the dependency of European islands on energy imports** by making better **use of their own renewable energy sources.**

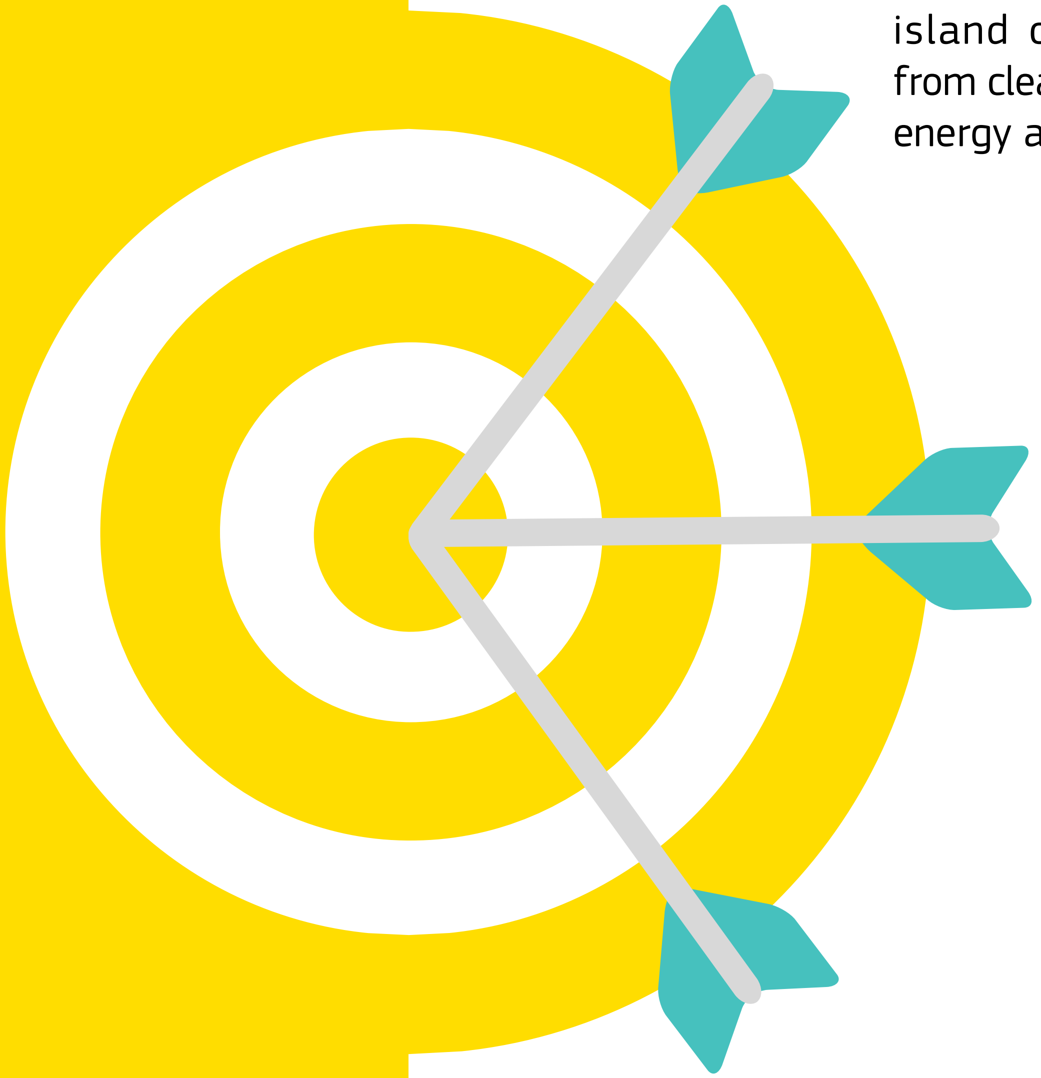
As a support to the launch of the initiative, the Clean energy for EU islands secretariat was set up in 2018 to act as a network for island stakeholders and to provide dedicated capacity building and technical advisory services.

Between 2018 and 2020, the Secretariat acted as a pilot project supporting the EU-wide community of islands in their efforts to **transition to sustainable energy and reduce energy consumption.**

Following the signature of the Memorandum of Split in 2020, the second phase of the Secretariat was launched in the beginning of 2021 and will run for two years.

The second phase will build on the results of the pilot years to create a pipeline of **bankable clean energy projects on islands in the EU.**

In Phase II, the objective of the Clean energy for EU islands secretariat is threefold to:



Empower

island communities to move from clean energy vision to clean energy action.

Support

a bottom-up approach to a decentralised energy transition that relies on proven solutions through transition processes that happen collectively and locally.

Match

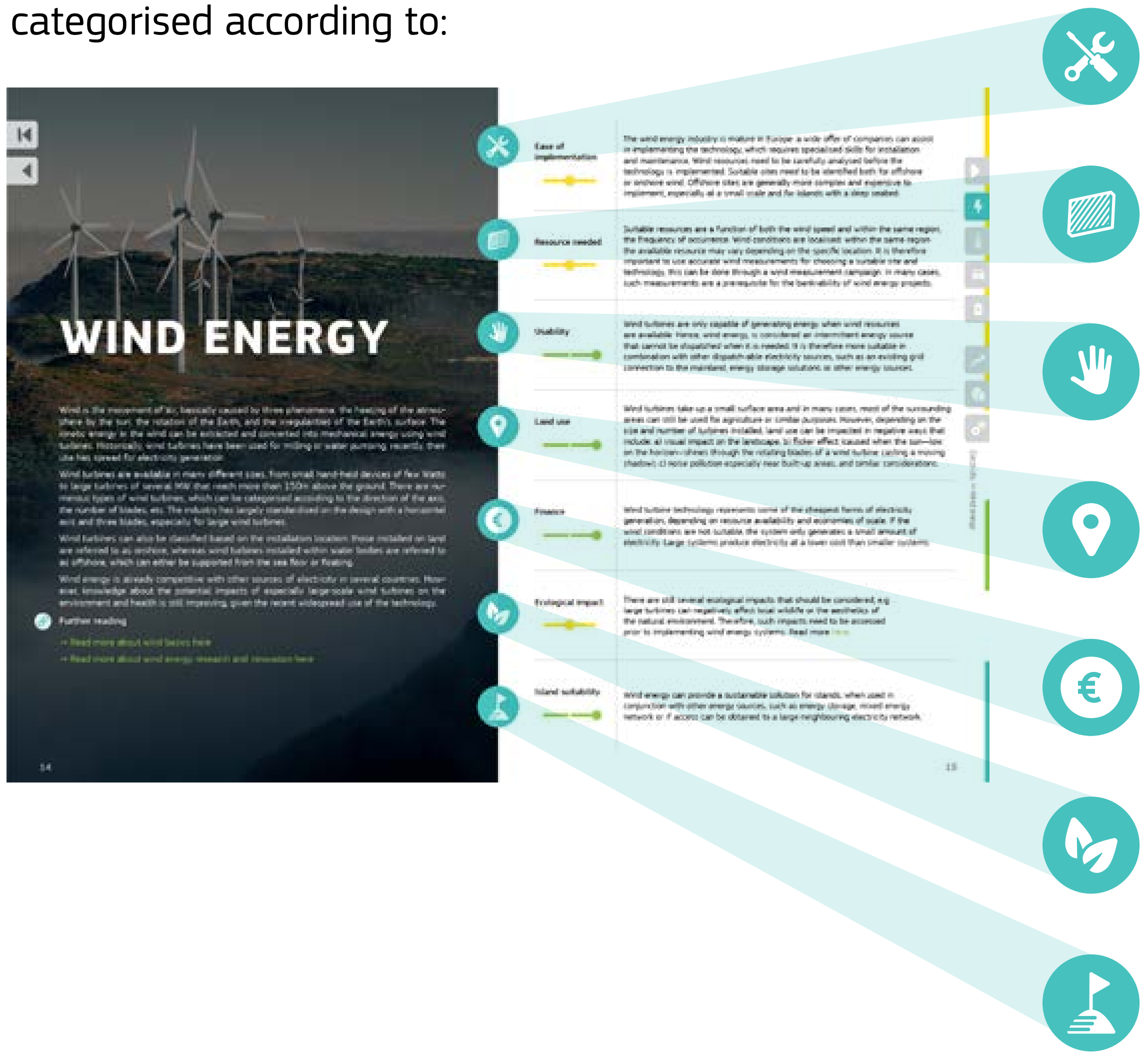
bottom-up initiatives with expert support that has a real impact on projects happening on the ground.

About this booklet

This technology solutions booklet provides an **overview of energy technologies** that are currently commercially available for islands to advance in their clean energy transition. Innovative technologies at early stages of development have not been included as they have not yet been proven to be implementable.

Each technology is presented following the same three-part structure:

1. **short description of the technology** followed by
2. the **pros and cons** for its implementation on islands, categorised according to:



Ease of implementation

Resources needed to produce energy using this technology

Usability

Land use required by the energy solution

Finance, based on a qualitative assessment

Ecological impact, which focuses on the environmental impact of the technology during its operation. That is, the lifecycle impact (considering required materials, disposal, etc.) is not assessed unless there is an issue that stands out.

Island suitability

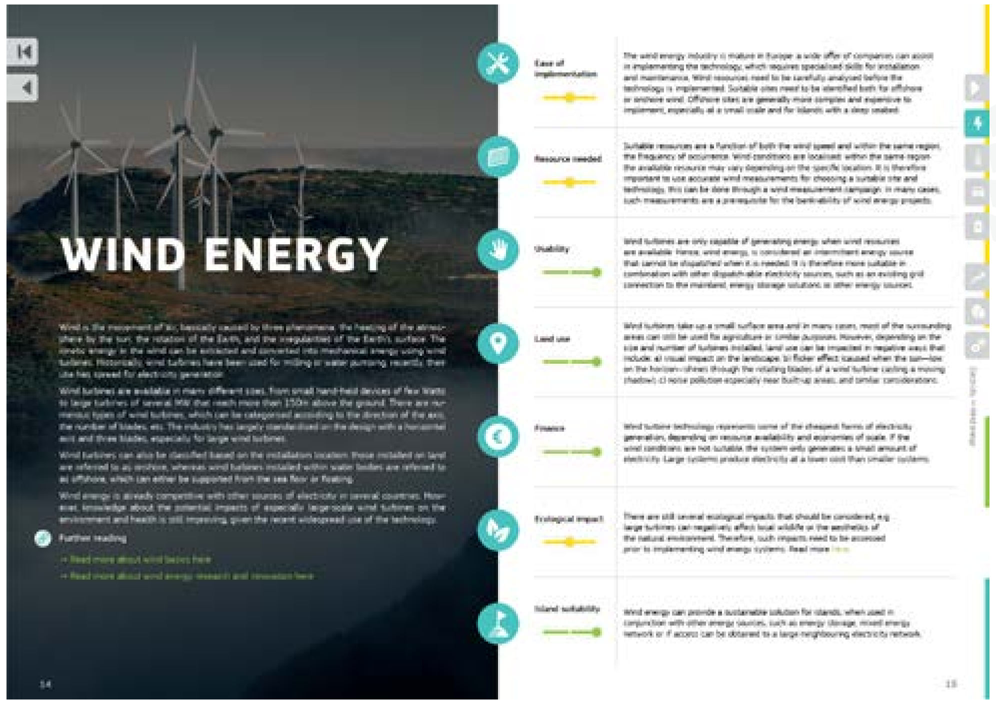
Each category is labelled as green, yellow, or red based on how the technology performs compared with the rest of the presented technologies.

Red = low

Yellow = medium

Green = high

3. a final section on **examples on islands** provides inspiration and shows how the **technologies are being currently applied on islands** around the world.



The technologies are grouped per sector:

ELECTRICITY:
wind energy, solar photovoltaic, geothermal, marine energy, combined heat and power

HEATING AND COOLING:
biomass, heat pumps, district heating and cooling, solar thermal

TRANSPORT:
electric vehicles, electric ferries and boats, hydrogen (maritime and road transport)

STORAGE:
battery energy storage systems, power to X, and pumped hydro

Acronyms

CCUS	Carbon Capture, Utilisation and Storage
CEC	Citizen Energy Community
CHP	Combined Heat and Power
COP	Coefficient of Performance
DHC	District Heating and Cooling
EV	Electric vehicle
FCEV	Fuel Cell Electric Vehicle
ORC	Organic Rankine Cycle
PtX	Power to X
PV	Photovoltaic
REC	Renewable Energy Community
V1G	Smart charging
V2G	Vehicle to Grid

These three energy solutions are presented as stand-alone options (not part of the previous sectors), with a dedicated structure that adapts to their specificities.

ENERGY EFFICIENCY,

COMMUNITY ENERGY,

SMART GRIDS

The focus of the following pages is to provide details of **ready-to-be-implemented technological solutions** for islands. Hybrid systems, combining several technologies, allow also combining their advantages and disadvantages so that they complement each other. Combinations are endless though, so they have not been analysed in detail in this booklet.

The suitability of a specific technology or a hybrid solution on an island will eventually depend on the specific characteristics of the island itself: its distance to mainland, its natural resources, whether it is interconnected to the mainland/other islands or not, etc. When transitioning to new energy systems, the focus should always be on decarbonising, i.e. on reducing greenhouse gas emissions.

To understand which areas contribute the most to CO_2 emissions and therefore should be first targeted, it is necessary to perform an energy consumption and emissions baseline as suggested in the Clean Energy Transition Agenda (CETA) and explained in the Islands Transition Handbook. Once critical sectors for decarbonisation have been identified, this booklet could help island communities to identify the potential pathways to achieve the island's decarbonisation objectives. In order to determine the exact solutions and projects to be pursued, pre-feasibility studies would be required to precisely analyse the expected outcome and cost of the chosen technologies.

Useful links are provided throughout the booklet for interested readers to find more information.

In addition, at the end of the booklet, we provide a list of useful links to studies, platforms, initiatives and projects.

Finally, the Clean energy for EU islands secretariat website offers information about ongoing projects on EU islands, best practices, webinars and workshops as well as additional useful documents.

Go to the next page
Electricity
Heating and cooling
Transport
Storage
Energy efficiency
Community energy actions
Smart grids

ELECTRICITY

WIND ENERGY

Wind is the movement of air, basically caused by three phenomena: the heating of the atmosphere by the sun, the rotation of the Earth, and the irregularities of the Earth's surface. The kinetic energy in the wind can be extracted and converted into mechanical energy using wind turbines. Historically, wind turbines have been used for milling or water pumping; recently, their use has spread for electricity generation.

Wind turbines are available in many different sizes, from small hand-held devices of few Watts to large turbines of several MW that reach more than 150m above the ground. There are numerous types of wind turbines, which can be categorised according to the direction of the axis, the number of blades, etc. The industry has largely standardised on the design with a horizontal axis and three blades, especially for large wind turbines.

Wind turbines can also be classified based on the installation location: those installed on land are referred to as onshore, whereas wind turbines installed within water bodies are referred to as offshore, which can either be supported from the sea floor or floating.

Wind energy is already competitive with other sources of electricity in several countries. However, knowledge about the potential impacts of especially large-scale wind turbines on the environment and health is still improving, given the recent widespread use of the technology.

