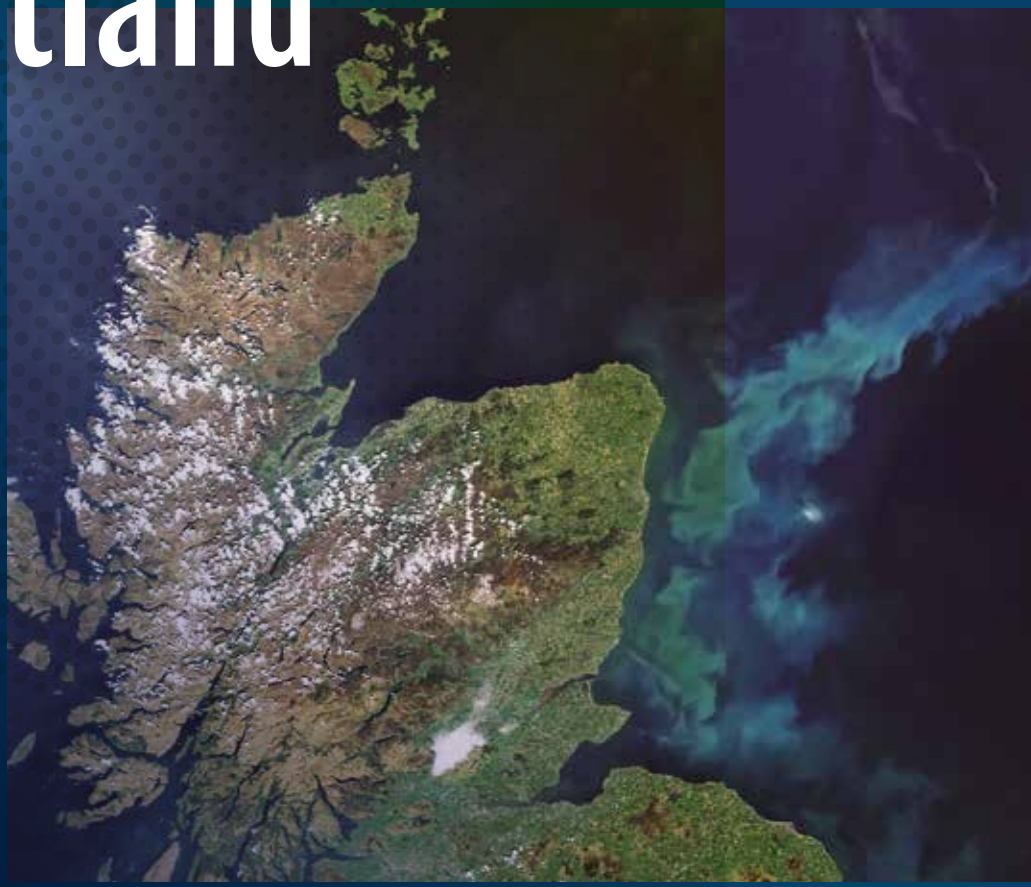
1000+ Profitable Solutions to Protect the Environment

Solutions Guide for Scotland



SOLARIMPULSE FOUNDATION

solarimpulse.com

Bertrand Piccard

Foreword from the Chairman

When the Solar Impulse airplane touched down in Abu Dhabi on the final leg of its journey around the world without a drop of fuel, we succeeded in demonstrating that clean technologies and renewable energies could do much more than people thought possible. Following this symbolic demonstration, the Solar Impulse Foundation has committed itself to proving that such technologies existed also on the ground, across dozens of other sectors, allowing the world to remain below the limit of 1,5°C. Furthermore, as the use of these technologies is ultimately one of cost, we also wanted to show that they had advanced to such an extent that the benefits they offered extended to the economic realm, allowing users to make savings and the companies behind them to turn a profit.

Five years later, we have reached our new goal of identifying over 1000 of these technological solutions: they represent systems, devices, products, materials, sources of energy, in the fields of water, mobility, construction, energy, industry and agriculture. They are available today, protect the environment, generate jobs and are fully profitable for the economy. They have been awarded the Solar Impulse Efficient Solution Label after a rigorous certification process. This shows that technology is not the obstacle, and that it is now up to the political and regulatory realms to move forward.

What you have in your hands is a selection of solutions aligned to the ambitious climate plan set out by the Scottish government, These solutions can help the government to identify the technologies that can reduce pollution and emissions, protect the environment, whilst increasing the quality of life of its citizens.

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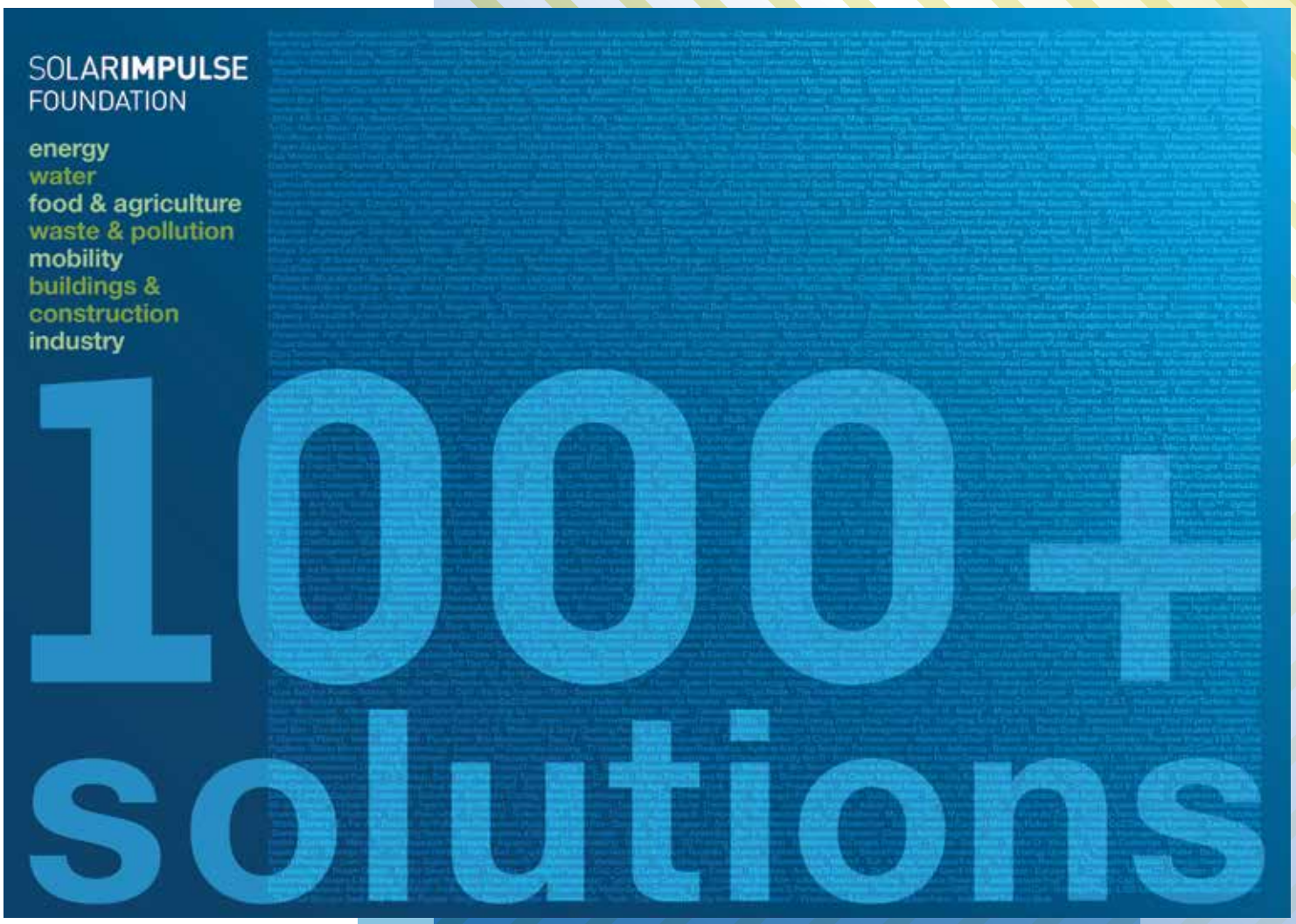

Five years ago, Bertrand Piccard set the challenge of selecting 1000 Solutions to protect the environment in a profitable way. In April 2021, the Solar Impulse Foundation met that goal, demonstrating that technology is not holding back the ecological transition. In fact, ecology can become the driving force for the economy.

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Glossary

AFV: Alternative Fuel Vehicle

CCS: Carbon capture and storage

CCUS: Carbon capture, utilization and storage

CHP: Combined Heat and Power (CHP), also known as Cogeneration

CO_2e: Carbon Dioxide equivalent units

COP26: 26nd Conference of the Parties to the UNFCCC

CSR: Corporate Social Responsibility

DMC: Domestic material consumption

DMI: Direct material input

EU: European Union

ESG: Environmental, Social and Governance

EV: Electric Vehicle

GDP: Gross domestic product

GHG: Greenhouse gas

GWP: Global warming potential

IPCC: Intergovernmental Panel on Climate Change

LCA: Life Cycle Analysis

LCOE: Levelised Cost of Energy

LNG: Liquefied Natural Gas

LPG: Liquefied Petroleum Gas

NGO: Non-Governmental Organization

PV: Photo-Voltaic

R&D: Research and Development

RMI: Raw material input

RoI: Return on Investment

SDGs: Sustainable Development Goals

SIF: Solar Impulse Foundation

UK: United Kingdom

UNFCCC: United Nations Framework Convention on Climate Change

Introduction to the Report

1000+ Solutions: Guide for Scotland

Bertrand Piccard and the Solar Impulse Foundation (SIF) have identified over 1000 clean and profitable solutions that can be implemented today to address environmental challenges without compromising economic growth. They are now committed to going even further. By offering political and economic decision-makers a Guide to Solutions that can be implemented on a large scale, the Foundation gives them the tools to establish roadmaps for the adoption of much more ambitious energy and environmental programs and thus achieve their sustainability objectives.

This report is a representative example of that effort. We have looked at the Scottish climate plan and identified a selection of technological solutions that could help the government, businesses and citizens to reach their environmental targets in alignment with their economic and social objectives, thereby improving citizens quality of life. We have organized this report in accordance with the Scottish Climate Change Plan Update 2018–2032: Securing a green recovery on a path to net-zero . Within these pages you will find over 200 solutions that can be implemented today and have been specifically selected to reduce Scotland's environmental footprint and grow the economy. There are of course many more to be discovered through our website.

The solutions we are putting forward within these pages are intended to demonstrate how much cleaner and efficient our society can be with the right technologies, services and products, and helps to indicate what is technically and financially possible if solutions such as these were to be deployed. This report and our online guide can help set the standard of what users should be looking for and what kind of benefits they can hope to see from their implementation.

"SOLUTIONS EXIST THAT ARE LOGICAL MORE THAN JUST ECOLOGICAL, THAT CAN CREATE JOBS AND GENERATE PROFIT WHILE ALSO REDUCING POLLUTING EMISSIONS AND PRESERVING NATURAL RESOURCES."

Bertrand Piccard

Our Methodology

How have these Solutions been selected?

The selected solutions are products, processes, or services coming from companies ranging from start-ups to large corporations. They benefit both the environment and the economy, and cover the sectors of water, energy, construction, mobility, industry, and agriculture.

Each solution has gone through a rigorous assessment process by independent experts before obtaining the Solar Impulse Efficient Solution Label.

The pool of 1000+ Solutions created from this process provides a unique resource and should become an essential part of all environmental decisions, media debates, and political negotiations as it is the only portfolio of this nature available to the public.

While most other labeling schemes provide consumer-facing guarantees, the SIF Label provides a more holistic approach that aims at bridging environmental and economic dimensions of sustainability.

The evaluation process is based on verified standards covering the three main themes of feasibility, environmental impact and profitability. This is based on charters drafted in accordance with the United Nations Global Compact and its principles. It is also audited by an external party (EY) in accordance with ISAE 3000 and is recognized and endorsed by public authorities, industry experts, and financial partners across all industries.

Given that innovation never stops, the Solar Impulse Foundation will keep labeling and adding solutions to the pool.

> "EACH TIME I SPEAK OF PROTECTING THE ENVIRONMENT TO HEADS OF STATE OR GOVERNMENT OFFICIALS, THEY TELL ME THAT IT IS TOO EXPENSIVE. THIS LABEL IS A STRONG MESSAGE TO THEM: SOLUTIONS EXIST AND REPRESENT THE BIGGEST MARKET OPPORTUNITY OF OUR CENTURY. AN OPPORTUNITY WHICH CANNOT BE MISSED."
>
> Bertrand Piccard

All solutions have convinced experts that they meet five criteria:

Feasibility

- Credibility of concept
- Scalability

+

Environment

- Environmental benefits

+

Profitability

- Client's economic incentive
- Seller's profitability

Setting the scene

The Scottish Context

SolarImpulse Foundation
#beyond 1000 solutions

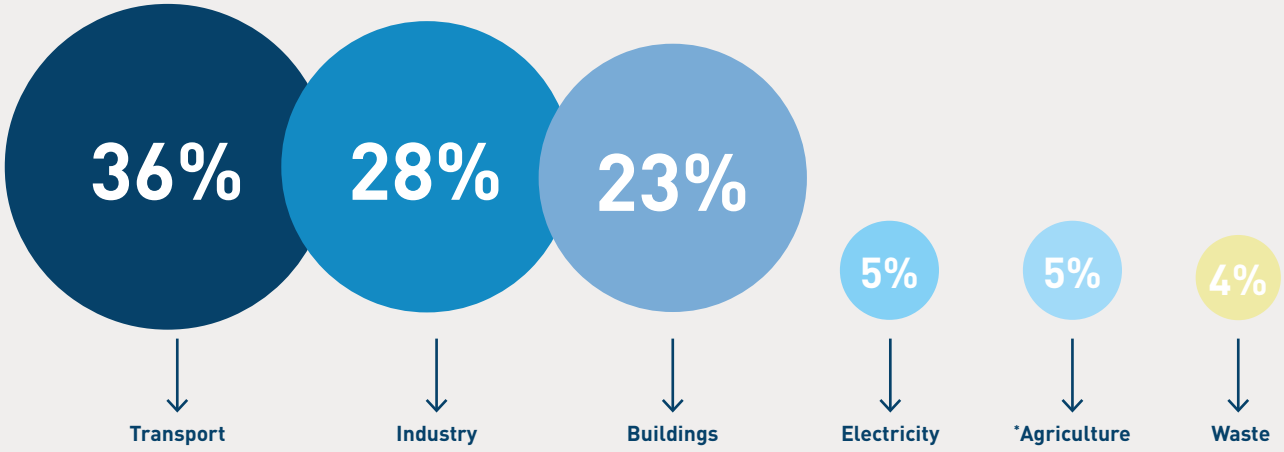
With Glasgow being the host city for COP26, it seemed a perfect opportunity to select Scotland as the focus of this report. However, what really makes the case for Scotland is its ambition. The marriage of political will, legally-binding commitments and a country seeking to diversify its economy to embrace sustainable models of production makes for an excellent demonstration of what our environment and economy could be like if finance, political will and technology were to be aligned. Scotland made international headlines in 2018 when they announced one of the most ambitious climate change plans in the world: net-zero by 2045, with three quarters of these cuts made by 2030. This was the toughest statutory target of any country in the world – and in April 2019, First Minister Nicola Sturgeon was the first leader of any national government to call a climate emergency.

Scotland is a country that has recognized both the need to diversify its economy and the opportunity that doing so will bring. Economic dependence on North Sea oil and natural gas remains significant, and represents up to 5% of Scottish GDP and over 100,000 jobs. However, the transition to clean energy has seen Scotland become a world leader in wave-based renewable energy technologies, and capitalise on its enormous potential in terms of harnessing wind power.

The government are clear-sighted in their recognition that by investing in infrastructure and people, Scotland can undertake the significant re-skilling of the workforce in anticipation of these new industries, whilst creating jobs and reducing energy poverty – a clear priority.

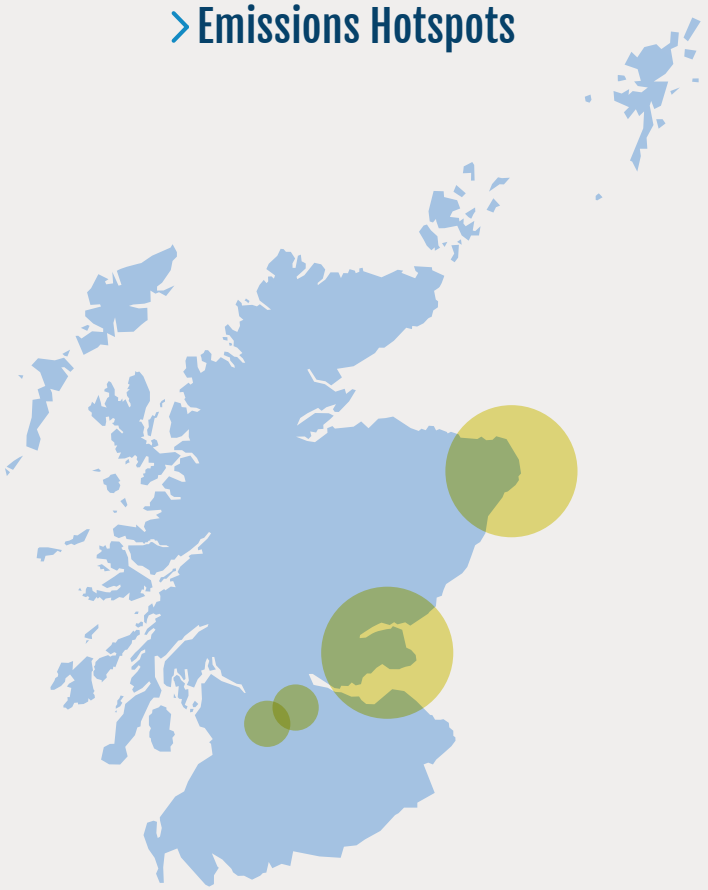
CENTRAL TO SCOTTISH AMBITION IS THAT THE ECOLOGICAL TRANSITION IS A JUST TRANSITION, COMMITTED TO REDUCING INEQUALITIES AND IMPROVING QUALITY OF LIFE FOR ITS CITIZENS.

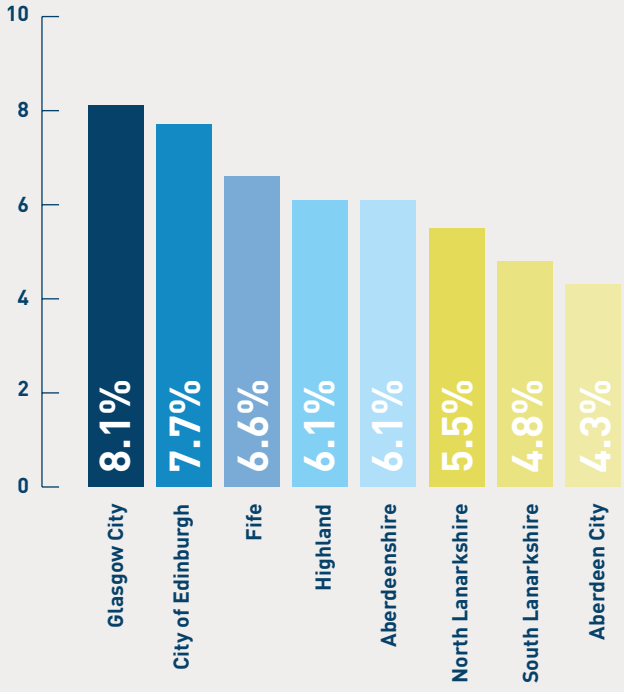
> CO_2 emission by sector (%) 41.6 Mt CO_2e



*Emissions from agriculture contributed to 18% of the total in 2018. However, emissions in land use, land use change and forestry are a net sink – they absorb greenhouse gases; accounting for -13% in 2018. However, this is set to change, and Land Use, Land Use Change and Forestry emissions are expected to rise by 283% due primarily to the inclusion of emissions from peatlands, which have not been accounted for up until this point.

> Emissions Hotspots

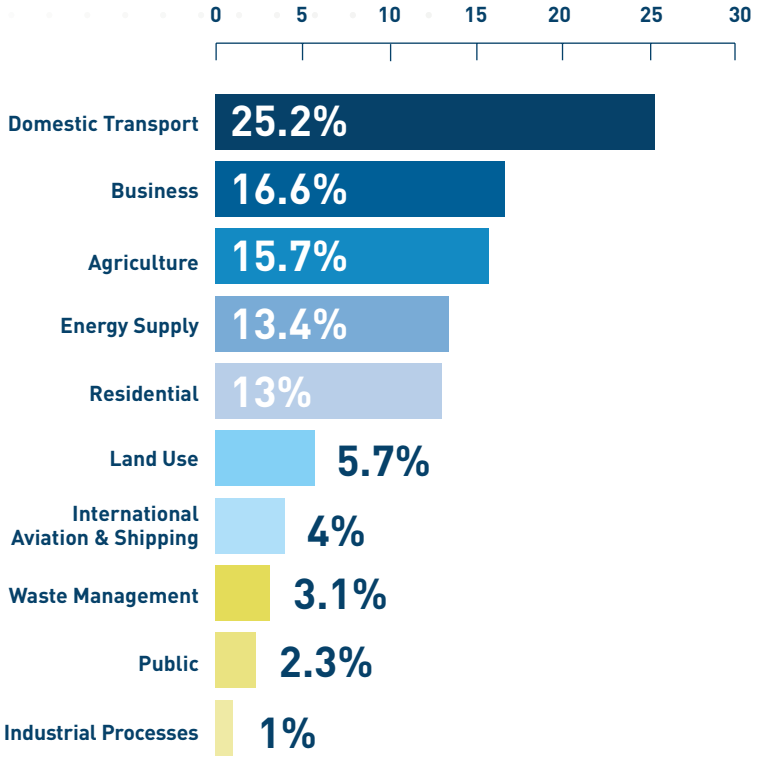




Scotland has significantly reduced its emissions over the last three decades. However, two-thirds of the total fall between 2008 and 2018 were from the power sector. Over the same period, emissions from all other sectors have fallen by just 14%. Despite a drop linked to the impact of COVID-19, the key structural changes that will drive emissions reductions have not been achieved, and the country as a whole is expected to have missed its target of a 56% reduction in overall emissions by 2020.

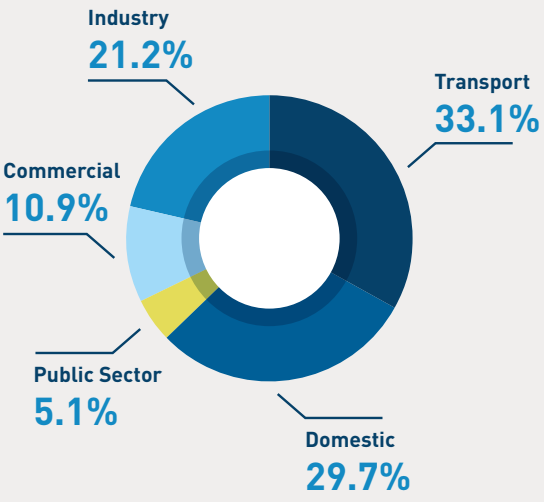
This document indicates some of the key areas that need to be targeted. Statistics show that the highest concentrations of emissions are found in a few locations – Aberdeenshire and Aberdeen City, Clackmannanshire and Fife, Edinburgh City and Glasgow City (see map) – and across a few key industries – notably the oil and gas sector. We seek to respond to this information over the following chapters.

> CO_2e emissions by sector (%) 47.7Mt CO_2e (2019)

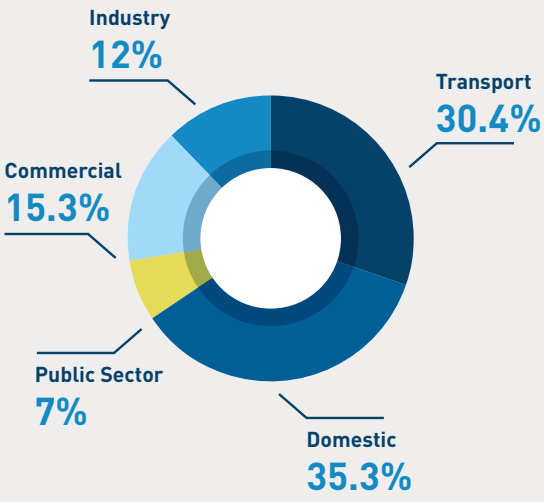


> CO_2e emission by region

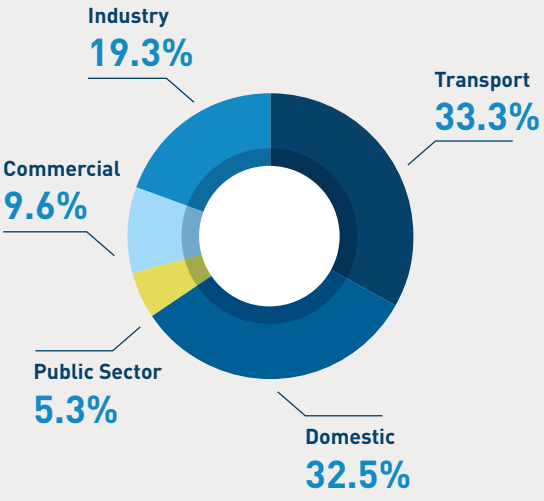
Aberdeen & North East



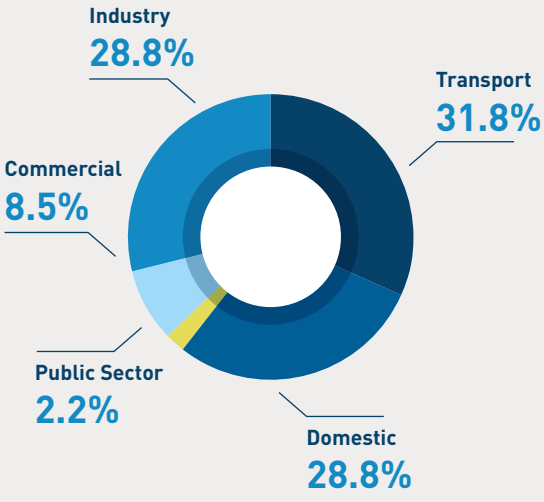
Edinburgh & Lothians



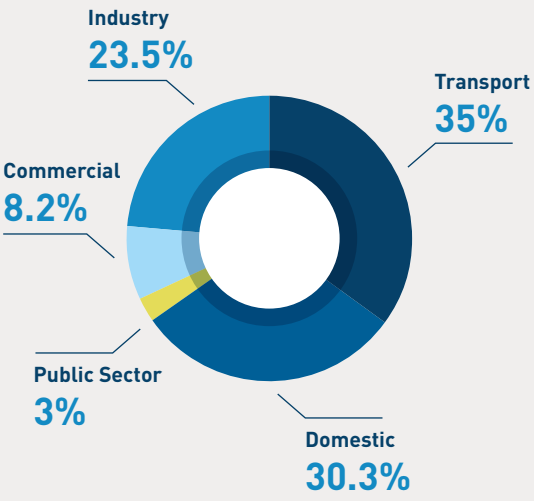
Tayside, Central & Fife



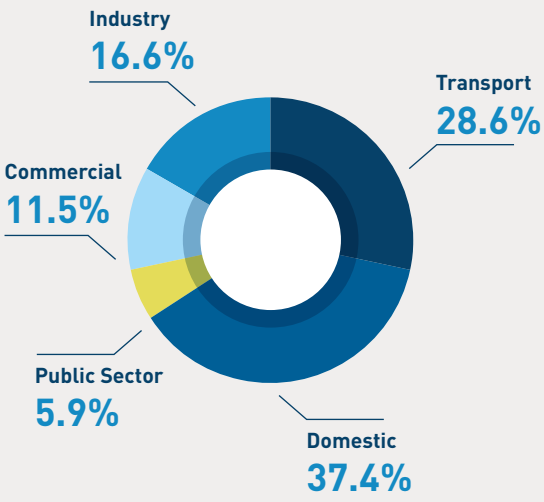
Scotland South



Highlands & Islands



Glasgow & Strathclyde



01

Electrification

Enabling Renewable-Powered Electrification

In the last decade, Scotland has made huge strides towards a decarbonised electricity system. The equivalent of nearly 100% of Scotland's electricity demand is now met by renewable sources, and there is a clear ambition to go further and continue to grow renewable electricity production. This will be particularly important to enable the transition to decarbonising other sectors, such as transport and heat, which are increasingly moving towards electrification, creating more demand for clean and abundant electricity.

The Scottish Government has set out three overarching outcomes for the future of Scotland's electricity system:

The electricity system will be powered by a high penetration of renewables, aided by a range of flexible and responsive technologies. These include developing between 11–16 GW of additional capacity by 2032, expanding offshore wind capacity to between 8–11 GW by 2030, and achieving 50% of all energy coming from renewables by 2030. Reaching these targets will require a significant increase in the installation and uptake of renewable sources of electricity.

Scotland's electricity supply is secure and flexible, with a system robust against fluctuations and interruptions to supply. The Scottish Government has set out its commitment to expanding solutions to ensure energy security and flexibility. Additionally, the Scottish Government has set a target to trial projects which can deliver a sustainable and secure supply by 2030, and to revise market and regulatory systems to incentivise these new services.

Whilst the technologies needed to achieve a transition towards renewable electricity already exist today, it is important to support the growth and development of new and innovative solutions which can help to achieve this transition and adapt to future conditions. This applies to both improvements on existing technologies, and to brand new technologies. The Scottish Government has shown commitment to supporting new solutions in renewable electricity through the £180 million Emerging Energy Technologies Fund which was launched in 2021.

> Growing Renewable Electricity

GE Haliade-X

One of the world's most powerful wind turbines, with a 12 MW capacity

Wind **Energy Production**

The Haliade-X solution is one of the world's most powerful wind turbines, with a 12MW capacity turbine. Thanks to its larger size and power, the solution enables a lower electricity price and reduces the requirement for cabling, foundations material and installation while increasing the electricity yield. By using new technologies, the solution is able to capture the advantage of scaling up wind turbines and can outperform by 50% the capacity of certain major competitors. This solution enables more power generation and a more economically attractive solution for Scotland's expanding offshore wind generation potential.

Where is this Solution being used?

The Haliade-X has been installed in the Dogger Bank wind farm, a 3.6 GW capacity located around 130 km off the north-east coast of England and spread between three offshore wind farms. If Haliade-X turbines were exclusively used in this project, the number of turbines required could be reduced by 80 whilst delivering the same power capacity.

Environmental and Economic Benefits

- **One Haliade-X 12 MW turbine can generate up to 67 GWh of gross annual energy production**
- **Up to 50% greater capacity than competitors**
- **Allows 26% fewer turbines to be installed for the same capacity**

What this means for Scotland

- **For every £1 million invested, 16 jobs could be created to build manufacturing facilities for offshore wind**

Encouraging uptake

- **As larger turbines become more financially viable, regulations for taller and more efficient turbines need to be encouraged**
- **Authorities should look into the benefit of replacing a number of small older turbines with few larger and newer turbines**

> Growing Renewable Electricity ■ Wind

Wind Tulips

Small wind turbines that combine efficiency, low noise, synergistic clustering, bird friendliness, and artistry

Wind is coming from the left, into a horizontal cross-section of the Tulip turbine. The wind hits one blade and then, thanks to the ratios of shaft size, blade size and overlap size, it recirculates and becomes faster than the prevailing wind before it hits the second blade, explaining the efficiency and ability to start at lower speeds. The shape also decrease edge effects and makes it easier for winds from different directions to push on the turbine, particularly at the top.

Benefits

- **Annual 5% reduction of emissions from grid produced electricity in windy areas within 20 years**
- **Reduce numbers of birds killed from small turbines**
- **2–10 years payback time**

> Growing Renewable Electricity ■ Wind

EO25 Distributed Wind Turbine

A non-intrusive direct-drive certified wind turbine for reliable, low cost distributed power production

This small wind turbine uses the same horizontal axis, upwind wind turbine design commonly found in today's large-scale wind turbines. The turbine was designed with the goal of having a simple design and few moving parts. It is connected to Eocycle Global Operations Centre, allowing remote monitoring and complete management of the wind turbine, resulting in decreased downtime and optimised performance. It is installed and maintained using a tilt-up hydraulic tower.

Benefits

- **Offsetting about 70,000 kg of CO_2 emissions per year**
- **Payback period is reached after 10 years**

> Growing Renewable Electricity ■ Wind ■ Electrical Grid

Grid stability with renewable energy?

Yes, Wind can!

A windflow power-train and a synchronous generator enabling wind turbines to provide physical inertia and system strength for grid stability

This solution is a mechanical Variable Speed system called the torque-limiting gearbox/low variable-speed system which leaves the generator speed constant (set by the grid) and has a differential in the gearbox. One output from the differential drives the generator (constant speed), the other drives a hydraulic pump (variable speed). A hydraulic circuit controls the torque, while the turbine speed is controlled by pitching the blades, the important stability benefits are conserved while renewable penetration increases.

Benefits

- **Avoid CO_2 emissions expenses by up to 20%**
- **Reduce wind turbine power train capital cost by 5%**
- **Savings of USD 20,000 per 2 MW turbine**

> Growing Renewable Electricity ■ Offshore ■ Wind ■ Construction

Damping pool floating foundation

A floating foundation for offshore wind turbines removing all depth-constraints

This technology is primarily based on the main patent for a Damping Pool, a hydrodynamic system comprising a central pool that allows for the creation of the floating foundation. The structure is also created thanks to three other patents: a solution to reduce the fatigue of mooring cables, a floater's installation concept (with legs) and finally, a mobility solution which reduces the wake effect.