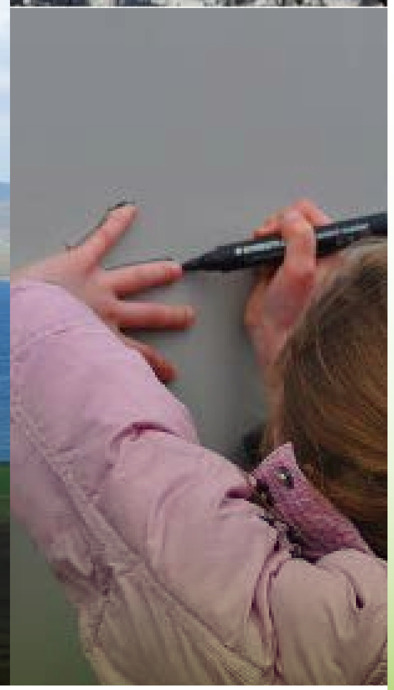
Further reading

→ Read more about wind basics here

→ Read more about wind energy research and innovation here

Ease of implementation	The wind energy industry is mature in Europe: a wide offer of companies can assist in implementing the technology, which requires specialised skills for installation and maintenance. Wind resources need to be carefully analysed before the technology is implemented. Suitable sites need to be identified both for offshore or onshore wind. Offshore sites are generally more complex and expensive to implement, especially at a small scale and for islands with a deep seabed.
Resource needed	Suitable resources are a function of both the wind speed and within the same region, the frequency of occurrence. Wind conditions are localised: within the same region the available resource may vary depending on the specific location. It is therefore important to use accurate wind measurements for choosing a suitable site and technology, this can be done through a wind measurement campaign. In many cases, such measurements are a prerequisite for the bank-ability of wind energy projects.
Usability	Wind turbines are only capable of generating energy when wind resources are available. Hence, wind energy, is considered an intermittent energy source that cannot be dispatched when it is needed. It is therefore more suitable in combination with other dispatch-able electricity sources, such as an existing grid connection to the mainland, energy storage solutions or other energy sources.
Land use	Wind turbines take up a small surface area and in many cases, most of the surrounding areas can still be used for agriculture or similar purposes. However, depending on the size and number of turbines installed, land use can be impacted in negative ways that include: a) visual impact on the landscape; b) flicker effect (caused when the sun—low on the horizon—shines through the rotating blades of a wind turbine casting a moving shadow); c) noise pollution especially near built-up areas; and similar considerations.
Finance	Wind turbine technology represents some of the cheapest forms of electricity generation, depending on resource availability and economies of scale. If the wind conditions are not suitable, the system only generates a small amount of electricity. Large systems produce electricity at a lower cost than smaller systems.
Ecological impact	There are still several ecological impacts that should be considered, e.g. large turbines can negatively affect local wildlife or the aesthetics of the natural environment. Therefore, such impacts need to be assessed prior to implementing wind energy systems. Read more here.
Island suitability	Wind energy can provide a sustainable solution for islands, when used in conjunction with other energy sources, such as energy storage, mixed energy network or if access can be obtained to a large neighbouring electricity network.



© Photos on this page: Rousay, Egilsay and Wyre Development Trust 2018 - 2021

Island examples: Orkney Islands

Orkney is an archipelago of 70 odd islands off the north coast of Scotland. As part of the North Isles of Orkney, Rousay (200 residents), Egilsay (20 residents) and Wyre (10 residents)—also known as REW—often work together as a single community, sharing services and infrastructure. The three islands have traditionally relied on farming and fisheries, but tourism is also a significant activity.

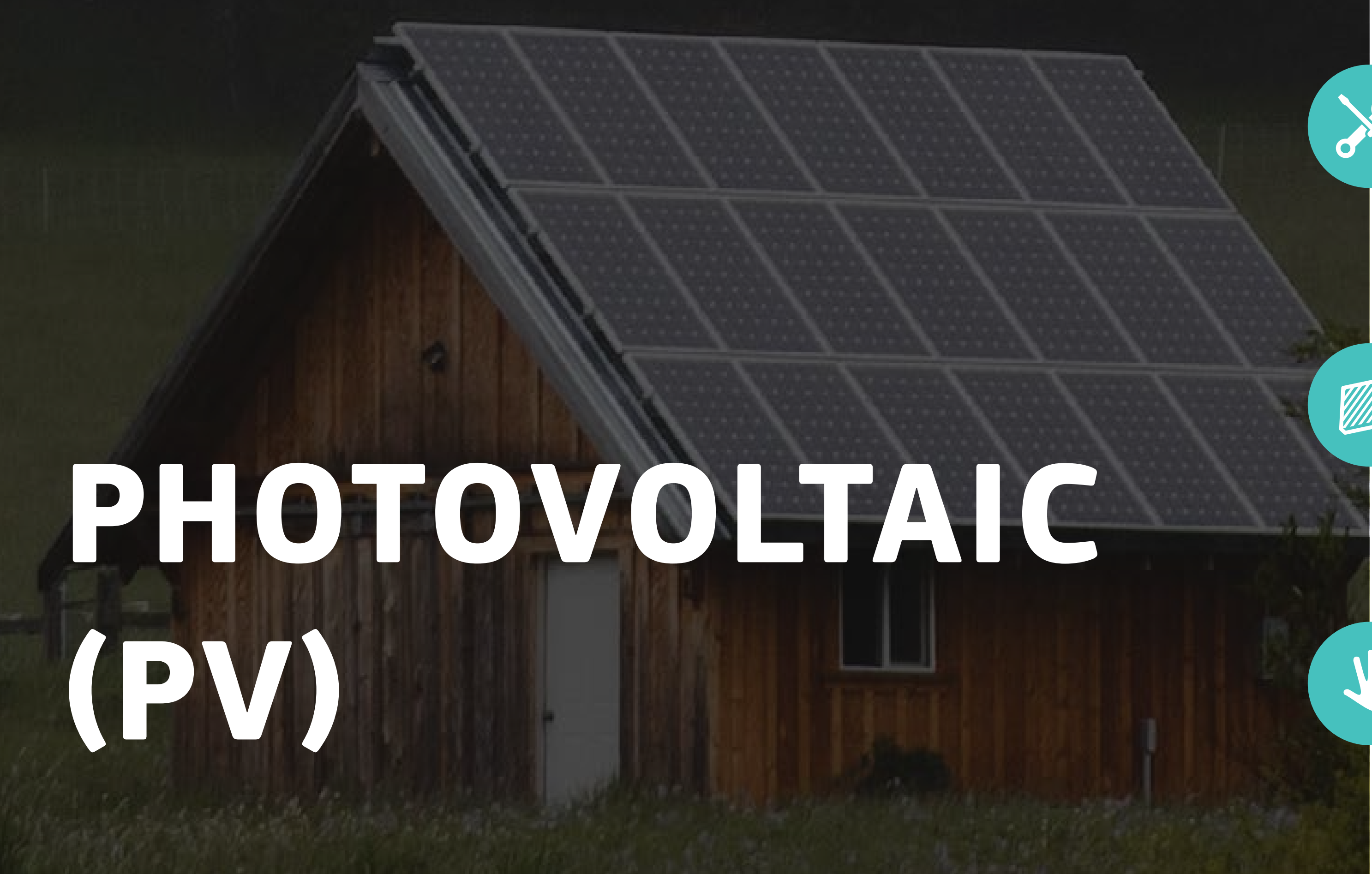
As a response to the social challenge that the islands were experiencing 20 years ago, the community was supported by the Government and independent charities like Community Energy Scotland to set up a Community Development Trust to drive local development and build future resilience for the community. A key plan from the Trust was to build a 900 kW commercial wind turbine to be owned and operated by the community. Completed in 2011, the turbine was sized to produce approximately the required electricity demand for the population. However, it is currently connected to the national grid, sells its production to the national market and the community uses the revenues for a wide range of projects and activities based on a local Community Development Plan. Ensuring that all the surplus funds generated are collectively owned reduces potential arguments and dissent based around more fortunate individuals benefiting from income and others missing out; often an important factor in (smaller) communities.

This turbine was developed using a “Scottish Social Enterprise Model”: a charitable social-enterprise non-recourse loan ownership and finance model which has allowed the community to retain full ownership of the generator without having large cash or collateral resources to finance its construction. This type of finance was possible thanks to the Government’s policy intervention guaranteeing income and providing certainty over a long period through their Feed-in Tariff initiative.

The turbine has experienced some challenges of reduced production due to grid capacity, but still has an average capacity factor over 40% and has contributed between £1-2 million directly to local community efforts. The three REW islands have also seen significant employment growth both directly linked to the turbine and indirectly to the Development Trust.

Further reading

→ Read more about it on REWIRED website



PHOTOVOLTAIC (PV)

The photovoltaic (PV) technology is used to convert solar energy into electricity. PV technology is produced by panels that have standardised sizes with different available dimensions and peak power values, the most common being 1.5 m^2 with a peak power of 250 W. The typical PV available on the market today has an efficiency of 15-20%, which means that it converts 15-20% of the available solar energy into electricity. Ninety-five percent of the currently used PV technology is based on silicone, while the other 5% is based on alternative materials and can be thinner, transparent, and flexible. Such PV panels can be therefore integrated into building facades, although this application is still a niche market.

PV technology is modular: it can be used as distributed small generation on the rooftop of a building or installed as a large-scale plant with a large number of panels. Moreover, due to its modular nature, PV can be placed on water surfaces as well, typically referred to as floating solar. Currently, most floating solar installations are large scale, but due to their multiple benefits, their usage is quickly increasing.

PV technology has been commercially used for more than 30 years and has decreased in price to be one of the cheapest forms of electricity generation.

Further reading

→ Read more about photovoltaic (PV) technology here

→ Read more about electricity generation here

Ease of implementation	PV technology is modular and easy to install. It is one of the rare technologies that can respond to both very low and very large consumption needs.
Resource needed	PV technology needs only solar energy as a resource. According to full life cycle analyses, materials used to produce PV technology are currently abundant. There is ongoing research to improve existing technologies and to find ways to reduce, replace and recycle the materials used for PV. However, for an optimal specific installation, a technical analysis is needed to define orientation, tilt, and needed mounting.
Usability	The electricity produced from PV panels can be used for self-consumption or can be injected into the grid. PV production is linked to the availability of sun irradiation; therefore, it is weather dependent and intermittent.
Land use	PV technology requires a surface on which it can be installed. However, due to its modularity and light weight, it does not necessarily have to be installed on land: it can be alternatively placed on rooftops, on carports, water, integrated into the existing structures, on greenhouses, or in combination with agricultural lands.
Finance	The energy generated from PV technology is currently the cheapest of all renewable and fossil fuel technologies. Since PV is a modular technology, these numbers are usually based on large PV plants on the mainland, where economies of scale play a role. The smaller the PV installation, the higher the costs of the system (design, administration, mounting, installation).
Ecological impact	The only ecological impact from PV technology (during its operation) is the glare effect due to the sunlight's reflection on the panels.
Island suitability	Islands located in areas with significant solar energy potential are suitable candidates for PV technology. For islands where land use is limited or land is protected, PV technology can be installed on existing buildings' rooftops. PV technology only produces electricity during the day though; therefore, it requires to be installed along with storage or in combination with other technologies that can produce energy during the night.

© Photo: Akuo Agri

© Photos: Akuo Agri

Island examples: French island La Réunion

La Réunion is a French tropical volcanic island lying in the Mascarene Archipelago (Indian Ocean), one of the most preserved biodiversity hot spots in the world. With a population of 860,000 inhabitants, 2,512 km^2 of land and managing 315,058 km^2 of marine exclusive economic area, La Réunion provides a unique presence of France and Europe at the crossroads of Africa and Asia, at the heart of a millenary world-system.

La Réunion has shown how synergies between renewable energy and agriculture can happen thanks to a project of PV integrated into greenhouses. Five of such greenhouses have already been developed on the island.

Agrinergie® is the intelligent combination of energy production and agriculture in a single project. This innovative concept, created by Akuo Energy SAS in 2007, was first deployed on Reunion Island in 2010 with the Pierrefonds project. Today, Akuo operates five Agrinergie® plants on Reunion Island with a total installed capacity of 33 MWp.

Unlike ground-mounted panels, Agrinergie® greenhouses avoid conflicts of use on arable land and offer the advantage of being resistant to climatic events such as hurricanes or cyclones. This ensures the safety of harvests in this region, which experiences an average of two cyclones per year.

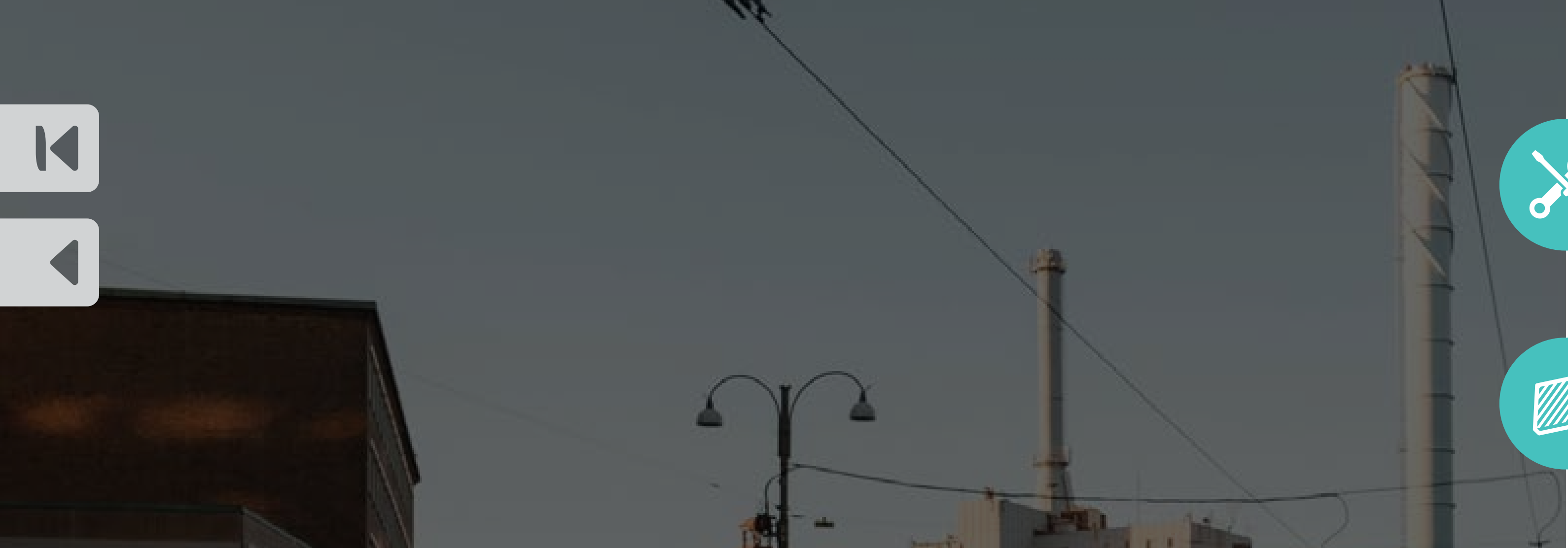
The Reunion Island is a pioneer in terms of innovation in sustainable agriculture while meeting the challenge of making this non-interconnected-zone self-sufficient in energy. Agrinergie® brings significant added value to the development of renewable energy projects on the island where arable lands represent only one fifth of the surface. It makes the projects more acceptable to the people who own the agricultural land.

Further reading

→ Projet Agrinergie® - en service (in English)

→ About La Réunion on the Outermost Regions Research and Innovation Platform

© Photo: Akuo Agri



GEOTHERMAL

Geothermal energy makes use of higher or lower temperatures in the earth's crust to meet energy needs for various processes. The heat from the earth's core is regularly flowing outwards as magma. Magma can occasionally reach the surface as lava, but it mostly stays within the Earth's crust heating nearby rock and water. This heated water is sometimes trapped in permeable, porous rocks under a layer of impermeable rock, forming a geothermal reservoir. Geothermal electricity generation and process heat applications are possible in areas where these high-temperature rock, water and steam is close enough to the surface to be exploited by drilling.

Geothermal energy is also available in the near surface soil due to absorbed solar energy and thermal inertia. Solar heat is retained in the soil, groundwater and larger water bodies from summertime throughout the year, which results in relatively constant temperatures a few meters deep all year round. This energy can be utilised for space heating in winter or cooling in summer through so-known as ground-source heat pumps (see section on heat pumps for more details).

One of the current challenges of geothermal energy is to gain a full understanding of its environmental and social impact. Another is to create systems that allow the widespread and cost-effective exploitation of these resources.