Benefits

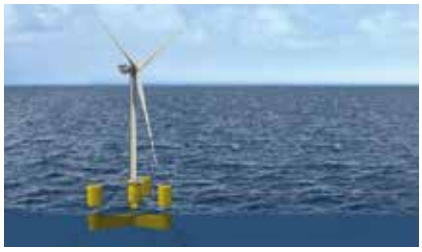
- **Carbon's footprint is diminished by 50% compared to traditional offshore wind installations**
- **Reduced overall cost of wind energy produced**

> Growing Renewable Electricity ■ Offshore ■ Wind ■ Construction

STAR

A semi-submersible floating system for offshore wind turbines providing access to the powerful winds in deep maritime areas

The turbine is installed in the centre of the foundation at quayside while the floating foundation is ballasted to compensate the motion of the whole system. When reaching the operating site, the floating foundation is connected through mooring lines to several anchors already installed on the deep-water soil. From this moment the solution should maintain its position and stabilise the turbine generating energy through offshore winds.



Benefits

- **Carbon payback time in around 1 year**
- **Largely made of recyclable material like steel**
- **Designed for a 25 year service life**

> Growing Renewable Electricity ■ Heat-exchanger ■ Electricity

Efficiency PACK: a cost-efficient, modular ORC product

Technology to convert waste heat from various sources into low-cost & carbon-free electricity worldwide

The solution is based on Organic Ranking Cycle (ORC) principles, converting low-grade waste heat to electricity: The evaporator transfers the heat into the Efficiency PACK. Thereby, the pressurized working fluid is heated and then routed to the expansion machine. The vaporized working fluid drives the expansion machine and thus the generator, producing electricity. The working fluid is condensed, releasing residual heat into the ambient air. The working fluid is then brought to high pressure in the pump.

Benefits

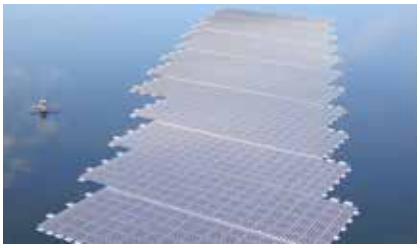
- **A single efficiency PACK can save 750 tons of GHG annually**
- **An environmental payback period of less than 2 months**

> Growing Renewable Electricity ■ Wave ■ Marine ■ Renewable

Hydrelio

Optimised floating system for solar plants on inland water bodies

HYDRELIO is a modular, scalable, adaptable floating solar panel system which offers a way to harness the power of the sun in an unconventional way. The panels float upon the surface or water bodies to produce a clean and innovative source of electricity. The panels are compatible with many types of water bodies – suitable for Scotland's many lochs and reservoirs. Floating solar helps to provide an electricity source where suitable space on land is in short supply or where other land uses take priority.



Benefits

- **Generating clean electricity from otherwise unused space**
- **100% recyclable plastic**
- **ROI in around 7 years**

> Growing Renewable Electricity ■ Wave ■ Solar ■ Off-grid

WAVEGEM®

An autonomous renewable energy solution for off-grid isolated sites using waves and the sun

With dimensions of 21 m x 14 m x 7 m and a deadweight of 200 MT, WAVEGEM delivers 150 KW of power. The platform is built with steel or aluminium hull, stainless steel turbine, rubber for internal flaps, standard anchors and chains. The main technical feature is the wave energy converter inside the hull: tubes in the shape of a cross contain water in a closed circuit. Each time the waves make the hull move, the water naturally flows inside the tubes and into the central water turbine linked to a generator.

Benefits

- **The solution avoids 2.2 tons of CO_2 emissions per year for each kW installed compared to a diesel generator**
- **The ROI is estimated at 3–6 years a unit**

> Growing Renewable Electricity ■ Turbines ■ Renewable

Micro Hydro Turbines

Small water turbines to produce energy in drinking water or irrigation networks

Can be installed in any point of the water network with pressure and a circulation flow. The turbines are PAT type (pump used as turbine) and they are derived from a standard pump. Attached to the PAT shaft is a high efficiency three-phase permanent magnet generator that results in very compact and easy to install equipment. The three-phase output of the generator is filtered and rectified, and this DC signal is connected to a battery charge controller (off-grid applications) or to a grid inverter.

Benefits

- **For every kilowatt of hydropower installed, a reduction of 3.59 tons of CO_2 per year is possible**
- **Payback between 3 and 6 years**

> Growing Renewable Electricity ■ Buildings ■ Solar

Photovoltaic solutions for professionally used real estate

Plans, contructs and operates solar solutions and sells the electricity to the tenants

The direct current from the solar installation is converted into alternating current with an inverter and the electrical distributor spreads the electricity close to the consumer in the in-house power grid. The tenants can use this electricity for domestic use. Most of the solar power is used for direct consumption in the house. Electricity that is not needed in the house is fed into the local distribution network.

Benefits

- **An average solar tenant power project saves over 71,682 kg CO_2**
- **PV panels can be recycled by over 80%**

> Growing Renewable Electricity ■ Buildings ■ Solar

Sunstyle

Fully integrated photovoltaic roof which provides waterproofing and clean electricity

The solution consists of a set of photovoltaic tiles which are assembled in a fish scale manner. Tightness is ensured by a 30 mm overlap of each tile over the one below it, in addition to rubber joints on the superior sides of the tiles (the ones that are overlapped). The standard system is designed for any roof with a slope above 15°. The technology of the tiles themselves, apart from the installation, is the same as the regular photovoltaic modules. Each tile has a capacity of 115 Watts peak (Wp).

Benefits

- **Reduction of 6,5 t CO_2/year for 1000 m^2 of roof**
- **Generates 33% of savings on installation**

> Growing Renewable Electricity ■ Pumping ■ Biodiversity

The fish-friendly Archimedean screw pump

Fish safe pump, with high efficiency, long lifespan even in salt water, low maintenance and impervious to debris

The screw pump is quiet which allows it to be installed in populated areas if required. Moreover, the pump has a low maintenance requirement and high pump efficiency. The screw blades are enclosed in a composite pipe which mitigates the danger of entrapment between the blades and trough. The leading edges of the blade have a special patented design: the width of the blades gradually decreases from the middle outwards during the last winding, making the design 100% fish-friendly.

Benefits

- **100% fish-friendly**
- **At least 30% energy savings, compared to conventional pumps**

> Growing Renewable Electricity

Eco Wave Power

Device installed near the shore to generate electricity from wave power

Wave Marine

The Eco Wave Power solution draws energy from wave power. This is done through floaters, which rise and fall with the upward and downward motion and forces of waves. The floaters are attached by robust arms to any type of man-made structure on the shore line. The motion of the floaters is transmitted to an onshore power station, which converts the energy from this motion into fluid pressure, which is used to spin a generator, producing electricity. By tapping into near-shore wave power, Scotland can generate a clean and consistent source of electricity in coastal areas.

Where is this Solution being used?

Eco Wave Power reached 15,000 grid connection hours in its pilot plant in Gibraltar, setting a new world record in grid connection hours for a wave energy developer and has been awarded Best Wave Energy Technology Development Company 2018 by the Sea Transport Awards and a UN Climate Action Award in 2019. EWP demonstrated that wave energy can successfully connect to the grid, with no fluctuation effects. EWP has a Power Purchase Agreement signed with the Government of Gibraltar for expanding the power station to 5MW. Upon expansion, this installation could provide 15% of Gibraltar's energy needs.

Environmental and Economic Benefits

- **Zero emissions from operation**
- **ROI in 3–6 years**
- **Avoids over 2500 tons of CO_2 per MW compared to fossil fuel use**

What this means for Scotland

- **Ocean energy could create 400,000 skilled jobs in Europe by 2050**
- **Ocean energy can deliver 100 GW capacity in Europe by 2050**

Encouraging uptake

- **Simpler regulatory framework needed for wave power installations**
- **Feed-In-Tariff, set at the right level, required to support wave power growth**
- **Innovative technologies like wave power often lack access to certain forms of financing (e.g. debt financing)**

> Energy storage and management

MAN ETES (Electro Thermal Energy Storage)

Tri-generation energy management solution for storage, use and distribution of electricity, heat and cold

Storage **Oil & Gas**

MAN ETES produces and stores heat, cold and electricity at a large scale through a heat pump system. MAN ETES, as a tri-generation solution, is capable of providing large volumes of heat and cold and storing electricity at the same time, therefore providing an intermediate link to balance out supply and demand of various forms of primary and secondary energy supply. It is the ideal system for the increasingly important 'sector coupling' – the merging of energy suppliers and consumers. In contrast to the majority of the competition, this solution uses CO_2 as a refrigerant, which is inexpensive and easily accessible.

Where is this Solution being used?

The first implementation of this solution is soon to take place in Esbjerg, Denmark, which will see the the world's largest transcritical CO_2 heat-pump with seawater as a heat source used for the local district heating network. With two large heat-pump units, 50 MW of thermal heat will be delivered at 90°C. This will deliver anticipated CO_2 savings of 100,000 tons per year. The proof of concept for the solution was established through extensive testing in Zurich in November 2020, where a complete cycle was constructed.

Environmental and Economic Benefits

- **Up to 80 MW thermal per heat pump unit**
- **Carbon neutral operation if supplied by renewable electricity**
- **ROI in 5–10 years (lifetime of 35 years)**

What this means for Scotland

- **The Thermal Energy Storage Market projected to grow at a CAGR of 12.6% (2020–2027)**

Encouraging uptake

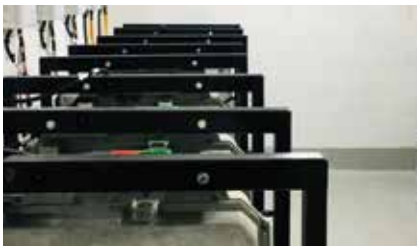
- **Need for higher price on carbon emissions**
- **Lack of funding for innovative technologies, particularly in energy storage**
- **Scandinavian countries setting good example for supporting low-carbon energy solutions**

> Energy storage and management ■ Lithium ■ Batteries ■ Energy storage

Elsa

Electrical lithium-ion storage assembled using 2nd life EV batteries for stationary application in buildings

By integrating 2nd life car batteries and an Intelligent Energy Management System, this solution can be used in a wide range of applications. It can balance electricity demand and local PV generation (i.e. in commercial buildings). In charging stations, it can shave load peaks of high demand and balance times of high generation. Distribution system operators can use it in sub-stations for frequency and power regulation. ELSA's storage systems uses second-life EV batteries directly as they were in the car, with no dismantling.



Benefits

- A recovered battery avoids the emissions of 392 kg CO_2eq/kW/year over 5 years
- Savings of 30 to 50% compared to a similar new battery

> Energy storage and management ■ Batteries ■ Energy storage

DERMS Mobile Storage

Flexible, modular and patented battery solution that fits in a container and can be transported for temporary needs

A large number of batteries which can be used for both mobile storage and grid interaction. After use, the battery is brought back to the warehouse, and being made to interact with the grid to generate further revenues. An aggregation software is used to remotely optimise distributed energy resources portfolio that is tailored to the regulatory framework of the country where the solution is used.

Benefits

- Rental prices offered compared to DIESEL are at similar levels
- Payback is modelled at an IRR of 11% for Western Europe

> Energy storage and management ■ Batteries ■ Energy storage

ZincFive

High-capacity, rechargeable, and recyclable nickel-zinc batteries

Manufacturing and deployment of rechargeable, and recyclable nickel-zinc batteries that provide high energy density and performance. These batteries can be used in data centers, intelligent (communicating) transportation, and stationary, motive (off-road applications to produce motion) and start-stop applications. Recyclability is one of the main environmental advantages of ZincFive's nickel-zinc battery – the raw materials can be recycled without losing their physical and chemical properties.

Benefits

- 3 x the power density and half the weight of lead-acid
- More than 90% of the battery is recyclable with no hazardous materials
- Low CAPEX with high revenue rate

> Energy storage and management ■ Solar ■ Batteries ■ Energy storage

SolarLEAF Energy Storage

Distributed energy storage solution installed directly underneath solar panels

This energy storage solution directly couples with PV panel and is seamlessly installed nehind them. The format is enabled by an advanced thermal management design which ensures that the batteries are maintained at optimal operating conditions. The solution directly addresses the high-cost variability of energy storage installations and can target specifically commercial installations in the 50 kWh to 1 MWh range, which often lack a location on site for energy storage.

Benefits

- **Potential to displace 5 gt of CO_2 by 2050**
- **Less than 5 year payback and as little as 3 years in some key markets**

> Energy storage and management ■ Solar ■ Water Treatment

Altivar 312 Solar

Variable speed drive for pumps with PV arrays, to help provide drinking water for people with limited or no access to grids

Operating pumps with solar photovoltaic PV panels for agricultural purposes poses challenges. Schneider Electric has sought to overcome this by creating an autonomous, maintenance-free and environmentally-friendly solution through 'speed drives' for pumps with photovoltaic arrays. The Altivar 312 allows the traditional challenges of this application to be overcome, making it a sustainable and efficient solution for use in agricultural systems.

Benefits

- **Reduces power loss by at least 4% compared to mainstream alternative**
- **Reduce at least 50% of installation costs compared to mainstream alternative**

> Energy storage and management

EcoStruxure Microgrid Advisor

Cloud-based platform based on predictive analytics providing energy optimisation services to energy managers

Energy management Digital Software

The EcoStruxure Microgrid Advisor solution seamlessly connects to distributed energy resources to automatically forecast and optimise how and when to consume, produce, and store energy. The solution solves two common major issues of a site enevrgy manager associated with the concept of "consuming better": optimising the cost of energy, and decreasing the carbon emissions of the site. The solution's web-based user interface makes it easy for site managers to have access to – and better understand – real-time savings, earnings, and CO_2 emissions data.

Where is this Solution being used?

An Australian food retailer intended to reduce energy costs and reduce pressure on the grid. The client installed a 2.5 MW solar system and a 4.6 MWh lithium-ion battery that will cut power bills by USD 500 k a year. EMA provided a fully automated operation, using machine-to-machine technologies and using predictive control analytics to optimise against the fastest, most volatile electricity market in the world. The client was able to limit the usage of complementary fossil energy sources and make considerable energy savings.

Environmental and Economic Benefits

- **Energy site owners can reduce 20% of energy consumption**
- **ROI in 4–8 years**

What this means for Scotland

- **Market growth extract expects a CAGR (2021–2030) between 10–25%**
- **Global energy management software market size set to grow by 13% CAGR by 2026 to a value of over $ 2 billion**

Encouraging uptake

- **Creation of energy communities must be facilitated, as is already the case in countries like the USA (unlike Europe)**

> Energy storage and management ■ Digital ■ Electrical Grid ■ Renewable

SynchroGuard

Real-time monitoring and automation solution for smart grids to facilitate the integration of renewable energy and improve efficiency

This solution uses measurement devices and advanced data-processing algorithms to provide to utility operators a real-time view of the grid status, enabling safe integration of renewable energies and EV's by managing power flows, and improving grid reliability by accurately locating electrical faults to reduce the number and duration of power outages. It uses synchrophasors that are very frequent and synchronised measurements of voltage and electric current.

Benefits

- **Between 604 and 3,622 kt CO_2 avoided**
- **Saves 1.9M €/year for a town of 400 k inhabitants**
- **Profitable in 6 years**

> Energy Security & Flexibility ■ Digital ■ Electrical Grid

GridEye

Digital tool to optimise the distribution of power on the network

A measurement and control unit (MCU), it is a DEPsys-developed piece of hardware with embedded software with a measurement frontend, a CPU for signal processing and control algorithms, a communication part based on IoT technology, and a number of interfaces to connect to communication infrastructures and controllable elements. Based on measurement data, GridEye provides different applications, such as network supervision, grid analytics, system planning, energy scheduling, etc.

Benefits

- **Reduces the environmental impact of electrical networks**
- **Saves up to 70% of the costs of network management**

> Energy Security & Flexibility ■ Digital ■ Electrical Grid ■ Renewable

Tiko

Hardware and multi-use platform to save energy and increasingly integrate renewables into the energy supply

An energy management system compatible with any residential device, thus allowing retrofits. The solution has the platform to connect millions of electrical devices worldwide and to provide the capacity as flexibility to energy markets. Combining EMS with a Virtual Power Plant generates additional revenue and makes this solution affordable and attractive for clients. This technology gives a better control and insight to the customers about their energy consumption, while generating revenue by connecting the devices to VPP systems.

Benefits

- **80 to 320 kg of CO_2/year saved through energy savings**
- **ROI in 3–4 years**

> Energy Security & Flexibility ■ Thermal ■ Energy Storage ■ Renewable

Azelio Thermal Energy Storage

Thermal energy storage solution to make clean power from solar and wind available at all hours of the day

This solution has the capability of addressing the resiliency in more mature renewable energy markets, by replacing diesel used today in baseload. This energy storage solution can balance the output and match demand through storing energy from day to night or from one day to the other. It uses recycled aluminium as a storage medium. It can be used over and over without any degraded capacity, and it does not use any scarce minerals.

Benefits

- **96% reduction of CO_2 emissions compared to diesel generator**
- **Less than 5 years payback time**

> Energy Security & Flexibility ■ Digital ■ Renewable

Darwin

Digital tool dedicated to increase operational efficiency of renewable energy farms

The tool collects data directly from renewable power plants in real-time and via historical data export without any need for local equipment installation. The data is acquired through SCADA and IoT technology. Darwin is hosted in the cloud and relies on PaaS and scalable big data services. Darwin is also capable of sending set points or control command orders from dispatch and control centres, operators or market aggregators in order to dispatch renewable capacity upwards or downwards.

Benefits

- **Renewable power plants accessible and actionable in one single platform and interface**
- **Generate 10 GWh more CO_2 free renewable energy per 1GW of installed capacity**
- **Up to +5% of plant production**

> Energy Security & Flexibility ■ Digital ■ Renewable

TEO

Web platform providing customers, employees and stake-holders with proof of origin for green energy in real time

Energy today represents 2–3% percent in operations costs but up to 20–30% of carbon footprint for industrials. Companies are moving to 100% renewable energy consumption to lower their carbon impact, but today the only mechanism is the 'Guarantee of Origin' scheme, a deficient system. With TEO, renewable electricity production and consumption is traced in near real time to let clients target 24/7 green energy consumption, with 100% production-consumption matched renewable energy.

Benefits

- **Using green electricity traced with TEO can save 507 kg CO_2/year per house**
- **2 to 3 times less expensive than usual green energy certification**

> Emerging Technology
WaveRoller
Innovative electricity generation from wave power

Energy Production **Wave**

This solution taps into the unused ocean energy resource that is readily available in the waves. The machine operates in near-shore areas (approximately 0.3–2 km from the shore) at depths of 8–20 metres, either mostly or fully submerged and anchored to the seabed. As the panel moves and absorbs energy from waves, a hydraulic piston attached to the panel pumps hydraulic fluids inside a closed hydraulic circuit. The high-pressure fluids are fed into a power storage, which through a hydraulic motor drives an electricity generator. The electrical output is then connected to the electric grid via a subsea cable. The technology can be deployed as single units or in farms.

Where is this Solution being used?

Installed 820 metres offshore from Peniche, Portugal, the installation of a 350 kW prototype for the commercial phase was completed in mid-September 2019. The intent is to install 5 MW of capacity to supply electricity to 4000 inhabitants. The ultimate aim is to create a large global park with an installed capacity of 50–100 MW, an investment totalling €100 million.

Environmental and Economic Benefits

- **Emissions intensity of just 34g CO_2/kWh, 30% less than solar PV installations**

What this means for Scotland

- **Wave and tidal power could deliver 20% of the UK's electricity demand**
- **Wave power, as a newer technology and more labour intensive, creates more jobs. Between 1,660 and 4,980 in the years ahead**

Encouraging uptake

- **The regulatory environment for ocean energy projects is not as well defined as for on-shore developments, delaying their implementation**

> Emerging Technology ■ Wave ■ Renewable ■ Marine

CalWave Wave Energy Converter

Electricity generation and fresh water production from wave energy for off-grid island and coastal communities

The wave energy converter operates fully submerged, allowing it to survive stormy seas while causing no visual pollution. The architecture consists of five main subsystems, an absorber buoy, a power take off, a mooring and anchor system, an electrical machine including export umbilical and a control system. The export infrastructure is identical to an offshore wind farm. All materials used follow the same design standards and corrosion protection that the offshore industry currently employs.

Benefits

- **Can reduce emissions of island communities by 50% through replacing diesel generators**
- **Can allow for savings of upt to 30% compared to diesel generators**

> Emerging Technology ■ Tidal ■ Renewable

Tidal energy from unconstrained flows

Tidal energy turbines to harness predictable renewable energy from tides and rivers

The Tocardo turbine is a fully submerged, direct drive, two bladed, horizontal axle, hydro turbine suitable for locations where an unconstrained flow is available for power production purposes. A simple blade-reversing mechanism allows the turbine to operate efficiently in bi-directional tidal flows. As a result from the low rotation frequency this technology is fish friendly.

Benefits

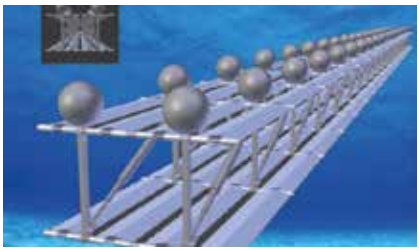
- **Saves ~1 kg CO_2 per kWh compared to a diesel generator**
- **ROI of 11 years**
- **100% reliable and 100% predictable energy source**

> Emerging Technology ■ Wave ■ Renewable ■ Marine

GENERMA WAVE ENERGY

Device using marine steel and aluminium blades to create electricity from wave power

This solution can generate electricity from waves, staying on the surface of the sea. The device is composed of interconnected parallel pipes, with a structure made of steel and aluminum. It moves according to the swell, activating the cylinders which produce electricity. The device is easily constructed and deployed and does not affect marine flora and fauna.



Benefits

- **Prevents up to 800 t CO_2/MWh**
- **Economic profit of over 30% per year**
- **ROI between 5 to 7 years**

> Emerging Technology ■ Tidal ■ Marine ■ Ocean

Marine current energy device solution for Fuel Free Islands

Hydroelectric turbine on the seabed relying on tidal energy to produce clean and predictable energy

This solution is a turbine technology, deployed on the seabed which can harness ocean currents to generate electricity. Sabella has developed a modular range of tidal stream power devices, from medium (50 kW) to high power (2000 kW), to fit the characteristics of each site and the needs of the communities. This solution can provide off-grid and island communities with clean energy.

Benefits

- **Reduces CO_2 emissions by 86% compared to a diesel generator**
- **Uses 6 x less energy to produce 1 kWh**

> Emerging Technology ■ Wind ■ Renewable ■ Electricity

Kite turbines, stable and competitive renewable energy

Kite turbine providing stable renewable energy from higher winds using 90% less materials than wind turbines

This solution uses a kite turbine which takes off like a drone using 4 propellers. Afterwards, they move in a circular cross-wind pattern, while a winch on the ground slowly unwinds a rope so that the kites fly higher and higher. Once the rope is fully unwound, the kite returns to the starting point for a new cycle. When the wind is too weak, the propellers are used to land the kite on a small mooring platform, so that it becomes almost invisible.

Benefits

- **Uses 90% less materials than wind turbines**
- **Increases the capacity factor by 20–30% compared to traditional wind turbines**
- **Reduces the cost of energy by 50% compared to wind turbines**

> Emerging Technology ■ Wind ■ Renewable ■ Electricity

EnerKíte EK200

Autonomous container-based kite system offering affordable, dependable and clean wind energy everywhere

An ultra-lightweight wing, with fully automated operations and ground-based energy generation secures the highest yield of all green energy sources, producing twice as much electricity as wind turbines and five times that of solar power. This solution targeting high altitude winds has the potential to reach megawatt-class utility-scale and a cost of energy of fewer than three cents per kilowatt-hour.

Benefits

- **75% less carbon footprint compared to a conventional wind turbine with the same yield**
- **Makes wind energy profitable in 80% of sites globally**
- **Reduces need for power-lines and storage**

> Emerging Technology ■ Infrastructure ■ Offshore ■ Wind

Low-cost substructure technology for offshore wind turbines

Bottom-fixed offshore turbine prototype that can be installed safely, simply and without cranes

This technology involves a self-floating gravity-based foundation system which integrates an autolift telescopic tower that can be fully assembled at the dock. The telescopic configuration of the tower brings down the center of gravity during the towed self-floating transport, allowing the bottom foundation platform to temporarily act as a self-stabilising floating barge over which the complete system can be pre-assembled onshore.

Benefits

- **30% carbon footprint reduction**
- **Low impact on seabed, moderate impact on marine ecosystem**
- **30% cost reduction relative to conventional method**

> Emerging Technology ■ Wind ■ Renewable ■ Electricity

Wind Energy 2.0

Containerised mobile wind energy system to reach strong high altitude wind

Wind Energy 2.0 uses a drone to get the wind power plant up in the air. The drone is tethered to a winch. While the drone is being carried by the wind the rope drives a generator via the winch. This creates clean wind power – without the need for the construction of a large wind turbine. Wind Energy 2.0 is built on minimal material usage, is compact and the mobile units can be fast and easily deployed.

Benefits

- **Replaces tons of steel and concrete of a wind turbine by a tether and an intelligent control algorithm**
- **Payback period of 4 years**

> Emerging Technology ■ Batteries ■ Energy storage

Inertia Drive

Mechanical batteries for energy storage solution to tackle renewable energy integration

Solar and wind power only produce when the wind is blowing or the sun is shining which causes grid instability due to loss of system inertia, which ultimately impacts energy supply to consumers. Inertia Drive is a flywheel: a mechanical battery that stores kinetic energy in the form of a rotating mass. This solution can help the stability of inertia, allowing further renewable energy integration.

Benefits

- **70% less CO_2 emissions compared to chemical batteries**
- **Lowest cost over 25 years (2–3x cheaper)**
- **ROI d in 6–10 years**

> Merging Technology

QED Naval Limited and Tocardo Turbines

Tidal energy platform that enhances site yield and reduces on-site costs

Tidal **Energy Production**

This solution is a submersible, gravity-based foundation used to support an array of tidal turbines. It integrates the whole tidal energy plant at the quayside, where everything is commissioned and tested in a safe, accessible environment. The solution is then used as a transportation barge to deploy tidal equipment straight to site using commonly available, low cost, harbour tugs. In a single offshore operation, the subhub along with turbines is installed in a quick and easy ballasting process, using its unique submerged stability characteristics to install itself on the seabed.

Where is this Solution being used?

The solution was recently deployed off the coast of Wales, moving 200 nautical miles to showcase its ease of operation, deployment, cost savings and minimal seabed impact. This was as part of the EU Interreg TIGER project. The subhub is currently being fitted with Tocardo T1 turbines before being showcased and data independently verified on the Isle of Wight through for TIGER project.

Environmental and Economic Benefits

- **Capable of generating up to 1,359 MWh per year**
- **Operations cost savings of 60%**
- **Expected LCOE reduction of £ 67/MW**

What this means for Scotland

- **Tidal could deliver up to 11% of the UK's energy requirements and a GVA of £ 1.4 billion by 2030**
- **QED has a pipeline of some 300 MW in the UK alone, worth £ 900 m GVA**

Encouraging uptake

- **Announce needed to give clarity and direction to the industry**
- **Expensive decommissioning bonds on R&D projects. Some governments (e.g. Netherlands) have removed these, which has helped**

> Merging Technology
PowerCone
Improving the efficiency of wind turbines

Wind Energy Production

This solution improves the power curve of wind turbines and makes wind power profitable in lower average wind conditions, opening up more locations to the possibility of wind power. By bolting to the hub of the turbine, this solution efficiently and passively harnesses wind in the centre of the rotor, redistributing it to the outer portions of the blades, eliminating the phenomenon of rotor root suction. The technology enables the wind turbine to produce around 10% more power, while reducing loads and noise. This innovative solution can help to maximise Scotland's wind power potential in a wider range of areas.

Where is this Solution being used?

Capstone Infrastructure, an Independent Power Producer in Ontario, Canada, trialed a first-generation PowerCone on a full-scale Vestas V100–2 MW turbine in Q1-Q2, 2021. Biome arranged for transportation and installation, working with preferred vendors. The use of PowerCone enabled a 10% increase in annual energy production with no negative impact on turbine loads, equating to 613 MWh of additional energy produced for this turbine. Once noise-emission testing is complete and demonstrated, further units can be installed without additional testing.

Environmental and Economic Benefits

- **Around 10% increase in annual energy production**
- **Lifespan of 25–30 years**
- **1000 direct and indirect jobs per 200 PowerCones produced and sold**

What this means for Scotland

- **The IEA estimates that wind will continue to increase at a rate of 17% year-on-year for the next 20 years**

Encouraging uptake

- **Reduce barriers to increasing production at wind farms through efficiency measures**
- **Simplify regulatory process for noise emissions**

> Emerging Technology ■ Solar Panel ■ Renewable ■ Buildings

Vertical Solar

Wall made out of solar-block PV panels enabling to the production of solar energy with PV panels settled on steep surfaces

The solution makes buildings themselves into potential energy producers. This technology combine solar PV technology with standard building materials, without drastically changing the construction methods. It turns buildings into potential energy producers, utilising wasted wall space in cities. The technology is hurricane-resistant and self-powered, changing the energy and safety outlook for vulnerable areas.

Benefits

- Improves the energy efficiency of buildings
- Reduces CO_2 emissions
- ROI in 6 years

> Emerging Technology ■ Solar Panel ■ Renewable

PanePowerSW

Highly transparent (80%) solar panel that generates electricity from solar radiation optimised for use in greenhouses

This technology is a solar glass technology that utilizes a combination of spectrum shifting nanomaterials with mono-crystalline silicon solar cells. This PV panel is made of 80% transparent solar glass and generates clean energy, reduces energy costs all while allowing the light to pass through it without affecting photosynthesis, fitting greenhouse applications.

Benefits

- 10% better solar cell performance
- 3% better photosythetic active radiation
- Average of 4–5 years payback time

> Emerging Technology ■ Solar ■ Agrivoltaics

THEIA: Translucency & High-Efficiency in Agrivoltaics

Translucency Solar Photovoltaic modules to be installed on agricultural crops

This technology combines agriculture and photovoltaics (Agrivoltaics) with no compromise between power generation and agricultural production. The modules are transparent and move horizontally of a few mm per day to align the cells with light beams. This system allows enough light for crops but also provides more energy than conventional PV modules. It can thus help decarbonising agriculture, increase farmers' income and reduce water consumption.

Benefits

- Up to 2x lower environmental impact than conventional PV
- 35% water savings on agriculture in semi-arid environments
- ROI in about 8 years

> Emerging Technology ■ Batteries ■ Energy Storage ■ Offshore

FLASC – Hydro-Pneumatic Energy Storage

Safe, reliable and scalable energy storage, designed specifically for offshore applications

A hydro-pneumatic energy storage solution which specifically targets offshore applications, a crucial energy sector where storage solutions are needed. The solution uses compressed air and pressurised seawater in a patented, pre-charged accumulator concept, resulting in an energy storage device that is inherently safe, reliable and also cost-effective with a 20+ year lifetime.

Benefits

- Use of steel, which can be easily recovered and recycled
- Lifetime matching offshore infrastructure needs
- Cost-saving of 20–50%

> Emerging Technology ■ Energy storage ■ Nanotechnologies ■ Batteries

LAYER® Light As Your Energetic Response

Printed technology which generates energy from ambient light to secure a power source for IoT and RFID

This solution relies on organic photovoltaic offering properties such as light weight, flexibility, design opportunity or low environmental impact. The high efficiency in low-light conditions make these Organic PV modules a good fit for indoor applications. It is a technology which generates energy from ambient light, created using digital printing. This specific printing method makes it possible to produce shapes or specific designs and print LAYER® on flexible supports which follow the curves.

Benefits

- Does not require rare earth elements
- Devices recyclable
- Total cost of ownership is 7.4 times lower compared to traditional CR2032 batteries

> Emerging Technology ■ Batteries ■ Energy Storage ■ Off-grid

Teraloop hubless flywheel

Energy storage for ultra-fast EV charging and micro-grid retrofitting

This flywheel technology (a mechanical structure used to store rotational energy) complements existing flexibility solutions to manage power and energy. Flywheels have demonstrated advantages such as high energy efficiency, high durability and high power density, making them ideal for applications requiring heavy cycling. It provides efficient energy storage for EV charging whilst avoiding high infrastructure installation costs.

Benefits

- Cradle-to-grave energy consumption 96% lower than a lithium battery
- ROI in 1–8 years through avoidance of infrastructure upgrades and grid charge costs
- 25% lifetime increase for lithium batteries

Case Study

Growing Scotland's Wind Industry

Scotland is blessed with huge potential for renewable energy, none more so than wind energy. Over the past two decades, Scotland has transformed its electricity supply by tapping into wind energy, both onshore and increasingly offshore. Wind now accounts for over 70% of installed renewables capacity and employs over 13,000 people in Scotland.

Haliade-X wind turbine

Utilising the latest technology to maximise generation will be important in the transition to a clean electricity system. The Haliade-X wind turbine is one of the world's most powerful wind turbines, with a capacity of 12 MW per turbine. This solution enables a lower electricity price compared to competitors by lowering the requirements for cabling, foundations materials and installation while increasing electricity yield, thanks to a larger rotor relative to the size of the generators. By using new technologies, the Haliade-X is able to capture the advantage of scaling up wind turbines and can outperform the capacity of competitors by up to 50%.

Used in the 3.6 GW Dogger Bank wind farm project. If smaller 9.5 MW turbines had been used instead, would have required 25% more turbines for the same capacity.

Offshore substructure system

Esteyco's bottom-fixed offshore substructure system offers a novel self-floating, gravity-based foundation which integrates a telescopic tower that can be fully assembled at the dock, and expands offshore wind and presents a huge opportunity for Scotland. The telescopic configuration of the tower brings down the centre of gravity during the towed self-floating transport, allowing the bottom foundation platform to temporarily act as a self-stable floating barge, over which the complete system can be pre-assembled onshore. This reduces the complexity and risk associated with installing the towers in unpredictable offshore environments.

Bottom-fixed offshore turbine prototype that can be installed safely, simply and without cranes.

Damping Pool Floating Foundation

Additionally, Ideol's Damping Pool floating foundation helps to remove the depth constraints often restricting bottom-fixed offshore wind installations. The solution is a patented technology that optimises the stability and performance of floating wind turbines, even in extreme conditions.
The solution generates an increase of power production per turbine, helping to cut the cost of energy generation.

Used in a 2MW floating wind turbine demonstrator off the coast of France, supplying 5,000 inhabitants with electricity.

Wind Tulips

Opening up urban areas to small-scale wind energy generation could also aid the transition to a clean electricity system in Scotland. Wind Tulips are small turbines using a unique and innovative design to unlock wind energy generation that can be used near people and buildings. The turbines can be placed on roofs and open spaces, and can generate energy in wind speeds as low as 1.2 metres per second. The turbines can also be clustered together in groups to optimise energy production. Wind Tulips make little noise and have little visual impact, making them ideal for clean energy production in urban areas.

Small wind turbines suitable for urban settings, combining efficiency, low noise and synergistic clustering.

PowerCone

Complementary solutions can also help to boost wind power generation. PowerCone is a structure fitted to the hub of a turbine which harnesses wind in the centre of the rotor, redistributing it to the outer portions of the blades, eliminating the phenomenon of Rotor Root Suction. The solution improves the power curve of the turbine and makes wind more profitable in lower average wind conditions, opening up a wider range of locations for wind energy generation.

Implemented on a full-scale Vestas V100–2MW turbine in Ontario, Canad, delivering a 10% increase in annual energy production.

Eocycle/EO25 Distributed Wind Turbine

The Eocycle/EO25 distributed wind turbine offers a small-scale wind solution for use on various types of terrain. The turbine is ideal for power generation in locations such as farmland, making it a useful tool for decarbonising rural parts of Scotland and providing an additional source of revenue for farmers. The turbine produces little noise and has a simple design with few moving parts, resulting in a reliable solution with at least 33% less downtime and as much as 50% more power generation than its competitors. A single turbine can generate around 100,000 kWh/year, offering an impactful and efficient solution for wind generation.

The use of this solution on a farm in the USA requiring 100,000 kWh per year could reduce electricity bills by 30% over 30 years.

02

Buildings

Improving quality of Life through more Efficient Buildings

Buildings are central to Scotland's ambitions to reach its climate targets. Firstly, it is fundamental to helping reduce energy poverty and ensuring the ecological transition is just and equitable, unlocking opportunities and increasing quality of life for people across society. Furthermore, if the next generation of infrastructure does not have sustainability in-built, this will 'lock-in' emissions that will render climate targets unattainable. In the residential sector, around 20,000 new homes were built in 2018–2019, a number that is increasing. New construction methods and materials can help these buildings to require less energy to heat, and also make the most of the energy that is produced.

Of course, one of the major job creators and opportunities to reduce energy demand is renovation and retrofitting. Heat in buildings (domestic and non-domestic) accounts for 20% of Scotland's greenhouse gas emissions. Currently, only 11% of households have a low carbon heating system, and while just over 50% of non-domestic buildings use zero-emissions heat, this figure hides the fact that many of the buildings which do not use zero-emissions heat are larger.

In order to meet their interim targets, the Scottish Government estimates that around 50% of homes, or over 1 million households, will need to convert to a low carbon heating system by 2030, and around 50,000 non-domestic buildings are converted to use these systems.

Over the course of the next Parliament, the Scottish Government has indicated that it will invest almost £1.6 billion of capital funding in heat and energy efficiency, though they estimate that the total investment required to transform homes and buildings will be in excess of £33 billion, a cost that cannot be borne by the public sector alone.

The Government is establishing a new Green Heat Finance Task Force to identify innovative solutions to maximise private sector investment, which must serve to finance these substantial investments and determine ways for investors to benefit from the energy savings themselves.

> Construction

Holcim Susteno 3R

Demolition rubble processed to be re-used as a component in cement, reducing landfill space and CO_2 emissions

Cement

Susteno is made of high quality processed mixed rubble from demolition projects, saving some 30% of CO_2 compared to a Type I cement. This is due to a reduction in the clinker content, which is responsible for roughly two-thirds of CO_2 emitted in cement production. Adhering to strict quality controls, it can be used like any common cement and exhibits moderate hydration heat development as well as low shrinkage and thus a reduced risk of stress cracking. It serves as a sustainable alternative to landfilling the unusable fine fractions.

Where is this Solution being used?

This solution has been used by more than 20 cement-clients for both structural and civil engineering, including shopping centres and apartment buildings. Susteno allows users to use the fine proportion of mixed granules from rubble that cannot be recycled in concrete production and use this as the grinding material, which would normally end up in landfill. In Switzerland, these projects allow for a reduction of 10% in CO_2 emissions compared to an already CO_2 optimised Swiss cement.

Environmental and Economic Benefits

- **30% CO_2 reduction compared to a Type I cement**
- **Reduce waste sent to landfill**
- **Up to 7% higher property value**

What this means for Scotland

- **The Green Cement Market is estimated to grow from USD 21.42 billion in 2019 to USD 43.59 billion by 2027, at a CAGR of 8.7%**

Encouraging uptake

- **Currently, Switzerland has the most advanced regulation in place, with a product standard that allows reusing construction and demolition waste in the cement directly**
- **Product standards development in other markets should allow higher reusing ratio of concrete in order to improve circularity of construction**

> Construction ■ Cement/Concrete

Holcim Maestro

A low carbon cement specially designed for high-quality masonry jobs

Holcim Maestro is suitable for many market applications including plastering and block or bricklaying. It offers users advantages in terms of performance, productivity and ease of use on the job site, thereby reducing the overall cost of masonry work. In addition, it helps to reduce the CO_2 carbon footprint of buildings as it provides a lower-carbon alternative to conventional cement. It also offers the option to compensate (offset) residual CO_2 emissions, becoming a carbon neutral cement.

Benefits

- **65% higher waterproofing compared to traditional cement and sand mixes**
- **General savings of up to 40% in USD per m²**
- **ROI in 3.3 years**

> Construction ■ Concrete ■ Waste-to-materials

RE-CREATE

High-performance pre-cast construction products

This innovation combines an eco-innovative manufacturing process with 100% natural material mixtures to create regenerative high-strength and high-thermal resistance green-building products (including decorative tiles, outdoor cladding and masonry bricks etc.). The production process uses only 5% of the embedded energy used in conventional building material production processes and creates less than 3% of the emissions of conventional methods.

Benefits

- **600% thermal insulation compared to cement**
- **90% energy savings compared to ceramics**
- **97% GHG savings compared to concrete**

> Construction ■ Waste-to-materials

ENVIROCRETE Bioclimatic Houses & Building Components

A construction system converting scrap waste and recycled wood into a material for the construction of Bioclimatic Houses

ENVIROCRETE speeds up construction and delivery of affordable green quality houses to address the global housing backlog. The system is made up of: 1) A green, light-weight aggregate combining properties of cement and wood. 2) A green concrete that when batched with ordinary Portland Cement and water can be used to produce a variety of concrete products. 3) A process that combines the best practice of Bio-Climatic Architecture & Engineering with off-site pre-fabrication industrial production technology operators.

Benefits

- **EV House brings 30–40% saving on electricity bill**
- **Costs 25% less than conventional housing**
- **60% lighter and 3x larger than conventional concrete**

> Construction ■ Cement/Concrete

PLANET

Improved airtightness for metal-frame buildings, reduced air leakage and improved energy efficiency

This solution allows the lowest carbon footprint in cement bags used for structural building applications, as well as an optional voluntary carbon compensation – zero waste on construction sites. Planet® relies on the most optimised cement in terms of carbon emissions due to its composition (less clinker, more slag, alternative fuels for its production), and on a disintegrating paper bag and an adapted weight making work easier on job sites. It can be immediately used by masons in a traditional way.

Benefits

- **Produces only 1/3 of CO_2 compared to reference cement**
- **No cost for waste management on construction sites**

> Construction ■ Sensors & Monitoring ■ Heat

The TERRAPOD

Robust fully recyclable concrete-free alternative foundation and floor system

After water, concrete is the most used material in the world. Concrete alone produces 8–11% of the world's carbon dioxide emissions. Terratonics system is comprised of TERRAPODs which are concrete-free modules used for the foundation and floor system of buildings. These structural pedestal beam carriers transfer the building's associated loads to the geo-engineered ground below. The system can be used for a variety of residential and commercial housing projects.

Benefits

- **Reduces carbon emissions by 90%**
- **Reduces water consumption in foundations by 100%**
- **Reduces costs by up to 27% per average semi detached house**

> Construction ■ Energy ■ Thermal insulation

Sopratec III

Improved airtightness for metal-frame buildings, reducing air leakage and improving energy efficiency

Energy losses in buildings are caused by both insulation and air leakage. In Western Europe, the thickness of walls has tripled to increase insulation, but airtightness has remained neglected. As such, the leaks due to poor airtightness are twice as high as the energy losses from insulation. A standard steel frame building shows an air permeability 6 $m^3/m^2/h$ whereas Sopratec III system allows for only 0.18 $m^3/m^2/h$. In practice, a traditional steel-frame building with 1,000 m^2 facade & roof surface will leak 6,000 m^3/h air. With an external temperature of +5°C and interior temperature of +20°C , the energy needed to warm up the leaked air will be 32,4 kW, compared to 1 kW for Sopratec III.

Benefits

- **100 KwH/m^2 heating/air conditioning saving annually**
- **ROI in 5 years**

> Construction ■ Insulation

Wall E+

Material that can be used as the only structural and insulating material from the foundation to the roof

Optimised for off-site construction, WallE+ is quick to erect and responds to the highest environmental standards. Easily assembled and disassembled without alterations, it extends the lifetime of a building with its great options for modularity and can infinitely be reused in other constructions. This new material optimises the lifespan of buildings with a 100% tridimemsional stability in all conditions (heat, humidity, etc.).

Benefits

- **Reduce around 30% the carbon cost of the building construction**
- **Savings of up to 9% on delivery**

> Energy Efficiency ■ Insulation ■ Bio-based

Zs2 TechPanels

Multi-functional structurally insulated panel system used to construct highly resilient, environmentally friendly building envelopes

Zs2 Techpanels are pre-fabricated in an advanced manufacturing facility, flat packed and then shipped to sites where they are easily assembled together. The result is a structure that has a minimum one-hour fire rating, is highly resistant to mould/mildew/bacteria/humidity, and is extremely energy efficient regardless of climate. This solution is profitable, greatly reduces the time building time and the amount of construction waste, increases the energy efficiency compared to other construction practices and is resilient for decades.

Benefits

- **Reduce heating/cooling costs by approximately 66%**
- **60% reduction in construction waste**

> Energy Efficiency ■ Insulation ■ Construction

Bhaluu

Continuous self-supporting cellular insulation envelope that allows building the most energy performant houses at the best price

This patented technology reduces the energy consumption of a home by 17 times compared to the current average. Bhaluu's technology consists of a continuous layer of self-supporting material avoiding thermal bridges which essentially blocks any exchange of temperature between the house and its environment. Combined with a construction process integrating logical steps, lean principles and automation, the technology is able to provide accessible and efficient housing to all.

Benefits

- **Lowers housing energy consumption by 17 times**
- **15 to 20% cheaper than the traditional construction**

> Energy Efficiency

SICLA

Highly efficient building insulation based on recycled silica from construction & demolition waste

Insulation **Circularity**

SICLA solution targets two of the main issues in the building sector, which are energy efficiency and the recycling of construction material. With a thermal conductivity as low as ~0,014 W/mK, lower U values can be achieved, and compared with available alternatives, only 33% of the insulation thickness is required for the same thermal performance. The company behind SICLA is currently establishing agreements with major mineral waste management companies in EU27 in order to ensure local supply of raw material.

Where is this Solution being used?

Through the H2020 project VEEP, the aim was to create prefabricated concrete panels hosting insulation material in the interior. The developed product had SICLA aerogel (7 cm thickness). 400 m^2 of panels were manufactured to build two mock-up buildings in two different climates, Madrid and Delft. They are able to reduce the cost of production by half through the extraction of silica from waste concrete rather than obtaining new silica, thus contributing to the creation of a circular economy.

Environmental and Economic Benefits

- **40% reduction in energy consumption in building applications**
- **34% reduction in weight compared to conventional material**
- **15% reduction of kg. CO_2 eq. contribution compared with organic insulation materials**
- **Up to 15% installation cost reduction in retrofitting application**
- **More than 60% reduction on final aerogel price**

What this means for Scotland

- **Global construction rates expected to grow 35% by 2030**
- **A large portion of the 850 million tons of construction and demolition waste in Europe still goes to landfills**

Encouraging uptake

- **Strict energy efficiency regulations for new and existing buildings are being implemented in EU27, leading to improvements in the thermal insulation and renovation market**

> Energy Efficiency ■ Waste-to-Materials ■ Materials

Cynthia

Material made of bio-based fibre that can be used for insulation

Water Hyacinth is a major environmental concern in more than 100 countries. When not controlled, the weed dramatically impacts water flow, blocks sunlight from reaching native aquatic plants, and starves the water of oxygen. CYNTHIA© fibres are made mainly of cellulose which give them a very high resistance to heat and a perfect candidate for roof insulation. For other applications such as walls and floors, CYNTHIA© boards have a better thermal conductivity than hemp and linen and are as robust as wood.

Benefits

- 95% biodegradable material
- Same cost as existing wood panels

> Energy Efficiency ■ Insulation ■ Materials

Sumfoam

Polymer based high-performance material for greater insulation

Sumfoam enables a new class of polymer materials by reducing the pore size within the foam by a factor 1000 compared to common foams. The production of these foams is made possible by using high-pressure extraction technology with climate neutral foaming agent in an industrial scale at short cycle times. This is a technology that allows an economical large-scale production of polymer based high-performance materials, which additionally influence numerous fields of applications in a positive and sustainable way.

Benefits

- Reduction of 20–25% CO_2 emissions
- Reduction of costs by up to 50%

> Construction ■ Waste-to-materials ■ Bio-based ■ Insulation

Gramitherm®

Bio-based insulation batt with a negative carbon footprint made from grass

Gramitherm® tackles the challenge of efficiency in buildings by providing an equally performant insulating material with an unrivalled environmental impact. The primary component of its insulation panel is grass. With an estimated lifetime of at least 50 years, Gramitherm® is easily and fully recyclable afterward. To source its panels' raw material, the solution's owner plans on primarily integrating local ecosystems, transforming grass from waste to useful product in order to build efficient buildings and homes.

Benefits

- 50% of total cost of ownership compared to mainstream alternative
- Thermal efficiency of 0,04 W/m²

> Energy Efficiency
Pavatex
Cellulose fibre-based insulation material

Waste-to-Materials Insulation

Targeting European single or multiple-storey residential, Pavaroof, Univercell, Pavaflex Confort, Pavawall and Isolair are five solutions based on the Pavatex bio-material to insulate buildings. The bio-sourced insulation is produced from raw materials originating from non-transformed vegetable biomass (wood fibre) or which have been transformed then recycled (cellulose wadding).

Where is this Solution being used?

The renovation of 42 home buildings in the Vosges (eastern France) was realised through the use of exterior thermal insulation (3800 m² of the Pavawall solution) to obtain a passive building and divide by 10 the energy costs of the tenants with the use of bio-sourced local resources. Concretely, the annual heating bill for the homes was reduced from € 1800 to € 170. The exterior insulation installed using the Pavawall system allowed exemplary thermal dephasing (from 2h30 to 17h00). When using the wood-fibre insulation, one can avoid the emission of 50 tons of CO_2 in the atmosphere for the building.

Environmental and Economic Benefits

- **3.5 times more effective than expanded polystyrene**
- **A collective building reduces its heating bill to 170 from 1800 €/year**

What this means for Scotland

- **+10 to 15% CAGR for biobased insulation products**

Encouraging uptake

- **Building codes should follow the French example that will arrive in 2022 (RE 2020). There is a switch from Thermal Regulations codes to Environnemental Codes with Complete Building CO_2 impact, summer comfort regulations & biobased products use**

> Energy Efficiency ■ Windows & Glass ■ Bioplastics ■ Insulation

KLIMA-PUR

Window frame made of a highly insulating bio-Polyurethane foam

Thanks to the use of bio-Polyurethane foam as single material, these window frames are highly functional while being highly thermal & acoustic insulating. KLIMA-PUR windows allow to reduce by up to 50% the energy consumption and associated occupant's bill for space heating and cooling of buildings and houses. Its circularity, repairability and low maintenance, as well as its easiness to recycle is the result of a simple but resource and energy-efficient design.

Benefits

- Saves up to 50% energy consumption for space-heating and cooling compared to conventional frames
- Costs 20% lower than wood framing

> Energy Efficiency ■ Windows & Glass ■ Polymers ■ Insulation

Windowskin

Polyester-based panel for window insulation

Windowskin is a retrofit solution that provides as much insulation as an added pane of glass at an affordable price. The polyester-based panels are attached to the inside window glazing of existing windows, optimising the volume of air trapped in between the existing window and the window insulation retrofit. This creates an insular barrier and improves the efficiency of the window. Each panel is designed in a way that minimises the possibility of air leakage to optimise the thermal barrier.

Benefits

- Reduces energy loss by 45% on single-pane windows and 22% on double-pane windows
- Provides up to a 10 times faster ROI than replacement window

> Energy Efficiency ■ Green roofs & vegetalisation ■ Water ■ Flooding

Skywater

Vegetalised roof to reduce heat islands, reuse rainwater, improve building insulation and recycle greywater

This vegetalised roof concept include several stormwater management solutions. It incorporates: the use of high potential evapotranspiration (PET) plants air cooling and stormwater retention; an IOT technology for monitoring, measurement and management of the greenroof irrigation and water storage; a rainwater discharge flow regulator; a stormwater performance calculator for roofs; and a proactive rainwater collection and buffer storage capacity on flat roofs.

Benefits

- Reduces the temperature by 4ºC during heat peaks

> Energy Efficiency ■ Refrigeration ■ Heat-recovery ■ Recycling

Ubiblue

Production unit for cold air or recovery of waste heat through magnetic refrigeration

Ubiblue is a magnetic refrigeration technology with a cooling power ranging from 20 kW to 100 kW answering the needs of various industries across the world. This technology can also be used to convert wasted heat into energy. Chillers are most commonly based on a refrigerant gas compressor which raises two major limitations: chillers have low efficiency and they have a very harmful impact on the environment. Chillers based on the magnetocaloric effect on the other hand can reach higher cooling power while having no impact on the environment.

Benefits

- **50% reduction in energy consumption**
- **ROI in 3 years**

> Energy Efficiency ■ Data centers ■ Cooling ■ Heat

Thermal Rail

Data centre cooling system that significantly reduces energy consumption and costs

By capturing all of the data centres waste heat and transferring it to a liquid coolant that never comes near electronic components, Thermal Rail™, can make every data centre carbon negative and help remove over 0.5 GT/year of CO_2 eq by 2050 whilst creating a new line of revenue for data centres. This modular system can be applied to existing servers in data centres, large or small, public or private.

Benefits

- **Reduces energy consumption by 30%**
- **Reduces costs by 20%**

> Energy Efficiency ■ Datsa centers ■ Heat-recovery

Computing Heater (QH-1)

Heating from waste computer heat

QH-1 heats buildings by reusing waste-heat from microprocessors performing high performance computations remotely. Given that data centres consume 3% of the world's electricity, QH-1 takes advantage of this lost heat and uses it as a heat source to warm rooms. Through a disruptive and distributed infrastructure, it provides cloud computing where computing power is no longer deployed in concentrated data centres, but split throughout the city.

Benefits

- **Carbon footprint of computations reduced by an estimated 70%–75%**
- **Building owners get a 5–7 years ROI**

> Energy Efficiency ■ Air-conditioning ■ Automation

VLT® HVAC Drive

Air conditioning drive for HVAC application, optimised for building automation systems and enabling to run motors at variable speeds

Large parts of mechanical ventilation systems in the existing building stock are running at fixed speed, and featuring low efficient belt-driven fans and low efficient motors. This solution can be sensibly installed on traditional motors, allowing them to be retained as efforts are made to reduce energy consumption and CO_2 emissions. By deploying AC drives and other system-wide efficiency measures, we can reduce motor energy consumption by up to 40%.

Benefits

- **Can lead to energy cost savings of about EUR 13.5bn for EU non-residential buildings**
- **Can reduce global electricity consumption by 10%**

> Energy Efficiency ■ Refrigeration ■ Heat-recovery

Recovering heat from CO_2 refrigeration systems

Ready-to-install unit designed to recover heat from refrigeration installations where CO_2 is used

In Europe, around 2% of the total energy consumption for electricity is used for refrigeration in supermarkets, and within five years, 50% of European supermarkets will use CO_2 as a refrigerant. If supermarkets in Europe were to use the waste heat from the CO_2 refrigeration units to heat the spaces and water in their own building, it could lead to energy savings of EUR 1.8 billion annually. This solution provides a link between a cooling unit and the heating installation, allowing supermarkets to recover the heat from the refrigeration system.

Benefits

- **Can lead to savings of final energy equivalent to 2,6 Mtep in European supermarkets**
- **Can generate € 1.8 M in energy savings**

> Energy Efficiency ■ Heating ■ Cooling ■ Facade shading

SAF – Solar Activated Facade

Exterior wall paneling system that can trap solar energy

The Solar Activated Façade (SAF) uses a passive solar approach, like the principles of passive solar heat gain through windows, by absorbing and storing daytime solar energy which at night is slowly discharged over a period of several hours thereby greatly reducing the building's heating energy demand. SAF does not replace insulation completely, but significantly reduces the amount required to achieve high-performance thereby giving more freedom of choice toward more eco-friendly and healthier insulation materials.

Benefits

- **Can reduce emissions of a building up to 85%**
- **An immediate return on investment may result from gains in valuable square footage**

> Energy Efficiency
Joulia

Reclaiming heat energy from used shower water by pre-warming the fresh water before it arrives at the mixer

■ Water-recovery ■ Heat-recovery ■ Construction

By means of an ingenious heat exchanger module, the heat energy of the used shower water is reused to warm the incoming cold water mains. In this way the cold water arrives at the mixing valve up to 15°C warmer than before (from 10°C up to 25°C), substantially reducing the volume of the water needing to be heated. A 4-person household can save about 1000 kWh per year. In Scotland, heat accounts for 50.7% of the energy demand, two-fifths of which is for domestic use. In the UK, average hot water consumption is 4 kWh per day.

Where is this Solution being used?

Swiss real estate developer Walter Schmid sought to build the world's first true energy autonomous apartment building in 2014. To achieve total, year-round energy independence, they needed the best possible energy efficiency on all devices, including showers, given that hot water is responsible fo 50% of energy needs in a modern building. Using Joulia-Inline, they were able to demonstrate savings of some 9000 kWh a year in the building. The solution is now installed in thousands of showers.

Environmental and Economic Benefits

- **42% of energy recovered**
- **No CO_2 emissions nor electricity used**
- **Product can be 100% recycled**

What this means for Scotland

- **11% of Scottish domestic energy use is dedicated to water heating, similar to lighting and almost four times as much as for appliances**

Encouraging uptake

- **Including drain water heat recycling within energy calculations required to get building permission would create a need**
- **Furthermore, if there were lower allowable limits on hot water generation it would make recycling the heat very attractive**

> Energy Efficiency ■ Heat-recovery ■ Hot water ■ Recycling

Flatmate

Shower heat exchanger for existing showers and bathrooms

The Sanura Flatmate recovers wasted heat from the shower's hot water and reuses it to pre-heat the incoming cold water. It can be installed on top of the existing shower floor and be connected to a standard shower faucet without any plumbing works. The device is composed of a flat tray heat exchanger, a connection tube, and a device that is mounted in between the shower faucet and the shower wall. Flatmate was integrally designed for disassembly which means that all components can be taken apart, repaired or recycled.

Benefits

- **Energy savings of 40%**
- **Saves up to 150 €/year for a household of 4 people**
- **ROI in 4 years**

> Energy Efficiency ■ Heat-recovery

Lepido

Energy recycling from restaurant ventilation

Recycling the energy in exhaust air from traditional restaurant ventilation systems is challenging due to large amounts of grease and soot damaging the equipment. With such a high particle density the air has to be filtered before it reaches the recycling unit. Through coils arranged in an optimized manner, the solution enables the majority of particles to not accumulate and be discharged through the cooling system, thus reducing the energy consumed by the system.

Benefits

- **ROI in 2-4 years**
- **Average savings over lifetime (20 years) of 2,000,000 kWhs**

> Energy Efficiency ■ Domestic ■ Detergents & Soaps

P&G Cold Wash

Laundry detergent formulated to work best at low temperatures, saving energy and reducing CO_2 emissions

Washing at a low temperature is not a new concept per se. While consumers understand the energy saving concept behind it, the main barrier remains washing performance. Ariel's Cold Wash detergent is formulated to use technologies that work their full potential at low temperatures. It uses several enzymes with low activation energy and is designed with a hydrophobic surfactant system that enables an efficient stain removal at low temperatures.

Benefits

- **Reducing the carbon footprint by 35%**
- **1.2 billions (30°C) to 2.8 billion (20°C) tons of CO_2 reductions in Europe**

> Heating and Cooling Buildings
Celsius Energy

Urban Geothermal with a small physical footprint as well as greatly reduced space requirements, complexity and CAPEX costs

■ Urban geothermal ■ Heat production

A turnkey solution for heating and cooling buildings using shallow geothermal energy that, due to a star-shaped drilling method and a much smaller physical footprint, is a viable option for densely populated areas. Celsius Energy are able to reduce the amount of real estate required for an installation from a football pitch to the size of five parking places. Using a system of inclined boreholes, they are able to extract heat through multiple locations from a single entry point. It is equally suitable for new builds as it is for renovation. Celsius Energy can heat and cool buildings by eliminating 90% of CO_2 emissions per kWh of heating generated compared to natural gas.

Where is this Solution being used?

Celsius Energy completed the first installation of its solution in December 2020 in Clamart, France. This is a 3000 sq. metre building built in the 1960's and serving as an office for 200 employees. The solution has been effectively providing building occupants with low-carbon thermal heating and cooling since construction was completed. So far, the solution decreased the CO_2 emissions compared to the initial system (gas heater and conventional air conditioning system) by 92% and facilitated a 40% reduction of operational costs.

Environmental and Economic Benefits

- **Reduces CO_2 emissions by up to 90%**
- **Energy savings up to 60%**
- **OPEX reduced by 40–50%**

What this means for Scotland

- **Job creation: 1.17/ person per MW. In some circumstances, GEA estimates the persons per MW employed is 19 times that of wind or solar PV**
- **Market growth: The UK market is expected to grow at a CAGR of +1%. It is largely untapped, but has the potential to deliver up to 20% of the UK's energy needs**

Encouraging uptake

- **Effective application of thermal regulation for buildings that encourages non-fossil fuel heating and cooling systems**
- **Public feed-in tariffs have enabled rapid geothermal uptake in some markets (e.g. Turkey, Sweden, Switzerland)**

> Heating & Cooling Buildings ■ Heat pump

BoostHEAT – 20kW for domestic application

Low-carbon heat pump boiler for domestic use that drastically reduces energy consumption

These heat pump boilers use a thermal compressor which uses heat from natural gas combustion to efficiently compress a natural coolant (CO_2) instead of harmful HFC refrigerants. The design of the thermal compressor allows the operation of a high temperature thermal compression cycle, pumping heat with an output of 200% Seasonal Gas Utilisation Efficiency (SGUE). The four-stage thermal compressor, optimiyed for size and with a hermetically sealed design allowing it to function at high pressure.

Benefits

- **Reduces gas consumption by 50%**
- **Heating-cost savings of 50%/year for the end user**

> Heating & Cooling Buildings ■ Heating ■ Electric ■ Hot Water

Twido

Modular and scalable hot water tanks

This solution can reduce energy costs associated with heating water while reducing the space needed. Directly connected to solar panels that supply the electrical device, this technology heats water instantly through a film that surrounds a stainless steel tank with double resistance. Installed sensors allow the MyTwido app to monitor the consumption (electricity network, water) and adapt the ideal hot water volume as needed.

Benefits

- **Reduction of the energy needed to heat the water from 50 to 80%**
- **Reduction of water consumption between 20 to 50%**
- **ROI of approx. 6 years**

> Heating & Cooling Buildings ■ Hot water ■ Storage ■ Offgrid

Thermoflex

Off-grid water heating and storage system powered by renewable energies

The Thermoflex™ is an off-grid hot water storage system, based on renewable energy (sun and wind). This is an ideal solution for remote locations that need hot water on a regular basis such as residential complexes, safari lodges, medical clinics, and others. A 16 CBM double layer water bladder is installed inside the container. Once the water in the bladder reaches the desired temperature, the small daily changes in the water temperature are compensated by solar and wind-turbine sources integrated within the solution.

Benefits

- **Uses 30% less electricity than a regular boiler**
- **Up to 30% cost saving compared to mainstream alternative**

> Heating and Cooling Buildings
Heat Tank

Phase-change material to store the energy in a more concentrated way and enabling energy savings of between 20–50%

Energy Storage **Thermal**

HeatTank uses eco-friendly bio materials as phase-change materials. Due to the concentrated heat storage, the storage volume is reduced, allowing clients to save space. In addition, HeatTank can store energy at different temperatures and increase the efficiency of the energy systems by 20–50% with a 3–5 years payback time . With HeatTank it is possible to generate energy when it is most efficient, store it and use it when most relevant and needed.

Where is this Solution being used?

MVM is the biggest Hungarian electricity supplier. HeatTank was installed in one of their telecommunication base stations in Hungary in January 2019. Their challenge was one of high cooling and operating costs and low efficiency of the cooling system. The results from the installation indicate a saving of 51.3% on electricity consumption per year, translating in this case to 5.81 tons. In this case study, the ROI is 4 years.

Environmental and Economic Benefits

- **90% smaller than traditional water storage**
- **20–50% energy savings**
- **One HeatTank unit = 54 tons of CO_2 saved during its 20 year life cycle**

What this means for Scotland

- **The global phase-change material market to grow at a CAGR of 19% (2019–2028)**
- **IEA estimates that energy efficiency retrofits are the 2nd most effective job creator per dollar of capital invested**

Encouraging uptake

- **In Hungary a portion of corporate tax can be reclaimed after energy efficiency measures are taken. Further, the electricity price dynamically increases, thus energy saving is ever more important**

> Heating & Cooling Buildings ■ Panels ■ Heat prdoduction

Energy and CO_2 savings in industrial buildings with KIGO

Radiant panels for low temperature heating of buildings

Industrial buildings are mainly using fossil fuels for their operation and are often poorly insulated. The KIGO Climate panels reduce the energy consumption of buildings. As heat tends to rise in rooms, the material of the panels, which operates at a low inlet temperatures, returns the heat to the ground. The panels can heat industrial and poorly isolated halls with very high ceilings and increase employees' comfort. Depending on the type of building, the energy consumption for heating can be reduced between 50 to 75%.

Benefits

- **Reduction of energy consumption for heating between 50 to 75%**
- **Reduces CO_2 emissions from 50 to 100%**

> Heating & Cooling Buildings ■ Heating ■ Biofuels ■ Electricity

EnerTwin

Micropower plant for houses and commercial buildings, operating on clean fuels and producing electricity and heat

EnerTwin can be used to improve the energy efficiency of a building and reduce GHG emissions where heat pumps and solar PV are not suitable. Apart from giving the necessary heat to the users of a building, it also provides locally generated electricity at great efficiency (94%) by using clean fuels such as biomethane, green gas and hydrogen. It is a very small domestic power plant where a boiler and an electricity generator are combined in a single durable device. The heart of the EnerTwin is a microturbine that drives a generator.

Benefits

- **CO_2 emission reductions are on average between 4–10t per system per year**
- **Generates electricity at 50–60% of utility price**

> Heating & Cooling Buildings ■ Heating/Cooling ■ Walls & Façades

NexGen Waterproof Graphite and Graphene Far Infrared Heating Film

Low-carbon heating film for homes and buildings that significantly improve energy efficiency

The solution aims at providing a fossil-free, low carbon, energy-efficient, waterproof Far infrared heating film for the heating of internal and external homes and buildings. The ultra-thin, flexible heating film can be installed on walls, ceilings and floors and can be cut on the graphene mix to accommodate lights, switches and plug sockets.

Benefits

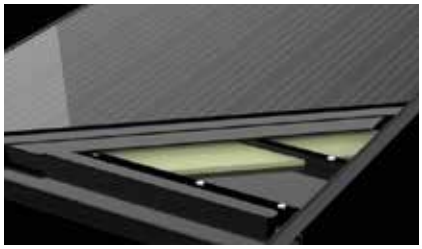
- **57% less energy needed to heat average UK home compared to fossil fuel gas heating**
- **Save up to 60% off energy bills**

> Heating & Cooling Buildings ■ Panels ■ Solar thermal ■ Hot Water

DualSun

2-in-1 solar panel that simultaneously generates electricity and hot water for homes and buildings

This hybrid solar panel aims to reduce the energy consumption of buildings by generating clean and affordable solar heat and electricity. On the front there is a conventional PV, whereas on the back there is a heat exchanger which will on the one hand cool the panel and on the other hand carry the heat to the required facility (shower, swimming pool, etc.). This process allows to increase the yield of a panel and makes more efficient solar installations.



Benefits

- **The installation generates 5000 kWh/year and about 1000 € in savings**
- **Profitable in 8–10 years**

> Heating & Cooling Buildings ■ Cooling ■ Infrastructure ■ Heat Exchanger

Sustainable cooling for a warming planet

District cooling system that significantly reduces carbon emissions whilst ensuring resilience

Providing cooling is expensive and demands power generation surges during the day for workplaces, and at nights/weekends for residential spaces. This industrial scale cooling solution is designed to answer this specific issue. District cooling is more energy-efficient than traditional cooling solutions, more cost-effective for customers, and it reduces peak power requirements. Moreover, district cooling works well with solar and other increasingly common renewable-energy technologies.