Further reading

- → Success Stories by Solid Solar Energy Systems
- → IRENA: European geothermal capacity could grow eight-fold by 2050
- → Renewable Energy in Cities from IRENA

Ease of implementation	Accurate geological understanding and measurements are required to determine the potential of a specific site, which can be complex and expensive. These measurements include exploration drilling, which can be a slow and high-cost endeavour.
Resource needed	Geothermal energy is regarded as a renewable resource due to the essentially limitless heat in the earth as well as continuous replenishment of groundwater and solar energy. Geothermal energy is clean, renewable, and relatively constant compared to other renewable energy resources that fluctuate. However, for power generation and other high-temperature applications, geothermal energy is limited to regions with shallow volcanic activity for affordable drilling costs.
Usability	The constant nature means that geothermal systems can be used for base load production or industrial heating processes.
Land use	A geothermal plant takes up a relatively small land area since it utilises underground reservoirs and no fuel needs to be mined or imported from other areas.
Finance	Geothermal systems are characterised by high initial start-up costs and low running costs when compared to alternative solutions. The high initial cost of geothermal plants can be attributed to the high-cost of exploration and resource confirmation prior to plant development, high well drilling costs, and building the required infrastructure for an operating power plant near the resources.
Ecological impact	Geothermal systems generate very little greenhouse gas emissions during their operation. However, non-condensable chemicals are often present in the extracted liquid (brine). The corrosive chemicals in brine can damage equipment and toxic chemicals can pose a risk to the environment. Brine needs to be treated before releasing it into the environment. Large plants are associated with seismic risks by changing the pressures within the earth, causing localised earth tremors. In general, geothermal systems do not directly compete with water users since the working fluid is mostly brine which after use to generate power gets pumped back underground to sustain the reservoir pressure.
Island suitability	The applicability of geothermal energy depends on the geology of the island. Geothermal energy is most accessible in areas of high tectonic activity, where magma is closer to the surface. Other areas can still make use of shallow geothermal potential at a smaller scale and retrieve them ground-source heat pumps.

© Photo: Terceira Pico Alto

© Photo: Sao Miguel Ribeira Grande

© Photo: Terceira Pico Alto

Island examples: Azores

The Azores is an archipelago composed of nine volcanic islands located in the middle of the Atlantic with about 250,000 inhabitants. The energy context for this autonomous region is quite specific, as there is no grid connection between the islands or to the mainland. This is due to the scarred basalt floor that covers several hundred meters of distance between each of the islands, causing power cables to be inoperable.

Because of this, the Azores have come to rely on the resources available on each of the islands as well as on imported fossil fuels. As of right now, there is one thermal power plant per island, together with a growing number of renewable power plants such as photovoltaics, wind power, hydropower and geothermal power stations. Altogether, these renewable energy sources allow the Azores to reach a renewable penetration of about 40%.

Currently, three geothermal power stations have been installed in the Azores (total of 34.3 MW), resulting in a cost-effective solution that is responsible for about one quarter of the total energy generated, serving as a base-load with a predictable and stable production. On São Miguel Island, the stations of Pico Vermelho (13 MW) and Ribeira Grande (16.6 MW) generated 37.5% of the total amount of energy produced on the island in 2019, although, as seen in previous years, these stations have achieved more than 40% of all energy produced on the island. During the same years, the station of Pico Alto (4.7 MW), located on Terceira Island, generated 12.5% of the total energy produced on this island.

At the moment, further investments are ongoing to increase these stations' geothermal capacity, which will reduce the need for importing fossil fuels in the Azores. The generation costs are estimated at less than 50% of fossil-fuel-based generation, largely due to the remoteness of the Islands. Due to the small size of the networks, the power market is less attractive to private investment and the geothermal projects have been driven with an emphasis on public service. The generation costs are estimated at less than 50% relative to fossil-fuel-based generation, largely due to the remoteness of the islands. At the moment, further investments are ongoing to increase these stations' geothermal capacity, which will reduce the need for importing fossil fuels in the Azores.

Further reading

→ Success stories

→ European geothermal capacity could grow eight-fold

→ Use of geothermal resources in the Azores islands: a contribution to the energy self-sufficiency of a remote and isolated region

→ A Direção Regional da Energia, DREn (Portuguese only)

→ Electricidade dos Açores, S.A. (Portuguese only)

MARINE ENERGY

Marine energy, also known as ocean energy, ocean power and marine hydrokinetic energy, comprehends a variety of technologies that allow harnessing energy from the seas and oceans. This section focuses specifically on tidal energy and wave energy.

Tidal energy technology uses underwater turbines to transform mechanical energy due to tides of the sea/ocean's water movement to electrical energy. Tidal power plants must be constructed close to the land, as high tidal currents are needed to produce power.

Similarly, wave energy technology uses underwater turbines to transform the mechanical energy of the waves into electrical energy. It is based on a simple principle: a wave's force powers underwater turbines that are attached to a buoy. The movement of the water makes the buoy move up and down, a wave energy converter transforms the kinetic energy of the buoy into electrical energy.

In both cases, sub-sea cables carry the electricity to the shore, where it can power the grid.

Further reading:

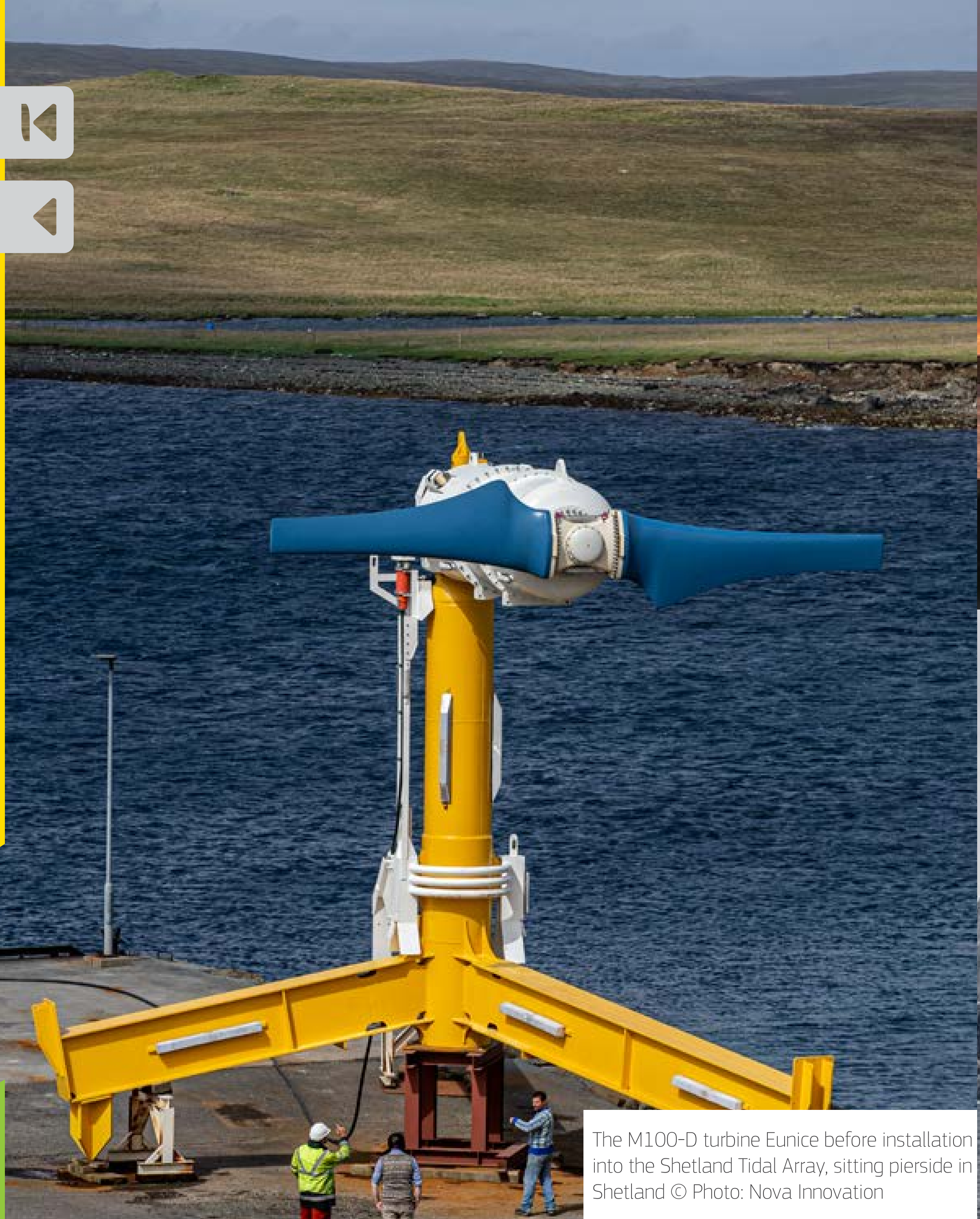
→ About marine energy on the European Marine Energy Centre LTD website: Profiling the top tidal power pros and cons

→ Ocean Energy Europe: Ocean Energy, the best big thing in Europe

→ Oceans powering the energy transition: Progress through innovative business models and revenue supports

→ Why the EU supports ocean energy research and innovation

Ease of implementation	The technology for harvesting marine energy is still considered to be in its infancy. There are only a small number of large-scale commercial solutions available throughout the globe. Therefore, wave and tidal technology has been mostly implemented as research and demonstration projects, with the associated challenges related to the application of innovative ventures. Furthermore, installation and maintenance of the water turbines can be challenging.
Resource needed	Wave and tidal energy plants make use of the natural motion of the sea. They do not consume additional resources to produce energy and can therefore be considered fully renewable.
Usability	Marine energy is a type of renewable energy with constant production. Therefore, it can provide security of supply for an island. Moreover, this technology can be coupled with other renewable energy technologies to complement each other and benefit from synergies (e.g. solar, wind, storage, hydrogen, etc.).
Land use	As this technology is implemented in the water, it does not consume land surface. However, the plant can have an impact on shoreline use. Electricity cables and transformers are needed to transfer power from the underwater turbine to the land.
Finance	As there are only a few operational installations of marine technology, installing this technology comes with a high price tag. It is expected that using tidal technology to produce energy could become financially viable once higher technology readiness levels are reached.
Ecological impact	Underwater turbines produce no greenhouse gases and have no unwanted waste products. However, the impact on marine life needs further investigation. As this technology is only in its infancy, long-term marine and shoreline impacts are unclear. Although sea life could be affected by the turbines (noise, quality of water), recent studies have concluded that impacts are very limited. Impacts from large-scale installations in the long run are not documented yet but are estimated as low.
Island suitability	Islands are surrounded by water and hence have suitable geographies to implement this technology. Tides and waves are more predictable compared to other intermittent renewable energy sources like wind and sun. Hence, the development of tidal and wave energy technologies could increase reliability and reduce the need for flexibility.



The M100-D turbine Eunice before installation into the Shetland Tidal Array, sitting pierside in Shetland © Photo: Nova Innovation

M100-D Eunice underwater in the Shetland Tidal Array © Photo: Nova Innovation

Island example: Shetland archipelago in Scotland

The world's first offshore tidal energy array was installed by Nova Innovation at Bluemull Sound in Shetland in 2016.

The 'Shetland Tidal Array' has been delivering clean, predictable power to local homes, businesses and the grid since it was installed five years ago. Following the success of the first four turbines and the positive impact they have had on the local economy and Shetland's carbon emissions; Nova is currently increasing the capacity of the Shetland Tidal Array to six turbines.

Since installation, the 600 kW tidal array has delivered further game-changing breakthroughs, including the world's first baseload tidal power station in collaboration with Tesla that can deliver power on demand, and the European Commission's flagship €20 million EnFAIT (Enabling Future Arrays in Tidal) project, which is demonstrating the 'bankability' of tidal energy. In 2021, Nova created the world's first electric vehicle charge point powered purely by the tide in Shetland.

The Shetland Tidal Array is widely supported by the local community and the project now uses over 40 local Shetland suppliers. In 2010, Nova Innovation was founded with an ambition to transform the power of the sea into clean, predictable electricity. This has been achieved in Shetland and it can now be recreated across the world.

Further reading

→ To find out more go to www.novainnovation.com

→ For videos on how our technology works including our EV charge point click here

→ Read more about Shetland example here

→ EnFAIT - Enabling Future Arrays in Tidal

→ Wavepiston projects in Gran Canaria ad Sardinia

→ Sinnpower project in Heraklion

M100-D Eunice installed in the Shetland Tidal Array © Photo: Nova Innovation

HEATING AND COOLING

BIOMASS

Biomass includes organic materials such as wood products, plants and waste (animal, agri-cultural, and fishery). Biomass is used for heat generation or electricity generation—or both in cogeneration plants that increase the efficiency of useful energy that can be extracted from biomass (see cogeneration section).

At present, biomass is the main source of renewable energy in the EU. When it comes to heat generation, biomass can be used in centralised generation plants that are connected to district heating systems or in single home heating systems.

Biomass has been used for energy generation for centuries: nowadays, its feasibility depends on how accessible and sustainable the resources are. Biomass-based systems are considered a renewable energy technology as long as the resources are local and the biomass is fed to highly efficient technologies.

Renewable energy sourced from biomass in the EU needs to fulfill sustainability criteria to count towards renewables targets, or to be eligible for subsidies by EU countries. The recast Renewable Energy Directive 2018/2001 provides an update in these sustainability criteria. Member states were obliged to transpose the Directive by June 2021, having the option of introducing more stringent sustainability criteria.

Further reading

→ Brief on biomass for energy in the European Union

→ European Commission: biomass

→ Recast Renewable Energy Directive 2018/2001

Ease of implementation	Biomass technologies can provide energy to either a single building or via district heating to multiple buildings. Single home systems are easy to implement and have been in use for a long time.
Resource needed	The supply of resources/fuel needed for the biomass generation plant has to be predictable, sustainably sourced, low-cost, local and adequate over the long term.
Usability	Biomass technology allows coupling the energy and waste management sectors: the organic waste that cannot be recycled or reused may be used for energy purposes.
Land use	Biomass technology is usually planned at the existing district heating plan or waste management facility. Centralised systems do not require significant land use. Household systems are integrated into an existing building or house, often replacing a fossil fuel-based system. In cases where organic waste is used to feed a biomass plant, the waste facility might already have a location that simplifies the implementation of the biomass facility.
Finance	Biomass-based energy represents one of the cheapest renewable energy systems. The cost may increase if a new heating network needs to be installed, if the biomass source used is not sustainable, or if its price changes from waste to useful commodity once it is used for energy.
Ecological impact	The ecological impact of the biomass source is the biggest concern with biomass energy. The EU has defined **sustainability criteria for biomass** use within its territory.
Island suitability	Biomass can offer a sustainable and local source of constant energy for the island. However, it is important to analyse the sustainability and long-term use of the biomass source for the island. It is especially critical to assess whether other industries depend on biomass and to ensure that the source is not limited or financially unstable.

© Photos: Samsø energy academy

Island examples: Samsø, Denmark

Samsø is a Danish island and municipality with an area of 114 km^2, home to approximately 3,700 permanent inhabitants. It faces similar challenges to many other islands and rural communities, namely population decline, and pressures to its economy, which is primarily based on agriculture and tourism. The most known agricultural product of the island is its potatoes, which are famous in Denmark and can get a very good price on the Danish market, especially the first harvest of the year. It is also a popular summer destination and its population increases by at least a five-fold in the summertime. The main energy needs are electricity, heating of buildings, road transportation on the island and sea transportation between Samsø and mainland Denmark.

The heating of homes and businesses is done through four collective district heating systems, of which three are based on local straw and the fourth is based on straw and solar thermal. Most houses and businesses in the main settlements, instead of having an individual boiler each, are connected to a central boiler, which heats up water centrally. The hot water then, through a network of underground pipes, circulates around the island's settlements and provides heat to each individual house or business. For example, one of the straw-based heat boilers used for district heating has a capacity of 1.6 MW and uses 1,500 tons of straw per year in order to cover 5,500 MWh of heating demand per year. It was implemented by a consumer led cooperative. The biomass plant was installed in 2005 with 187 connected consumers and grew to 258 consumers. Consumers use district heating with an annual fee and pay the heat they use. In addition, each new consumer has an initial connection fee.

In 1997, Samsø decided to stop importing fossil fuels, like oil, and get rid of the uncertainty that fluctuating market prices, accidents of all sorts or just the will of oil sheikhs and oligarchs in oil-producing countries used to create. This was an opportunity for local farmers to provide straw and organic matter from their fields that remains after harvesting to the central boiler. This way they get paid for something that would otherwise be disposed of. As a result, the households' heating bills dropped and have remained more or less stable ever since.

Further reading

→ Samsø energy academy

COMBINED HEAT AND POWER (CHP)

Combined Heat and Power (CHP), also known as cogeneration, consists in the simultaneous production of electricity and useful heat by an engine that runs on a single fuel. Electricity is produced in a generator connected to the engine's rotating shaft. The heat, obtained as a by-product of electricity generation, is recovered instead of being released to the atmosphere or lost through the cooling system. Recovered heat is available as hot water or steam for space heating, cooling, domestic hot water or industrial processes.

Different technologies can act as CHP units, such as reciprocating engines, gas turbines, fuel cells, steam turbines, and Stirling engines. A variety of fuels can be used to feed these engines, such as natural gas, biogas, biomass, etc.

The main advantage of CHP technology is the high efficiencies achieved compared to the separate production of electricity and heat. This high efficiency, in turn, translates to financial and CO_2 savings.

Further reading:

→ What Is CHP? (EPA)

→ What Is Cogeneration? (Cogen Europe)

→ About COGEN Europe (an advocacy group based in Belgium)

Ease of implementation	Commercially available CHP units usually fit in standardised container sizes which eases their transport and implementation. In terms of installation, the CHP unit needs to be connected onsite to the heating network where the produced heat is delivered. The complexity of this connection may vary according to the required temperatures and the form in which heat is needed (steam, hot water, etc.).
Resource needed	CHP units need a fuel to run on, which can be fossil-based, like natural gas or renewable-based like biogas and biomass. According to *Cogen Europe*, 27% of fuels currently used in cogeneration in Europe are renewable.
Usability	CHP plants usually run following the user's heat demand as the excess or curtailment of heat is more complicated to manage than electricity. Cogeneration units come in a wide range of sizes: from 1 kW to nearly 1 GW and can therefore adapt to the users' needs. Transmission and distribution costs are reduced because both heat and electricity are generated close to the point of consumption.
Land use	CHP units are compact and have a high power-to-volume ratio. They are usually located close to the source of the heat demand.
Finance	CHP units offer financial and CO_2 savings compared to the separate production of heat and electricity in two different units. The specific savings depend on the base-case scenario and on the fuel used.
Ecological impact	The ecological impact of CHP depends on the fuel used to run the engines: it will be higher with fossil-based fuels and reduced for renewable fuels.
Island suitability	CHP technology would be interesting for islands with relatively constant heat demand over the year, to ensure that the units are run long enough to be financially attractive.

© Photo: Værket Forår 2018, heatplants and CHP on Bornholm

Island examples: Bornholm

Bornholm is a Danish island lying off the coast of Sweden in the Baltic Sea, to the east of the rest of Denmark. It has a population of around 40,000 inhabitants. Bornholms Energi og Forsyning (BEOF) is the local utility company covering wastewater treatment, freshwater, district heating, and power production.

BEOF's cogeneration plant, in Rønne, supplies power and district heating to Bornholm's residents. The boiler was built in 1996 and was originally designed with the possibility of using 20% biomass in the combustion process.

In 2016 the combined heat and power in Rønne was rebuilt to be fueled with 100% biomass (200,000 m^3/year wood chip), instead of coal/oil/wood chip as co-firing, and was equipped with a flue gas condensation unit. The flue gas is cooled by the domestic heating water returning from the city from a temperature of 1800 °C to 600 °C. The building for the flue gas condensation unit is prepared for a heat pump which enables to further cool the flue gas to increase efficiency and reduce the consumption of biomass.

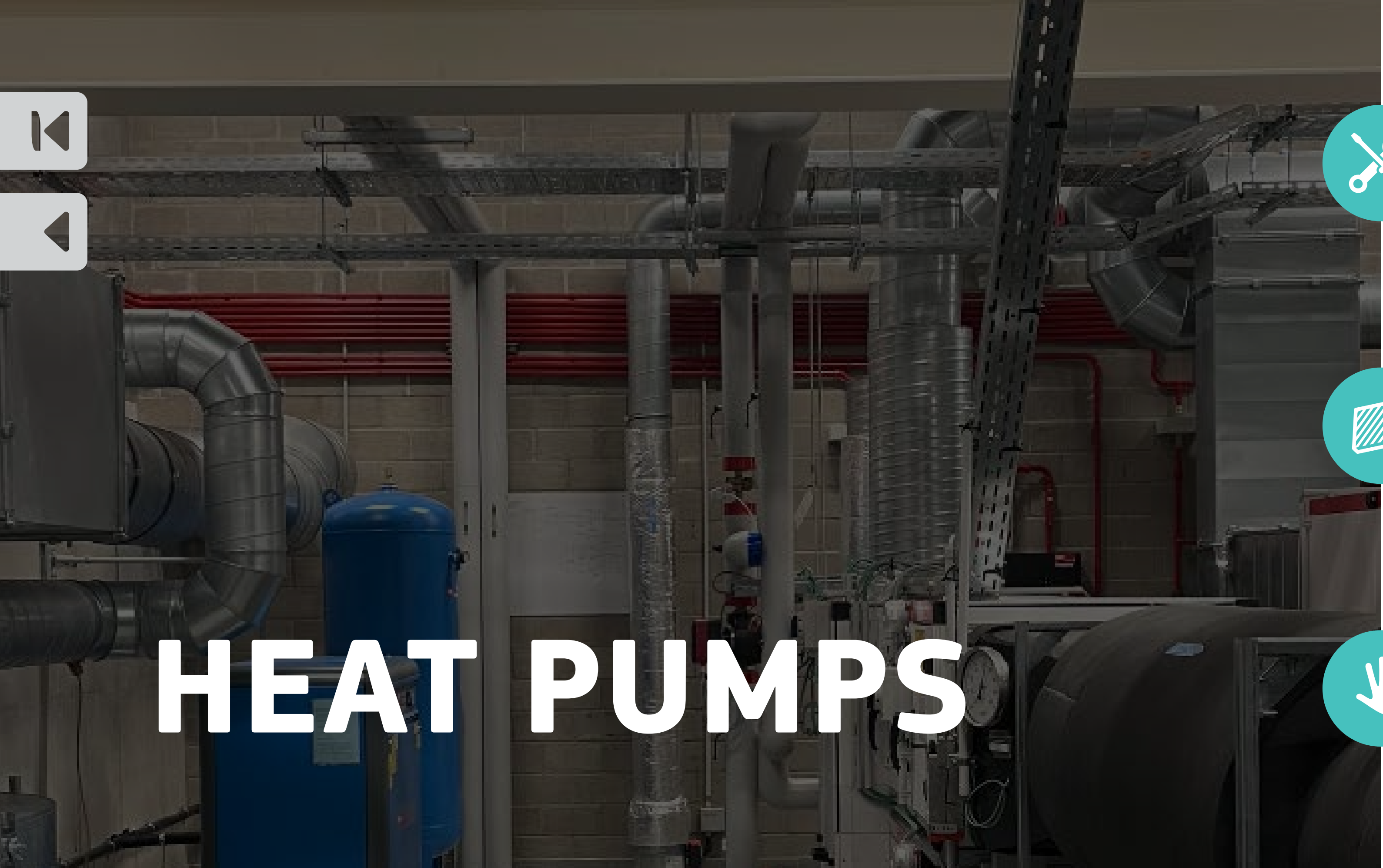
During Christmas 2017, the sub-sea cable between Denmark and Sweden stopped working and the power connection was disrupted. This did not pose a problem to the island of Bornholm thanks to the flexibility provided by the cogeneration plant of BEOF, which was able to increase production during this time to ensure energy security of supply on the island.

Aside from biomass CHP, the island has a PV plant and onshore wind. It plans to become 100% CO_2 neutral by 2025. Currently on a yearly basis, approx. 70% of the electricity consumption is covered by renewable energy, wind, PV, biogas and woodchips.

Further reading

→ Aalborg Energie Technik a/s Biomass Cogeneration Plant Østkraft - Rønne, Denmark

→ Island of Bornholm Winner of the 2019 RESponsible Island Prize (PDF download with press release)



HEAT PUMPS

A heat pump is a device used for space or water heating or cooling in buildings, or process heating or cooling in industry. Heat pumps can be used as single home/apartment units or as heat pump-driven district heating systems.

A heat pump transfers thermal energy to or from a source of renewable heat, such as the air, water, or ground with the help of external power (electricity or gas).

Heat pumps generate more useful thermal energy than the energy they require to operate; thus, their efficiency is expressed as a Coefficient Of Performance (COP): the higher the COP, the more efficient the heat pump is. While a heat pump's COP is based on average conditions, it varies depending on the difference between the temperature of the source and the desired delivered temperature level. The higher the temperature difference, the more external power is required, and the lower the COP. The COP value depends on the type of heat pump and can vary from 2 to 5.

Heat pumps have been used for almost a hundred years and have improved in efficiency over time. In the past decades, they have become more and more popular in Europe as an electricity-based, decentralised, and mostly renewable way of satisfying heating and cooling needs. In addition, heat pump capacity can be controlled during operation to offer flexibility to the grid.

Further reading

→ More about heat pumps here (White paper Heat pumps)

→ More about heat pump-driven district heating systems

→ More about types of heat pumps here

Ease of implementation	Heat pumps are easy to implement as they can be used as single house/apartment installations. They can also be implemented for larger applications, such as a central heating/cooling system of a large building, a district heating sytem, or a hot water installation. The implementation of geothermal heat pumps may be more complex as they require a study of the resource potential at the specific location.
Resource needed	Heat pumps consume electricity and require access to a heat source or sink, like the ambient or exhaust air, water (groundwater, lakes, sea, ocean, wastewater) or the ground (geothermal). All these sources are renewable. Ground-source heat pumps which use a shallow ground area, require the use of a substantial amount of land, which could be problematic on islands with limited space.
Usability	Heat pumps provide at least twice as much energy as they consume (for a COP value of 2, while more advanced heat pumps may reach COPs of 5). Thanks to their variable operation, they can be used in aggregation or for providing flexibility to the electricity system, e.g. through demand-side management.
Land use	Small-scale heat pumps can be installed in existing or new buildings and do not require additional land. Land is needed in case of district heating or geothermal technology.
Finance	Heat pumps could be a very economical solution depending on the available energy source potential (outdoor air temperature ranges, water or ground temperature), electricity prices and energy needs of the application.
Ecological impact	The negative effects of heat pump devices may come from leakage of refrigerants (if halogen-containing refrigerants are used), the misuse of the water or the ground resource. The issue of misuse of water is typically regulated by defining the temperature at which the return water can be released and the operational temperature of geothermal technology.
Island suitability	Heat pumps provide an efficient way of satisfying heating/cooling needs (including hot water) while using renewable energy resources. If electricity produced by renewable energy sources is used as external input, then it is overall a sustainable device.

© Photo: Armando Buzzo

© Photo: Armando Buzzo

Island examples: San Pietro, Italy

The Island of San Pietro is located to the south-west of Sardinia, with 6,133 inhabitants and an area of 51 km^2. A relevant economic part rests on the sustainable fishing of bluefin tuna, unique for its culinary and healthy properties. On the island, the tuna is also processed and prepared for shipments around the world!

Through *project REACT*, the Municipality and the European Commission want to integrate smart grid technologies in the Island electricity network. Up to June 2021, 53 buildings have been considered for the demonstration activities of the pilot, which is transforming the San Pietro Energy community into a Virtual Power Plant.

In the design phase of the technologies to be installed, the need to deal with the hot summer conditions was considered. Consequently, it was planned for air-to-air heat pumps to be installed to provide both space heating and cooling by directly treating the air in the space. Furthermore, taking into consideration the time-alignment of diurnal cooling demand and solar irradiance profiles, the adoption of air-to-air heat pumps has allowed increasing the efficacy of the PV installed on the building rooftop, by favouring the self-consumption. “Mono-split” and “multi-split” room air conditioners complete the systems installed in the residential buildings, while larger variable refrigerant flow systems have been thought of in the public buildings.

A different solution has been adopted for the buildings with significant domestic hot water demands: with the purpose of fulfilling even this need, air-to-water heat pumps have been deployed. For almost all the pilot cases, 200 l domestic hot water tanks have been used, apart from the Sports Centre where a 15,000 l domestic hot water tank has been necessary for the thermal storage, considering the electrical load shifting. There, with a domestic hot water tank temperature of 50-60 °C, a total thermal storage capacity of about 150 kWh can be provided. Lastly, also the tourism sector has benefited from these technologies, indeed they have been installed in hotels and B&Bs.

The project has been a huge success and even the families initially not interested in the adoption of these technologies have started to exploit state incentives for an almost total transition. The next step consists of the remote and automatic control of the devices, in a suitable way with respect to the resting part of the system. Intelligent Energy Management software wants to be adopted, getting the full exploitation of the Island green potential. Only with this systemic vision of energy flows, the advantages in the electric bill and for the environment will be really equal to what the Island offers with its weather conditions.

Further reading

→ Read about the Energy Transition of San Pietro here

DISTRICT HEATING AND COOLING

District heating and cooling (DHC) is a technology that delivers heating, hot water or cooling through a system of insulated pipes from a central generation plant or distributed heat generation sources to the customers. Due to these characteristics, DHC systems are mostly deployed in densely populated urban areas. Historically, DHC has been popular in Northern and Eastern Europe as an energy-efficient heating solution. Recently, they are being increasingly adopted across Europe as they allow integrating different types of low-temperature heat sources with local renewable sources. This, in turn, enables the increase in shares of renewable energy in the heating sector.

DHC can make use of heat generated from a wide variety of sources: biomass, solar thermal, geothermal or biodegradable waste, waste heat from industry or commercial buildings, heat from cogeneration and heat from heat pumps. Furthermore, DHC systems can be used as flexible assets for integrated energy systems to absorb excess electricity generated from renewable energies.

DHC systems have been employed for the last hundred years. They can be designed for different loads and sizes and they use a variety of heat sources. Both DHC technology and efficiency are constantly improving. DHC is expected to have a crucial role in the decarbonisation of the European energy system.

Further reading

→ More about District heating and cooling (European energy system)

→ More about DHC in densely populated urban areas

→ Smart Cities Marketplace solution booklet on Heat Pump Driven District Heating Systems

Ease of implementation	DHC systems require distribution pipes and therefore are relatively complex to implement unless the pipe distribution system already exists. This should be considered when planning the renovation of buildings.
Resource needed	DHC systems can use locally available sources and even waste heat from existing industrial systems or commercial buildings; therefore increasing energy efficiency.
Usability	DHC systems can be used to satisfy local heating/hot water/cooling needs but also as a storage system for intermittent renewable electricity generation.
Land use	DHC systems need land for the central plant and for distribution piping system. Therefore, they are recommended for urban areas.
Finance	The finances of DHC depend on the local resources available, size and load of the DHC system. However, with the latest generation DHC systems, many customers are becoming distributed heat providers as well, moving the business model from production and selling to distribution and trading approach.
Ecological impact	DHC systems provide a way to use a local renewable resource or waste heat to satisfy heating/cooling energy needs; therefore, further enabling a fully sustainable energy system.
Island suitability	DHC systems may be a favourable solution for island systems as they can integrate multiple heat sources and provide security of supply. In addition, they can be used as flexible assets for higher integration of renewable electricity generation such as PV or wind.

© Photo: Henner Busch, Lund University

Island examples: Ærø island

Ærø is a Danish island and municipality with an area of 88 km^2, and a population of 5,956 people. Marstal is the biggest settlement on the island and an economic centre with 2,300 inhabitants. Marstal has a long-standing naval history. It is well known for its shipbuilding and its naval academy. Marstal Fjernvarme is a consumer-owned co-operative that started with the installation of the initial district heating network in the 1960s. Since then, the company is still owned by the inhabitants of Marstal and has been transformed into a renewable-based district heating system. Homeowners buy a share in the network when buying a house in Marstal that is connected to the network.