Benefits

- **Lifecycle cost reduction of 10% compared to conventional cooling**
- **Electricity savings equivalent to reduction in CO_2 emissions of 183,000 t/year**

> Heating & Cooling Buildings ■ Heat Pump ■ PV Panels

HYSS – Hybrid Solar System

Dual-system comprising of a hybrid solar panel and a heat pump providing buildings with heating, hot tap water, cooling and electricity

This solution is the result of crossing two industries; the solar energy industry & the heat pump industry. Solar thermal energy makes the heat pump 50–100% more efficient. With this energy reduction, the number of PV-panels needed to reach zero energy buildings is significantly reduced. With its software, HYSS is also available for the retrofitting of existing ground source heat pumps. Thanks to this innovative technology, energy traditionally used for heating can be diverted towards other purposes such as electric mobility while reducing CO_2 emissions.

Benefits

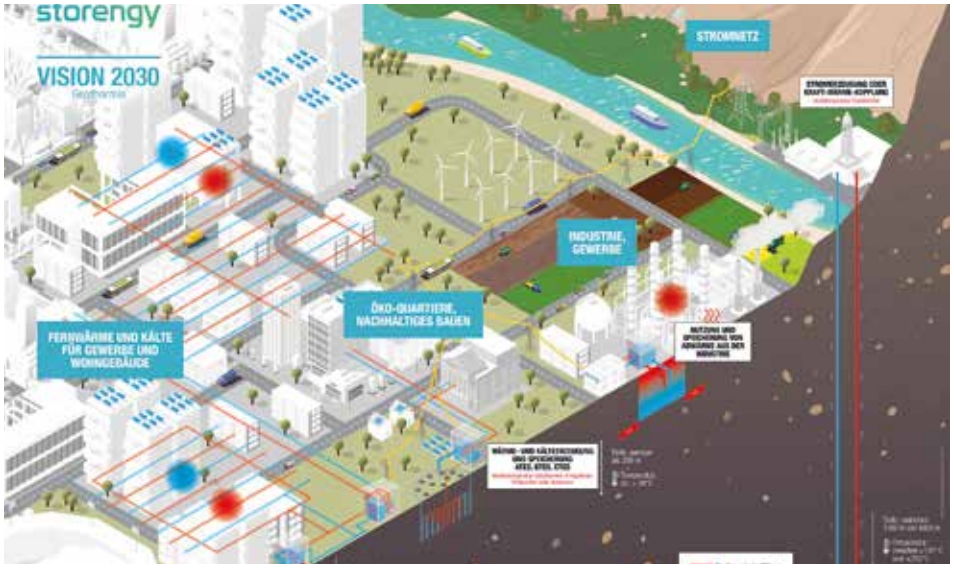
- **ROI in 5–10 years, with expected life span of 30–40 years**
- **For every kWh, HYSS returns 5–7 times as much heating and hot tap water**

> Heating & Cooling Buildings

Targeo

Carbon-free heat based on shallow geothermal

Geothermal



Targeo provides a digital interface enabling a building-specific view of a region's geothermal potential. It gathers data on the underground (potential, rocks, water protection, groundwater); the infrastructures (gas and district heating network) and the buildings (size/type of building, heat and hot water demand, drillable parcels). The data is then processed giving the dimensions of each building's geothermal system needed. Municipal utilities can enter their own business parameters, select buildings, simulate the scaling effect and the benefits to be made. The interface gives the CO_2 emission per building and the CO_2 saving per simulation. The technical solution is cold district heat or a campaign installation of ground-sourced heat pump systems.

Where is this Solution being used?

A representative customer for Targeo would be a region with 100,000 inhabitants while the buyer of the solution would be the local Stadtwerke/municipal utility. Assuming a district heat price of 75 €/MWh (plus installation fee) and 500 installations, the following impact can be derived: customer gets green heat, a new room in their house (the oil boiler and oil tanks disappear) and a problem free kWh model.

Environmental and Economic Benefits

- **Replacing every gas heating system in Germany with a geothermal system would save 60 M/t of CO_2/year**
- **With a consumer heat price of 92 €/MWh, a one time connection fee of 3,800 € and power prices around 165 €/MWh the client can end up with a net cash generated of 1.7 Mio € serving 500 clients over 15 years**

What this means for Scotland

- **10% market growth per year on a global basis**

Encouraging uptake

- **Ideally, PV self-consumption should not be taxed while CO_2 should be in order to create a level playing field**
- **Different rules for implementing geothermal in the different countries hinders scale and speed**

> Management & Software ■ Cooling ■ Infrastructure ■ Heat Exchanger

AVOB Smart Demand Response

Advanced energy management platform for smart buildings and smart grid

This solution is an advanced SaaS platform that enables real-time management of the consumption on multiple sites (homes, offices, hotels, public places...) to save or consume energy based on the needs of the electrical grid. During peak hours, end-users electricity consumption is reduced to soften the load on the electrical grid and enable a proper distribution to all customers, avoiding congestions and blackouts. During off-peak hours, the excess electricity present in the network is used and not wasted.

Benefits

- **Up to 15% reduction in energy consumption in Residential and Commercial buildings**
- **Avoid wasting electricity during off peak hours**
- **ROI 1 year**

> Management & Software ■ Software ■ Energy Management

EFICIA smart building

Solution for 24/7 remote-control of buildings to save energy whilst increasing comfort

Many buildings have technical equipment such as HVAC systems or lighting systems that consume a lot and are complicated to control. EFICIA smart building provides a fully integrated solution to monitor and manage energy usage in buildings. It provides a 24/7 remote building control service using wireless equipment, machine learning software and a 24/7 Energy Center. Highly modular, this solution can be integrated into existing buildings or new constructions thanks to wireless technology.

Benefits

- **Average saving of 15% across 2500 buildings**

> Management & Software ■ Senors & Monitoring ■ Façade shading ■ Energy Use

Animeo Connect

Complete system with sensors, motorisation and auto-learning software for blind management

This solution integrates sensors on roofs and facades of buildings to measure real-time conditions allowing for intelligent and efficient remote blind management. The system takes into account parameters such as shadow movements, sunlight levels, weather and building location allowing for a significant reduction of energy consumption. The software enable all blind motors to work separately or collectively depending on shadows, lights factors and many others. Any individual in the room can also control its blinds.

Benefits

- **Reduce building energy consumption by 30–70%**
- **ROI in 3 years**

> Management & Software ■ Artificial intelligence ■ Energy Efficiency

Vertuoz Pilot, powered by Ubiant

Heating and light control system for small-sized buildings

This energy-efficient system allows to save energy while keeping the individual comfort of occupants. By placing connected and wireless objects, an artificial intelligence controls light and heating room by room. Different data are included: temperature, occupancy, light and energy consumption. The system can then control radiators, air flow, lamps. A detached app also allows occupants to change the temperature ergonomically.

Benefits

- **Allows 10% to 15% energy savings**
- **ROI in 3–5 years, depending on installation size**

> Management & Software ■ Sensors & Monitoring ■ Lighting ■ Energy Use

Long range & high bay occupancy detector

Occupancy detector for lighting control and automation of high warehouses, parking lots, industrial and urban areas

The long range motion sensors on the occupancy detector have a sensitive area of up to 3000 sq meters. This allow for better lighting control and greater automatisation. The K2150 sensor operates on radiation of surrounding area of the electromagnetic field and recording its changes caused by the reflection of objects moving in the sensor sensitivity zone. The radiation power is only 100 mW which is half the radiation power of your home Wi-Fi router, so the sensor has no harmful effects on humans.

Benefits

- **Allows for up to 80% in energy savings**
- **ROI in 1 to 1.5 years**

> Management & Software ■ Sensors & Monitoring ■ Lighting ■ Retrofitting

LightFi

IoT sensors detecting live room occupancy, reacting automatically to ameliorate conditions

LightFi is an easy-to-install retrofit solution that requires no rewiring and can connect to existing Building Management Systems. Its sensors detect occupancy through WiFi radio to create responsive lighting and heating, Ventilation and Air Conditioning (HVAC), optimised to improve indoor air quality while reducing energy consumption. Furthermore, the sensors communicate via cellular networks, removing security risks involved in connecting through private/corporate Wifi network.

Benefits

- **Average reduction of 3 t CO_2 in 200 m^2**
- **ROI in 1 year through energy savings**

> Management & Software ■ Circularity ■ Modular ■ Construction

BHEP – Hybrid Positive-Economy Building

Concept-building combining self-generation of the resources it needs to operate and real-time configuration

The BHEP concept are specific features that must be put in place in the conception and exploitation of a building. These specifications include resources optimisation; self-sufficiency in water, energy and heat; reversibility/modularity of the building, re-use and recycling of the materials; and taking into consideration the full price of the carbon to valorise the green value of the building. The concept can be applied to all building projects around the world, especially in cities that need to anticipate urban population growth.

Benefits

- **Average savings of CO_2 emissions: 22 kg/m²/year**
- **Water savings: 28,000 m³/year**

> Management & Software ■ Cooling ■ Heating

BatiSense

Energy analysis tool optimising the use of energy to heat or cool buildings

Based on sensor data and artificial intelligence algorithms BatiSense can optimise the energy management of tertiary buildings. It automatically and remotely pilots the technical equipments on buildings to deliver optimal comfort while saving energy. It can be installed in both new or old buildings and adapted to instrumented buildings. The measures allow for a full understanding of the thermal behaviour of the building. Only two different sensors per zone are necessary and measures are stored with a time step of 5 minutes.

Benefits

- **15 to 30% of energy consumption in heating and cooling of old buildings**

> Management & Software ■ Cooling ■ Data centres ■ Machine learning

Dynamic Cooling Management System

A.I.-driven thermal management system that optimises the environment in data centres and other commercial buildings

Cooling, which accounts for 40% of overall data centre energy use is needed to keep critical IT applications running. This solution allows for thermal management by using machine learning to make decisions about which cooling units to dispatch to extinguish hot spots, and to allocate capacity across a set of cooling units to optimise efficiency. As such, data centres and commercial buildings benefit from reductions in CO_2 emissions and energy.

Benefits

- **30% reduction in energy use and CO_2 emissions**
- **30% increase in HVAC life**
- **ROI in 3 years**

> Complementary

SHAYP

Combines a single non-invasive sensor with software to automatically assess leakages in real-time and alert building operators to reduce losses

Water Water-networks

Over 35% of clean distributed water is lost in buildings and infrastructure. Further, 25–30% of leaks can be from the pipework within private premises rather than leaks in the public distribution network. For property insurances, around 30% of their operating costs are associated to claims due to water damage caused by the distribution network. Thanks to this IoT-connected solution, leaks can be detected and communicated in real time. Further, this retrofit solution is a much more affordable way to step into smart metering and a new business model without the high costs of migration to smart meters. It can also help utilities to predict demand, reduce energy and save water.

Where is this Solution being used?

The city of Brussels manages many different types of buildings – offices, schools, sports facilities, fountains, nurseries, swimming pools and more. Each year, they were losing 25 million litres of water, 83% of which were due to recurring issues. Since the installation of Shayp, not only have they stopped losing this water, they have saved an estimated 13 million litres, and financially speaking, they are saving €190,000 per year. The ROI from their Shayp installation was realised within 12 months.

Environmental and Economic Benefits

- **Save 20% in water bills and much more from avoided water damage**
- **ROI in 18 months**

What this means for Scotland

- **463 Ml/d of water is lost to leaks in Scotland**
- **Just 1 in 10 peoplemin Britain have a leak detector installed, and 11% don't have insurance that would protect them against leak damage**

Encouraging uptake

- **Water has been overlooked in the European Green Deal and the same is true in various national legislations to upgrade European building stock**
- **Belgium is currently looking into new norms and standards that include water leakage**

> Complementary Ubiquitous Energy

Turns every window in every building into an electricity-generating window while maintaining the window's look and transparency

Solar **Photovoltaic Glass**

This solution serves to meet the requirements and aesthetics of traditional energy efficient windows, but with the added benefit of capturing solar energy. With transparency ranging from 40 to 80%, it matches the look and view of standard windows. Working with up to 10% efficiency, it is able to offset a building's electricity consumption by 10–30%.

Where is this Solution being used?

Installation of the world's first truly transparent solar window façade in Redwood City, California, replacing single-pane windows with approximately 100 square feet of transparent solar windows as an exterior facing façade. This generates electricity whilst maintaining high transparency, colour neutrality, and aesthetics of traditional low emissivity (low-E) windows. Electricity produced by the windows is used to power the LED overhead lighting in its adjacent room.

Environmental and Economic Benefits

- **10–30% offsetting of a building's electricity consumption**
- **ROI in 3 years**

What this means for Scotland

- **The global solar photovoltaic glass market is projected to reach USD 37.6 billion by 2026, growing at a CAGR of 30.3% from 2019 to 2026**

Encouraging uptake

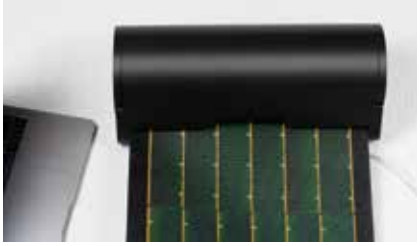
- **Aggressive standards for new and renovated buildings to require higher energy performance windows and glazings to improve the overall energy efficiency of buildings**
- **Canada and the United States are further ahead in this area**

> Complementary ■ Solar ■ Energy Efficiency ■ Windows & glass

Plug & Play Rollable Solar Panel for your Home & Outdoors

Smart solar blind system that reduces your carbon footprint and cuts energy bills

Although most solar panels need to be installed on the roof, the majority of us live in buildings with little to no access to the roof. Plug & Play Rollable Solar Panel offers the possibility to use the window's surface to harvest solar energy. The blinds harvestsenergy and inject the electricity directly to the main grid. Using this solution will cover up to 60% of the energy needs with a 7 meter square surface and an average of 5kWh per day per home.



Benefits

- **Saves up to 50% on energy bills compared to the main electricity grid prices**
- **Reduces energy carbon footprint by 90% compared to the main utility grid**

> Complementary ■ Lighting ■ LED ■ Energy Efficiency

LED Bulb for Household Philips

Basic light bulb using LED technology to maximise efficiency in a widespread lighting system

The Philips bulb is a classic one, with a height of 104 mm and a width of 60 mm, fitting every standard domestic lamps and lighting device. The warm-white light functions at 7 W with wattage-equivalent of 60 W. Its lifespan is 15 years (or 15,000 hours). This light bulb reduces energy consumption without inhibiting user comfort or light intensity.

Benefits

- **Consumes 8x less than an incandescent bulb, 6x less than a halogen**
- **ROI in less than 9 months**

> Complementary ■ Lighting ■ Energy Efficiency ■ Solar

Solatube Tubular Daylighting

Lightning modules bringing daylight into interior spaces inaccessible to skylights and traditional windows

Solatube units are modular and easy to connect to ceiling systems. Once installed, the domes capture the sunlight which is then transferred through tubes made of reflective material, allowing the light to hit where traditional skylights and windows cannot reach. Thanks to solar cells inside the tube, the system can still operate at night. The devices filter infrared and ultraviolet rays.

Benefits

- **Can save up to 37,000 kWh & reduce CO_2 emissions by up to 30,000 kg over its lifetime**
- **Reduction of up to USD 4500 over its lifetime**

> Complementary ■ Sensors & Monitoring ■ Air Quality

Somfy Air

Home ventilation system that maximises the energy efficiency of buildings

Air quality is the first cause of human deaths in the world. Interior air quality is 2 to 8 times more polluted than outside air. To ease the renewal of interior air in homes and buildings, the Somfy Air solution provides an automated solution that can open and close windows, in a secure mode, even when not there. The solution has three different levels of natural aeration depending on people's wishes.

Benefits

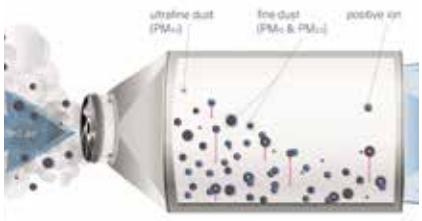
- **Productivity increases by 8% with better air ventilation according to a Harvard Study**

> Complementary ■ Filtration ■ Air Pollution

Lungs of the City

Air purification system aiming at particulate matter removal at pollution hotspot locations

The Lungs of the City system can be invisibly integrated into the urban tissue. It is based on an energy-efficient positive ionisation technology that captures fine particles and ultrafine particles without the use of traditional filtering techniques. Installation of Lungs of the City at air pollution hot-spots, such as parking garages, tunnels, train and bus stations, and busy traffic junctions, has been shown not just to reduce emissions at these locations, but also to contribute to the overall improved air quality in the urban environment.



Benefits

- **Reach 80% reduction in energy consumption compared to conventional technologies**
- **A PM (particulate matter) reduction of more than 50% locally**

> Complementary
Smart Cities Through Smart Lighting

Dynamic and reactive street lighting system to minimise electricity consumption, light pollution in cities

■ Smart City ■ Energy Efficiency

The solution adapts street lighting levels to traffic density without sacrificing security or visual comfort. Sensors attached to each LED along the street allow the module to dim its light based on its own sensor or from the message coming from another pole, ensuring smooth transitions. The solution software can also be adapted to suit specific needs, and internet connection enables tele-monitoring as well as remote updates, improving maintenance efficiency. Moreover, the street lighting network can collect traffic information, and through a range of remote sensors, can be used for a host of other applications such as parking lot management, street sound level or pollution monitoring.

Where is this Solution being used?

Smart Lighting in Wavre (Belgium): the solution was installed in a residential area of 400 houses in Wavre, Belgium. The region witnessed energy savings of 70% when compared to traditional, non-dimming street lights. Further, the sensor systems and on-board communication tools allow the system to address other city needs, recording data such as traffic counting and related services around mobility. This solution is unique in Belgium.

Environmental and Economic Benefits

- **Up to 80% energy savings and light pollution reduction compared to non-dimmed LED fixtures**
- **ROI in 4 years thanks to energy savings**

What this means for Scotland

- **Street lighting can account for up to 25% of local authorities' electricity spend, and Scotland has already replaced almost 50% of streetlights with LED equivalents**

Encouraging uptake

- **Several European cities still opt for conservative approaches versus new IoT solutions**
- **Replacing sodium streetlights with LED-based lights must be driven by sustainability targets and new governmental standards**

Case Study 1

Keeping Scotland's Homes warm

Heating buildings is responsible for 20% of Scotland's GHG emissions. Furthermore, almost a quarter of households in Scotland currently suffer from fuel poverty. The country's climate, as well as the distribution of its people makes tackling this issue a great challenge. Already it costs significantly more to heat homes in the north of Scotland than it does further south in the UK, largely as a result of distribution costs.

However, whilst up-front costs to decarbonise heat and increase energy efficiency are high, the impacts cascade downward, helping to economically empower and increase the quality of life of citizens. The Scottish Government has recognized this, and has sought to make £1.6 billion available over the next parliament to address these issues. It is also an area with significant job creation potential, estimated at some 3,000–5,000 new positions being created in the coming years. However, whilst up-front costs to decarbonise heat and increase energy efficiency are high, the impacts cascade downward, helping to economically empower and increase the quality of life of citizens. The Scottish Government has recognized this, and has sought to make £1.6 billion available over the next parliament to address these issues. It is also an area with significant job creation potential, estimated at some 3,000–5,000 new positions being created in the coming years.

In 2020, only around 11% of households had a low carbon heating system. The Scottish Government has set a target of over 1 million homes to be converted to using zero or low emissions heating systems by 2030, meaning some 64,000 homes will have renewable heating systems installed by the middle of this decade.

Heat pumps have been identified as central to this effort, and a recent report indicated that 23% of housing stock is suitable for using ground-source heat pump technology. This is fortunate as there are a variety of technologies coming to the fore that serve to reduce the costs and logistical challenges of making use of geothermal energy, a source of heat that can cut GHG emissions by up to 90%.

Celsius Energy

Opening up urban areas to small scale wind Celsius Energy is one of these. They have developed a solution using inclined boreholes that allows them to enter the ground at a single point and access deep geothermal with a much smaller footprint, thus reducing the complexity of operating in urban areas.

Used in an office building housing 200 employees in Clamart, France, this has lead to a reduction of 92% in carbon emissions and -40% reduction in operating costs.

Accenta

Complementary technologies like that from Accenta make it possible to access inter-seasonal geothermal storage, using waste heat produced during summer that is stored in the ground for use during winter.

Used in a 68,000 sq.m warehouse in Moissy-Cramayel, France, leading to a 46% drop in energy demand and thus 54% fewer carbon emissions.

Energy Geostructures

Given the focus on urban settings, Energy Geostructures have developed a system that uses underground infrastructure as geothermal heat exchangers. The latter two technologies can even be coupled with intermittent heat sources such as solar thermal panels to make the most of Scotland's somewhat limited solar resources by turning the ground into a thermal battery. These are just three ways that heat pumps can be integrated into the system.

A system to heat and cool urban districts using underground infrastructures.

SOLARIMPULSE
FOUNDATION

Case Study 2

Energy Efficiency – Key to a just Transition

All residential properties in Scotland will be required to achieve an Energy Performance Certificate (EPC) rating of at least EPC C by 2040, with currently 55% of housing stock falling below that rating. Both for new and old builds, there is a very significant amount of housing stock to address and help save energy. So as to address this, energy efficiency strategies will be launched across all local authorities by 2023.

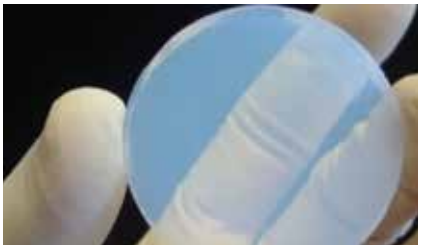
Sopratec III

Insulation is usually the first place people look for such savings – and with good reason. However, in recent years walls have become thicker to increase insulation potential, but air gaps have been neglected. It is estimated that they contribute up to twice as much to energy leaks. Sopratec III is a technology that helps steel-frame buildings to achieve airtightness comparable to that of a concrete building by massively reducing the air permeability of facades and roofs. With this technology it is possible to save up to 100 kWh/m² on heating annually.

Used in a 6,800 m^3 building in Poitiers, where it has didivded the heating expenses by three.

SICLA

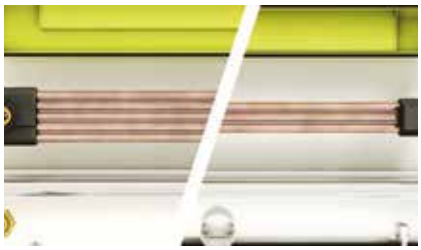
Thicker walls also means reduced living space. However, SICLA have developed an aerogel based on recycled silica from construction and demolition waste that is only a third of the thickness of competitors whilst providing the same thermal performance. It is lighter and cheaper, and its production contributes less to CO_2 emissions than other organic insulation materials. There are many types of insulating material out there, increasingly making use of waste or other materials that do not have a market, and given Scotland's commitment to developing a circular economy, there is significant potential to be found in such solutions.



Part of an H2020 project in Madrid and Delft where it has been used in 400 m^2 of panelling.

Joulia Inline

Heating and hot water in Scotland often costs a great deal, but there are quite simple fixes that can help to address such costs. The wasted energy used to heat our showers that immediately goes down the drain is just one such example. Joulia-Inline solves this by reclaiming heat energy from used shower water, pre-warming the fresh water before it arrives at the mixer. It can be easily installed, functions without electricity, and can save 42% of the energy required to heat water.



Showerdrain reclaiming heat energy from used shower water by pre-warming the fresh water before it arrives at the mixer.

HeatTank

Another technology that helps heat water efficiently is HeatTank, which uses phase change materials instead of water to store heat, thus storing energy in a much more concentrated way and saving between 20% and 50% compared to competing technologies. Further, it takes up far less space than traditional water heating systems within people's homes.

Used in a mountainous part of Hungary at a telecommunication base station, and calculated savings of 51% of electricity over one year with 4 year ROI.

03 Transport

Phasing out Fossil Fuels in Transport

Despite good progress to reduce carbon emissions in Scotland, the transport sector has failed to make similar reductions. It is now the biggest emitting sector in Scotland, accounting for over 35% of total emissions in 2018, with road transport accounting for almost two-thirds of total transport emissions. The Scottish Government has set out a number of targets, strategies and policies to reduce emissions to ensure this vital sector plays its role in the transition towards net-zero emissions. A focus has been placed on achieving a shift towards public transport and active transport, with an ambition to reduce total car kilometres by 20% by 2030. To facilitate this shift, £500 million has been provided for bus priority infrastructure, as well increasing funding for cycling infrastructure, access to bikes and behaviour change schemes.

A strong emphasis has been placed on decarbonising various transport modes, with a target to phase out the need for petrol and diesel cars and vans in Scotland by 2030. This is accompanied by commitments to decarbonise the rail network by 2035, to have most new buses purchased from 2024 be zero-emission, and to achieve 30% of Government-owned ferries to be low emission by 2032. The Scottish Government has also set out ambitions to decarbonise the aviation sector, such as by supporting the introduction of zero-emission aircrafts, and establishing the world's first zero-emission aviation region in the Highlands and Islands.

Although many approaches will be needed to decarbonise transport, such as modal shift to public transport and active travel, there is an important role for technological solutions, particularly in challenging sectors such as aviation and road transport. A number of solutions exist within the Solar Impulse Foundation's Labeled Solutions which can help to address challenges across a number of different transport modes. These solutions have been selected with consideration given to a number of factors, including the desire for a modal shift to sustainable modes of transport, and to support Scotland's bus and ship manufacturing industry.

> Commercial Vehicles

KERS for HGVs

Retrofittable kinetic energy recovery system for HGVs using novel electric machine and energy storage technology

Fleet **Retrofitting**

The Kinetic Energy Recovery System can be fitted to existing HGVs to reduce fuel consumption and emissions by over 20%. An electric machine (motor/generator) is fitted to the truck's drivetrain. During braking, this machine acts as a generator, slowing the vehicle and sending electricity to be stored in graphene ultracapacitors. During acceleration this machine acts as a motor, drawing electricity from the ultracapacitors and providing power to accelerate the vehicle, significantly reducing fuel consumption.

Where is this Solution being used?

A UK-based company fitted the KERS solution to a 12-ton euro VI Heavy Goods Vehicle (HGV). This vehicle was tested on an urban drive cycle of five stops per km. The results demonstrated a 25% better fuel economy on the cycle, verified by a third party. The best result was 32% better compared to a vehicle with no KERS.

Environmental and Economic Benefits

- **25% reduction in fuel burn**
- **ROI in under 3 years**
- **A lorry travelling 45,000 miles per year would save £ 6500 of fuel and 15 tons of CO_2 per year**

What this means for Scotland

- **Truck tonnage per year continues to rise: solutions to mitigate emissions will be vital**

Encouraging uptake

- **The UK has no regulatory impediments to the implementation of the system on trailers**

> Commercial Vehicles ■ Cars ■ Retrofitting ■ Electric

Carwatt

Conversion of industrial/special vehicles into electric vehicles

This solution modifies the internal combustion engines in vehicles with a recycled electric motor through retroffiting. The second hand Li-ion batteries come from the automotive industry and can be installed on river transports (barges, tourist boats), or industrial vehicles (garbage trucks, buses, delivery vehicles, terminal tractors, locomotives, etc.).

Benefits

- 3 t CO_2/year less per vehicle
- ROI of 3–6 years

> Commercial Vehicles ■ Biking ■ Electric ■ Cargo

VUF Bikes

Electrically assisted cargo bikes for professionals operating in urban areas or on tourist and industrial sites

VUF is a brand of cargo bikes whose objective is to decarbonize the business of professionals operating in town centres or on closed sites with motorized vehicles. The bikes are three-wheeled bicycles equipped with electric assistance and are robust, compact and 100% modular, appropriate for the transport of large loads and volumes (up to 250 kg for a volume of 1.7 m^3) in urban areas, industrial and all-terrain. They are equipped with boxes, bins, and/or trailers.

Benefits

- A light vehicle emits 25 kg of CO_2 eq/day, replacing it with a bike-cargo would reduce all direct emissions
- Cost of use divided by 10, cost of purchase by 3

> Commercial Vehicles ■ Heavy-duty vehicles ■ Hybrid ■ Retrofit

Active Stop-Start Technology

Upfit or retrofit hybrid system for class 6–8 vocational vehicles

The solution is an electric system designed to shut down the engine of (new or existing) heavy-duty vocational trucks when they are stationary and to provide electric power to the vehicle equipment, cab and chassis accessories including the HVAC system. Since these vehicles spend a large proportion of their operating time immobile, the technology creates value by reducing engine operating hours and corresponding fuel consumption, emissions, and maintenance.

Benefits

- Reduction of 30% in GHG based on a customer report
- For 300 working days at 14.9 hours of operation, the fuel savings = 399,900 liters

> Commercial Vehicles

MISER Hydraulic Hybrid Transmission

Hybrid hydraulic transmission system for trucks

Public Transport **System Optimisation**

The solution from MISER is a hydraulic hybrid transmission for heavy-duty vehicles that offers significant reductions in fuel consumption and emissions through optimised engine performance and regenerative braking. The hydraulic hybrid transmission has fewer energy flow paths, fewer valves and fewer energy losses than existing hydraulic hybrid systems. It is ideal for new vehicle designs where the engine can be chosen, but can also be fitted to existing vehicles, offering opportunities for retrofitting of existing fleets.

Where is this Solution being used?

In a pilot test the technology was independently verified at Gerotek, a world-renowned testing facility. The results for city cycles showed fuel savings of above 40% and reduced emissions of around 40% in certain drive cycles.

Environmental and Economic Benefits

- **Above 20% fuel saving and emissions reduction**
- **ROI in about 19 months**

What this means for Scotland

- **30% CO_2 reduction target for heavy duty vehicles in Europe by 2030: solutions will be needed to cut emissions**

Encouraging uptake

- **High market entry costs need to be alleviated**

> Commercial Vehicles ■ Electric ■ Freight ■ Biking

K-Ryole

Smart, electric trailer which can carry a load up to 250 kg behind any bike securely and without any additional effort

To avoid traffic congestion, CO_2 emissions and fuel consumption, K-Ryole has developed an innovative 100% electric trailer to transport loads of 250 kg. With two electric motors and a controller, the load requires no additional effort from the cyclist and can help facilitate deliveries in congested city streets.

Benefits

- **Gains up to 3h/day for deliveries by avoiding traffic jams and parking problems**

> Commercial Vehicles ■ Pallets & Containers ■ Digital ■ Logistics

MagicPallet

An online collaborative platform dedicated to the exchange of reusable pallets in road freight transport

This tool allows road freight transport companies to make very significant savings on pallet logistics since this platform enables owners to exchange their pallets in order to save on the costs of restitution. The European pallet is reusable and usually returnable: carriers sometimes must bring them back to their owners in empty trucks, increasing emissions.

Benefits

- **Avoid the emission of 5 Mt CO_2 in Europe**
- **Profitable as soon as 175 km of transport are avoided**

> Commercial Vehicles ■ Freight ■ Electric ■ Logistic

Autonomous Freight Transport

Small autonomous electric vehicles for the transport of goods in rural areas

Delivery vehicles currently used in rural areas are inefficient and emit twice the CO_2 emissions than when used in urban environments. This solution is able to transport goods, parcel deliveries, food, general supplies and baggages, collection of waste and restitutions to central locations. The vehicles are equipped with multiple cameras that allow them to move safely.

Benefits

- **Reduce 6 t CO_2/year for each van replaced**
- **ROI in 12 months**

> Commercial Vehicles ■ Biking ■ Corporate ■ Logistic

Cargobici

Electric cargo bicycles for first and last mile transport services

The providing company provides a distribution system for first/last mile deliveries for companies and through the use of electric cargo bicycles. In addition, the provided operating system is based on a software developed to be in charge of all the logistics stages such as route planning, order and shipping management. This way, local stores have a tool to maintain door-to-door service (such as during the COVID-19 pandemic). This tool also provides a guide with lessons learned and best practices.

Benefits

- **80% reduction in CO_2 footprint compared to conventional truck delivery**
- **A company can save up to EUR 3000 per year per vehicle using electric cargo bikes**

> Commercial Vehicles ■ Heavy-duty vehicles ■ Refrigeration ■ Freight

5C: Cryo-City for Cleaner Cold Chain

Innovation for light carrier vehicle refrigeration unit using dry-ice

CryoCity is an innovation for light carrier vehicle refrigeration unit using dry-ice. It offers sustainability, silence and operational excellence. Liquid CO_2 is instantaneously transformed to dry ice; a powerful cold source at -78 °C to keep products under temperature control for the duration of the trip. The desired temperature (fresh or frozen) is guaranteed for 10 hours with up to 25 door openings by trip.

Benefits

- **Savings of 3 tons of CO_2 eq per year per unit**

> Commercial Vehicles ■ Refrigeration ■ Trucks ■ Nitrogen

Blueeze

A solution using liquid nitrogen for a clean, quiet and performant refrigerated transport

Most of the generators currently on the market produce cold using a standalone diesel generator: they are noisy and also account for more than 90% of the total particle emissions generated by a refrigerated truck as a whole. In the Blueeze cryogenic cooling unit, air that circulates is cooled through the circulation of liquid nitrogen cooled to -196°C in one or more hermetically sealed exchangers before the nitrogen is released as a gas into the atmosphere.

Benefits

- **-85% reduction of carbon footprint compared to conventional standalone diesel cooling**

> Passenger Vehicles
Transition-One car

Converts combustion engine vehicles into electric vehicles with optimised driving

Passenger vehicles Retrofitting

Transition-One aims to respond to the ecological transition in the automotive field by developing solutions to positively impact CO_2 emissions. Transition-One offers a transitional solution: it convert existing vehicles to increase the number of electric cars on the market and thus reduce the quantities of CO_2 emitted daily. Transition-One converts small internal-combustion vehicles into modern cars which are electric, connected and affordable. Transition-One has developed a retrofitting technology that consists of extracting all the specific elements of the combustion engine and to replace it with a 100% electric powertrain.

Where is this Solution being used?

Two prototypes of the solution were tested by a number of citizens in France. The prototypes (a Fiat 500 and a Renault Twingo) were driven every day to deliver a real-world test. The results of the project showed several key advantages, including no carbon emissions and heavily reduced fuel costs. The retrofit comes with a 2 year guarantee, unlimited mileage, as well as a five year guarantee on the battery.

Environmental and Economic Benefits

- **1 ton of CO_2 saved per 10,000 km traveled**
- **New electric car reduces CO_2 emissions by 47%, a retrofitted car reduces CO_2 emissions by 66%**
- **ROI in max 4 years**
- **40% savings on maintenance**
- **75% savings on fuel**

What this means for Scotland

- **This retrofitting service could convert around 100,000 cars in Scotland**

Encouraging uptake

- **Update regulation to allow easier retrofitting of cars, as it has been done in France**

> Passenger Vehicles ■ Solar ■ EV charging ■ Software

Solar Powered Carport Energy and Mobility Hubs

Grid-connected EV charging solutions integrated into one hardware and software platform

A solar power, grid-connected electric vehicle charging solution with services that range from OS management of all solar and EV charging, smart lighting and air quality sensors as well as batteries providing either off-grid power or grid-services, all integrated into a single hardware and software platform.

Benefits

- **2 MW of annual power for clean powered EV charging**
- **24hr resilient power due to 90 KWH battery**

> Passenger Vehicles ■ EV Charging ■ Infrastructure ■ Collaborative

Wattpark

Smart-grid ready and collaborative solution to charge all electric vehicles

WattPark sells EV charging points through distributors and installators. Each owner can make money out of it as they are renting their car park and providing electricity. WattPark takes only a 10% fee on every transaction. For less than 600 EUR, each user can have their own charging system, which they can share and monetise through an app.

Benefits

- **Charging time is 60% faster compared to a standard plug**
- **ROI in 2 years**

> Passenger Vehicles ■ Vehicles ■ Monitoring ■ Electrical Grid

JuiceNet

A platform that matches drivers' historical charging patterns, real-time input, and signals from grid operators and utilities

This patented control and communication platform allows electric vehicle owners to be compensated when network operators use the vehicle batteries as storage. Vehicle2Grid is an enabling technology that helps overcome network changes, incorporate additional renewable energy into the grid and improve grid reliability.

Benefits

- **Savings of USD 260/year for the operator**
- **Savings of USD 220/year for the consumer**

> Passenger Vehicles ■ EV Charging ■ Energy Efficiency ■ System Optimisation

EVlink Load Management System

Smart management system to efficiently manage EV charging while ensuring building power availability

This system can charge electric vehicles while managing the local system autonomously. When the electricity demand of a building is likely to exceed the supply, the EVlink system will redistribute the current, eliminating the need to upgrade the transformer or the electrical equipment in buildings. It records usage data to allocate costs. Through a single point of remote management access, you can manage a network of up to 100 AC or DC chargers.

Benefits

- **Less than 10% of the cost and implementation time of an ordinary power grid upgrade**
- **ROI in less than a year**

> Passenger Vehicles ■ Batteries ■ Recycling ■ Data collection

La Belle Batterie

Offers accurate, independent and transparent information on the state of electric vehicle batteries in the second-hand market

La Belle Batterie is the first certification service for EV and PHEV batteries. Its mission is to unlock the second-hand electrical market by offering consumers and professionals accurate, independent and transparent information on the state of health of electric vehicles (EV) and plug-in hybrid vehicles batteries (PHEV).

Benefits

- **ROI in less than 3 years**
- **40% to 70% cheaper than mainstream alternative**

> Passenger Vehicles ■ Cars ■ Hydrogen ■ Fleet

HYPE

Zero-Emission solution for passenger transportation in large cities with hydrogen vehicles

HYPE taxi offers a zero-emission solution for passenger transportation in large cities with hydrogen vehicles. The objective for HYPE is to become a mature H_2 service provider that can be implemented in major metropolitan areas. A dedicated and specific communication and dispatch platform is used to optimise operational efficiency.

Benefits

- **No additional costs for the end user**

> Public Transport

Single-Stage Variable Transmission for Electric Transport and Industrial Applications

An innovative technology to extend the driving range of EVs

System Optimisation

MAZARO has developed an innovative transmission system for vehicles that offer substantial energy, emissions and cost savings while enhancing performance and comfort. MAZARO's transmission system is designed with a higher mechanical efficiency than regular transmission systems, enabling the motor to operate at higher efficiency. The solution is able to handle the high torques required of large vehicles, and unlike the mainstream options on the market, MAZARO's system is controlled by high-efficiency hydraulics. The solution can be used on a wide range of vehicles, including buses and lorries, and can be applied to a range of fuel types, including electric.
This solution could help to boost Scotland's electric bus industry whilst extending vehicle range and helping to reduce emissions.

Where is this Solution being used?

Tests were performed on an electric truck fitted with this solution by an independent test centre. The gearbox was replaced by MAZARO's SVT230, including the transmission controller and hydraulic powerpack. The results showed that the vehicle was able to travel 16.8% further and had a 50% higher top speed, whilst using no additional power.

Environmental and Economic Benefits

- **Can extend electric vehicle range by around 16%**
- **Emissions savings of 11–19%**
- **ROI in less than one year**

What this means for Scotland

- **EVs set to account for over 25% of market by 2030: this solution can help to extend vehicle range and reduce costs**

Encouraging uptake

- **California has very supportive regulations for MAZARO as it is so committed to reducing emissions and enabling energy consumption savings in transport**

> Public Transport ■ Efficiency ■ Electric ■ Motors

Magnax Yokeless Axial Flux Motors

A new generation of electric motors reducing vehicle weight by up to 10% and increasing range by 7%

Magnax Yokeless Axial Flux Motors brings extreme power density and efficiency to the future of EV powertrains. Compared to traditional EV motors, the Magnax electric motors are 4x lighter, 3x thinner and deliver increased vehicle range. Due to its compactness and short axial length, the motor technology brings opportunities for new powertrain solutions such as super-compact hybrid powertrains and eAxle modules.

Benefits

- **A 4–10% increased efficiency would save 76,000 tons CO_2eq**

> Public Transport ■ Materials ■ Lightweight ■ Vehicles

AmpliTex & powerRibs™

Up to 40% lighter automotive interior panels, using 80% less plastic thanks to natural fibre reinforcements

This solution provides a new high-performance renewable material with a unique price/performance ratio to meet the strong and growing need for lightweight materials in today's mobility industry. The proprietary powerRibs reinforcement technology is inspired by the thin veins in leaves to provide maximal stiffness at minimal weight

Benefits

- **Flax fibres are CO_2 neutral over their lifecycle**
- **Exterior panels have 30% lower material cost**

> Public Transport ■ Reuse ■ Efficiency

CMF drive

Upcycling used diesel city buses into clean, efficient, silent and cost effective buses driving on 100% renewable fuel

CMF recovers public old buses and remove all diesel components like tanks, engine etc. and install their patented CMF drive. It consists of an electric drivetrain with an onboard charger and enables 3-fold energy savings: through the recovery of braking energy, usage of engine waste heat and constant optimal load at the on-board charger. The CMF drive runs on liquid natural gas (LNG), Bio-LNG or synthetic natural gas.

Benefits

- **30% more energy efficient than conventional buses**
- **€200,000 to €400,000 cheaper acquisition costs than battery electric or H_2 buses**

> Public Transport ■ Retrofitting ■ Hydrogen ■ Combustion Engine

KEYOU-inside

Redesigned internal combustion engine running on pure hydrogen as sustainable and clean zero-emission fuel

A sustainable drive technology that is both clean and economical – without compromising performance, range or robustness. The independent manufacturer KEYOU-inside kit transforms conventional engines into emission-free hydrogen combustion engines and enables original equipment manufacturers to integrate zero-emission vehicles into their portfolio.

Benefits

- **40–80 % lower TCO compared to other zero-emission solutions**

> Public Transport ■ Vehicles ■ Electric ■ System Optimisation

Zero Emission Energy Recovery Brake System

New generation of brake systems for the automotive industry: 100% Electric, 0% thin particles emission

Mazap provides a braking system where an electrical generator replaces the usual mechanical brake system with the same integration constraints. It drastically reduces the estimated 16–55% contribution of brake wear dust to non-exhaust traffic-related emissions. The solution is based on an electromechanical generator and associated electronic device to convert AC electrical power to DC power.

Benefits

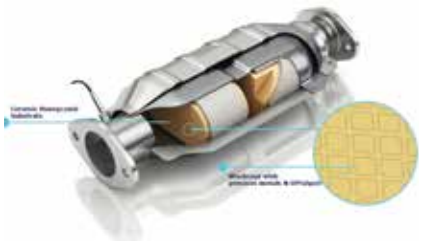
- **Fully eradicate particulate matter generation during braking phase**
- **Final user average economy of USD 400 a year**

> Public Transport ■ Materials ■ Emissions ■ Vehicles

OPtalys

High stability inorganic oxygen-buffer material that enhances the catalytic activity and durability of advanced gasoline catalytic converters

OPtalys® is a key component of advanced gasoline catalytic converters developed to meet the more stringent exhaust emissions regulations for the vehicles fitted with new Gasoline Direct Injection (GDI) technologies. This new technology will be used alone and in combination with electrification for CO_2 emissions reduction. In addition, the Gasoline Direct Injection technologies allows the use of current biofuels (Ethanol) and future e-fuels according the Automotive Low Carbon Pathway.



Benefits

- **90% reduction of exhaust pollutants**

> Public Transport ■ Public Transport ■ Carpooling/Carsharing ■ Service

Shotl

Mobility platform that matches multiple passengers headed in the same direction with a bus service

Shotl is a mobility platform that matches the demands of users and the movements of on-demand buses. This solution complements existing public transportation systems and is especially suitable for unprofitable or unserved routes. Shotl has developed an app for users, one for drivers and one to manage the network.

Benefits

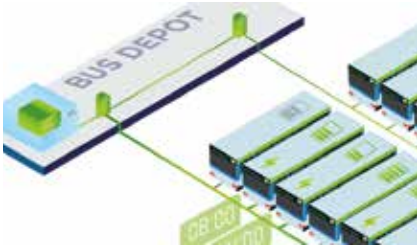
- 60% reduction in long distance trips
- The operating costs of bus lines can be reduced by 15%

> Public Transport ■ EV Charging ■ Public Transport ■ Fleet

charge&go

Fleet charging station for e-buses for innovative and smart mobility projects

To support cities in their search for simple and ecological solutions for mobility, charge&go are electric vehicle charging solutions that find and bring the energy from the city directly to the vehicle. This solution enables charging from different energy sources, is adaptable to different bus manufacturers and is plug and play, hence avoiding significant infrastructural investment.



Benefits

- 400 to 2000 kW charging power

> Public Transport ■ Electric ■ Carpooling ■ Platform

SuburVan

Autonomous, electric minivan that is specifically tailored to serve an area of 10 km radius around suburban railway stations

SuburVAN are door-to-rail autonomous electric minivans. Combined with commuter railways, SuburVAN autonomous electric minivans can provide the fastest commute in metropolitan areas and small and mid-size cities. They can pick suburban commuters up at their door and take them to a commuter railway station in less than 10 minutes.

Benefits

- One minivan replaces 70 private cars
- 70% transport costs saving for suburban commuters

> Aviation

H55 – Electric propulsion and battery management solutions EPS 55

Electric propulsion solutions to accelerate the transformation of the aviation industry by making it quiet, clean and affordable.

Electric flight **Batteries**

H55 is an enabler of clean aviation, providing turn key solutions for aircraft manufacturers. H55's products offer a fast track to electric aviation; quicker to certify, modular and easy to integrate. H55 provide an independently certified Electric propulsion system (EPS) for aircraft manufacturers. The EPS is composed on the propulsion side by the electric motor, the motor controller, and the gear (Electric propulsion unit, EPU) and on the energy side by the Battery packs, the BMS, the coupling box, the EFIS system and the DC/DC converter, the Energy Storage System (ESS). The entire EPS, the EPU or the ESS can be integrated in different application to retrofit existing aircraft (STC and TC), new fixed wing design, new concepts and eVTOLs. For this exercise the example use case is our first customer application the Bristell B23 Energic. H55 provides a full EPS to convert the B23 combustion aircraft in an electric aircraft.

Where is this Solution being used?

H55 first customer application is the Bristell B23 energic manufactured by BRM aero a Czech aircraft manufacturer. The B23 energic is a 2-seater flight trainer with 1 hour flight time and 30 min reserve. 1 hour of flight time is typically the length of regular pilot training session. The B23 Energic powered by the EPS55 has a maximum take off power of 100 kw, maximum continuous power of 80 kw and 50 kWh battery capacity.

Environmental and Economic Benefits

- **Reduction of 250 kg CO_2 eq per hour flying**
- **For a 1-hour flight, the electricity cost is 6 EUR compared to 40 EUR in fuel combustion**

What this means for Scotland

- **Electric aviation market to reach over USD 4.5 billion globally by 2027**

Encouraging uptake

- **In Scandinavian countries, strong milestones have been set to decarbonize the aviation industry. For example, Norway has ruled that all regional flight should be electric by 2040. Consequentially, the government offers important support to electric aviation actors**

> Aviation

Refuel the Future

Producing renewable fuels for use by air, ground and marine vessels to reduce emissions quickly and at large scale

Renewable Fuel Industrial waste

Refuel is acting on a plan to profitably develop sustainable aviation fuels for major airport hubs at a cost that is competitive with traditional fossil fuels, but with a significant environmental benefit. Starting with Toronto Pearson International Airport and to be replicated at other global hubs, the use of sustainable fuels by air transport operators will be key to reducing aviation's environmental footprint and to meeting ICAO carbon emissions reduction goals starting in the early 2020s. In a sector which needs significant action to act on climate change, this solution offers real potential to reduce emissions.

Where is this Solution being used?

The solution has been used by a major airline in the USA since 2017. The first clean fuels production facility was established in 2016, and produces 35 m gallons/year, mostly supplied under contract the client airline. Other airlines are supplied with a limited volume of SAF from the facility. The facility is set to expand eightfold resulting in a production of 272 m gallons by 2022. The main customer documented a 60% carbon emission reduction from the displacement of fossil jet fuel by SAF.

Environmental and Economic Benefits

- **Can deliver 80% lower emissions than conventional jet fuel**
- **Over 20 years, customers can save over 10% compared to traditional fuel**

What this means for Scotland

- **SAF market to grow by over 70% CAGR between 2020–2030 to a value of USD 15 billion**

Encouraging uptake

- **Need for more stringent requirements for use of renewable fuel in aviation, and faster timeline for implementation**
- **California's Low Carbon Fuel Standard sets a good example for how to support renewable aviation fuels**

> Aviation

APU OFF Service

Reducing emissions at airports while generating fuel savings for airlines at the gate

System Optimisation **Air conditioning**

Auxiliary Power Units (APU) are turbines in the tail of every aircraft providing energy for functions other than propulsion which are used significantly during ground operations, mainly due to the lack of performing air conditioning equipment. This generates significant emissions. The APU OFF solution allows airlines to switch off the APU on the runway, whilst maintaining the same level of functionality and comfort. This also allows a reduction in emissions from planes when on the ground, helping to significantly decrease emissions from airport operations. Airlines will save fuel and sanitize their aircraft cabin while reducing their CO_2 and NOx emissions at airports.

Where is this Solution being used?

APU Off was used in one of the world's busiest airports for three months in 2019. The system was used at four gates by four airlines. Over this time, APU Off enabled the reduction of nearly 550 tons of CO_2, and 1 ton of NOx.

Environmental and Economic Benefits

- **16% less CO_2 and 9% less NOx emitted**
- **Around 30% savings for airlines compared to mainstream option**

What this means for Scotland

- **Close to 100 airports already have net-zero targets for 2030 or sooner**

Encouraging uptake

- **There is a lack of regulation forcing airlines to ban the use of APU systems: now that an alternative has been demonstrated, regulations to ban the usage of the APU while the aircrafts are grounded can be implemented**

> Aviation ■ Efficiency ■ Hybrid

ENGINE OFF Service

The TaxiBot® is a semi-robotic hybrid towing vehicle designed for taxiing airplanes from the boarding gate to the takeoff runway without the use of jet engine power

The ENGINE OFF Service is deploying the TaxiBot®, a semi-robotic hybrid towing vehicle designed for taxiing airplanes, combined with an on-site dedicated supervision guaranteeing airlines to switch off the aircraft main engines during taxiing while maintaining the same level of comfort and decreasing significantly the emissions at the airport.

Benefits

- **42% less CO_2 emitted at airports**
- **35% reduction of NOx emission at airports**
- **20% savings for airlines compared to current operating costs**

> Aviation ■ Aircraft ■ Software ■ Efficiency

Skybreathe Fuel Efficiency

Eco-flying solution to save fuel/reduce CO_2 emissions by detecting manoeuvres or best practices to implement

This software provides support to aircraft pilots by providing advice and a series of recommended actions to help pilots reduce their fuel consumption. The system is based on an extensive flight data collection – pulling in information gathered from black box data recorders, weather and airline traffic – coupled with artificial intelligence.

Benefits

- **Reduces CO_2 emissions by up to 5% per flight**
- **Savings of USD 50M/year of fuel for airlines**

> Aviation ■ Hydrogen ■ Motors

Hydrogen electric powertrain for aviation

Hydrogen-electric propulsion solution for short-distance aviation

One of the world's first practical, zero-emission aviation powertrain powered by a hydrogen fuel cell system and associated with proprietary software/controls, which can be installed on both existing and new aircraft. The solution initially targets existing airframes flying up to 500 miles, offering a zero-emission, hydrogen-electric propulsion solution for these distances. This is particularly relevant for short-distance, small-scale flights, such as those between Scotland's islands.

Benefits

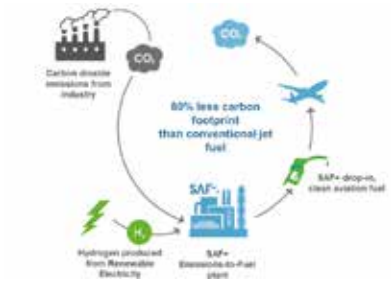
- **Estimates savings of up to 115 Mt CO_2 by 2033**
- **Operators can benefit from 50–60% lower operation and maintenance costs**

> Aviation ■ Fuel ■ Emissions

SAF+

Sustainable aviation fuel using innovative CO_2 conversion technology

SAF+ captures carbon and combines it with hydrogen to produce ASTM-7566 compliant jet fuel. By doing so, its jet fuel leads to an 80% reduction in life cycle GHG emissions when compared to conventional jet fuels. This helps airlines by complying with mandates set by international and national organizations seeking to meet their GHG reduction targets.



Benefits

- **One liter of SAF+ fuel needs only between 1.2 l to 3 l of water, or a 86% reduction compared with regular jet fuel**

> Maritime

Norsepower Rotor Sail solution

An auxiliary wind propulsion system for commercial and passenger ships

Freight Boats

The Norsepower Rotor Sail solution provides shipping companies with a way to reduce the environmental impact of their operations to meet tightening environmental regulations. The Norsepower Rotor Sails solution provides ships with additional thrust force by harnessing the wind, utilizing the Magnus effect. The solution provides the means to reduce operational costs and the risks related to the fuel price fluctuation. The Rotor Sail is the most efficient wind propulsion system known to the market and it can be used alongside other energy saving technologies. The technology used in Norse Rotor Sails has been proven to be reliable, easy to use and effective in delivering fuel savings.

Where is this Solution being used?

A partnership was established between Maersk Tankers, The Energy Technologies Institute (ETI), Shell Shipping & Maritime and Norsepower to install the rotor sails on a tanker ship. Two Rotor Sails were installed on the ship in August 2018, with testing and analysis at sea carried out until the end of 2019. Measurements were conducted by Lloyd's Register, confirming fuel savings of 8.2% during the first year of operation. The two Rotor Sails are expected to reduce average fuel consumption on typical global shipping routes by 7–10%.

Environmental and Economic Benefits

- **Annual fuel savings of 300–400 tons**
- **Reduction of yearly CO_2 emissions of 900–1200 tons**
- **Typical average fuel savings of around 5–20% per ship**

What this means for Scotland

- **Wind-assisted commercial ship market predicted to grow by £ 300 million per year in the 2020s**

Encouraging uptake

- **Effective use of the IMO's forthcoming Carbon Intensity Indicator and Energy Efficiency Existing Ship Index to identify ships' potential sustainability**

> Maritime ■ Freight ■ Retrofitting ■ Efficiency

Fluidic Air Lubrication (MPS FAL)

Add-on retrofit solution for ships that reduces fuel consumption by up to 20%, lowers emissions and controls fouling

An advanced fluidic air lubrication technology that reduces fuel consumption, emissions, and fouling, enabling ship owners to reduce operating costs by up to 20% and contribute to a better environment. It delivers important financial savings and reduction of emissions, controlled by artificial intelligence. Every ton of fuel reduced equals to 3.2 tons CO_2 saved.

Benefits

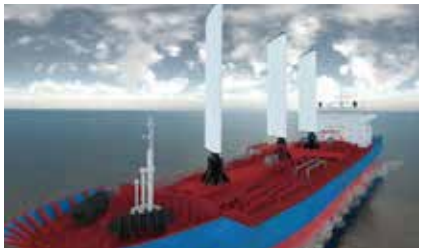
- **ROI of 2–3 years**
- **Up to 20% reduced fuel consumption**

> Energy Efficiency ■ Wind ■ Shipping ■ Mariner

bound4blue – Wingsail system for fuel efficiency in the shipping industry

Foldable wingsail system which brings fuel savings from 10% to 30%, to be used both in existing and newly built commercial shipping vessels

Bringing aviation technology to shipping, the wingsail system Bound4blue reduces fuel consumption to make maritime transport more efficient and sustainable. The solution may be installed on ships carrying liquids and having a surface available on the deck. Depending on weather conditions, the sails are retractable.



Benefits

- **Reduces pollutant emissions by 40%**
- **ROI under 5 years**

> Energy Efficiency ■ Maritime ■ Electric ■ Efficiency

Shore-to-ship power

Shore-to-ship power systems allowing vessels to plug into an onshore power supply and shut down their auxiliary engines while berthed

When ships are docked, they need power to support all the port activities such as loading, heating, or lighting, and they do this through highly polluting auxiliary engines.
Shore-to-ship power is a state-of-the-art electrification solution that can allow boats to use the electric grid for their activities while berthed, reducing overall emissions and increasing air quality in port cities.

Benefits

- **Allows harbours to reduce their environmental footprint**
- **Consumes 0.5 to 16 MWh depending on the type and size of vessel**

> Maritime

VACON® NXP Grid Converter

Alternative power for ships in port

Maritime Clean Generator

VACON® NXP Grid Converter enables ships in port to use an alternative source of power: the local electrical grid. By sourcing electrical power from the on-shore electricity grid via a set of cables, ships no longer have to rely on their auxiliary diesel engines to generate electrical power for communications, lighting and other on-board equipment. This helps to reduce not only carbon emissions, but also harmful air pollutants, helping to improve air quality in and around ports. This solution offers an innovative approach to help improve the sustainability of the maritime sector whilst delivering environmental benefits for coastal settlements.

Where is this Solution being used?

This solution has been used at the Coast Centre Base (CCB) in Bergen, Norway. Vessels visiting the CCB now benefit from significant power savings thanks to a shore supply system with VACON® NXP Grid converters, developed and delivered by SEC and Frekvensomformer.no. By avoiding running their auxiliary engines, ships save up to 5000 litres of diesel every day (equivalent to 1 to 1.5 MW power demand/generator size). The use of this solution is creating energy savings, whilst delivering cleaner air and a quieter port.

Environmental and Economic Benefits

- **Can save ships around 5000 litres of fuel per day**
- **Cuts harmful air pollution from ships**

What this means for Scotland

- **Global shore power market to grow by up to 13% CAGR by 2027**

Encouraging uptake

- **Stronger regulations are needed to reduce emissions in port, such as the IEC 80005-1 standard for HVSC on the west coast of the USA**

> Transport – Cross-cutting
Electric-Hydrogen propulsion solutions

A solution for clean, quiet and high power mobility

Public Transport **Hydrogen**

GreenGT's high-power propulsion solution can help to deliver market-ready, hydrogen-powered, heavy-duty vehicles. This solution generates no sulphur oxides, nitrogen oxides or carbon dioxide emissions, reducing emissions from heavy-duty vehicles as well as engine noise. Combining power, autonomy and fast refuelling time, hydrogen fuel cell trucks are a promising solution to meet the dual challenge of climate change and air pollution. This solution can help to reduce emissions from road transport in Scotland and ensure that trucks and other heavy-duty vehicles play a role in the journey to net-zero emissions.

Where is this Solution being used?

The solution provider is engaged in projects with two supermarkets: Carrefour (in France) and Migros (in Switzerland). The projects involve developing a 44 ton hydrogen propulsion system integrated onto a Kamaz truck platform. For the project with Carrefour, the 44 ton refrigerated truck has to cover up to 1000 km per day with one refuel. This will be the first one of its kind.

Environmental and Economic Benefits

- **Up to 900 tons of CO_2 saved per year for a truck (assuming use of green hydrogen and an average mileage of 100,000 km per year)**

What this means for Scotland

- **Road freight activity on course to more than double by 2050: solutions are needed now to reduce emissions from freight**

Encouraging uptake

- **Heavy Goods Vehicles and Light Goods Vehicles are significant contributors to road emissions (12.9% and 11.8%), thus incentivising uptake of Hydrogen trucks**
- **Switzerland has introduced a particularly high tax on heavy vehicles, which favours a rapid transition to more environmental energy, which has lead to Hyundai selling 1000 Hydrogen trucks in the country, which will create the beginnings of the necessary infrastructure and demand**

> Cross-cutting ■ Hydrogen ■ Vehcles ■ Fuel Cells

Stor-H

Compact hydrogen storage solution for use in light urban vehicles

The STOR-H solution is enabled by 3 key elements: an innovative cartridge that safely stores hydrogen, a distribution network of state-of-the art connected vending machines, and a smartphone app allowing users to easily access the STOR-H ecosystem and managing all user data. The STOR-H hydrogen cartridge stores hydrogen absorbed in a solid multi-material, multi-functional matrix at very low pressures (9 bars at 20°C).

Benefits

- **The total cost of hydrogen mobility is cheaper than its thermal equivalent**

> Cross-cutting ■ Biomethane ■ Trucks ■ Biofuels

Biomethane for clean transportation in Europe

Production and distribution of biomethane as fuel

Bio-LNG and Bio-CNG are the main alternatives to conventional fuel used to provide a response to the challenges of clean transportation. Refueling stations in Europe work as distribution centers and render these alternatives available to the public. The production of biomethane also occurs internally, allowing control over the entire clean mobility chain – from the production of biomethane to its usage through the supply of biomethane for road transportation.

Benefits

- **Reduces up to 90% of CO_2 emission and 70% of the NOx emission compared to diesel**

> Cross-cutting ■ Hydrogen ■ Vehicles ■ Efficiency

Antismog

Pre-combustion system adding hydrogen to a vehicle's fuel mix in order to reduce emissions

Hydrogen is added to the air-fuel mix which allows for a more complete combustion of the fuel, thus reducing the number of unburned gases and particles. Unlike filters or selective catalytic reactors, which are post-combustion technologies used today, the hydrogen fuel enhancement is a pre-combustion solution, which is the core of their innovation. Tests show a reduction of harmful emissions by up to 80% (up to 55% for NOx and up to 95% in terms of particles).

Benefits

- **Vehicle harmful emissions reduction up to 80%**
- **Equipment fully recyclable**

> Cross-cutting ■ Heavy-duty vehicles ■ Platform ■ Efficiency

Alertgasoil

Patented IoT sensing technology reduces CO_2 emissions of heavy-duty vehicles while reducing fuel costs

Heavy-duty Vehicles represent 25% of the total road transport greenhouse gas emissions. Thanks to a combination of hardware, firmware and software, the Alertgasoil's solution is designed to digitalize, monetize and optimise the fuel consumption chain of any company operating heavy-duty vehicles (road, rail, or even maritime transportation), no matter the fleet size.

Benefits

- **Reduces fuel consumption by 7% to 30%**
- **Reduces fuel costs by 13% to 17%**

> Cross-cutting ■ EV charging ■ Infrastrucutre ■ Road

Elonroad

High-tech electric road system autocharging all types of electric vehicles when parked as well as when driving

Elonroad is a high-tech electric road system that auto charges electric vehicles both while driving and when parked. Suitable for use by cars, trucks and buses, It can contribute to the uptake of EV's, especially given concerns around range anxiety, whilst also allowing for reduced battery size and thus cost.

Benefits

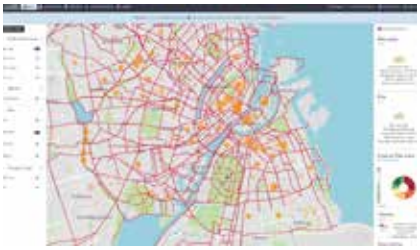
- **Conductive charging transfers high power up to 300 kW with a 97% efficiency**

> Cross-cutting ■ Vehicles ■ Sensors & Monitoring ■ Digital

Urban Radar

Efficient transportation planning for cities enabling the reduction of congestion, GHG emissions, and improvement of air quality

Urban Radar provides a sustainable and efficient solution to plan, execute and measure city planning. It sells a data visualisation and analytical software that transforms public and private data into actionable insights and analytics for planners (such as transportation companies and public consulting firms). It produces strategies and planning for cities at a fraction of the time and cost.



Benefits

- **30 to 50% more efficient than traditional city planning**
- **ROI in less than 1 year**

SOLARIMPULSE
FOUNDATION

Case Study

Supporting Scotland's Bus Industry

Public transport has a vital role to play in helping to reduce these emissions whilst also delivering a number of wider social, environmental and economic benefits. Buses are the most used form of public transport in Scotland, but in recent years bus patronage has undergone a worrying decline of 12% in the last five years, recently exacerbated by the COVID-19 pandemic.

However, the Scottish Government has ambitions for this sector. Scotland is home to the UK's largest bus manufacturer in Alexander Dennis Ltd, as well as Stagecoach, one of the UK's biggest bus operators. The bus industry supports over 13,000 jobs in Scotland and is worth £684 million to the Scottish economy. Supporting the creation of a sustainable and successful bus sector could lead to new markets and job opportunities whilst reducing emissions, with claims that electric buses will account for half of the market in 2025.

Magnax

Magnax has developed a yokeless, axial flux motor for electric vehicles. Compared to traditional EV motors, the Magnax electric motors are four times lighter and 3 times thinner, delivering increased vehicle range. Due to its compactness and short axial length, the motor technology brings opportunities for new powertrain solutions. Magnax estimates that their solution can increase vehicle range by as much as 10%, offering a more economically attractive and greater convenience for EVs.

Bringing extreme power density and efficiency to the future of EV powertrains.

Mazaro

Mazaro's innovative 'Single Stage Variable Transmission System' helps to extend EV driving range by delivering a more efficient transmission system. The SVT system helps to reduce energy losses when shifting through gears, a particular issue for 'stop-start' vehicles such as buses. The solution is able to handle the high torques required for large vehicles, and can be applied to both diesel and electric buses. This solution can extend EV range by at least 16%, and when applied to diesel vehicles, can reduce emissions by as much as 19%.

An electric truck fitted with this solution was able to travel 16.8% further and had a 50% higher top speed.

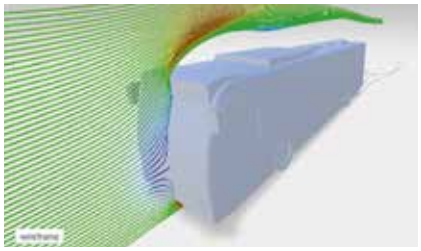
Engie's charge&go

To have a fully functioning and efficient electric bus system, charging infrastructure will be vital. Engie's charge&go offers a comprehensive, modular charging solution for bus fleets in urban areas whilst offering intelligent management and control of charging and recharging according to the capacities of the network.

Fleet charging station for e-buses for innovative and smart mobility projects.

AirShaper

To optimise vehicle design and efficiency, minimising aerodynamic resistance can be taken into consideration. AirShaper is a tool for optimizing the aerodynamics of vehicles which can be used to reduce fuel consumption of vehicles. Indeed, vehicle weight remains a key priority in reducing fuel consumption and extending vehicle range.



An automated online platform to analyze & optimise the aerodynamics of vehicles.

PowerRibs

The PowerRibs solution is a high-performance, lightweight, bio-based solution for vehicle interiors, using flax as a basis that allows the weight of interior panels to be cut by up to 40%, whilst using 80% less plastic.

Used in Volvo's demonstrator XC60 vehicle, delivering a 50% weight cut compared to mainstream panels.

04 Industry

Clean & Efficient Processes at the Heart of Tomorrow's Industry

The Scottish Government's Climate Change Plan seeks to achieve a 43% reduction in industrial emissions between 2018 and 2032. The industries in the Plan's scope are categorised into eight energy-intensive sectors with their total emissions accounting for almost 30% of the country's emissions, second only to transport. Notably though, three-quarters of all emissions from industries in scope occur in only seven sites and across three highly-polluting sectors (chemicals, oil and gas, and cement).

Indirect high-temperature heating processes employed in the oil and gas as well as petrochemical industries are the single largest category of industrial emissions (33%), whilst natural gas combustion is the biggest source of industrial emissions, followed by the use of internal fuels. However, nearly 80% of the energy demand for heating processes is met via internal fuel combustion, underlining the importance of Carbon Capture Utilisation and Storage (CCUS) process changes for decarbonisation. Additionally, indirect heating processes making use of steam account for some 29% of all industrial emissions.

The Scottish Government has identified three major pathways to reduce emissions in the industrial sector over the next 25 years:

By improving energy efficiency: Incremental improvements in energy efficiency would offer an overall moderate contribution (an average of 11%) but play a more important role in certain sectors (e.g. food and drink).

Through fuel switching: Or the replacement of fossil fuels with hydrogen, electricity or bioenergy.