Marstal Fjernvarme today runs 100% renewable energy sources district heating system, with 50-55% coming directly from the solar heat collectors, 40% from wood chips, 2-3% from a heat pump. The heat pump takes advantage of the intermittencies in wind power production and is preferably put to work when an abundance of cheap wind energy is available. Solar heat, which is abundant in the summer months, is stored in two pit storage systems: Sunstore (10,000 m^3) and Sunstore (75,000 m^3).

The original district heating network in the 1960s was financed by the inhabitants of Marstal, with the project being pushed by two local inhabitants. Subsequently, the company financed the transition by tapping into available subsidies and funding programmes. 35% of the costs were covered by subsidies from an EU fund (40 million DKK). The remaining money (90 million DKK) was raised through the so-called Kommune Credit, which is a Danish funding programme that allows borrowing money at favourable rates. The company uses a not-for-profit business model, which means that all potential profits return to the members in the form of lower energy prices. This innovative project attracted between 2,000 and 4,000 visitors over the years.

Further reading

→ Read more about Ærø island here

→ Island of Ærø Winner of the 2020 RESponsible Island Prize

SOLAR THERMAL

Solar thermal technologies extract heat from solar radiation and store it as heat in either a liquid or a gas form.

There are two key solar thermal systems available, high-temperature and low-temperature systems. High-temperatures can be achieved through the use of concentrator technology that focuses the solar irradiation onto a small surface area to increase the energy absorption. This type of technology is less common for heating application and more often used in electricity generation. Low-temperature solar systems absorb energy from the sun through flat plate collectors or evacuated tubes, this is the most common technology type used in both small household applications and large industrial systems.

Some of the applications for low-temperature solar thermal heating include:

- **In a district heating system, the heat is generated on a larger scale.** Therefore, solar thermal can be scaled up to provide large quantities of hot water.
- **The use of low-temperature heat in industrial processes is quite diverse.** The largest potential is seen in the food and beverage industry (like washing and pasteurisation) but also in the metal and mining sector.
- Domestic hot water demand is generally consistent year-round. Depending on the size and on the demand of the system, solar thermal collectors are suitable to meet this demand: Solar thermal for hot water can work as decentralised applications on individual buildings or for centralised applications, such as hotels, hospitals, shopping centres, restaurants, and other high demand areas for hot water.
- **Cooling from solar thermal** is possible when the heat generated from the collectors is fed to thermally-driven chillers. These chillers satisfy cooling needs by transferring heat from the source to the environment, which is at a higher temperature.

Further reading

→ Solar Heat Europe factsheets

Ease of implementation	Solar thermal technology can be incorporated into existing heating systems. The most specialised equipment is the solar collectors that require their own experts, the rest of the equipment (pipes, valves, tanks, etc.) can be operated and maintained by process industry experts already available in many industries. It is therefore easy to implement for islands.
Resource needed	Solar collectors are reliant on solar radiation and thus most suitable for warm climates. However, since the heat is captured in a liquid or gas form, solar thermal can be implemented into existing infrastructure and is also used in colder climates to partially replace existing energy sources.
Usability	Solar thermal systems can be integrated into buildings, such as roof-mounted systems, or they can be installed as ground-mounted systems. In sunny areas, solar heating systems can operate independently to supply the heating or cooling needs of a facility without the need for electricity. Solar thermal can also be integrated into existing heating systems to reduce the energy usage from other sources, such as electricity or gas.
Land use	Smaller systems can be integrated into existing infrastructure, such as roof-mounted systems. However, when solar thermal systems are installed in open spaces, such as ground-mounted systems, it can have an impact on land use.
Finance	Solar thermal systems consist of mechanical and piping systems, which require a high capital cost. They do provide a good payback over the lifetime of the project, especially in warm climates and when compared to imported fossil fuels. Solar thermal is financially viable in applications with consistent and high hot water demands, such as hospitals and residential facilities.
Ecological impact	When integrated into building systems, solar thermal poses very few ecological impacts. This changes if areas need to be cleared for large ground-mounted systems. Most of the components are recyclable components, such as glass, steel and copper.
Island suitability	Solar thermal is suitable for islands with high heating or cooling demand and good solar resources, allowing to reduce the reliance on fossil fuels or electricity for heating or cooling.

© Photo: Symi, Nikolaos Mavrikakis

© Photo: Symi, Nikolaos Mavrikakis

© Photo: Symi, Nikolaos Mavrikakis

Island examples: Symi, Grecee

Symi is part of the Dodecanese island chain in Greece, located about 41 km north-northwest of Rhodes and 425 km from Piraeus port, with 58.1 km^2 of mountainous terrain. The island has 2,580 inhabitants, mostly engaged in tourism, fishing, and trade but during the tourist season, tourists and other visitors increase the number of people on the island to as much as 10,000.

Regarding solar thermal energy generation on the island, an interesting example is that of Iapetos Village Hotel in Symi which covers 95% of its hot water needs through solar collectors, resulting in savings of 7,440 kg CO_2 annually. Payback time of the investment was 4.5 years, proving once more that solar thermal technology is a cost-efficient and environmentally friendly way for hot water production.

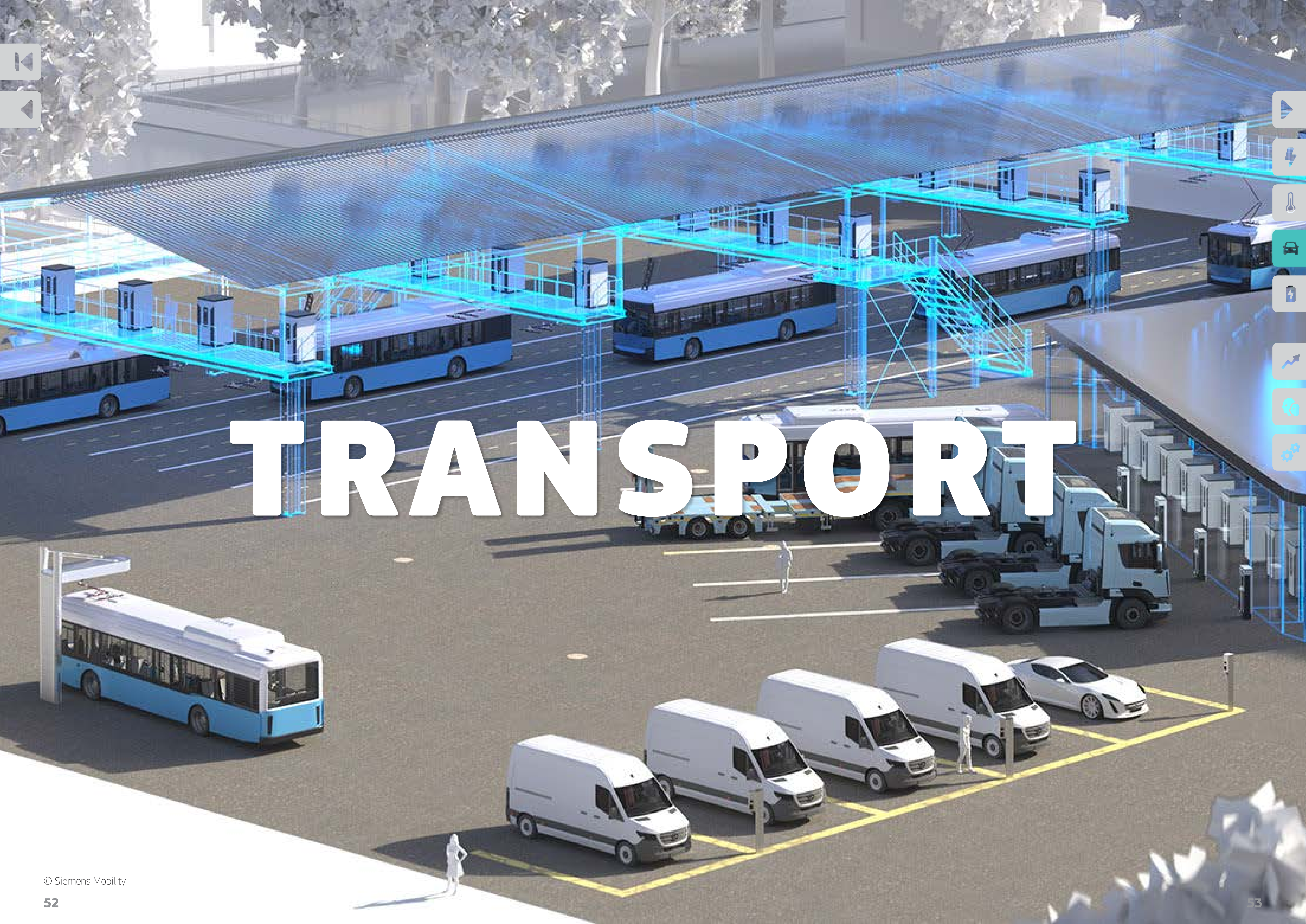
Symi, as one of the non-interconnected islands in Greece, relies heavily on the electricity produced from local diesel-fueled generators, which are expensive and not environmentally friendly. However, there is great solar and wind potential for renewable energy generation. Therefore, Symi has been selected as one of the islands to receive technical assistance from the Clean energy for EU islands secretariat on its way to clean energy transition. The initial plan for Symi forsees a central solar thermal system to cover hot water needs by 80%, resulting in CO_2 savings of 5,168 t annually.

Further reading

→ Read more about the success stories on SOLID solar systems website

→ Solar thermal world on installations

TRANSPORT



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ELECTRIC VEHICLE (CHARGING)

Electric Vehicles (EVs) have been actively promoted on the European market for almost a decade thanks to the improvement in battery technology. The transport sector on an island can be electrified by focussing on passenger vehicles on the one hand, and on public transport fleets on the other. These two approaches differ in how they can be implemented and in the required supporting measures.

The transition towards electric mobility brings opportunities and challenges for an island's energy system.

Compared to the typical household power peak (2 kW - 3 kW) battery-powered vehicles need to be charged at a relatively high power (3.6 kW - 11 kW), which poses additional stress on the local electricity grid. This is especially relevant when multiple EVs are simultaneously charged, thus representing a high-power load. Smart charging allows mitigating such high-power loads by coordinating the charging process of different EVs. Coordinated charging is often referred to as smart (unidirectional) charging or V1G. The charging process is shifted in time and/or the power (load) is decreased to reduce the stress on the grid. Innovative business models can valorise this power shift to promote grid-supporting behaviour.

All EVs contain a battery, which could also be used to send energy back to the grid. The possibility of not only coordinating charging behaviour but also reversing charging (discharging) is called smart bidirectional charging or V2G (vehicle-to-grid). Once EVs are considered as "batteries on wheels", a whole new range of possibilities opens up. With V2G technology, EVs can store excess renewable energy, which can be used later just like stationary battery systems. The energy storage potential is high considering that most of the time a vehicle is parked and not moving.

Further reading

→ Public transport fleets

→ About smart charging and V2G technology

→ Batteries can be part of the fight against climate change - if we do these five things

Ease of implementation	Without careful planning, the roll-out of EV charging infrastructure may have a significant impact on the local electricity grid. By implementing smart (bidirectional) charging, the EV fleet can instead help to balance the grid. Numerous successful examples of infrastructure integration on the mainland exist. However, V2G is still in its infancy and integrating this technology comes with associated difficulties.
Resource needed	Instead of traditional fossil fuels, EVs are powered by electricity. This electricity can be locally produced on the island by means of renewable energy sources. Transitioning towards a fully electric fleet, therefore, increases the security of supply on the one hand, but also increases the demand for of electricity on the island on the other hand.
Usability	Electric vehicles allow road transport without direct air pollution. With smart bidirectional charging, aggregated EVs can be used as storage for electricity produced from renewable energy generation, such as solar and wind. EVs offer sector coupling between the transport and energy sectors.
Land use	Charging infrastructure does not require extensive land surface. Chargers are small (< 1m^2) and can be integrated into existing buildings or parking lots.
Finance	To promote the uptake of EVs, a sufficient amount of public charging infrastructure is required. The initial investment costs can be significant (ca. €1,000/charger), especially when integrated with smart charging functionalities. However, these ensure that the coordination of charging is possible, which is essential to reduce the impact on the local electricity grid. Additionally, the transition away from fossil fuels allows avoiding costs and helps towards fulfilling climate goals.
Ecological impact	Electric vehicles enable road transport without local air pollution. In addition, EV charging has limited to no impact on the environment. Fauna and flora are unaffected while the charging process creates no waste products. The increased demand for electricity requires attention because without coordination with renewable energy production this can impact the island's energy mix. V2G technology has the potential to further increase the integration of renewable energy sources due to the energy storage feature.
Island suitability	Electric vehicle charging infrastructure benefits from a holistic approach in the planning phase. The highest efficiency can be achieved by coordinating the charging process. As islands are a confined geographical space, they are ideally suited for this coordination. Together with a minimal environmental impact, this technology is ideally suited for islands.

Island examples: Porto Santo, Portugal

In the initiative "Sustainable Porto Santo: Smart Fossil Free Island", Porto Santo Island was turned into a "living lab", and EEM, together with the local Regional Government and AREAM - Regional Agency for Energy and Environment, made some investments and developments related to smart grids (advanced metering infrastructure), renewable energies, battery energy storage system (4 MW/3.3 MWh), energy efficiency (smart telemanagement public lighting), etc.

Additionally, together with Renault Group and The Mobility House (TMH) a smart ecosystem with electric mobility was created:

- use of 20 electric vehicles (EV) by local stakeholders like public institutions, businesses and private citizens during a test phase, transformed today into an operational phase with 40 local EVs users;
- testing of 2-second AC V2G with 2 Renault Zoe during 18 months;
- implementation of smart-charging for all users entering the ecosystem;
- use of two second life energy storage systems (ESS) (with Renault's EVs "2nd life" batteries) installed in two different EEM's MV/LV substations;
- development of an intelligent aggregation platform allowing the control of this electric intelligent ecosystem.

Further watching and reading

→ BBC News realiza vídeo sobre o Porto Santo - YouTube

→ The solar-power charged electric cars making money - BBC News

→ Intelligent software from The Mobility House makes the island of Porto Santo fossil free - YouTube

→ Intelligent software from The Mobility House makes an entire island fossil free

→ Read the UNIDO Paper here

ELECTRIC BOATS AND FERRIES

Electric boats and ferries are extremely important for the decarbonisation of maritime transport in the EU. They have started becoming more commercially available in the past 10 years, with Norway, Denmark and Scotland leading the way in this green transformation. Electric boats feature on-board batteries and electric engines for propulsion 100% of the time, while hybrid boats use electric propulsion only near coastal regions to reduce emissions and noise pollution. Fully electric boats are usually employed as ferries, while hybrid boats are preferred for cruising or fishing.

Electric and hybrid boats and ferries currently use Li-ion batteries. Due to the weight and volume of the batteries, the length of purely electric vessels is small (21 m - 39 m) with a battery capacity of 50 kWh - 500 kWh, while the hybrid vessels are longer (40 m - 160 m) with a battery capacity of 500 kWh - 5,000 kWh. The speed of electric ferries is 7.5 - 30 knots, while the speed of hybrid vessels is from 7 - 21 knots. Hybrid vessels are currently mainly used for the transport of passengers and tourism.

Electric boats have existed since the second half of the 19th century. However, their wider uptake has been restricted due to limitations of the battery technology. The design of electric boats is a trade-off between battery capacity—determining the travelling distance—, battery weight and price. Moreover, a larger utilisation of electric boats and ferries requires a higher capacity charging infrastructure at the ports. Therefore, collaboration among ports, municipalities and distribution/transmission system planning is needed. While electric boats used for short trips (fishing, tourism) are long available on the market, their main barrier to high uptake is consumer (i.e. boat owner) acceptance.