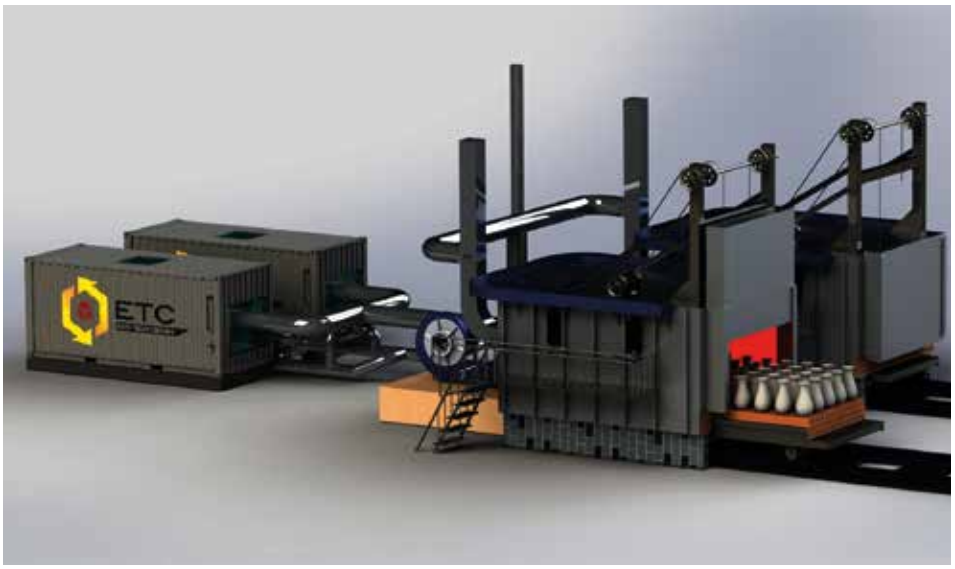
By implementing carbon capture, utilisation, and storage technologies – the main decarbonisation pathway for the highest emitting sectors, delivering some 60% of the required emissions abatement. Without CCUS, emissions would be 2.7 M t CO2e higher in 2045.

> Energy Efficiency

EcoStock

Mobile thermal storage solution for industrial waste heat recovery and renewable storage in recycled ceramics

■ Energy Recovery ■ Storage



This solution's purpose is to recover the heat contained in industrial fumes and store it in refractory ceramics made from industrial byproducts. This accumulated heat can either be used as a heating source – hot air at constant temperature level is provided (up to 1000°C) – or be converted into electricity. Each EcoStock unit could avoid 1000 t CO_2/ year, and produce heat at a price up to 80% lower than natural gas.

Where is this Solution being used?

Tegulys, a family-run tile and brick manufacturer in Haute Corrèze (France), requires heat to dry and bake its product. However, they lose more than 70% of the heat from the cooking. Installing the Ecostock allowed them to capture this waste heat and improve their energy efficiency by 10%, as well as reduce their energy costs and shorten the drying time of their tiles and bricks. In addition, Tegulys did not have to invest or take much financial risk, as the savings pay for the lease on the installation.

Environmental and Economic Benefits

- **Produces heat 80% cheaper than natural gas**
- **1 unit can prevent 8000 tons of CO_2 in its lifetime**
- **1 MWh of CO_2 free high temperature heat/per unit**

What this means for Scotland

- **The Thermal Ceramics Market was valued at USD 3.11 billion in 2017 and is projected to reach USD 5.02 billion by 2023, at a CAGR of 8.4%**

Encouraging uptake

- **Regulations can hasten the implementation of the solution as its profitability strongly depends on energy cost: increasing the carbon tax price will strongly impact the payback time of the solution, hence the interest from industrials**
- **Regulation on energy efficiency would encourage industrials to pay attention to the way they use gas – waste heat is about 20–40% of energy consumed today**

> Energy Efficiency ■ Energy Recovery ■ Oil & Gas

IoT Microturbine

Tool for recovering energy in the gas pipelines

This micro-turbine recovers energy lost during pressure variations in the gas pipelines.
The recovered energy can power the sensors needed for the monitoring and the maintenance of facilities. The innovation lies in the integration with the generator: this design, placed entirely within the gas flow, eliminates several couplings, bearings, seals and separate housings The losses from other transmission components are thus eliminated while maintaining optimum efficiency.

Benefits

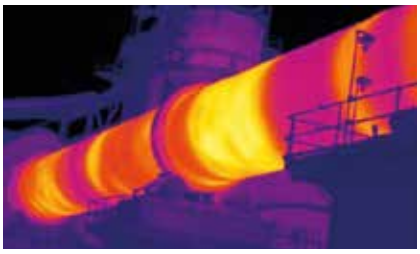
- **ROI in 1 year**

> Energy Efficiency ■ Heat valorization ■ Energy Recovery

Heat Recovery from Rotary Kilns

Heat recovery system in rotary kilns

Heat recovery system that captures heat lost from rotary kiln surfaces. The heat recovery panels are made of aluminium with copper pipes embedded in them: as the panel temperature is lower than the kiln surface, the heat radiated by the kiln surface is captured by the panels and transferred to the heat transfer fluid circulating in the copper pipes. The heat captured (between 90–110°C) can be used for power generation, boiler pre-heating, cooling or drying of raw materials.



Benefits

- **Captures 2.5–5% of heat lost which reduces overall input costs**

> Energy Efficiency ■ Motors ■ Industrial use

IE5 Synchronous reluctance motor (SynRM)

Solution to reduce energy losses in industrial motors

The IE5 level of efficiency is made possible by their design which combines the performance advantages of permanent magnet technology with the simplicity of an induction platform. The permanent magnets do not feature rare earth materials. IE5 SynRM motors can be used in several industrial applications where they offer accurate control and high efficiency even at partial loads i.e. induction motors in pumps, fans and compressors as well as in extruders, concha mixers, winches, and conveyors.

Benefits

- **Increased reliability lowers the TCO**
- **A 315 kW IE5 motor can reduce the CO_2 emissions by 22,000 kg /year compared to IE3 motor**

> Energy Efficiency ■ Software

METRON-EVA® Factory

Solution for the analysis and energy optimization of industrial sites

This platform aims to create efficient energy plants by detecting the types of energy used in real time (electricity, steam, compressed air, etc.). Using the data collected, the platform virtualizes the factory by creating digital models. With an algorithm linked to machine learning, this solution will then predict the energy behavior and continuously identify opportunities for optimization to reduce energy bills and environmental footprint.

Benefits

- **ROI in 1 year**
- **Reduced energy consumption up to 15%**

> Energy Efficiency ■ Manufacturing ■ Industrial ■ Energy storage

Tamturbo – Touch-Free Compressor Technology

A new industrial compressor technology providing energy, maintenance savings and lower TOC

This solution combines multiple tested technologies to provide a more efficient compressed air system for industries preferring oil-free compressed air. It is based on centrifugal (turbo) compression, high-speed electric motors, Active Magnetic Bearing technology and an ingenious control system. Together this results in significantly lower electricity consumption, practically maintenance-free use and one of the most reliable compressed air production system on the market.

Benefits

- **Saves up to 150,000 EUR/a per compressor**

> Energy Efficiency ■ Industrial additives ■ Lubricants ■ Turbines

Fill-4-Life

Lubricant making turbine last longer while emitting less CO_2

This new product helps to make oil more efficient and reduce its consumption in gas or steam turbines, compressors or gearboxes.

This solution is based on two patented products: the Infinity Turbine Oil (lubricant) and the Boost AO (additive). The additive can be recharged during the operation, increasing its life and reducing maintenance costs.

Benefits

- **40% savings over its lifetime compared to standard oils**

> Energy Efficiency

Starklab / TerraoSave

Technology to catch the pollution of fumes while recycling their heat, increasing the air quality and reducing energy consumption

Heat Valorization **Air Pollution**

The TERRAOSAVE technology consists of 3 main parts:
1. Extraction: A pipe is inserted on the chimney, allowing fumes to be extracted.
2. Heat exchanger: This allows a double circulation of the extracted fumes and of the water. The fumes are sucked out by a fan connected to the output of the heat exchanger, obliging them to pass into the water circulating and to go out through the fan. The fumes are condensed by the water, liberating latent energy and water.
3. Water circulation: Water circulates in a closed circuit integrating a treatment and filtration module. The energy contained in the hot water is transferred to other points of use. This energy can be used to preheat combustion gas, dry biomass or supply a heat network.

Where is this Solution being used?

The solution has been implemented for the recovery and reuse of waste heat in the animal nutrition industry (Ajinomoton) in Amiens (France) since 2016. The site has a 110 t / h steam boiler and a 12 MW solar Mars 100 turbine, with summer boiler operation and cogeneration from November to March. The steam used in the process does not allow it to be reused as it condensates upon return. The specific request was to preheat the boiler feed water with the waste heat released by the chimney, for a thermal requirement of between 300 and 750 kW depending on the site's steam demand, and to reduce the consumption of chemicals on the site – in particular to neutralize the boiler purges.

Environmental and Economic Benefits

- **The cost of installation is amortized within 3 years due to energy savings**

What this means for Scotland

- **The UK industrial sector consumes about 17% of the country's energy consumption leading to 32% of the UK's heat-related CO_2 emissions**
- **72% of the UK industrial demand is from thermal processes from which 31% is classified as low temperature process heat. Almost 20% of that has potential for industrial waste heat recovery**

Encouraging uptake

- **Implement standards restrictive enough/high enough carbon tax to force manufacturers to change**

> Energy Efficiency ■ Manufacturing ■ Digital ■ Smart-grid

Truegreen

Provides electrification, flexible consumption and energy storage to reduce carbon emissions, energy consumption and costs

GridManager II offers a Smart Grid solution involving energy storage and demand response to better manage energy consumption. Implementing this solution with Carlsberg in Denmark has allowed cooling and storage to become batteries for green power, reducing ventilation costs and indeed the total cost of ownership for a power-based system. By lowering costs and cutting energy consumption, this solution offers a profitable way to transition to carbon neutrality.

Benefits

- **ROI less than 1 year**

> Energy Efficiency ■ Software

Monitoring Industrial Greenhouse Gas Emissions from Orbit

Detection and quantification of GHG emissions in industrial sites

This solution allows users to identify and track emissions from industrial sites. It uses nano-satellites to study emissions of CO_2 and methane in the selected sites. Each GHGSat satellite orbits the Earth in a polar orbit enabling measurement of any source within days. As each gas absorbs light at different wavelengths the instruments are tuned to measure the amount of light absorbed at specific wavelengths, which in turn enables the quantification of concentrations of gases of interest.

Benefits

- **Cost reduction from 20–50%**

> Energy Efficiency ■ Software ■ data collection ■ Sensors & monitoring

Enabling Smart and Green Factories

A social manufacturing platform connecting man, material and machine

This solution is a cloud platform designed to address the needs of small and medium manufacturing enterprises. Without any manual interventions, Qpulse uses a variety of smart sensors to monitor, energy consumption, operations efficiency, workforce availability and productivity. Gathering this information, Qpulse generates electronic analytic reports and alerts enabling smoother processes and better decision-making.

Benefits

- **Increases managerial efficiency by 10%–20%**
- **Reduces energy consumption by 15%–20%**
- **Increases data archiving and retrieval efficiency by 30–40%**

> Fuel Switching

Fresnel Solar Steam Generator

Collectors which concentrate sunlight to produce steam up to 400ºC

Steam Production **Solar**

The solar collector is composed of uniaxially tracked mirror rows that automatically concentrate the solar rays onto an absorption tube, which is fixed above the mirrors. Water is circulated inside the absorber tube to collect the heat being converted into steam. The Fresnel collector is constructed in modules that are connected in series to increase the power output according to the customer's needs.
The system can provide temperatures up to 400ºC and cover a large share of the industrial heat demand which has steam as the heat carrier for several processes.

Where is this Solution being used?

Industrial Solar installed 18 Fresnel modules for direct steam generation at RAM Pharma in Jordan in order to reduce the fuel consumption of their diesel fired steam boiler. The total aperture area was 396 m² with a peak capacity of 222 kWth, directly connected to the steam supply of the factory. This led to a reduction in CO_2 emissions of 500 tons CO_2e/year and a reduction of fuel consumption due to the 1350 MWh of solar heat generated per year, amounting to 85,000 €/year.

Environmental and Economic Benefits

- **+ 25 years lifetime**
- **1 kWh generated = 216 g CO_2 avoided**
- **Additional costs for operating the system would be 0.01 €/kWh**

What this means for Scotland

- **Job Creation: 24 people/ MW of thermal capacity installed.**
- **Positive market growth was recorded in Germany (26%), Brazil (7%), Cyprus (7%), the Netherlands (7%), Turkey (2%), (2%) and Portugal (1.1%)**
- **Growth from 93 MWth in 2014 to around 850 GWth in 2030 (almost 10,000 times more capacity) to fulfil this potential. 700 GWth of the 850 GWth would be located in non-OECD countries**

Encouraging uptake

- **Countries need to set targets for renewable heat, accelerate capacity building for solution providers and off-takers, support project development and, most importantly, accelerate the uptake of suitable financing schemes which consider the investment constraints by industrial end-users**

> Energy Efficiency ■ Steam Production ■ Waste-to-Energy

HP2 steam generation

Innovative, high-performance, integrated steam generator, combining biomass preparation, condition and combustion

An innovative integrated steam generator with high performance, modern and proven technologies to prepare, condition and combust biomass, to be integrated with the rest of a common power plant technology to produce renewable energy. Compared to conventional approaches, HP2 steam generation presents an optimal complete combustion (up to +99%), reaching up to 92% efficiency compared to 80% for conventional fuel burners used in the boilers.

Benefits

- **30–40% less raw material consumption compared to conventional steam generation**
- **98% CO_2 reduction compared to fossil fuels**
- **Footprint reduced by 50%**

> Energy Efficiency ■ Heat Production ■ Solar

Heliac Solar Thermal

Solar thermic concentrators for large parks

This solution is designed for large-scale heat production through the Concentrated Solar Power (CSP) technology. It is based. on lenses which concentrate direct sunlight to generate heat up to 400°C. The lenses focus the sunlight onto receivers where it heats up a heat transfer fluid that flows through the receivers. The output temperature is controlled by adjusting the flow rate of the heat transfer fluid. The fluid then flows through a heat exchanger where it transfers the heat to the system.

Benefits

- **ROI in 3–5 years**

> Energy Efficiency ■ Heat Production ■ Solar

Concentrated Solar Thermal Solution

A platform to produce green heat for industries and cities

The CST platform seeks to provide high temperature thermal energy without CO_2 emission. The parabolic mirrors concentrate solar irradiation on a collector-tube in the focal line, generating temperatures up to 400°C in the collector. The thermal oil running through the collector tube is piped into a heat exchange unit. Depending on the customer application the exchange unit generates steam or heated thermal oil going into the industrial process of the customer.

Benefits

- **0 EUR CAPEX**
- **CST platform delivers close to 4x more energy per m^2 than PV**
- **ROI in 8–10 years**

> Fuel Switching

APT-HP High-power plasma torch

Alternative to fossil fuel burners by producing thermal energy from low-carbon electricity for use in industrial applications

Energy Production **Heat Production**

The high power of the APT-HP (up to 1 MW) enables a plasma plume exceeding 5000°C and transformation of (waste) materials into valuable products in various industrial settings.
The APT-HP offers a lightweight, vortex-stabilized, compact configuration which can be retrofitted into existing installations such as iron ore furnaces and cement kilns, and features long electrode life, low maintenance, automated operation, and a high level of safety and reliability. When replacing conventional fossil fuel burners, plasma torches potentially reduce operating costs by up to 30% and GHG emissions by about 250 MT CO_2e per GW·h when using hydropower.

Where is this Solution being used?

PyroGenesis Inc. has signed an initial contract to provide 1 high powered (1 MW) plasma torch to a major iron ore producer, for approx. USD 1.8 MM. The Client is a major international producer of iron ore pellets and has over ten plants, each possibly requiring up to 50 torches. Indeed, it is estimated that a typical pellet plant producing 10 million metric tons of pellets annually emits approximately one million metric tons of CO_2. The total world pellet production of 400 million metric tons of pellets represents a potential market for torch sales in excess of USD 10B worldwide and generates about 40 million metric tons of CO_2 every year.

Environmental and Economic Benefits

- **Can reduce operating costs by up to 30%, with the possibility of higher savings from carbon pricing**
- **ROI in less than 3 years**
- **99% reduction in GHG emissions**

What this means for Scotland

- **The iron ore market is expected to experience a yearly growth (CAGR) in production volume of 3.0% from 2021 to 2027. The yearly growth in revenues (CAGR) is evaluated at 3.4%**

Encouraging uptake

- **The availability of government grants helping to finance the purchase price of GHG reducing technology, such as the plasma torches, will greatly help the customers overcome the initial cost challenge of the upgrade**

> Fuel Switching ■ Steam production ■ Solar ■ Oil & Gas

Smart Solar Boiler for Industry

Smart concentrated solar boilers for industries

The system harnesses solar power to provide temperatures (80°C–300°C) for processes requiring steam, very hot water, cooling or intense heat. These collectors increase the intensity of the sun's rays by concentrating them on a central tube filled with a circulating heat transfer fluid. The heat is then transported to a thermal battery or directly to the process. This piping system is controlled by a smart control panel to optimise the heat transfer.

Benefits

- **Savings of 93,533 USD per year when replacing 1 MW LPG boiler**
- **1 MW Smart Concentrated Solar boiler versus a 1 MW LPG boiler saves 7,414 metric t. CO_2 in 20 years for the same quantity of energy**

> Fuel Switching ■ Hydrogen ■ Steam Production

Dynamic Combustion Chamber™ (DCC™ or Hydrogen Boiler™)

A hydrogen powered steam boiler for combined heat and power (CHP) producing only heat and water without ghg emissions

The design of the system allows the capture of heat for useable work from the enthalpy change, when two moles of hydrogen react with one mole of oxygen in an exothermic reaction, or when hydrogen gas combines with oxygen gas to form water. The water immediately flashes to superheated steam in a 2800°C environment, transferring heat from the tubes of the boiler to the water in the boiler shell to create cycle steam for heat and power without emitting GHG's.

Benefits

- **Almost half the cost of diesel without GHG**
- **A net saving of USD 2.3 Mio in average life cycle cost is realised with the system over diesel**

> Fuel Switching

Renewable gas for industrial burners

Enables industries to produce renewable gas on-site using local biomass for industrial burners and process heat

■ Waste-to-Energy ■ Industries producing biomass residue ■ Fuel

These cost-efficient and pre-fabricated gasification modules enable the production of renewable gas from local biomass residues directly at the customers' manufacturing plants.
MEVA's solution uses locally-produced biomass residues to create a renewable gas replacement, including fine fraction biomass such as sawdust, rice husks and wood fiber, which many industries currently struggle to dispose of. The decentralized, renewable solution creates a local circular system, cutting down costs and negative impacts.

Where is this Solution being used?

IKEA Industry has decided to implement this solution at one of their sites in Poland. The gasification solution will be used to generate combined power and heat through a genset. Processing wooden boards (MDF) generates wood dust contaminated with glue, which is considered a waste and leads to elevated NOx emissions if combusted. Hence, the plant pays to dispose of it while relying on Polish grid power at the factory. The fine fraction biomass residue is optimal in Meva's entrained flow gasification principle and the reduced atmosphere in the gasifier avoids the formation of NOx, enabling IKEA to reduce their CO_2 emissions (-14,000 tons CO_2/year), eliminate their residues, reduce their power purchase and heat their buildings.

Environmental and Economic Benefits

- **19% cost reduction for process heat**
- **Cost of combustion ranging from 25EUR/MWh – 50 EUR/MWh depending on feedstock**

What this means for Scotland

- **The total market is over 100 MEUR including both gas and combined heat and power application**

Encouraging uptake

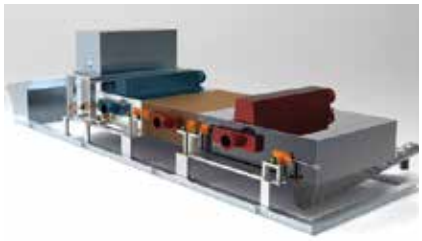
- **An environmental classification for gasification of wood board/ panel residues would make the environmental permit process easier**

> Fuel Switching ■ Biochar ■ Gaseous waste capture ■ Soil remediation

Horizontal Bed Kiln Technologies

Horizontal bed pyrolysis kiln

The pyrolysis kiln decomposes carbon to various forms of biochar, humic and fluvic acid. The solution distributes heat to each biomass particle that passes through it. It does this by a) spreading the particles out on a moving horizontal bed and b) applying direct heat to the particles via hot gas, in 3 stages, drying (~120°C), torrefaction (~250°C) and final pyrolysis (from ~250°–800°C). c) extracting the final solid product and cooling it.



Benefits

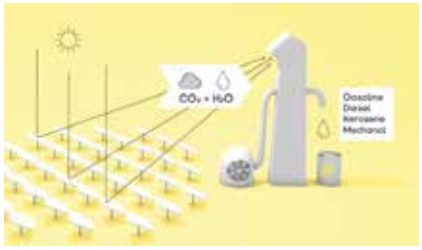
- **4x higher daily capacity at the same cost than the reference**

> Fuel Switching ■ Waste-to-Energy ■ Solar

Synhelion Solar Fuels

Turns CO_2 and sunlight into synthetic fuels, which are carbon-neutral and compatible with the existing global fuel infrastructure

Synhelion uses high-temperature solar heat to convert water and CO_2 into synthetic fuels – solar fuels. These fuels are compatible with the current global fuel infrastructure and reduce net CO_2 emissions by up to 100 percent. The solutions of Synhelion combine state-of-the-art solar tower systems with proprietary high-temperature thermochemical processes for the production of solar fuels.



Benefits

- **Short term cost is estimated at EUR 1–2/liter, long-term cost is at EUR 0.5-1/liter**

> Fuel Switching ■ Hydrogen ■ Fuel

Electric Reactors for Cleaner Hydrogen and Syngas

Supplying industry with low carbon, low cost fuel

This micro-reactor technology synthesizes hydrogen by reforming natural gas using renewable energy. The micro-reactors are designed to be heated from concentrated sunlight or clean electricity. The numerous process steps are integrated in a single monolithic unit, including the Steam Methane Reforming (SMR) reaction, water-gas-shift, evaporation, and heat recovery. The integration allows thermal losses of the high temperature sections to be recuperated, leading to thermal efficiencies up to 90%.

Benefits

- **10% cheaper than the mainstream alternative (Gas-Fired Steam Methane Reforming)**
- **5 x cheaper than electrolysis**

> Fuel Switching

SaltX EnerStore

Low-cost energy storage using nano-coated salt that stores electric power and releases heat and steam

Steam Production **Storage**

The patented solution provides a nano-coated salt (NCS) and oxide technology that is perfect for energy storage applications. To store the energy, the salt crystals are heated up with electricity or heat when available. When discharging the salt, high-quality steam (of up to 450°C)nis released and serves for many applications. The model system has four key components: two storage tanks and two reactors. The reactor size is flexible and can be custom fitted to the capacity required. The storage tanks are scalable and simple to install.

Where is this Solution being used?

A pilot was set up in Vattenfall's Rutger C plant in Berlin and was designed at a 0.5MW to 5 MWh. Wind power close to Berlin was used to charge the salt when the electricity price was low and then succesfully discharged into Berlin's district heating network. Results showed 72%–85% energy efficiency (electrical power to heat) – compared to the theoretical maximum of 92% Energy Density (Chemical) ≈ 500 kWh/ton (excluding sensible energy).

Environmental and Economic Benefits

- **Energy density of 500–600 kWh/ton**
- **ROI in 3–5 years**
- **€35 per MWh when commercialised, lower than the average molten salt energy storage system**

What this means for Scotland

- **Large scale energy storage is expected to grow with a CAGR of 25%+ in the coming 10 to 20 years**

Encouraging uptake

- **Tougher penalties for fossil fuels and/or governmental policies for the replacement of fossil fuels with excess wind and solar power in winter heating**

> Fuel Switching ■ Heat Production ■ Steam Production ■ District Heating

Absolicon T160

Solar thermal concentrator for industries and district heating

This technology provides heat and steam up to 160°C for district heating, cooling and industries. Easy to mass produce and install, it converts to heat over 76% of the direct solar radiation thanks to the tracking of the sun and an effective parabola (hollow, less than 2 meters). The collector is protected from dirt and abrasion with an anti-reflex coated hardened glass. With a control system from Siemens, the collector is following the sun within a fraction of a degree.

Benefits

- **Provides energy at €10/MWh to €40/MWh and without CO_2 emissions**
- **ROI 3–5 years**

> Fuel Switching ■ Heat Production ■ Steam Production ■ Solar

Vacuum Panels

Solar thermal panel for urban heating networks

This technology provides heat and steam up to 180°C for feeding into industrial processes and district heating networks.

The high-vacuum technology allows flat panels to exhibit minimal thermal losses and no degradation over time. Without the need for cleaning and only minimal maintenance, these 100% recyclable solar collectors can operate for 25 years to deliver emission free thermal energy.

TVP's solar fields generate usable heat year-round around 800 kWh/m² of panel/year on average.

Benefits

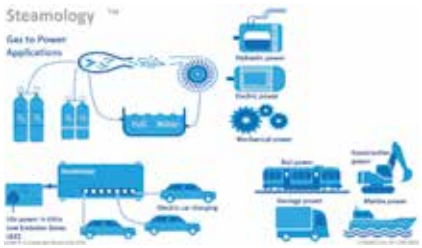
- **ROI in 5 to 10 years**
- **Reduces energy bills by up to 40%**

> Fuel Switching ■ Hydrogen ■ Energy Production

W2W Zero Emission Energy Generation and Storage

A solution for generating mechanical, electrical or hydraulic power from 10kW to 1MW with hydrogen and oxygen from sustainably powered electrolysis

At the heart of the W2W (Water to Water) system is a compact energy dense steam generator. Steam is generated by converting the energy stored as compressed hydrogen and oxygen gas in tanks into steam through clean gas combustion. The high-pressure superheated steam is used to drive a turbine to generate electricity. Clean energy is used to power electrolysis generating hydrogen and oxygen gas and to compress the gas into storage tanks.



Benefits

- **Total Operating Cost comparable to current diesel engines**

> Carbon Capture Utilisation and Storage

CryoCAP

Solution to capture and purify CO_2 from industrial gases

Applicable to Hydrogen and Steel Production **Cryogenic, membrane, adsorption**

This solution allows businesses to capture, separate, purify, compress and liquefy CO_2 from industrial gases. Based on the cryogenic technology, the goal is to store CO_2 and exploit it. This method can be used by many industries, such as refineries, metallurgical industries and oxyfuel processes.

The technology is a combination of membrane and cryogenic technologies, mainly powered by electricity. When fitted onto hydrogen-producing facilities, the solution enables the production of decarbonized hydrogen at much cheaper cost than electrolysis, and can be easily equipped on existing production units in the world. It also enables higher production of hydrogen from the same quantity of feedstock.

Where is this Solution being used?

The Zeeland refinery (a joint venture between Total and Lukoil) in the Netherlands will inaugurate a Cryocap™ Flue Gas plant in 2025 which will capture more than 90% of the emissions on the site's existing hydrogen production units and will have the capacity to liquefy 2400 tons of CO_2 per day. As part of its decarbonisation project, the refinery will be able to reduce its CO_2 emissions on the site by more than 800,000 t per year. The pure and liquefied carbon dioxide will then be transported for storage in the Dutch North Sea.

Environmental and Economic Benefits

- **30–50 € per t/CO_2 compared to 50–70 € per t/CO_2 for the alternative**
- **Up to 30% CAPEX reduction compared to mine Increase of H_2 production**

What this means for Scotland

- **Carbon Capture and Storage has a job creation potential of 1000–3125 future jobs in Scotland**
- **Capex savings are expected to total £1.3 bn between 2030 and 2050, focusing on the North Sea**

Encouraging uptake

- **Subsidies and/or tax favorable environment to trigger the investment decision for a CC plant**
- **Storage field of CO_2 needs to be developed to allow CO_2 sequestration**

> CCUS ■ Oil & Gas ■ Gaseous waste capture ■ Membranes

Cold Membrane CO_2 Capture Process

Technology to capture greenhouse gas (CO_2) from the stack of power plants or industrial sources

The technology consists of a hybrid membrane-liquefaction process to capture CO_2 from the stack gas of a power plant or other industrial sources, hence enabling electricity production from fossil fuel without emissions.

Benefits

- **Carbon capture cost of 40–45 USD / ton of CO_2 compared to 56 USD /ton for amine process**
- **90% CO_2 emission reduction**
- **Mitigates contaminants in flue gas (SOx, NOx, Hg)**

> CCUS ■ Anaerobic digestion ■ Biogas & biomethane ■ Algae

Industrial Carbon Sink

Industrial CO_2 capture solution based on the growth of micro algae in a closed photobioreactor and biomass revalorization

Solution capable of capturing large scale quantities of CO_2 from industrial emissions, with a negative carbon footprint based on the revalorization of the captured carbon.

The algae captures fine particulates, nitrogen dioxide and excess CO_2 and transform them into green energy. In cities, a carbon sink can absorb the equivalent of the pollution emitted by 150 vehicles.

Tests of the system showed reductions in the levels of fine particulates of about 66%–99%, and of nitrogen dioxide of 76%–97%.

Benefits

- **ROI of 6 years**
- **90% capture of fine particles (80% of NO2)**

> CCUS ■ Oil & Gas ■ Waste-to-materials ■ Gaseous waste capture

CCm Technologies Ltd

Transforming waste streams into low CO_2 footprint products

CCm Technologies converts carbon captured and other waste streams (ammonia, phosphate) into stable value-added materials for the agriculture, sewage treatment, food production and waste sectors. The significantly exothermic patented process is based on high primary capture efficiencies from novel cellulose/amine capture material which retain 95% of flue-sourced CO_2.

Benefits

- **ROI in 4.7 years**
- **15–18% in economic returns**

> Carbon Capture Utilisation and Storage
Carbon Recycling

A carbon recycling platform to make fuels and chemicals from waste emissions displacing fossil resources

■ Waste-to-Energy ■ Carbon-capture ■ Biofuels

Using bacteria, LanzaTech carbon recycling technology converts a variety of input streams ranging from industrial off-gases (refining, steel, ferro alloy), to unsorted unrecyclable MSW, biomass wastes and residues. LanzaTech uses a living, naturally occurring organism to ferment gases, such as carbon monoxide (CO), carbon dioxide (CO_2) and hydrogen (H_2), to make chemicals, such as ethanol, that can be used in consumer products and packaging. In addition, this solution is also able to convert the ethanol into a drop-in jet fuel.

Where is this Solution being used?

Through their innovative partnership, LanzaTech, Total and L'Oréal have premiered the world's first sustainable packaging made from captured and recycled carbon emissions:

- LanzaTech captures industrial carbon emissions and converts them into ethanol.
- Total converts the ethanol into ethylene before polymerizing it into polyethylene that has the same technical characteristics as its fossil counterpart.
- L'Oréal uses this polyethylene to produce packaging with the same quality and properties as conventional polyethylene.

Environmental and Economic Benefits

- **ROI in 3–5 years**
- **For PET fabric, 30% reduction in GHG emissions**
- **3.7x the revenue generation per unit of CO_2-rich gas fed process**

What this means for Scotland

- **Per facility around 20 FTW and 900–1500 indirect and induced jobs**
- **While there were no working CCUS sites in 2019, estimates suggest that by 2030 anywhere between 7000 and 45,000 UK jobs could ultimately be associated with CCUS, with Scotland securing 40% of the carbon storage element of a European CO_2 management market. By 2050 this could rise to 22,000–105,000 UK jobs**

Encouraging uptake

- **Increase price on carbon**
- **Support for capture of all carbon oxides (not just CO_2)**
- **Promotion of technology neutral or outcomes based policies: avoid being prescriptive or feedstock based policies**
- **Financing for scale up**

> CCUS ■ Chemicals

High Productivity CO_2 circular economy

Solution to recycle CO_2 into valuable products for the food and chemical industry

Equipment that recycles industrial loads of CO_2 by farming microalgae. It pays for itself by providing algae and extracts for the foods and feeds (spirulina, chlorella etc), pharma (carotenes, omega-x fatty acids), cosmetic and fine chemicals industries. The process' core is a patented device that optimises energy transfer to microalgae in an industrial photosynthesis process. The investment for large plants is computed at €0.10 per kg CO_2 recovered over the lifetime of the equipment.

Benefits

- **End products: 1/5 of the competition's manufacturing costs; 200x its productivity in kg/m²**
- **EUR 3–4/kg: provides end products at a competitive price**

> Industry – Cement

ECOPact green concrete

Concrete with lower-embedded carbon content, containing upcycled construction and demolition materials

Constructction **Waste-to-Materials**

ECOPact range offers sustainable concrete for high-performing and circular construction. The product is sold at a range of low-carbon levels from 30%–100% lower embedded carbon compared to standard (CEM I) concrete. ECOPact has a 30–50% lower embodied carbon content compared to a mix design with CEM I. ECOPactPRIME has a CO_2 reduction level between 50–70%. The product is technically more demanding providing a significantly higher reduction than the general standard available in a given market. ECOPactMAX exploits the technical possibilities to the maximum. This product pushes the technical expertise to offer a top of the line product with a CO_2 reduction greater than 70%.

Where is this Solution being used?

The project ran from 2017 to 2020. The project is a retail residential development in the centre of Edinburgh.

The solution provider was approached by a client (private sector property developer) to tender for 80,000 m^3 of concrete for the new St James Quarter development in Edinburgh. Consideration was given to reducing the carbon footprint of the concrete supplied to this project. The client therefore selected ECOPact Prime on a significant volume (c50,000 m^3). An average C50 RMX produced in CEMI is 360 kg CO_2e/m^3 and where compared to ECOPact Prime the average reduces to 169 kg CO_2e/m^3. On 50,000 m^3 this would save over 9500 t. of Carbon for the whole project.

Environmental and Economic Benefits

- **Reduced maintenance and repair costs of 70–100% compared to concrete**
- **ROI in less than 2 years**

What this means for Scotland

- **ECOPact could be used for a significant share of the total ready-mix concrete needed in Scotland (~2 Mio m^3 per annum)**

Encouraging uptake

- **Regulations following up on minimum recycled content of the materials to be used in major construction development projects**

> Industry – Cement ■ Construction & demolition waste

Aggneo®

Valorization of recycled aggregates from concrete waste in low-carbon concrete

Aggneo is an industrial dispositive aiming to recycle concrete waste by having dedicated platforms located near concrete plants and close to city centres (-2km). The process is a circular economy loop. An exemplification of the above is the LHB concrete plants in Lyon which transfer their waste to the Saint Fons platform, which in turn recycles it into aggregates for the road and for concrete.

Benefits

- **The operation of one platform can result in saving 100 kt of natural raw materials**

> Industry – Cement ■ Infrastructure ■ Recycled

TerraFlow

Specialized solution for more efficient backfilling in underground mines

TerraFlow is a specialized engineered blend of cementitious and other construction materials. It has been used in a number of soil mixing applications to improve the geotechnical requirements of native soils. It is specifically designed for paste or rock backfill of underground stopes and can reduce the total binder consumption when compared to portland cement.

Benefits

- **ROI in under 1 year**
- **Carbon cost saving = 5 EUR/ton assuming a carbon price of 50 EUR/t**
- **6-7% cost saving assuming cement price of 55 CHF/t**

> Industry – Cement ■ Industrial additives

CarbonCure

Retrofit technology that chemically mineralizes waste CO_2 during the manufacturing process to make greener and stronger concrete

A metering system feeds a controlled supply of pressurized liquid CO_2 through to a discharge conduit where it is delivered into the concrete mixer. The CO_2 converts from a liquid to a solid and gas as it is injected. The mineralized CO_2 forms $CaCO_3$ reaction products in-situ. An optimal dose of carbon dioxide can lead to increased compressive strength without negative impacts on other fresh or hardened properties.

Benefits

- **A concrete building made with CarbonCure reduces CO_2 by 25 pounds per cubic yard/17 kilograms per cubic metre through reducing cement by 5%**

> Industry – Cement

Solidia Cement™ and Concrete™

Cement production with reduced CO_2 emissions, and concrete production utilizing CO_2 during the curing process

Carbon-capture

The solution consists of the production of a low-lime, calcium silicate cement (CSC) as a replacement for ordinary Portland cement (OPC). CSC can be made in existing cement kilns, and it consumes less limestone and requires less energy than OPC all while reducing CO_2 emissions from the kiln by 30 to 40%. When CSC-based concrete is cured with CO_2, it costs less to produce, cures in less than 24 hours versus the traditional 28 days and has a higher durability than its OPC counterparts.

Where is this Solution being used?

The application of Solidia Cement was demonstrated at an industrial scale at a commercial OPC-paver manufacturing facility.

Solidia Cement was added to the existing production line, using all of the existing standard equipment for storage, mixing, pressing and material handling. The only change to the plant process equipment was the modification of the curing chamber to allow for the introduction of CO_2 for Solidia Cement carbonation as well as conditioning of the gas – the process where Solidia Cement is cured and CO_2 is consumed (typically a 24 h process). The mix design for the OPC-paver was slightly modified by changing admixtures and included a one-to-one replacement of OPC with Solidia Cement. Solidia pavers as well as commercially-available OPC pavers of similar dimension were tested for compressive strength (for an average of 10,000 psi), porosity and freezethaw durability in salt water with similar performance.

Environmental and Economic Benefits

- **Reduces energy consumption in the cement kiln by 30% compared to OPC production**
- **Saves up to 80% water**
- **Savings from USD 13–26/t. for the concrete producer**
- **Total savings at the cement plant: USD 6–10/t**

What this means for Scotland

- **Green Concrete Market size is projected to grow to USD 44.65 billion by 2027**

Encouraging uptake

- **The ETA process allows products to go through an accelerated approval process and receive clearance to be CE marked, providing new technologies a level market with incumbent materials**
- **Allowing for fast evaluation and classification of new technologies through ASTM (USA) and EN (Europe) standards for cement and concrete would speed the adoption process and lower the risk for the specifiers and concrete and cement producers**

> Energy Efficiency

SOLVAir

Flue gas-cleaning solution using sodium based sorbent for air pollution control by dry injection

Air Pollution Heat Valorization

When in contact with flue gases, SOLVAiR effectively neutralizes the acids to mitigate pollutants. With a bag filter, the sodium bicarbonate forms a homogeneous layer on the whole filtrating surface (filtration cake). This allows for the efficient neutralization of the acid gases while complying with the strictest emission limits and optimizing sorbent consumption. Thanks to its thermal activation, the milled sodium based product succeeds in achieving the highest abatement rates of acids with a very low excess. This result is achieved through a fully dry system with a silo, an injection system and a filter as equipment.

Where is this Solution being used?

The company AMSA needed to increase the energy production efficiency at their Waste to Energy plant to provide steam to a growing district heating network in Milan. The first step was to reduce consumption of energy in the Flue-Gas Condenser. (FGC). The implementation of a DeNOx system operating a catalyst required a low acid content at the inlet of the catalyst, to protect the catalyst, and a higher operating temperature. This was possible by modifying the previous FGC (using lime) with SOLVAir, and lead to an energy efficiency increase from 61% to 91%.

Environmental and Economic Benefits

- **No moisture: less corrosion, less maintenance**
- **Fully compatible with the most efficient nitrogen oxide (NOx) mitigation technology**

What this means for Scotland

- **Flue Gas Treatment Systems Market was valued at USD 55.11 billion in 2018**
- **Projected to reach USD 82.45 billion by 2026, growing at a CAGR of 5.2% from 2019 to 2026**

Encouraging uptake

- **Global / enforced regulation: controls are necessary for real regulation implementations**
- **EU / BREF revision: old Best available Techniques documents should be revised, for example Production of Cement, Lime and Magnesium Oxide, Manufacture of Glass, Iron and Steel Production, Refining of Mineral Oil and Gas**

> Energy Efficiency ■ Glass

3D Printed burners for flame applications

3D printing technology for lighter, more reliable and efficient burner for polishing application in the glass industry

This solution aims at improving the efficiency of the polishing step of glass articles during the manufacturing process. Once a glass article is formed by pressing molten glass in a mould, some defaults remain and need to be polished with a flame from burners. Where classical burners waste most of their flame in the atmosphere, this solution improves the flame efficiency, hence allowing for a reduction in natural gas and oxygen consumption and decreasing the CO_2 emissions assocaited with glass polishing.

Benefits

- **10% – 20% cheaper than the alternative depending on the number of units**
- **ROI in less than 1 year**

> Fuel Switching ■ Chemicals

Sustainable and cost-competitive chemicals production from biomass

Production of chemicals from biomass

This solution allows to enhance biomass by insulating two components: lignin and cellulose. The first allows for aromatic molecules for perfumes and food. The second is sold to the textile industry in order to replace the synthetic fabrics obtained from fossil fuels, and thus reduce their use. Bloom sources biomass feedstock from raw material suppliers, is versatile and any lignocellulosic feedstocks can be used – such as soft or hardwood, nutshells or peach pits.

Benefits

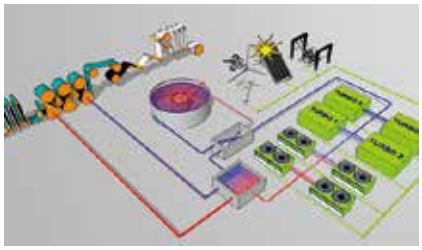
- **97% GHG emissions compared to the alternatives, mainly petroleum-based**

> Energy Efficiency ■ Storage

Cool Green Energy Factory

Innovative cold energy storage technology and integration into the energy cycle of the cooling process

The solution consists of two water circuits that are connected via a plate heat exchanger. The cooling circuit for the production process works as follows: cold water passes from a plant cooling tank to the production process, with the cooling temperature being dependent on outside temperature. The heated water flows back into the tank for recooling. Hence, the storage capacity of the fire tank can be used as an energy storage. Only in exceptional circumstances does the energy come from the grid. Any excess energy is used to cool the fire water down to 4°C as a means of storage.



Benefits

- **ROI in less than 5 years**

> Energy Efficiency ■ Iron ■ Applicable to hydrogen and Steel production

Nexelia for metal melting

Digital energy and resources saving optimisation tool for iron melting through supersonic oxygen injection into shaft furnaces.

This tool is dedicated to the metals industry and especially foundries, where shaft furnaces are used to melt metallic scraps together with coke to produce cast iron. BoostAL Digital technology consists of an oxygen injection system coupled with an advanced control system to operate shaft furnaces more efficiently – namely by increasing operating flexibility of the furnace, improving temperature homogeneity inside the furnace and finally by reducing maintenance/control operations linked to oxygen lances.

Benefits

- **Savings of 1000 t CO_2/year for a typical foundry production**
- **Yearly energy savings of 5600 MW**

> Fuel Switching ■ Liquefied Natural Gas

Powerfin

Producing carbon-free electricity from Liquefied Natural Gas cold, vaporising it in import terminals

Powerfin is a LNG vaporisation system for import terminals, able to produce carbon-free electricity using the otherwise wasted cold energy contained in the LNG. It is based on a thermodynamic cycle which achieves cold recovery and high reliability. The CO_2-free electricity can be exported and/or used locally. The environmental impact of the product depends on the CO_2 footprint of the electrical grid of the country: Powerfin produces on average 40kWh per ton of LNG vaporized.

Benefits

- **ROI in 10–13 years**
- **Reduce by up to 70% the energy consumption of the terminal**

> CCUS ■ Oil & Gas

THIOPAQ Oil and Gas Biodesulfurization System

An oil and gas bio-desulfurization system

Thiopaq allows the removal of H_2S from biogas and conventional gas production, and conversion of the H_2S into usable sulfur-based products including fertiliser. Thiopaq uses non-hazardous and naturally occurring bacteria to convert hydrogen sulfide into a sweet gas stream and solid elemental sulfur. Both are highly marketable products, the latter of which might otherwise be wasted, or burned to produce sulfur dioxide in the absence of an efficient separation mechanism.

Benefits

- **A 40% improvement in operating cost compared to alternative techniques**

> Other ■ Cleaning

Fouling Cleaning Software-Guided Power Ultrasound

Power ultrasound solution to keep industrial production equipment constantly clean without stopping production or using toxic chemicals

Altum's solution purpose is to clean and/or prevent fouling within industrial production equipment such as pipelines, heat exchangers, evaporators, valves and more, without the need to stop production or use toxic chemicals to achieve this. This is done via Altum's software-guided high-power ultrasound solution: the plug and play system is clamped on externally so there is no need to make changes to the target equipment in order to apply the solution.

Benefits

- **ROI in 6 months to 3 years**
- **100% savings in chemicals purchases for fouling cleaning/ prevention can be achieved**

SOLARIMPULSE
FOUNDATION

Case Study

Oil & Gas at the Core of Scotland's Transition

When looking at the industrial carbon footprint in Scotland, 75% of all industrial emissions are found in just three sectors – chemicals, oil and gas, and cement. The challenge to reach net-zero by 2045 is particularly consequential for the oil & gas sector, linked to 2.6 Mt CO_2 e/year in 2018.

Of course, the sector and its associated services have long played an important role in the Scottish economy, accounting for 10% of GDP and around 100,000 jobs. Investment in its decarbonisation is paramount, especially as it is expected to remain a £15 billion strategic sector through to 2050.

Concentrated Solar Platforms

The second largest emitting process in the oil and gas industry relates to indirect heating processes making use of steam, equating to 29% of all industrial emissions. Concentrated Solar Platforms targets industrial customers in need of process heat up to 400°C and creates this using parabolic mirrors, heating thermal oil running through the collector tube that is then piped into a heat exchange unit to generate steam, or fed directly into the industrial process.

A Belgian logistics company operating over 50 trucks used the solution to generate temperatures over 140c, reducing CO_2 by over 10%.

APT-HP

Where technically feasible, electrification of industrial processes is a major area of focus. A hard to decarbonise area due to geography is offshore platform electrification. Currently, three quarters of CO_2 emissions from offshore platforms come from combustion equipments that either provide the electrical power to the platforms or drive mechanical loads such as compressors, accounting for more than 8% of total UK power demand. PyroGenesis' APT-HP is a plasma torch capable of exceeding 5000°C that can be powered by renewable energy. When replacing conventional fossil fuel burners, plasma torches could potentially reduce operating costs by up to 30% and GHG emissions by about 250 MT CO_2e per GWh when using hydropower.

A high-power plasma torch offering a direct replacement for fossil fuel burners in industrial applications with greatly reduced greenhouse gas emissions.

HP2 steam generation

Industrial heating processes are the main cause of these emissions and are critical to the functioning of the industry, enabling industrial plants to reach temperatures above 850°C by passing process gases through furnace coils. Whilst substitutes are not always an option (hence the importance of CCUS), for those plants using organic waste to produce energy, HP2 steam generation can help them reach their cogeneration energy more efficiently, offering a substantial advantage over traditional furnaces with an optimal complete combustion reaching more than 99%.

An integrated, high performance biomass steam generator, already in use across several continents.

Dynamic Combustion Chamber

Another, the Dynamic Combustion Chamber (DCC) is also able to produce steam up to 400°C and does so by making use of a break-through method for burning hydrogen and oxygen in a vacuum chamber, allowing for 95% overall thermal boiler efficiency, and is 30% more efficient than conventional steam boiler. After the reaction, the fuel, now water, is collected in a closed loop system to be electrolyzed and returned as a fuel source.

Used at a commercial Sustainable cooling for a warming planet heating loop in Juneau, Alaska, to generate hot water, reaching temperatures of over 100c and reducing the use of 7,775 gallons of diesel per month.

Cold Membrane CO_2 Capture Process

As mentioned earlier, CCUS will be required for many processes, both during the transition and well into the future. Furthermore, the IPCC estimates that it would cost 138% more to restrict the rise in global temperatures to no more than 2°C without using CCS. Cold Membrane CO_2 Capture Process is one such technology that can lower CO_2 emission by up to 90% while also mitigating other pollutants, such as SOx, NOx and mercury.

A real-world tested technology to capture CO_2 from power plants or industrial sources.

SOLARIMPULSE
FOUNDATION

Case Study

Stop Emissions lock-in in the Building Sector

The Scottish cement sector is represented by a single site, the Tarmac plant at Dunbar. However, this one location emits about 0.5 Mt CO_2e/year, of which around 60% are process-related emissions from calcination. In 2018, the single-plant cement sector emitted 574 kt CO_2e, becoming the country's third most polluting industry.

To reach its sustainability targets, the Dunbar site is currently relying on waste derived fuels but additional improvements in energy efficiency, fuel switching, substitution and CCUS could contribute to the decarbonisation of the cement sector. Typically, it is assumed that a mixed-fuel kiln using biomass, hydrogen and electricity should be used in the sector. However, as 42% of all process emissions in Scotland occur from the calcination reaction within the cement kiln, abatement of emissions from this sector cannot rely on fuel switching.

Solidia

Labeled technologies such as CO_2 Cured could provide a partial answer to the challenge of reducing emissions from cement production in Scotland. Indeed, this technology produces a low lime calcium silicate cement (CSC) as a replacement for ordinary portland cement, and cures concrete by having it react with CO_2 rather than with H_2O. Effectively, CSC can be made in existing cement kilns, consumes less limestone, and requires less energy than the alternative, reducing CO_2 emissions from the kiln by 30–40%. Using the same raw materials, mixing equipment and forming processes as traditional concrete, the resulting concrete products cost less, cure under 24 hours (compared to 28 days for the mainstream alternative) and are more durable.

Clean cement and concrete technologies that produce superior products with reduced emissions at a profitable level.

CarbonCure

Similarily, CarbonCure is a retrofit technology that chemically mineralizes waste CO_2 during the manufacturing process to make greener and stronger concrete. Technically speaking, a metering system feeds a controlled supply of pressurized liquid CO_2 through to a discharge conduit where it is delivered into the concrete mixer and converted from a liquid to a solid and gas as it is injected. The mineralized CO_2, now $CaCO_3$, can lead to increased compressive strength without negative impacts on other properties. A concrete building made with CarbonCure reduces CO_2 by 17 kilograms per cubic metre by reducing cement-use by 5%.

Used for a mixed use project in Atlanta, using 36,700 cubic metres of concrete produced with the CO_2 utilization technology saving 680 tons of CO_2.

05

Waste & the Circular Economy

Reduce, reuse, recycle
Waste & the Circular Economy

Whilst the Circular Economy Bill from the Scottish Government has been delayed, the ambition and potential to develop new industries within the waste sector is significant. It is estimated that more than 8% of jobs – or more than 200,000 – are related to the circular economy, and a recent report indicated that a further 23,500 new and ongoing jobs could be created in the coming years. Indeed, research shows that for every 10,000 tons of waste created, 296 jobs in repair and re-use are generated, compared to only one job in incineration.

Importantly, Scotland has already reduced its emissions from waste significantly in recent years and recycling rates are at a significant percentage of 60%. Furthermore, the waste sector is only responsible for 4% of the country's emissions, suggesting that reducing emissions in other sectors may be more pressing – such as was highlighted in previous chapters. However, consumption of products and materials accounts for an estimated 74% of Scotland's carbon footprint, thus improving the means by which waste is treated could have a very significant overall impact.

Furthermore, developing this sector can have knock-on effects in other areas, such as transforming waste to energy, re-using raw materials, and reducing food waste, thereby making the most of existing resources and saving money for users and clients.

> Reduce Landfill Emissions

Wagabox

Novel solution to upgrade landfill gas into pure biomethane

Methane Waste-to-Energy

This solution extracts methane from landfill gas so that it can be injected in gas grids as a substitute for fossil natural gas. Methane is separated from air and other compounds with a process combining membrane filtration and cryogenic distillation.
The result is 98% pure, grid-compatible biomethane. More than 90% of the methane contained in the biogas is delivered to the grid.
Biogas from the waste of 100,000 inhabitants provides around 25 GWh per year, and can supply 3000 households or 200 buses, while preventing 4000 t of CO_2 emissions each year.

Where is this Solution being used?

Their first landfill gas upgrading unit began operating in February 2017 in Saint-Florentin, France. Having signed a 15-year agreement with the landfill operator to buy the biogas, the solution owner and their partners provided 3 million Euros. They get revenues from selling biomethane to gas providers, revenues that are shared with the landfill operator, which allows them to commission the first unit in only 12 months. The Saint-Florentin unit was the very first to inject landfill gas in the natural gas grid. They are now able to produce 12 GWh during the first year of operation and 20 GWh/year 12 months later. Since the commissioning, the Saint-Florentin unit has injected more than1.6 million cubic meters of biomethane in the grid.

Environmental and Economic Benefits

- **A landfill site can supply 3000 households therefore saving the emission of 4000 tons/year CO_2 eq**

What this means for Scotland

- **Each project will create 3 to 4 Full-Time Jobs (FTJ) for design, construction, then 1 permanent FTE per site for for the operation during 15 years (non relocatable jobs)**
- **Scotland wishes to double the number of landfill gas capture sites in Scotland that undertake investigative or development work (from 12 to 24 sites) by 2025 and will provide additional funding to support this. This will harness the energy generated from landfill gas capture and maximise circular economy opportunities**

Encouraging uptake

- **Promoting biomethane as a key pillar for the energy transition**
- **Public incentive of biomethane injection as its main drawback is its production costs (more expensive than fossil natural gas)**

> Enabling a Circular Economy

TPS Process

Delaminate materials from waste to enable recycling and reuse

Recycling

The TPS process solution has been designed as a semi-batch process to dissolve bonds between the different layers of materials from a complex product/waste. The operating principle is to insert a certain volume of product inside a reactor which is then sealed using pressure clamps. Supercritical CO_2 with co-solvents are then injected using high pressure pumps and heated to the chosen temperature. Treatment time is usually around 10 minutes. The reactor is then depressurized and delaminated waste are taken out. The entire process also includes a recycling and purifying line to reuse the CO_2 in a closed loop as well as a reuse system for the co-solvents.

Where is this Solution being used?

TPS Process is adaptable in size and capacity upon application and context; its cost directly depends on required throughput and reactor dimensions. I.e. a TPS Process with a 30 l reactor would be estimated 450 k€, but scale-up or scale out possibilities can be addressed. A TPS process with 3 x 30 l reactors in rotation, CAPEX would be around 900 k€ for a tripled production. Process OPEX varies upon waste characteristics and reactor heating/pressure needed.

Considering a single 30 L TPS Process to recycle e.g. cosmetic' packaging with an annual capacity of 60 tons (1x 8 hours shift/250 day per year), the annual OPEX to process waste would be around 4000 €, meaning an average 66 €/ton (without manpower handling the waste).

Environmental and Economic Benefits

- **Between 50% and 90% of the materials from waste become recyclable**
- **A 30L reactor costs 450 K and OPEX for a 30 l TPS Process to recycle 60t annually = 4000 € (66 €/ton)**

What this means for Scotland

- **Scotland's Raw Material Consumption was 100 Mt of materials (2017), or 18.4 tons per person, which is 38% higher than the global average**

Encouraging uptake

- **Destructive solutions for waste such as incineration or landfill still have low costs compared to more complex recycling solutions, which must be solved**
- **In France, producers have a legal obligation to pay an eco-tax calculated on the environmental impact and recyclability of their packaging as well as disposal fees**

> Enabling a Circular Economy ■ **Agriculture**

Afynerie

Converts the by-products of the agro-industry into raw materials, replacing their equivalent derived from petroleum

This green chemistry process contributes to a low-carbon and circular bio-economy replacing the petroleum derivatives in our everyday products. The non-food biomass fermentation (i.e. residues from sugar beet cultivation, which are otherwise of little value) enables the production of biomolecules intended for the cosmetics, flavors and fragrances, human and animal nutrition and fine chemicals.

Benefits

- **CO_2 emissions reduction potential of 31%**
- **Annual savings of 20 MWh**

> Enabling a Circular Economy ■ **Software**

Wasteloop

Fully electric waste management system

Citizens eliminate waste via compactors available 24/7 that are silently exchanged with a renewable-energy electric vehicle when full. The mini compactors compress the waste directly on site, significantly increasing the capacity of collection sites. The frequency of emptying is reduced, which reduces significantly the number of trips required.

Benefits

- **Reduces energy consumption by 80%**
- **Lower operational costs in waste management**

> End Landfilling ■ **Electronics** ■ **Recycling**

Pyrocycle

Recycles electronic waste without emitting toxic matters while minimizing the loss of precious metals and recycling plastic

This machine relies on a thermochemical process that separates metals from plastic at lower temperatures than smelters. In this process, the heat source powered from grid electricity is applied to the electronic waste to degrade the plastic, "free" the metals and separate the two components. The true innovation is the enabling of the plastic degradation without emitting toxic matters though adding carefully selected additives at very specific steps in the decomposition process. Gas from the degraded plastic can be then condensed, recovered, and reused as raw materials for various types of virgin plastic production.

Benefits

- **A facility using the technology to treat 1 ton of end-of-life circuit boards per week will recover 250 g of gold, 1,000 g of iron and silver and 300'000 g of copper**

> Enabling a Circular Economy ■ Software ■ Digital

Powering Connected Products and Circular Commerce

IoT Platform for the global identification and management of products and materials in circular economy

The solution creates connected products with a focus in fashion retail, in order to bring data into the circular value chain. A digital identity for each garment is generated when the brand issues the purchase order to the manufacturing partner. The digital identity stores all of the data of the product's purchase order (ie: product name, brand, color, size, material), as well as other data from the brand's ERP system.

Benefits

- **solution can contribute to cut by 70% CO_2 emissions by 2030 if policy measures for circular economy are adopted**

> Enabling a Circular Economy ■ Software

ZERØ

Software to help organisations manage their waste in an intelligent way

ZERO allows total traceability of all waste from its place of origin to its final treatment, streamlining the preparation of inspections, audits, and sustainability reports. The solution helps to ensure compliance with waste shipment regulations by providing a platform where customers can generate and directly access waste-related documents.

Benefits

- **100% automated waste management**
- **Emissions from data collection 95% lower than paper-based alternative**
- **90% of waste recycled due to more control over operations**

> End Food Waste ■ Sensors & Monitoring ■ Digital

Winnow

Food waste reduction digital tool for chefs and canteens

Winnow connects commercial kitchens to the cloud allowing them to record and analyse exactly what is put in the bin – and what they waste. Using a camera, a set of smart scales and machine learning technology, Winnow Vision 'learns' to recognise different foods being thrown in the bin and calculates the financial and environmental cost of this waste. Businesses and chefs can then adjust their food purchasing decisions accordingly, reducing their spending.

Benefits

- **33,000,000 USD in total savings from Winnow users**
- **40–70% reduction in food waste within 6–12 months**

> End Food Waste

MEAL CANTEEN

Anti-waste solution in collective catering to know in advance the affluence and the choice of the guests

Food waste **Software**

The solution can be seen as two main components: on one side, a web and mobile application allows clients to see their catering daily menus, and to make their choices by ordering the food items they would like to eat in advance. The customers can also rate their experience after each meal, giving a feedback to their kitchens.
MealCanteen also provides the kitchens with the tools allowing them to manage their menus, to see the daily orders and review the ratings. MealCanteen has developed algorithms to predict precisely how many people will eat in a given day, based on various parameters, mainly the historical data for a given restaurant and the real attendance numbers collected on a regular basis.

Where is this Solution being used?

The Anne Frank high school in Saint-Just-Saint-Rambert is attended by some 600 students. 90% of them have a Meal Canteen account each day around 230 orders are taken by the students. The canteen staff can see in real-time the orders and thus plan accordingly, with the students receiving their orders during the lunch break. This helped kitchen staff to save by avoiding food waste. Meal Canteen splits the savings with them and charges only 0.33 € for each order. Compare this to the figure from the French Environment & Energy Management Agency, ADEME, which estimates that 0.68 € worth of food is wasted each meal.

Environmental and Economic Benefits

- **Avoided 88 tons CO_2 related to food waste through more than 95,000 orders**
- **Cost reduction of 18–23%**

What this means for Scotland

- **ADEME estimated the average food waste per meal at 0.68 €**
- **This market is chronically declining by 1 to 2% per year due to new forms of competition with food trucks or meal delivery**

Encouraging uptake

- **The normative inclusion of an obligation to reserve meals in collective catering would make it possible to initiate a significant and impactful change**
- **France is the country whose legislation is the most advanced in establishing the principle of compulsory reservations. Luxembourg had also tested compulsory reservations in its higher education establishments**

> End Food Waste

Boxilumix

A lighting solution to decontaminate fruits & vegetables allowing longer conservation, reduction of food waste and chemicals usage

Pest control Chamical alternatives

The solution is an intelligent lighting device using a database for the treatment of fruits and vegetables. It is both a product and a service, as the company provides technical support in setting-up, maintaining and improving yields, shelf life and quality. The system relies on the latest technologies applying smart-LED light which allows a modulation of a combination of precise wavelengths with a reduced energy consumption of 90% compared to pulsed lamps. The system applies specific light on the target to be treated, depending of predefined parameters. This activates the natural mechanisms of the plant allowing decontamination, better preservation and/or quality enhancement.

Where is this Solution being used?

The solution has been tested in Toulouse, France in 2020 on carrots for a month from the day they were harvested. A significant improvement was observed, with the vegetables preserved for much longer: shelf life extended from 4 days in a dark, refrigerated location to 28 days when treated with Boxilumix. The carrots only lost 20% of their mass compared to 80% normally, and they remained rigid and visually similar to how they did the day the experiment began.

Environmental and Economic Benefits

- 10 x less nitrogen fertilizer needed on carrot or lettuce
- 100%–400% shelf life extension
- Up to 90% energy savings

What this means for Scotland

- The fruits & vegetable segment dominated the food waste market and held the largest market share of 32% in 2020, largely due to the large amounts of waste generated from fruits & vegetables along with tubers and roots

Encouraging uptake

- The European regulation on functional and novel food should be clarified for start-ups

> End Landfilling

The Ways2H Hydrogen solution

A thermochemical process converting waste streams, such as municipal solid waste, sewage sludge, plastics, into clean hydrogen without incineration

Waste-to-Energy Hydrogen

Ways2H aims to solve two problems: demand for renewable hydrogen to replace fossil fuels and reduce greenhouse gas emissions for transportation and power generation, and the need for sustainable and affordable waste disposal. This solution seeks to improve the global environment by eliminating waste while producing carbon-negative renewable hydrogen. With 95% of hydrogen fuel currently produced from natural gas or other fossil fuels, the world needs new sources of renewable hydrogen to reach a carbon-negative future. The thermochemical process producing the syngas leaves char as a byproduct, which is virtually pure carbon. The char is collected and used as fuel together with the remaining tail-gas to generate the energy needed for the thermochemical conversion of the waste feedstock. Therefore, the system self-supplies the energy and heat it needs to operate and produce hydrogen and does not require any outside fuel except to start up a new unit for the first time.

Where is this Solution being used?

The solution is implemented in Martinique (French Caribbean) to address a dual problem: The first aspect being that of waste management, with a fraction of the waste being shipped to mainland France (8000 km away) and the only local landfill being expected to reach saturation within 5 to 10 years.

Environmental and Economic Benefits

- **1 ton waste or biomass feedstock yields 50 kg hydrogen**
- **One 24 ton/day system provides 1.2 ton hydrogen**
- **Potential to reduce waste hauling mileage by → 75%**
- **Reduction of landfill waste by → 80%**

What this means for Scotland

- **The global waste market will increase from 2 billion tons today to over 3 billion tons by 2050 (WorldBank)**
- **Energy consumption around the world is set to increase by 50% between 2018–2050 (EIA)**

Encouraging uptake

- **Several countries fail to recognize thermochemical conversion (gasification) of waste as a viable pathway to replace incineration or landfilling**

> End Landfilling ■ Waste-to-Energy

Large-scale urban/ocean plastic carbon recycling

Recycling plastic from oceans and cities into fuel

The technology employs a four-step thermochemical process; 1) Feedstock preparation: The waste/plastic is first sorted and shredded. 2) The resulting material is fed to a fluidized bed gasification vessel to be broken down, and these molecules are then blended with steam to produce pure and homogeneous syngas. 3) The syngas is fed into a cleaning and conditioning process. 4) The last component is the catalytic conversion of the syngas into liquid methanol and fuel grade ethanol.

Benefits

- **Reduces GHG emissions 600 kg CO_2eq/ton vs. incineration**

> End Landfilling ■ Methane ■ Waste-to-Energy

Methavos

Biogas, electricity and green fertilizer produced in a turnkey dry methanization plant to recover biowaste

This dry methanization solution produces both biogas and green fertilizers as nitrogenous compost. This technology operates in a thermophilic regime (55°C) over 21 days with a dry matter content representing 25% of the raw material. This process allows the introduction of a wide variety of inputs (agricultural, industrial and urban organic waste) and is designed around a zero-nuisance odour objective. The biogas can be used directly on cogeneration units, as fuel for vehicles or even be injected into the city gas network.

Benefits

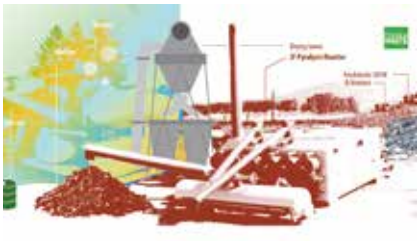
- **1 t of bio-waste is equivalent to the amount of energy contained in 70 l of diesel**
- **0% water added in the anaerobic digestion process because that already contained in the bio-waste is sufficient**

> End Landfilling ■ Waste-to-Energy

JF System

Technology for the conversion of post-recycling municipal/ plastic/agricultural waste into products

This system uses a slow pyrolysis technology to convert waste into products (bio-oil, biogas and biocoal/biochar) to use as soil amendment and fossil fuel replacements, to produce secondary products or to generate electricity with a hybrid generator. Pyrolysis technology converts feed-stock into products by heating them between 300–700°C in the absence of oxygen. The process is self-fueling: as the gases released during the pyrolysis process are reclaimed as bio-oil or biogas, part of the biogas is used as fuel for the reactor furnace.



Benefits

- **Processing capacity 1–3 tons per hour**
- **10 t. of dry biomass generates 4 t of biochar**
- **The waste disposal option reduces 90% of CO_2eq emissions and increases carbon drawdown by 55% compared to a disposal site**

> End Landfilling

Modul'O

A containerized, standard and modular digester that transform organic wastes into renewable energy, fertilizer and water

Waste-to-Energy **Food – municipal solid waste** **Anaerobic digestion – waste treatment**

The solution is based on a biological reaction that degrades the matter and fix the contained carbon into biogaz and the organic elements into liquid fertilizer. The basic module is a digester providing the right conditions for the bacteria's development. It is designed in a 20 foot container (capacity of 250 kg/y) that is fully modular and automated. Modules can be added to enable collection reception, cleaning, depacking, pre-treatment, co-generation etc.

Where is this Solution being used?

Modul'O's first demonstrator is in development in the Yvelines and currently treats the food waste of all the restaurants of the "departement" (or county) middle schools as well as a handful of additional private local actors for up to 8000 t/y. The turnkey solution includes the development, construction, exploitation and maintenance during over 15 years.

Environmental and Economic Benefits

- **ROI of 4–8 years depending on size and customization of the unit**
- **Reduces the cost of food waste management by reducing its collection by up to 100 €/t**

What this means for Scotland

- **The industrial Anaerobic Digestor sector is the largest in the country for biogas production, with 84.6 million m^3 produced in 2017**

Encouraging uptake

- **Measures to support investors in EU (tax financing) would lower their risk and provide a resilient business environment**
- **Improving regulations on collection, sorting and design for recyclability will help reducing the recycling cost**

> End Landfilling ■ Waste-to-Energy

Notar®

Production of clean synthesis gas from biomass

This process produces clean synthesis gas from biomass. Its principle lies on the physical separation of the three phases of the process: Pyrolysis, Combustion and Reduction. These reactions take place in dedicated zones and parameters are controlled. This design base is what allows the reactor to produce a clean syngas without tar residues and directly compatible with biomass cogeneration engines.
The main step is pyrolysis, which also helps eliminate heavy metals and organic pollutants.