Further reading

→ Study on Electrical Energy Storage for Ships

→ Download Article "Towards Ferry Electrification in the Maritime Sector"

→ Download "Decarbonising maritime transport: The EU perspective" European Parlament briefing here

Ease of implementation	Electric boats and ferries require a charging infrastructure at the port/marina that should be implemented in coordination with the electricity grid operator and a local municipality. Moreover, the use of electric boats, just as electric vehicles, requires a system for end-of-life recycling of the Li-ion batteries.
Resource needed	Electric boats can use locally produced renewable electricity as their fuel, avoiding the import of fossil fuels.
Usability	Electric boats and ferries are used as sustainable solutions for passenger transport, tourism and industry on the islands (fishery). However, electric vessels are becoming part of the overall energy system, charging and offering storage capabilities and flexibility to the energy system when not in use.
Land use	Charging for electric vessels can be organised at the existing ports and marinas without additional land use.
Finance	Electric vessels have higher initial costs due to the need for large batteries and their still low production numbers. However, their operational costs are lower compared to traditional vessels due to the use of locally produced electricity.
Ecological impact	Electric vessels have a lower ecological impact during operation due to reduced emissions, noise pollution and vibrations. Their operation is decarbonised if they are charged with electricity generated by renewable sources. However, the ecological impact of batteries needs to be considered in the life cycle assessment, and there should be plans for organised recycling.
Island suitability	Electric boats and ferries can offer sustainable maritime transport with minimal negative effect on the environment, using energy produced using locally available renewable resources.

© Photos: Ærø municipality

Island examples: Ellen Denmark

The E-ferry Ellen connects the two islands of Ærø and Als in southern Denmark, it is in the western Baltic. Also, with its population of 50,000 people is connected to the mainland via two bridges. Ærø, where the E-ferry was conceived, designed and built, has no land connection to the mainland and depends on the island's fleet of ferries. Ærø Municipality operates four ferries in total, servicing a population of 6,000 people.

As is the case with many islands around the world, Ærø's ferries are the largest obstacle to achieving its goal of complete CO_2 neutrality. The municipality realised that it would have to break technological barriers to become emission-free, because previous electric ferries could not achieve the distances required to service the island.

The E-ferry sails 22 nautical miles (40 km) between charges, which is seven times more than any other electric ferry in operation. The 22 nautical mile distance is covered up to seven times per day. It has no fossil fuel onboard, instead, it relies completely on batteries and the fast charger located in the homeport in Søby. Ærø's six wind turbines supply more energy than the island consumes, and some of this surplus goes to charging the Ellen. This means that Ellen truly operates emission-free, saving the global environment of 2,520 t of CO_2, in addition to other greenhouse gasses, compared to a similar modern diesel with the same capability. It also saves the local environment from half a tonne of particulate matter each year.

A group of local maritime and battery experts got together to design a revolutionary, fully electric ferry, and they presented the design to the municipality. The municipality liked the idea and took charge of project development. It located nine European partners who could supply the needed components and specialist know-how and applied for funding from the EU Commission's Horizon 2020 research and innovation programme. Horizon 2020 decided to back the project and funded half of the expenses. However, Horizon 2020 required that certain criteria be met, not least that the E-ferry should be able to demonstrate at least 5 daily round trips. The E-ferry achieved all the required goals and has been in full operation for two years, showing that emission-free sailing is a reality, also on longer regional routes. The E-ferry has revealed a huge potential for emission reductions, the E-ferry type can operate on 900 routes in Europe alone.

Further watching and reading

→ The E-ferry evaluation video

→ The E-ferry evaluation report

→ The ferry company where you can book a trip with Ellen

HYDROGEN FOR THE TRANSPORT SECTOR

Hydrogen offers higher energy density compared to electrical storage systems such as batteries. This enables a longer-range transport compared to batteries-based options. There are various ways to produce hydrogen, generally classified as follows:

- **Grey hydrogen** is produced from fossil fuels through steam reforming, mostly from methane. Grey hydrogen releases approximately 10 kg CO_2 per kg H_2 produced, placing its carbon footprint between that of natural gas and coal.
- **Blue hydrogen** is also produced through steam reforming, but production plants are retrofitted with carbon capture, utilisation and storage (CCUS) technology. Depending on the technology and the fossil fuel used, blue hydrogen plants can capture 50-90% of CO_2 emissions, finally releasing approximately 2–5 kg CO_2 per kg H_2 produced.
- **Green hydrogen** is produced by electrolysis, which splits water into hydrogen and oxygen using electricity. Green hydrogen is the only form of hydrogen with a virtually carbon-free production process. Electrolysis using electricity generated by renewable energy produces less than 5% of the CO_2 emissions of grey hydrogen (non-zero due to emissions generated during transportation and electricity generation). The costs of green hydrogen production are significantly higher than for blue or grey hydrogen, however, green hydrogen offers the only sustainable and mass-produced fuel source for the shipping industry.

Hydrogen fuel is used for various applications, like powering vehicles and ferries using fuel cells. A fuel cell works much like an electric battery, converting chemical energy into electrical energy using the movement of charged hydrogen ions across an electrolyte membrane to generate current. There they recombine with oxygen to produce water – a fuel cell's only emission, alongside hot air.

Further reading

→ Watch European Commission short movie called "EUGreenDeal - Transport" on YouTube here (takes one minute)

→ Watch European Commission short movie called "EUGreenDeal – Energy" on YouTube here (takes one minute)

→ Watch CNBC "What Is Green Hydrogen And Will It Power The Future?" on YouTube here (takes 15 minutes)

Hydrogen technology is still at an early stage of development; however, there are EU initiatives to promote further development and the use of hydrogen in various transport applications, which includes the following:

BUSES: JIVE and JIVE 2 project

Fuel cell electric busses include both a hydrogen fuel cell and batteries/capacitors. In such hybrid architecture, the fuel cell provides the energy for the vehicle operation, whilst the batteries/capacitors are able to provide peak power to the motors to meet rapid acceleration and gradients. By using a fuel cell in conjunction with a battery, the size of each can be optimised for a given route. The fuel cell power module onboard the bus generates electric energy through an electro-chemical reaction leaving only water and heat as by-products, thus there are no local emissions. The electric energy is used to provide direct electric traction and keep the batteries charged. The by-product heat is stored on the brake resistors and is used to maintain passenger comfort and increase energy efficiency. The batteries also provide storage for regenerated braking energy. All the energy required for the bus to operate is provided by hydrogen stored onboard. Because the fuel cell generates only water as an emission it will always be a zero-emission bus.

VEHICLES: H2ME and H2ME 2 project

Fuel Cell Electric Vehicles uses compressed hydrogen gas as fuel to generate electric power via a highly efficient energy converter, a fuel cell. The fuel cell transforms the hydrogen directly into electricity to power an electric engine. However, this requires adequate infrastructure to ensure refuelling of the vehicle can be done to the same convenience as standard internal combustion vehicles. The H2ME2 project will significantly expand the European hydrogen vehicles fleet and in so doing, aims to confirm the technical and commercial readiness of vehicles, fuelling stations and hydrogen production techniques. With its more than 1,100 cars, vans and trucks and 20 hydrogen refuelling stations, H2ME2 will produce recommendations and identify any gaps that may prevent full commercialisation, as well as collect results to support future investments.

REFUELLING STATIONS: ZEFER project

ZEFER started in September 2017 and will run until September 2022. The project will deploy 180 Fuel Cell Electric Vehicles (FCEVs) in Paris, London and Brussels. It will demonstrate the viable business cases for captive fleets of FCEVs in operations that can realise value from hydrogen vehicles.

TRUCKS: H2Haul

which are hydrogen-powered electric vehicles with a range and refuelling time equivalent to that of today's diesel. Hydrogen trucks have the same advantages as electric vehicles because they use the same electric motors (more power, instant torque, zero emissions, etc.) while eliminating many of the problems associated with battery-electric vehicles (long recharging times, limited range, cold start, extra weight, etc.).

FERRIES: Hyseas project

Ferries and the maritime shipping industry face pressure to decarbonise in the coming decades. Maritime shipping accounts for approximately one-quarter of all emissions from the global transportation sector.

Out of the several various clean fuel alternatives being currently piloted, hydrogen is the clear leader. A Global Maritime Forum study from March 2021 examined 106 projects looking at zero emissions in maritime shipping worldwide and found that nearly half of these initiatives focused on hydrogen as a low-carbon fuel source. A key advantage of hydrogen over other fuel alternatives is the relative ease of retrofitting existing ships with hydrogen fuel cells. Hydrogen-powered ferries and smaller shipping vessels have been piloted in the United States, Belgium, France, and Norway.

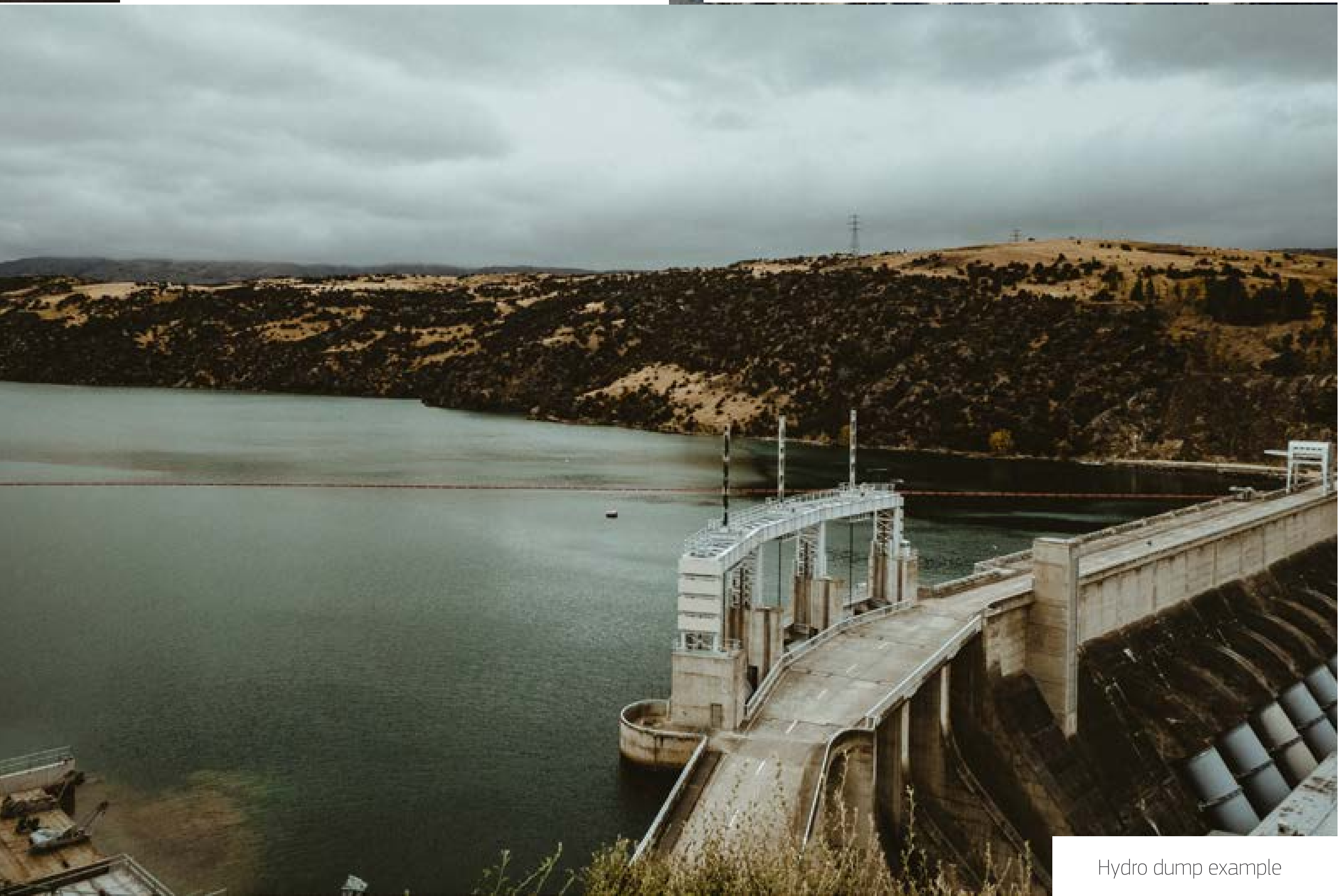
HySeas III is the final part of a three-part research program that began in 2013 looking into the theory of hydrogen-powered vessels (HySeas I), followed by a detailed technical and commercial study to design a hydrogen fuel cell-powered vessel (Hyseas II 2014-2015).

→ Further reading about hydrogen ferry.

STORAGE

Battery energy storage systems at Th!nk E battery lab

© Photos: Rousay, Egilsay and Wyre Development Trust 2018 - 2021

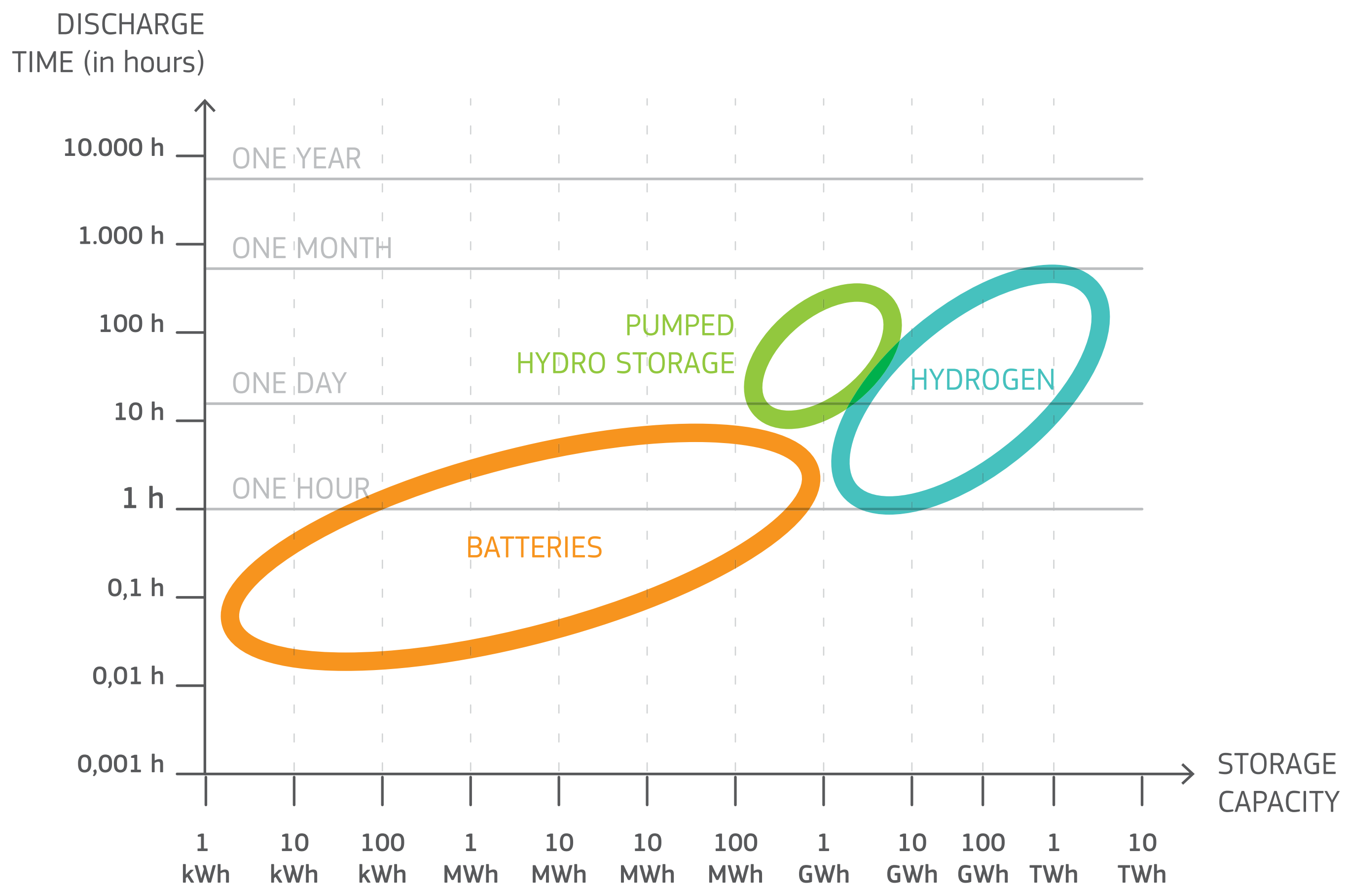


Hydro dump example

Renewable energy sources like sun and wind have an intermittent nature, making it difficult to match electricity production and demand at all times: the sun may not shine, and the wind may not blow just exactly when we need our electricity.

With increasing shares of renewable energy generation, there might be moments of excess electricity production as well as periods where the electricity demand is higher than production. The gap between generation and demand is even more of an issue in islands whose population multiplies for example during the summer months.

Electricity storage allows closing the gap between generation and demand by removing the need for both to be instantaneously matched. Storage technologies can be classified according to several criteria: the nature of the process by which energy is stored (mechanical, chemical, electrical, electro-mechanical), the storage capacity, and the release time (short term and long-term storage), as shown in the Figure below.



The suitability of storage technologies depends on the storage capacity required and the amount of time during which energy needs to be stored. This graph shows only the three storage technologies that are included in this booklet. Graph adapted from: unendlich-viel-energie.de

BATTERY ENERGY STORAGE SYSTEMS

Battery energy storage systems are used to store electrical energy as chemical energy in the short term; for example for storing solar energy during the day and retrieving it at night. Battery systems can also be used to improve quality of supply when installed at the end of a long low-voltage distribution line, as well as for the frequency regulation at transmission level.

There are many different battery technologies on the market that differ on the type of chemistry used for electricity storage. Lead-acid batteries have been used for various applications due to their efficient operation at low cost, e.g. back-up power supplies, lighting, automotive starting, etc.

Given the economies of scale related to the rise of e-mobility, lithium-ion batteries are also increasingly used for stationary electricity storage. Lithium-ion batteries are employed in short-duration applications where services can be stacked and adapted to market pricing (e.g. hourly balancing, peak shaving and ancillary services).

Even if battery energy storage systems are not a new technology, ongoing research is focused on further enhancing the technology, for example with Lithium-ion batteries. Furthermore, alternative battery technologies for stationary energy storage are being developed that do not use critical raw materials and can offer cost-competitive solutions: redox flow batteries, sodium-ion batteries, molten-salt batteries, etc. In particular, redox-flow batteries are one of the main lithium-ion battery competitors currently entering the market.

Further reading

→ More information on easy storage here

→ Smart Cities Marketplace solution booklet on PV and battery

→ Detailed information about different technologies can be found here

Ease of implementation	Battery storage energy systems have a high technology readiness level; for example, electric vehicles and electronic devices (laptops, smartphones) use lithium-Ion technology. To implement batteries on a large scale, an island can opt for larger-size batteries or "neighbourhood" batteries: they are often more cost-efficient as compared to home battery systems. From an implementation viewpoint, the challenge is in the regulation: in many cases, grid codes and legislation do not yet consider the possibility for neighbourhood batteries that allow energy "sharing" between private citizens.
Resource needed	This technology does not require resources to operate, it stores electric energy without the need for inputs. However, as rare minerals are the underlying source of the chemical reactions for some types of batteries, resource use is important at the production and end-of-life of the battery systems (which is often between 10 and 20 years, depending on the technology).
Usability	Battery energy storage systems can be used for increasing local self-consumption. In addition, if a neighbourhood-size storage system is installed in the middle or end of a low voltage line, it can be used to improve the quality of supply. Larger storage systems or aggregated smaller storage systems can be used for ensuring security of supply in case of blackouts or in combination with intermittent renewable energy generation such as wind and solar.
Land use	Battery energy storage systems have a very high energy density. In comparison to other battery types, lithium-ion batteries have higher energy density (they can store more energy in a smaller volume), which is why they are used in electric mobility. Consequently, they only have a minor impact on the land surface.
Finance	The biggest downside of battery technology is the financial factor. Batteries require a high initial investment and there are few viable business cases for storing energy in this manner. Nevertheless, batteries can be a crucial step for islands to transition towards higher shares of clean energy generation while ensuring the security of supply.
Ecological impact	Because of the limited surface area required, battery systems have a minimal impact on fauna and flora on the island. However, for a proper assessment, the entire life cycle needs to be considered: including production and end-of-life or reuse impact. The extraction of rare metals like lithium has a significant impact on the environment. On the positive side, energy storage systems like batteries allow for a higher penetration of renewable energy sources which of course has an impact on the sustainability of the island.
Island suitability	Battery energy technologies are suitable in the island context thanks to their minimal impact on the land surface. They can be a crucial component in the transition towards increased renewable energy sources, ensuring the security of supply but also quality of supply. However, the biggest downside is the financial cost of this technology.

Photo: © Tilos European H2020 project

Photo: © Tilos European H2020 project

Photo: © Tilos European H2020 project

Island example: Tilos

Tilos is a Greek island - municipality located in the Aegean Sea. The island has a permanent population of 500 people that rises considerably during the summer months due to the tourism. The peak energy demand rises close to 1 MW.

Different clean energy technologies have been developed in Tilos: a smart metering platform for monitoring and remote control of distributed loads, energy saving measures in public buildings, and a PV-based EV charging station that promotes clean electro-mobility. Aside from this, a hybrid power station has been installed comprising a medium scale 800 kW wind turbine, a PV plant of 160 kWp and an advanced molten salt sodium nickel ($NaNiCl_2$) battery storage system of 2.88 MWh and 800 kW of capacity. This battery system is fully recyclable, does not require cooling, has highly reduced maintenance, and does not age with heat.

The battery storage system is a key element to ensure 70% renewable electricity level in Tilos. During the winter, renewable electricity generation sometimes surpasses the demand: electricity is then exported to the neighbouring interconnected islands of Kos and Kalymnos.

One of the main challenges the project had to overcome relates to regulatory aspects for hybrid plants. Tilos developed the first-ever fully licensed RES-battery hybrid power station and introduced battery technologies in the local regulatory framework.

One of the most beneficial aspects of the system is that it is of local, community scale and character, and as such it builds on the directions of sustainable development.

Owing to local clean energy developments, the local islanders are now demonstrating increased awareness on energy issues, coming forward with new ideas and solutions, both at the individual and community level, appreciating the benefits that may accrue from local-scale clean energy production.

Further reading

→ Tilos European H2020 project website

→ Examples of energy storage use on islands

→ An example of use of a battery energy storage system (TILOS publications website)

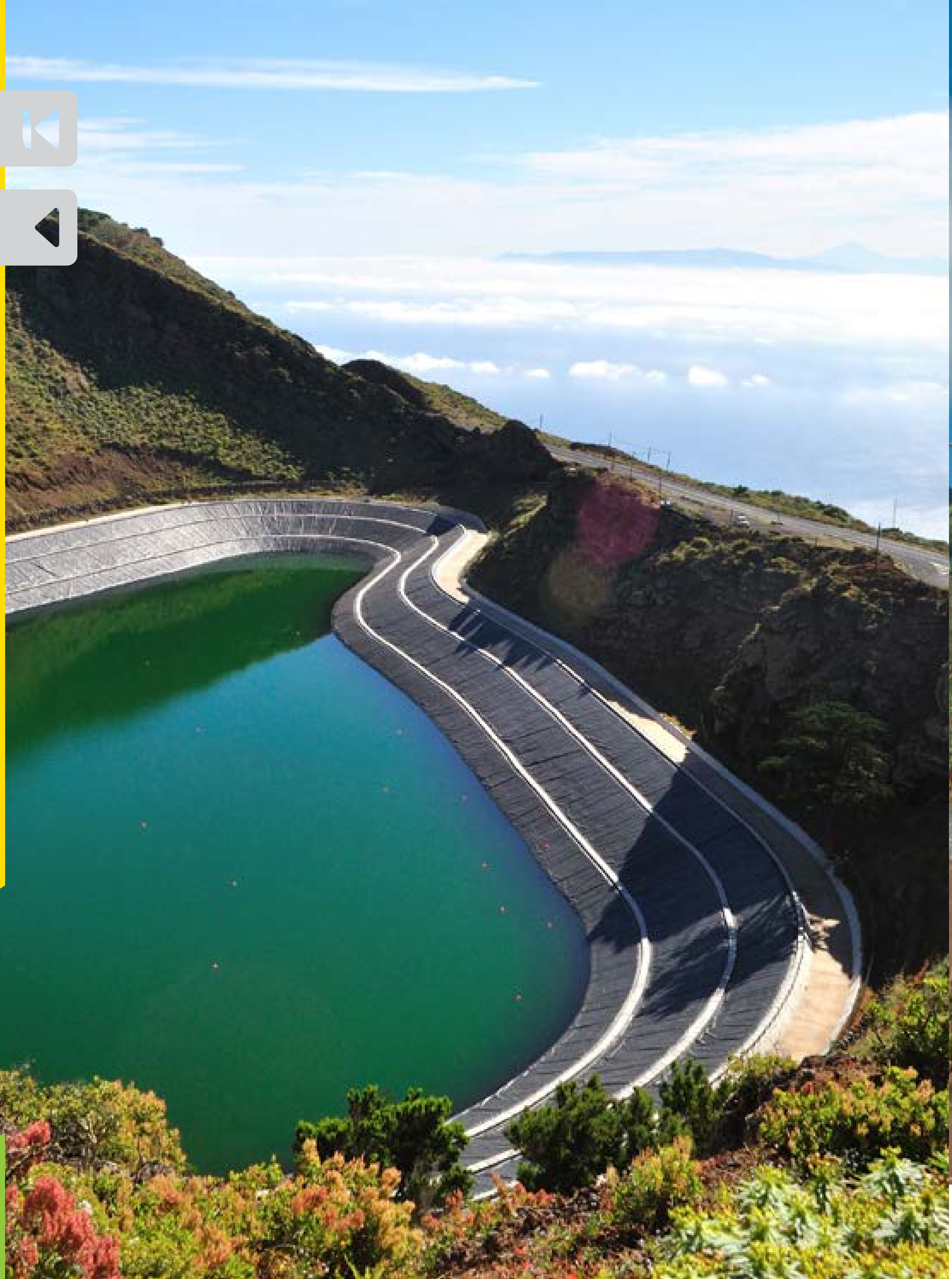
PUMPED HYDRO

Hydro storage works on a very simple principle: mechanical energy is transformed into potential energy by pumping water from a lower to a higher reservoir. When this energy is needed, the water flows down from above thanks to gravity, driving a turbine. Pumped hydro technology has been used for centuries. Due to the simplicity and scalability of hydro storage, almost all large-scale energy storage projects are based on it. Balancing of the electricity grid on the mainland is also done on a large scale by means of this technology.

Further reading

→ Pumped Hydro Storage technical description

Ease of implementation	Some areas have a greater potential for hydro storage because of their geography. Italy or Switzerland, for example, have natural altitude variations in their landscape which makes it easy to implement hydro storage. In more level geographies, such as the Netherlands or Belgium, it is more difficult to find suitable sites. Artificial elevations are a solution in these cases but they significantly increase the complexity and cost of the implementation.
Resource needed	This technology makes use of natural geographies or artificially created slopes and water. It is therefore ideal where freshwater resources are available and its planning should be coordinated with other water usages on the island, where it can create synergies and win-win situations.
Usability	Pumped hydro can be used as seasonal storage so that electricity produced at one point can be delayed for usage over multiple months. Pumped hydro reservoirs also allow collecting rainwater for later use. This technology, therefore, enables the coupling between energy and water sectors to ensure that water is available when needed by the islanders.
Land use	Hydro storage requires a certain volume of water in the higher reservoir to store a relevant amount of energy. The energy density of this solution is low, requiring larger amounts of land than other technologies to be efficient. The energy density of this storage technology is low. Consequently, this solution requires large amounts of land to be efficient.
Finance	The initial investment cost due to the large turbine and large scale of this project is high. However, the operational cost is low and has a lifetime of 80 years.
Ecological impact	Pumped hydro technology can have an impact on the natural scenery and biodiversity because of the changes that it implies on the landscape. Therefore, each potential location needs to be carefully analysed. However, as an energy storage technology, this can be classified as very sustainable: there are no waste products, no additional emissions and no expensive resources needed to operate and build this installation.
Island suitability	This technology is suitable for islands with natural mountains due to the need for natural variations in altitudes and the high impact on the surface of the land. It can be a very sustainable solution to make the island energy independent from the mainland.



Photos: © Gorona del Viento, Pumped hydro pictures from El Hierro

Island example: El Hierro, Spain

El Hierro is the smallest of the Canary Islands (Spain) with an area of 278 km^2 and a population of 10,000 inhabitants. Island El Hierro became the World Biosphere Reserve in 2000. The electricity demand of the island population and of its de-salination plant is supplied by the 11.5 MW wind farm coupled with a pumped hydro storage facility of 11.3 MW in order to assure the security of supply of the island. Currently, RES pen-etration on the island is ca. 56% with an aim for the island to become 100% RES based.

The power wind-pumped hydro system is installed and operated by Gorona del Viento El Hierro, a company co-owned by the Island Authority of El Hierro (Cabildo de El Hierro) (66%), the Regional Canary Islands Government through its technological centre The Canary Islands Institute of Technology (4%); and the local utility ENDESA-ENEL (30%). The project received support through multiple means, sub-vention of the capital investment by the Spanish Government and EU grant through 5th Framework Programme. The island has been part of EU projects in order to expand knowledge and experiences and improve their practices, and has received a second prize for Responsible island from EU.

Further reading

→ Read more about El Hierro here.

→ An article about Gorona del Viento El Hierro

→ IRENA on hydropower

→ Wind-pumped-hydro Power Station of El Hierro

→ Island of El Hierro 2nd Winner of the 2020 RESponsible Island Prize

POWER-TO-X

Power-to-X has arisen as a long-term storage solution that allows making use of excess electricity and storing it over long periods of time. P stands for power, while X stands for the type of energy into which the electricity surplus is being converted—gases, liquids or heat—for storage. Power-to-X uses various energy conversion technologies. The application of this technology has changed over time. At first, the targeted field of application for Power-to-X was fuel production, for example for hydrogen buses, combined heat and power generation, and subsequent injection into the natural gas grid. Today, alongside fuel production, industrial applications have also gained importance.

Further reading

→ How do Power-to-X technologies work?

→ Review of Power-to-X Demonstration Projects in Europe

→ IRENA Landscape solution

Power-to-Hydrogen

At the heart of most Power-to-X concepts is the utilisation of renewable excess electricity to produce hydrogen through the electrolysis of water. This hydrogen can be used directly as a final energy carrier or it can be converted into methane, synthesis gas, liquid fuels, electricity, or chemicals for example.

There are two main issues with Power-to-X for producing hydrogen: first, converting electricity into hydrogen implies energy losses; second, the source of hydrogen, which can be renewable or fossil-based. Most hydrogen today is produced from natural gas, a fossil fuel that emits CO_2 when burned. Power-to-Hydrogen aims to achieve an emissions-free process by using renewable electricity in an electrolyser to produce hydrogen from water.

Hydrogen is often converted into synthetic methane or natural gas, which can be injected straight into the gas grid for use in industrial processes. This process requires adding CO_2 to the hydrogen: at present, that CO_2 is mainly obtained from fossil fuels such as coal, crude oil or natural gas.

In the promotion of artificially-produced hydrogen, it is crucial to ensure that it does not end up harming the environment and further contributing to climate change.

Further reading

→ How do power to X technologies work?

Power-to-heat

Renewable power-to-heat is another enabling technology that involves using excess electricity from renewable energy sources to generate heat through heat pumps or large electric boilers. Energy can be stored in the form of heat for days or even months to help address seasonal variability in supply and demand. This is of particular benefit for regions whose heating and/or cooling demands substantially vary between seasons. Surplus heat produced with renewables in the summer can be used for thermal storage, which can in turn be recovered to meet the heating demand in winter thereby reducing the need for non-renewable sources of heat during peak times. Heat energy can also serve to store natural cold in winter, to then supply space cooling during the summer. Key technologies for seasonal storage are aquifers or other forms of underground thermal energy storage.

Island examples: Scotland and Denmark

Heat Smart Orkney project, Scotland: A wind power-to-heat scheme is being implemented as part of the project, which secured funding of £1.2 million through the Scottish Government's Local Energy Challenge Fund. Households will be provided with energy-efficient heating devices that will draw the excess power generated from the community-owned wind turbine, otherwise meant to be curtailed. The household heating devices will be connected to the Internet and will get switched on when the wind turbine receives a curtailment signal.

HyBalance is a Denmark-based project that demonstrates the use of hydrogen in the energy system. In this project, excess wind power is used to produce hydrogen by electrolysis, which helps to balance the grid. The hydrogen that is produced is then used in the transport and industrial sectors in Hobro, Denmark. The project will help identify potential revenue streams from hydrogen as well as changes in the regulatory environment that are required to improve the financial feasibility of power-to-hydrogen.

Further reading

→ Heat Smart Orkney project

→ HyBalance project

→ Scotland: Publication of hydrogen ferry feasibility report

ENERGY EFFICIENCY

What is energy efficiency?

Energy efficiency means using less energy to perform the same task, i.e., reducing to the maximum extent energy waste.

Improving energy efficiency will benefit society by reducing emissions and our dependence on energy imports, while also lowering energy costs for citizens and businesses.

Energy efficiency is diverse and may include a combination of technologies and processes to achieve the desired benefits. In many cases, energy efficiency can be achieved in existing systems without any fundamental changes required. This may include replacing specific equipment with more efficient equipment or implementing technologies to reduce losses in a system.

Further reading

→ Read more about Energy efficiency here

→ Focus new generation EU energy labels

→ Smart City Marketplace solution booklet on building envelope retrofit

→ Clean and energy efficient vehicles

Energy efficiency can be subdivided into following sectors:

© Photo: Symi, Nikolaos Mavrikakis

Buildings

Buildings are the single largest energy-consuming sector in Europe, accounting for approximately 40% of the EU's energy consumption. Renovating buildings and user behaviour improvements can contribute to more efficient use of energy and the reduction of CO_2 emissions, while improving the indoor thermal comfort.

Research shows that educating and involving the users in managing the building's energy consumption results in significant decreases in electrical consumption and improvement in air quality. User behaviour is a low cost first option for improving building energy efficiency.

Various energy retrofit measures can be considered, targeting the building envelope on the one hand (namely reducing the thermal losses both from transmission and infiltration) and the building's thermal and electrical systems on the other hand.

The European Commission launched in 2020 a new strategy to boost renovation called "A Renovation Wave for Europe—Greening our buildings, creating jobs, improving lives". The renovation wave aims to double annual energy renovation rates in the next 10 years, reducing emissions and enhancing the quality of life of people living and using those buildings.

Equipment can be replaced using modern, more efficient variants of the same technology. The EU energy label" promotes equipment replacement and has been—together with minimum "ecodesign" requirements—a success story key in boosting the energy efficiency of everyday electric appliances like lighting, heating, fridges, freezers and televisions, but also products like fuel boilers, tyres and air conditioners.

Industry

Industry accounts for both **heat and electricity usage**. In most cases, energy consumption can be reduced through efficiency initiatives. The implementation of energy management systems and energy system optimisation within the industry can **improve capacity and increase both energy and financial savings for organisations.**

Energy management systems provide a structured and systematic approach on how to integrate energy efficiency in daily practices and core industry management values, such as cost reduction, increased productivity, environmental compliance and global competitiveness.

The system optimisation approach requires looking at the industrial system as a whole, not just at the individual pieces of equipment, and to analyse both the supply and demand sides of the system and how they interact.

As part of the European Green Deal, the European Commission has set up an indicative target to increase renewable energy use in industry by 1.1 percentage points per year.

Public sector

Publicly-owned facilities are major energy users and ready targets for energy efficiency measures. Reduction in government's energy costs can open up fiscal space for investments in other socioeconomic priorities, such as improving basic services.

Energy efficiency in the public sector can be achieved through multiple initiatives that address energy usage in schools, hospitals, street lighting, transport, water and sanitation, efficient service provision and other public services. Public sector energy efficiency requires a holistic approach that includes adjusting the procurement policies, revising budgets, awareness campaigns, incentives, regulations and redesigning public spaces.

In terms of new targets for the public sector, the strengthened Energy Efficiency Directive will:

↳ Require Member States to renovate at least 3% of the total floor area of all public buildings annually,

↳ Establish a new target for Member States to reduce energy use in the public sector by 1.7% every year,

↳ Encourage public bodies to use Energy Performance Contracts for renovation of large non-residential buildings.

Further reading:

→ European Commission's Building Factsheet from 14 July 2021

Transport

Clean and energy efficient vehicles have an important role to play in achieving EU policy objectives of reducing energy consumption, CO_2 emissions, and pollutant emissions.

The Directive on the *Promotion of Clean and Energy Efficient Road Transport Vehicles* aims at a broad market introduction of environmentally-friendly vehicles. It addresses purchases of vehicles for public transport services. Alternative low-carbon fuels should gradually substitute fossil fuels for transport propulsion in the long term.

The new Renewable Energy Directive will include new targets for more renewables in the transport sector. The targeted reduction in transport GHG intensity is 13% by 2030, while the target for the share of renewable hydrogen and synthetic fuels is 2.6% by 2030 and for advanced biofuels 2.2% by 2030.

Further reading:

→ European Commission's "Make Transport Greener" Factsheet from 14 July 2021

COMMUNITY ENERGY ACTIONS

Why energy actions?

The EU Clean energy package and Green Deal are placing proactive citizens at the centre of the sustainable and clean energy sector.

EU Directives—such as the Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (IEMD)—are providing an enabling framework to get citizens involved.

The involvement of citizens is encouraged through:

- the definition of active consumers and renewable self-consumers, often named prosumers,
- the energy sharing such as jointly acting renewable (self) consumers (IEMD and REDII)
- citizen energy communities (IEMD), renewable energy communities (REDII) and peer-to-peer trading (REDII).

Further reading

→ EU Renewable Energy Directive (REDII)

→ Internal Electricity Market Directive (IEMD)

→ Smart Cities Marketplace solution booklet on energy communities

→ Community Energy: A practical guide to reclaiming power - summaries on the role of local authorities

→ What Member States should know when designing support schemes for energy communities: the example of Ireland

→ Smart Cities Marketplace solution booklet on citizen engagement

Living Lab in Oud Heverlee, Belgium.
©Photo: Frank Vetmans, Th!nk E

Multi-apartment block energy sharing in Kortrijk, Belgium.
©Photo: Agata Smok, Th!nk E

Kids painting the community battery in Oud-Heverlee, Belgium (pilot site of MUSE GRIDS project)
©Photo: Agata Smok, Th!nk E

Prosumers

Prosumers are also called **active consumers or renewable self-consumers.** In essence, they are **consumers that produce electricity locally**—within their premises—and can use, store or sell that electricity. Prosumers can be residential or industrial, as long as generation, storage and sale of electricity is not their primary commercial activity. An overview of some EU country regulations for prosumers can be found on SmartEN and PROSEU.

Prosumers can be off-grid (i.e. completely separate from the electricity grid), connected to the grid but only interacting with the grid to use or inject electricity when they have needs or surplus of generated electricity, or connected to the grid and actively interacting with it by providing flexibility with their assets (battery, heat pump, EV, etc). Prosumers can take full advantage of energy management systems and demand-side management to **ensure that the energy produced locally is optimally used and stored to minimise their energy costs.**

Technologies or energy solutions typically used by prosumers are: PV, batteries, heat pumps, EV, energy management systems, and demand-side management.

Energy sharing

Consumers located in the same building or multi-apartment block can organise to share energy as jointly acting consumers, typically implemented as collective self-consumption.

This concept is very much similar to the prosumer, but on a **single building with multiple consumer levels**. Consumers have the **right to generate, store, use, and share electricity.** Collective self-consumption is being faster implemented in national regulation than energy communities, as it is simpler to implement in existing energy systems.

Just like prosumers, consumers involved in collective self-consumption use energy management systems and demand-side management to optimise costs or maximise self-consumption, depending on the electricity prices, state of the energy market and existing incentives.

Technologies typically used in collective self-consumption are PV, batteries, heat pumps, EVs, energy management systems, and demand-side management.

Community energy initiatives

Organising a community of residential, industrial or other users to collectively act in regards to energy qualifies as a community energy initiative. The recast renewable energy directive (RED II) and the recast electricity market directive (EMD) recognise and offer an enabling legislative framework for Citizen Energy Communities (CEC) and Renewable Energy Communities (REC). Such energy communities can take the form of a cooperative but also other types of collective actions exist, such as collective use of energy service, etc.

Basic characteristics of RECs and CECs based on EU directives:

REC	CEC
The primary purpose is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits.	
Generate, consume, store or sell renewable energy.	Generate electricity, including from renewable sources, distribute, supply, consume, aggregate, store, provide energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders.
Shareholders or members can be natural persons, SMEs or local authorities, including municipalities.	Shareholders or members can be natural persons, local authorities, including municipalities, or **small enterprises.**
Open and voluntary participation, autonomous, and effectively controlled by shareholders or members that **are located in proximity.**	Open and voluntary participation as well as effectively controlled by shareholders or members.

As energy community initiatives typically build on existing community initiatives or groups, islands may find it beneficial to organise community energy initiatives that deal with multiple sectors such as energy, water, wastewater, tourism, etc. Technologies used by community energy initiatives are all in electricity, heating or transport.

Photo: © Ivan Brčić, picture of the Cres-Lošinj archipelago

Photo: © Ivan Brčić, the energy cooperative "Apsyrtides" during a meeting in 2021.

Island example: Cres-Lošinj, Croatia

The Cres-Lošinj archipelago is the largest archipelago in the Adriatic Sea with a total land surface of 513 km^2 (16% of the total surface area of all the islands of the Croatian Adriatic coast). It consists of seven islands - Cres, Lošinj, Unije, Ilovik, Susak, Vele Srakane, Male Srakane - and numerous uninhabited islets and reefs.

The municipalities of Cres and Lošinj share the authority over the archipelago. Cres includes 26 settlements with a total of 2,879 inhabitants, 75% of which live in the town of Cres. Lošinj has 14 settlements and population of 8,016 inhabitants. The main economic activity on the archipelago is tourism, which is very intensive in the summer period and in August reaches daily peaks of up to 30,000 tourists.

In 2019 the Cres- Lošinj archipelago was selected as a pilot island from the Clean energy for EU islands secretariat. Cres-Lošinj completed its Clean Energy Transition Agenda (CETA) successfully, involving all island stakeholders in this exercise and building a coalition on energy transition which has resulted in the archipelago hiring a sustainable energy coordinator. As a natural continuation of its transition, the energy cooperative "Apsyrtides" was established on 30 April 2021.

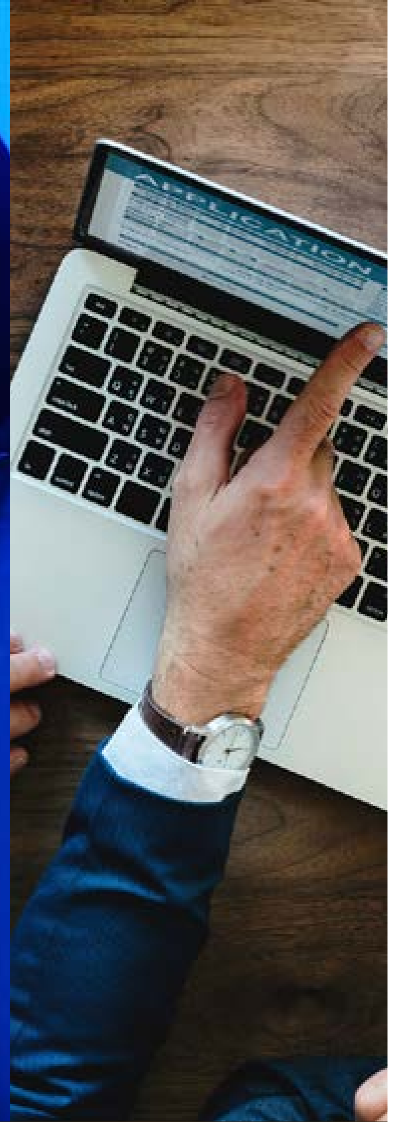
From the very beginning, the cooperative has been based on quadruple helix model, involving members from academia, civil sector, businesses, and two local municipalities (the first case in Croatia). The cooperative has 29 funding members, but the interest of the local community to join the cooperative is great and almost 50 citizens and entrepreneurs have expressed their will to become members. The cooperative is registered as for-profit body, which means that for now it cannot become a citizen or renewable energy community. The actual goal of the cooperative is the mobilisation of the local stakeholders to participate in crowd-funding investment initiatives in non-integrated and integrated solar power plants. The main project in the pipeline is a 500 kW PV farm, which has gotten support of the NESOI programme. The co-operative has also applied for technical assistance support to elaborate a series of small PV plants on rooftops of public as well as commercial buildings. The intent is to develop several business models that will allow PPP agreements and joint ventures with private subjects.

Further reading

→ Read more about NESOI: New Energy Solutions Optimized for Islands

→ Find out more about Cres-Lošinj Clean Energy Transition Agenda

SMART GRIDS



What are smart grids?

Smart grids are energy networks (grids) that can automatically monitor and manage energy flows adjusting to changes in energy supply and demand accordingly.

Existing low voltage electricity grids are hard to manage as there are not enough measurement points to monitor the state of the grid. Installation of smart meters creates a way to monitor the local conditions on the grid, but also manage the local energy flows.

Smart grids are more flexible systems that can integrate renewable energy generation ensuring the security of supply and more efficient operation. Depending on the available data, a digital twin of the smart grid can be created. Digital twins can be used to simulate the current state of the grid, forecast the future state and optimise grid state taking into account consumption and generation.

Moreover, smart grids offer new possibilities to any user connected to them, allowing end-users to optimise their own energy use and costs, depending on the changes in electricity prices, by using energy management systems for demand-side management. In addition, smart grids allow for two-way energy flows, fostering exchange of energy with the grid and among connected users. In order to make the most of smart grids for all users of the grid, the electricity market needs to be open and dynamic as defined by the Clean Energy Package.

Further reading

→ Read more about Clean energy for all Europeans package

→ European Commission on smart grids and meters

→ Horizon2020 projects Smile on what is a smart grid

Smart (digital) meters

Smart meters are digital meters that allow for remote communication and control are called smart meters.

Implementation of smart meters aims to empower consumers to become more active in the energy system by providing them **real-time or accurate information** of their consumption and allowing **two-way energy flows**.

Digital twin

A digital twin is a digital copy of the electricity grid, generated based on the data from sensors and meters located in the substations but also at the consumer and producer locations.

It can be used by the distribution system operator to **map out the grid, simulate the current or future status of the grid and assess potential future needs or possible integration of new producers or consumers.** It can be also used by aggregators or other actors in the energy market.

Energy management system

An energy management system is any ICT tool that manages the energy consumption, storage, and generation of a consumer, a building, group of buildings or an industrial system.

Energy management systems can include **management of electricity, heating, cooling or ventilation, and mobility.**

Interoperability

With the digitalisation of energy systems comes the use of multiple ICT devices for monitoring and managing energy consumption or generation of different devices.

In order to ensure the whole system, either at the level of the household, building, neighbourhood or city is functioning without problems, it is important that the devices and their software are **interoperable and use open communication standards.**

Aggregation

Aggregators are introduced in the Clean Energy Package as a third party that can aggregate and manage energy from multiple consumers and represent them in the energy market.

The aggregation of a number of producers (PV, wind, CHP), storage systems and/or flexible devices (heat pumps, EVs) into a single system that functions in coordination with each other is called a Virtual Power Plant.

Demand-side management

Managing own consumption and generation to ensure optimised costs based on electricity pricing signals, or ensuring optimal self-consumption, is done using ICT tools and smart meters and is referred to as demand-side management.

Demand-side management can be useful for a single consumer or multiple consumers. Depending on its implementation, it has the potential of increasing **the reliability and flexibility** of the grid.

Cybersecurity

The collection and exchange of **energy system data and their manipulation** comes with security risks and the need to ensure cybersecurity.

This is especially important when it comes to the energy sector, as much of our daily life depends on the operation of different electricity-driven devices and sensors.

Bibliography

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- Renewable electricity requirements to decarbonise transport in Europe with electric vehicles, hydrogen and electrofuels

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