Benefits

- **Emits 40x less CO_2 than fossil fuels**

> End Landfilling ■ Waste-to-Energy

Gazeotherm

Biomass plant using green trimming as fuel for heating and Combined Heat and Power (CHP)

This solution turns green waste into thermal and electrical energy in small scale plants, from 500 kWth to 5 MWth.
The plants can adapt to multiple kinds of green waste thanks to big data optimisation. Shredded biomass is transported from the biomass storage unit into the gasifier where it is converted into syngas. The syngas is then burnt in a post combustion chamber connected to a recovery boiler. A range of biomass are compatible (green waste, crushed branches, wood residues or rice husk.)

Benefits

- **To heat an aquatic center (4300 MW h/year), the system can use 2000 tons of local green waste = representing 200,000 €/year**

> End Landfilling ■ Waste-to-Energy

KubeKo

Clean energy production from biomass

Integrated waste management approach using green chemistry to generate value from excess biomass and includes a smart micro-grid to distribute the biogas and electricity. The approach relies on biological treatment for wastewater and sludge, namely Anaerobic Baffled Reactors (ABR) to hydrolyse and perform the acidogenesis and acetogenesis phases and Upflow Anaerobic Sludge Bed (UASB) Reactors for high rate methanation to produce the biogas. The units generate clean gas, electricity and a nutrient rich liquid digestate.

Benefits

- **Purification of the digestate to produce fertilizer for local use**
- **Reduction of GHG emissions by 80%**

> Enabling a Circular Economy

REE4EU

Closed-loop rare earth recycling process that allows a sustainable access to raw materials

Electronics Recycled Landfill

The rare earth contained in the permanent magnets are recycled following two steps: retrieving oxalates and rare earth oxides (REE) and then making an alloy in ingot form. The REE-Extraction Process is a leaching process involving low-cost and environmentally friendly solvents. In this step more than 90% of the REE contained in the wastes is extracted as pure REE-oxalates (→ 99.5%). Specially designed reactors allow to use metallic-wastes as big ingots, avoiding the use of metallic powder material. In the High Temperature Electrolysis (HTE) step, the REE-oxalate mixtures obtained are calcined (standard process) into pure REE-oxide mixtures. The electrolysis process allows using the REE-oxide mixtures directly into the HTE reactor and obtain REE-alloys suited to be used in the manufacture of new products.

Where is this Solution being used?

The solution has been validated and demonstrated in an industrially relevant pilot in the case of two value chains, namely neodymium permanent magnets and nickel metal hydride batteries for hybrid and electric vehicles. The REE final products manufactured with the recycled material showed the same properties as those made from virgin materials. Moreover, the results obtained during the pilot trials showed outstanding environmental gains of the REE4EU solution, not only because it will reduce landfilling, but also because the technology has undeniable environmental improvements, especially on the Climate Change impact category (kCO_2 eq). It also highlights competitive cost compared to the conventional scenario of primary REE extraction (mining) in China.

Environmental and Economic Benefits

- **Material yield close to 100%**
- **Total current efficiency close to 75%**

What this means for Scotland

- **The EU is the largest importer of China's rare earth magnets with (52% of exports), for → 9 B EUR/ year. This dependency will become crucial, as the global market size for RE magnets is expected to grow at 6% CAGR**

Encouraging uptake

- **Measures to support investors in EU (tax financing) would lower the risk for investors and provide a resilient business environment**
- **Improving regulations on collection, sorting and design for recyclability will help reducing the recycling cost**

> Wastewater Treatment

Aqua Assist

Biocatalyst for wastewater sludge reduction

Sludge | Anaerobic digestion – waste treatment | Biogas & biomethane – biofuel

The biocatalyst accelerates microbial activity and the degradation of organic matter through biological digestion – either aerobic and anaerobic depending on the application. Aqua Assist has been successfully applied to wastewater treatment and industrial pig farms, remediating sludge and manure. Biosolids reduction between 30% and up to 70% has been repeatedly observed as the main impact of using the solution. In addition, findings from university studies include odor and hydrogen sulfide reductions of up to 43% and 50% respectively.

Where is this Solution being used?

South Deerfield Wastewater Treatment Plant is a facility that serves a town of 1800 people in Massachusetts, USA. The challenge was not capacity but cost as the facility faced tripling waste-hauling costs. A 3-month trial started in Nov 2017 and provided product based on the plant's size, flow and configuration, along with technical support and assistance. No capital investment was required. To jump start the population of Aqua Assist microbes in the system, the plant began by adding 2lb of product per day to the aeration tank. After the initial weeks, the dosage was reduced to 1lb/day. By August 2018, biosolids were reduced by 78% vs. Aug. 2017 volume.

Environmental and Economic Benefits

- **Up to 10% reduction in chemical costs**
- **Reduced methane emissions at landfills (-0.43 kg/ton of sludge): (with an estimated of 0.43 kg of methane per ton of sludge)**

What this means for Scotland

- **The global wastewater treatment services market is predicted to grow from USD 48.5 billon in 2019 to USD 65.1 billion by 2025 with sludge management alone making up at least 25% of that market**

Encouraging uptake

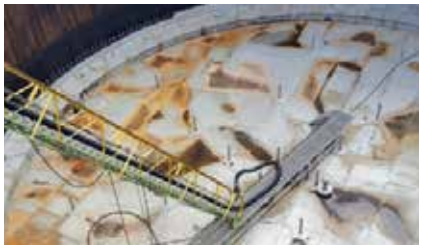
- **High costs of sewage sludge disposal, and stricter regulations on reducing environmental footprints of wastewater treatment plants**

> Wastewater Treatment ■ Non-hazardous ■ Nanotechnologies

MagnetoSponges

Magnetic micro-sponges providing an economical and sustainable waste water and gas stream treatment

MagnetoSponges are micron-aggregates of magnetic nanoparticles and are able to remove by absorption different type of pollutants from hydrocarbons, organic compounds to metals. The use of this technology enables water to be recycled directly on site and reduces the amount of space needed for purification infrastructure while being suitable for use on-site as a turn-key service or even in mobile water-treatment plants. It can also be used for gas stream treatment and purification to reduce the presence of volatile organic compounds.



Benefits

- **30% reduction in energy consumption compared to mainstream alternative**
- **40% cost saving for treatment on-site compared to through external providers**

> Wastewater Treatment ■ Filtration & purification

Biosfilter

A brand new technology that removes chemical and biological micropollutants from water

Treatment to depollute drinking water and wastewater plants from micropollutants. The solution uses a new polymer, developed as an agent at capturing micropollutants: the molecule is based on natural components stemming from green chemistry researches. In Waste Water Treatment Plants, this molecule captures all kinds of micropollutants, merely by fixing a filter column at the end of the treatment process. Once the content is released, it can be recycled up to five times.

Benefits

- **Neutralises 85% of pollutants compared with 35% for techniques currently in use**
- **25% less expensive**
- **No capital expenditure**

> Wastewater Treatment ■ Irrigation ■ Filtration & purification

OXYSTRONG® 15 for reuse in irrigation of disinfected wastewaters

Disinfection of treated urban waste water to reach the high quality standard required for water reuse in irrigation

The water treatment process for municipal wastewater comprises several steps such as sedimentation, filtration, digestion and disinfection before discharging waters back in the environment. This solution functions on peracetic acid, a strong biocide with high bactericidal, virucidal, fungicidal and sporicidal effectiveness. This acid works by disrupting the chemiosmotic function of the lipoprotein cytoplasmic membrane by dislocation or rupture of the cell walls, impeding cellular activity.

Benefits

- **10% reduction in CO_2 emissions compared to sodium hypochlorite**

> Wastewater Treatment ■ Cooling ■ Ventilation ■ Buildings

VLT® Aqua Drive FC 202

AC drive for wastewater treatment

VLT® Aqua Drive FC202 is a variable speed drive for motor control on rotating equipments such as pumps and blowers in water or wastewater treatment plants. As a type of adjustable-speed drive, the VLT AQUA Drive controls the speed of the desired machine, making it economically feasible for the user to have full control. Its high lifetime availability and low energy consumption and maintenance costs provide users with the lowest cost of ownership.

Benefits

- **Energy saving of around 3–8%**
- **First-year cost savings between 10–30%**

> Wastewater Treatment ■ Soil remediation

Mobile on-site soil and wastewater treatment machine (MST)

wastewater decontamination with conversion rates of up to 97% achieved within one hour

Soil remediation based on two proprietary processes of simple on-site and real-time synthetic generation of highly concentrated superoxide radical, stabilization, and implementation of this unique radical and oxidizing agent as a soil treatment material. The solution can be applied for the rapid remediation of all commonly encountered soil contaminants such as Hydrocarbons, TPH, BTEX, Petroleum waste, Aromatics, PAH, Chlorinated Solvents, PCB, Dioxins, Pesticides and Herbicides from 1 ppm up to 100,000 ppm at a fraction of the cost.

Benefits

- **Emits only 0.1 tons of CO_2 compared with 2.5 and 4 tons respectively for bioremediation and incineration**
- **Save €10–40/ton of soil, and treat previously untreatable soil that would otherwise be landfilled or incinerated**

Case Study 1

Putting an end to Landfilling

The Scottish Climate Change Plan Update calls for an ambitious target of a 52% reduction in emissions in the waste sector by 2032, and significant progress has been made already with emissions from waste having halved to 4% of total national emissions between 1990 and 2018.

Pellenc ST

To help meet this target, interim milestones have been put in place for 2025, including putting an end to the landfilling of biodegradable municipal waste; reducing the overall waste sent to landfill to 5%; and recycling 70% of all waste.

Pellenc ST can help to ensure different waste streams are valorised and diverted from landfills by optically scanning and automatically sorting complex materials. Waste is placed on a high-speed conveyor belt above which the optical scanner sits, identifying the waste that passes below it and triggers blasts of air to blow the material into the right place according to the specified sorting strategy. High quality sorting enables the sale of rPET from 800 USD/t to 1,240 USD/t, reducing the price gap between recycled and virgin materials.

A multi-material optical sorting machine designed to recover recyclables from household and commercial waste.

Wagabox

To reduce the emissions generated from waste that can not be diverted from landfills, the government plans to make use of landfill gas capture technologies: in 2018, the emissions resulting just from the management of residual waste amounted to 422,892 t CO_2e. In order to avoid the atmospheric loss and flaring of the methane-rich biogas generated by landfill waste, Wagabox upgrades it into grid-compliant pure biomethane, packaged in an automated plant about the size of a basketball court. This process enables the recovery of 90% of the methane and produces a 98% pure biomethane ready to be sent to an injection station nearby.

Used in Burgundy, France, producing 12 GWh in the first year and using over 1.6 million cubic metres of biomethane.

Ways2H

Given the strong trend in the reduction of waste landfilling, the sector has seen a 72% increase in incineration. Attached power plants cannot be considered a low-carbon energy source given their high carbon intensity – hence the pressing need to make these more energy efficient. Nevertheless, sending them one ton of residual waste in 2018 led to 246 kg CO_2 e/t, which is still 27% lower than the resulting emissions from sending the same content to a landfill site. Ways2H seeks to divert waste from landfills and upcycling it to create valuable clean energy – hydrogen. The self-fueled thermochemical process consists of cracking chemically organic materials into their gaseous components in an inert atmosphere, or without combustion of the feedstock. The Ways2H process handles biomass, sewage sludge, food waste and municipal solid waste amongst others and the process leaves only char as a byproduct, or virtually pure carbon, which is collected and used as the energy source for the process, along with the off gas from hydrogen filtration.

Proposed for use with a municipal solid waste facility, where it would mitigate 24 tons of waste going to landfill per day and generate 50 MWh of renewable electricity.

Plasma Assisted Gasification (PAG)

Alternatively, the solution Plasma Assisted Gasification (PAG) combines pyrolysis, gasification and plasma treatment in one integrated process to turn non-recyclable and hazardous waste into power, heat, cooling or hydrogen. Gasification is a clean and efficient way to recover energy from any carbon-based material. As energy carriers (CO and H_2) are released in an oxygen-poor environment, very few toxic compounds are formed, which makes downstream flue gas cleaning cost-efficient. Most toxic material ends up in the ash, which then is vitrified with plasma into an inert slag which is usable as a construction material. In comparison to incineration, the PAG process produces an up to 70% lower volume of gas, for which a gas cleaning and conditioning process would be needed.

Turning medical and non-recyclable waste into clean and affordable hydrogen, power, heat or cooling for direct local use.

Case Study 2

Cutting back on Food thrown away

Food waste accounts for a disproportionate amount of Scotland's emissions, making up only 5% of total waste by weight (2018), but 25% of Scotland's overall waste-related emissions. As such, the Scottish Government has set the target to reduce this number by a third by 2025. In addition, it is important that what waste is generated is dealt with in as sustainable a manner as possible. According to Zero Waste Scotland, digesting all the food waste in the country could lead to £23 million of savings in avoided landfill costs, and £27 million of added value from the energy generated.

H_2H

To this end, H_2H helps recover food that might otherwise become landfilled, making use of a proprietary enzymatic digestion process which recycles supermarket food waste into liquid H_2H fertilizer as well as dried H_2H pet food in only a matter of hours. The process enables participating supermarkets to reduce their waste costs by over 20% and farmers using the fertilizers to increase crop yields by 10%–20%.

Recovers supermarket food, upcycling it into fertilizer and feed with a 3 hour enzymatic digestion technology.

Winnow

The problem is repeated in restaurants, where some 53,500 tons of food are thrown out each year, 34% of which are meal leftovers (plate waste), amounting to 800,000 full meals. Winnow helps ameliorate this problem by using cameras and artificial intelligence to record and analyze exactly what is thrown away to then help establishments purchase, plan and serve more intelligently. As the kitchen staff throw food into the bin, its weight is recorded and the object recognized. Restaurateurs are then able to assess waste quantities and composition, the share of avoidable/unavoidable waste, and their associated costs.

Used in Hilton Dubai, reducing food waste by 70% in just 12 weeks, reducing costs by USD 65,000 per year and saving 25,000 meals per year.

Mimica Touch

At home, households are estimated to throw away about 630,000 tons of food each year, though two-thirds of this waste could be avoided with better planning and management – hence saving the country over £1 billion. Mimica Touch offers a solution to reduce household and supermarket food waste by providing an accurate indication of a product's freshness. The technology is a temperature conditions-based cap, the texture of which becomes bumpy when food or drinks spoil. Retailers can cut their food waste in half and households up to 60%. Based on internal estimates and verified consumption, Mimica is expected to save up to 30 million tons of juice, milk and meat from landfill in European households yearly.

Temperature sensitive labels and caps that indicate food's true freshness as an alternative to the wasteful and overcautious expiry date system.

Innovafeed and Protifly

The issue of food waste is found further upstream too. A 2017 study found that Scotland generates about 500,000 tons of unused or landfilled agricultural feedstock yearly. Using only 10% of this feedstock for Black Soldier Flies (BSF) farming could lead to an additional revenue of £5.4 million and provide over 2,700 tons of feed ingredients yearly for Scotland's salmon farming sector. Innovafeed and Protifly use the larvae of the Black Soldier Fly, which can grow on any organic substrate, to recycle organic waste into high quality molecules, mainly protein and oil sold to animal feed manufacturers while the residue of the rearing makes for good organic fertilizer. The localised supply chain enables the saving of up to 80% on transportation costs.

Producing a new source of protein from insect rearing for aquaculture.

Using insects to turn organic byproducts into high quality protein and oil for animal feed manufacturers.

06

Agriculture & Land Use

Mitigating the Impact of Livestock & Crop Production in Agriculture & Land Use

The agricultural sector is responsible for 18% of Scotland's total emissions and thus at first glance can be a less significant sector than transport, industry or buildings. However, given that Scotland seeks to double the value of its food and drink sector by 2030, the sector's share could certainly start to grow if more sustainable approaches are not embraced. Furthermore, the impact is somewhat obscured given that almost three-quarters of Scotland's agricultural emissions are removed through natural carbon sinks. Indeed, it is in part due to these carbon sinks that the Scottish Government has been able to adopt a net-zero target half a decade in advance of the rest of the UK, and it is of critical importance that peatlands and forests are maintained.

As such, a delicate balance must be kept in the agriculture and land use sectors, ideally increasing economic growth whilst simultaneously uncoupling from emissions growth. Doing so will ensure that many more jobs can be added to a sector that already employs 67,000 people.

The majority of emissions come from livestock, due to the impact of methane generated by ruminants, and nitrous oxide from manure and fertiliser, two gases that are significantly more potent than CO_2 (about 28 and 300 times so respectively). As such, the Solar Impulse Foundation is suggesting solutions that can rapidly reduce these impacts. As we are focused on technologies and processes that deliver economic benefits, we do not suggest solutions that would enable carbon sequestration, but rather improvements to existing processes, such as additives to bovine feed, or re-balancing micro-organisms in manure to avoid excessive ammonia emissions.

We also touch on how to derive higher yields from crop production, supporting as it does many industries including distilleries. As salmon is the UK's top food export, we also address aquaculture and ways to ensure that seafood remains of the highest quality and is produced in as sustainable a manner as possible.

> Livestock farming

Kopros

Chemical-free solution to reduce emissions from livestock farming by eliminating ammonia before it is emitted into the atmosphere

Sludge Manure Ammonia

As animal-specific mixture of microorganisms, these bacteria occur naturally in animal husbandry and accelerate the composting process or the binding of nitrogen. However, too few of these microorganisms are present in our stables, manure heaps and manure pits. Harmful bacteria take their place and produce gases such as ammonia, methane or sulfur dioxide. Kopros rebalances and reactivates the natural microorganisms, which leads to an improvement in the nitrogen cycle in the farm fertilizer. As a result, nitrogen is no longer lost through the gases, but reaches where it is needed during the application of manure and manure: directly into the soil.

Where is this Solution being used?

The solution has been used in more than 700 hundred farms in Switzerland, decreasing ammonia emissions by 95 to 98% with one application per month. This helps increase the farms productivity, and reduces veterinary costs.

Environmental and Economic Benefits

- **95% reduction in ammonia emissions**
- **A decrease of 50% in electricity consumption for ventilators in barns**
- **90% decrease of use of antibiotics**

What this means for Scotland

- **88% of ammonia pollution due to agriculture in UK, a key contributor to particulate matter**
- **Some 2500 deaths annually due to air pollution in Scotland**

Encouraging uptake

- **Municipalities seeking to improve tourism to their community as the bad odours put off potential visitors**

> Livestock farming ■ Manure & slurry management ■ Ammonia ■ Livestock

SyreN System

Transform ammonia to ammonium in slurry by balancing the pH so as to reduce emissions during application

SyreN System reduces ammonia emissions by up to 70%, and can help to eliminate airborne eutrophication, by applying the correct amount of sulphur as sulphate fertiliser. Further, this allows for 15–50 kg (depending on the slurry type) more nitrogen per hectare of plant, reducing the need for mineral-based fertilisers. The reactive nitrogen emission reduction also results in a one-fifth reduction in fine inhalable particles (PM 2.5 and smaller).

Benefits

- **Reduction of 200 kg CO_2 eq/ha**
- **Reducing ammonia emissions by 70%**
- **ROI in less than 3 years**

> Livestock farming ■ Manure & slurry management ■ Ammonia ■ Animal health

DELTA X

Conveyor belt to avoid the formation of slurry, greatly reducing barn emissions of ammonia

DELTA X can reduce ammonia emissions by 70% and CO_2 emissions by a quarter. The conveyor belt allows for a quick separation of urine from manure allowing it to flow to the drainage system and to outdoor storage. With no time spent exposed to free air, it does not mix with dung. Diseases of hoof, Mortellaro, mastitis are currently mainly caused by the liquid / solid mixture (slurry) and its prolonged exposure to the animals. This solution can cut those cases in half, improving the overall health of dairy cows and making them more productive.

Benefits

- **-70% ammonia emissions, -25% CO_2**
- **Cut veterinary costs in half**
- **Gain of 18 kg of organic nitrogen per year and per dairy cow**
- **ROI of 3.3 years**

> Livestock farming ■ Manure & slurry management ■ Ammonia ■ Animal health

Sop Lagoon

A manure additive to keep liquid manure fluid and to mitigate the release of ammonia, odors and GHG at the storage and distribution phases

A powdered additive to treat liquid manure of dairy cows. It is used at 2 grams per cow per week, making it practical for farmers and helping them with the management of liquid manure, dissolving any crusts or sediment, keeping it fluid and reducing/eliminating the need for agitators. The application of the product can reduce the emissions of methane, CO_2, Nitrous Oxide and ammonia. The reduced ammonia that can be achieved in barns with slatted floors improves the health of the animals and the working conditions of the operators.

Benefits

- **-20% CO_2 and -25% Methane versus untreated manure**
- **-45% to -100% Nitrous Oxide, Ammonia**
- **-60% energy on liquid manure management**
- **ROI in less than 1 year**

> Livestock farming
Agolin Ruminant

Feed additive that drastically reduces methane production from bovine populations and improves productivity in dairy cows and beef cattle

Livestock Farming Methane

Methane emissions from livestock are responsible for approximately 50% of the greenhouse gas emissions associated with agriculture in Scotland. Methane production in the rumen is an energy-intensive process. By blocking parts of this production, Agolin have detected methane reductions of up to 20%. A blend of high quality plant extracts from medicinal herbs and spices, which is effective, innovative, easy to use and safe. The feed additive produces rumen responses, both in vitro and in vivo, that leads to better energy and protein utilisation and consequently improved productivity in the animals.

Where is this Solution being used?

1. About 60% of all Norwegian dairy cows and beef cattle are fed with Felleskjopet's compound feeds supplemented with Agolin. They have detected methane reductions of up to 20% or some 100,000 tons of CO_2, with higher productivity. This means more milk and meat on the same amount of feed.

2. Global chocolate manufacturer Barry Callebaut teamed up with Agolin and Gold Standard to develop a methodology to quantify CO_2 emission reduction in dairy cattle as a result of feed additives. They tested in some 15,000 cows in the Netherlands and the USA.

Environmental and Economic Benefits

- **Increased milk yield and feed efficiency of 3–5% was observed in diary cows**
- **Reduction of entheric methane production by 10–20% in dairy and beef cattle**

What this means for Scotland

- **The dairy sector could be worth £ 1.4 billion to the Scottish food and drink industry by 2030 (up from £ 800 million in 2018)**
- **Carbon offset credits available for cattle methane emissions reduction**

Encouraging uptake

- **Registration with the European Food Safety Authority is a long (but fair) process**
- **A new program by Fenaco in Switzerland has launched to provide farmers with climate-friendly feed at no extra cost as financing is provided through CO_2 emission certificate trading**

> Aquaculture Farming ■ Aquaculture ■ Pest control

Paramove

Hydrogen peroxide based solution that removes sea lice from salmon leaving only oxygen and water in the environment

An effective long-term solution for lice control on farmed Atlantic salmon when used as part of an integrated pest management strategy and veterinary controlled rotational treatment programme. It will help farmers to secure their turnover by harvesting healthy salmon. It provides clients with a means to efficiently remove sea lice with the least possible adverse impact on the health of the fish and the environment.

Benefits

- **Hydrogen peroxide disperses to less than 1% of its treatment dose within 15–30 minutes**
- **Efficacy of the treatment is up to 90–95%**

> Aquaculture Farming ■ Aquaculture

Vacuum Airlift

Water treatment for recirculating aquaculture systems enabling low cost, locally produced, high-quality fish

Water quality in fish farming systems rapidly deteriorates as fishes consume O_2 and discharge CO_2, and as uneaten food and feces accumulate. The Vacuum AirLift provides water circulation, carbon dioxide and other undesirable gas stripping, oxygenation and particulate removal in a single simple device. It does so by using a vacuum pump to power a microbubble airlift pump, allowing undesirable gases and fine particulates to be extracted by the vacuum. The waste is 1000 times less voluminous than waste water, making it easy to dispose of.

Benefits

- **Energy demand as low as 15% of competing solutions**
- **Demonstrated 99.9% reduced pathogen loads in 12 hours (notably E. coli concentration dropped 16,750 u/ml to 27 u/ml**

> Crop farming

Aqua-4D

Higher yield crops with less water through low-power, chemical-free electromagnetic water treatment technology

Irrigation **Chemical-free** **Mobile Aeroponics**

AQUA4D's electromagnetic water treatment technology enables a better dissolution and distribution of minerals, promotes water retention in the soil and allows for better absorption of minerals by plants. Further, it increases the natural resistance of plants against diseases, avoids nematode attacks in roots and prevents clogging and biofilm in pipes. The technology brings all these advantages without changing the chemical composition of the water, does not create any by-products, and consumes little energy, enabling it to be powered by a small solar panel. Users see a range of results, but typically an increase of 20% in yield using 25% less water.

Where is this Solution being used?

The innovator installed their system on a 20 hectare farm in Tunisia where they were growing tomatoes for 200 days per crop cycle. They irrigated 160 m^3/h of land for 10 hours per day. Implementing this technology negated the need for investment in reverse osmosis technology to deal with saline water conditions. This led to an energy savings of 640,000 kWh (given that 2 kWh were needed to treat 1 m^3 with reverse osmosis compared to only 1 Wh with Aqua-4D). Yield increased by 9% whilst reducing water usage by 15% and saving 20% on fertilisers.

Environmental and Economic Benefits

- **Typically 20% increase in yield**
- **25% less water needed**
- **ROI met in 6–24 months**

What this means for Scotland

- **Frequency of drought expected to double by 2050**
- **Efficient use of water to enable ambitious growth of Scotland's food and drink sector**
- **Global market for mechanized irrigation systems: 14.97% CAGR to 3.76 billion**

Encouraging uptake

- **Initiatives like the Sustainable Groundwater Management Act in California will require growers to cut back on water use by 20–30%, pushing adoption of available practices and innovative technologies while using substantially less water**

> Crop farming ■ Indoor farming ■ Mobile aeroponics ■ Agriculture

Mobile aeroponics farming Solutions

Soilless farming solution that produces high quality, clean and fresh leafy vegetables with 97% water efficiency and no pesticide

There are various drivers behind this system: Firstly, the mobile aeroponics irrigation system uses 30 times less water than traditional field farming thanks to automated spraying and a closed-loop water circuit. Further, it avoids the use of phyto-sanitary products, meaning no pesticides, herbicides or fungicides. Lastly, by improving the cultivation process and disrupting the supply chain, the system allows for an 85% produce yield – 4 times more than the current chain.

Benefits

- **Closed loop recycling with 97% of the water being reused**
- **20 times more productive than open field farming**
- **No soil means reduced contamination**

> Crop farming ■ Weed control ■ Chemical alternatives

RootWave

Zap weeds with electricity instead of chemical herbicides

An electrode touches a weed which creates a circuit. The natural resistance of the weed turns that electricity energy into heat. This boils the weed inside out from the root upwards. RootWave uses high frequencies to miniaturise the equipment and ensure it is inherently safer and minimises the risk of electrical shock. RootWave is cost-comparable to using herbicides, but does not use water and can be powered using energy from solar and wind. It does not disturb the soil and thus reduces soil erosion.

Benefits

- **ROI in 5 years**
- **Cost-comparable to herbicides**

> Crop farming ■ Pest control ■ Chemical alternatives

Soilprep 2020

Use steam to eliminate pests and weeds in soil without using pesticides

More and more pesticides are being banned, and farmers need a viable solution for treating their fields and removing weeds, seeds, fungi and nematodes in the soil. Soilprep 2020 uses steam technology to heat up the soil down to 30 cm deep and has a capacity to cover 500–1500 m^2/hour depending on the depth you want to steam, the temperature in the soil, the moisture and the type of soil. Yields have increased significantly, as has storage time of vegetables, without using any pesticides.

Benefits

- **Increase yield up to 74% depending on vegetable**
- **Increases storage time for up to 6 months**
- **ROI in 1 year**

> Crop farming ■ Protein ■ Circularity ■ Nitrogen

Power to Protein

Natural protein production process, using clean water, carbon dioxide and green energy

Power-to-Protein is about closing the artificial nitrogen cycle by direct upcycling of nitrogen as microbial protein. The basis is a highly efficient microbial resynthesis process with a mixed culture of bacteria that use hydrogen as an energy source. It allows for local production of high-quality proteins will lower the independence of import. The solution is 100% GMO-free, contains more than 70% of protein and also vitamin B12.

Benefits

- **0.85 kg CO_2 eq consumed per kg of protein produced (instead of 106 kg CO_2 eq for beef)**
- **Price competitive with whey and pea protein**

> Crop farming ■ Soil ■ Fertilizing ■ Chemical alternatives

Nutrigeo

A soil prebiotic, that activate microorganisms for soil health, fertility and accelerated carbon sequestration

According to the FAO, more than 66% of the world's agricultural soils are degraded, with major consequences on their fertility and capacity to feed the world. This product is a crop input that helps to awaken and develop humifying fungi. As they develop, fungi will improve soil structure, increase minerals available to the plant and accelerate carbon storage in the soil. Further, this technology allows for more efficient use of water, better soil resources and increase in humus.

Benefits

- **25 l of product can increase the fungic biomass of a hectare by 10% in 9 weeks**
- **25L sprayed over one ha can help to sequester 4.6 t CO_2e/year**
- **ROI less than 1 year**

> Crop farming ■ Agricultural equipment and machinery ■ Farming

Solectrac Electric Tractors

Electric alternative to sub-40HP diesel tractors especially made for small size organic farmers

Able to be charged by renewable energy such as wind and solar, this solution can provide all the power and versatility of a comparable diesel tractor. Further, any hitches can also load and carry exchangeable battery packs to extend run time and balance the weight of implements. The electric actuators are 10 times more efficient than the hydraulic lifts on diesel tractors and have no toxic fluid to leak on crops. Maintenance costs are significantly reduced, with an ROI of 5–10 years.

Benefits

- **Low noise: 2000 times quieter than diesel tractors**
- **No hydraulic fluid leaks**
- **ROI in 5–10 years, longer lifespan than comparable diesel tractor**

> Complementary ■ Biogas ■ Carbon-capture

Biomethane enrichment and storage

Transform agricultural waste into biogas through biogas digesters that can be used as a clean fuel

Grassroots Energy sets up reliable and rugged proprietary biogas digesters to process agro and animal waste. The solution offers a decentralised, modular CO_2 scrubbing system operating at atmospheric pressure and is three times more energy efficient than the mainstream alternative. In addition, the innovative adsorption-based cylinder storage can reduce storage pressure by three times for the same storage mass. Each module is capable of generating biomethane that can displace 4500 kg CO_2 /year.

Benefits

- **Cost savings of 25–35% compared to mainstream alternative**
- **Water used in production is recycled**
- **ROI in 4 years**

Case Study

Making the most of Scotland's Cropland

The Scottish Government has recognized the importance of developing a thriving net-zero economy, which is why reducing the country's environmental footprint goes hand in hand with continuing to develop and diversify their economy. Thus, the ambition to double the value of the food and drink sector by 2030 to some £30 billion is a valuable exercise in making this a reality.

This is not an easy balance to strike. Already, some 45% of farmers do not make enough money to pay themselves the minimum wage, and without support payments, many farms would lose around £15,000 a year. Placing too heavy a burden on these farmers to reduce emissions without effective solutions would be very harmful to this vital sector. This is not helped by 85% of Scotland's agricultural land being considered of low quality and thus requiring more hectares to achieve acceptable yields.

Much of Scotland's land is given over to various types of agriculture. Crop production constitutes around 10% of the agricultural area. Barley is a very prominent crop, with about half used for animal feed and another third being used for malting to support the hugely important whisky industry, as well as potatoes and some soft fruit production.

Rootwave

As with any crop production, handling weeds is a significant challenge. Rootwave is a machine that uses electricity to zap weeds without using any chemicals, and functions by sending electricity through the weed and boiling it from the root upwards. The costs are comparable to using herbicides, uses less water and reduces soil erosion. However, if farmers wish to continue using fertilizers, there are several solutions that can help them better target their efforts.

By only using electricity to eradicate weeds, the solution emits zero pollution and can deliver return on investment in five years.

Fallow weed detection system

Infarm's fallow weed detection system uses drone technology to indicate exactly where tractors should spray, saving up to 97.5% of the pesticide. A technology like this helps to avoid polluting soils and wastewaters more than is necessary, and allows for significant savings on fertilizer use.

Used on a 750 hectare farm in Queensland, Australia, saving the farmer USD 10,875 AUD through minimising the need for chemical use.

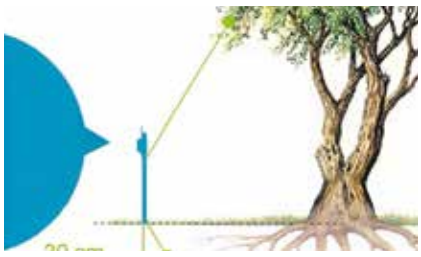
Combagroup

Given the low quality of significant amounts of Scotland's agricultural land, it is also worth considering aeroponics solutions, such as that developed by Combagroup which allows for 30 times less water than traditional field farming thanks to their closed-loop circuit that allows for 97% of water to be re-used. Furthermore, it avoids the use of any pesticides or herbicides. The solution also sees a produce yield four times in excess of traditional approaches.

Being used in a greenhouse in Leicester, supplying 2,000 tons of salad to a large sandwich manufacturer whilst using no chemicals and only using rainwater.

SinaSens Smart Agri

In a similar line of using data to make better judgement calls, SinaSens Smart Agri is a low-cost, high quality system that helps farmers monitor the temperature and humidity of the soil and air and the humectation of the leaves. Depending on their objectives, farmers can reduce their water consumption, increase crop quality and shelf-life, increase crop yield, anticipate and reduce leaf-borne diseases, and reduce their use of phytosanitary treatments. SinaSens Smart Agri uses capacitive sensors to measure these parameters and send the data over a low-frequency network to a secure website where the clients can consult the data and even download it in an open-data format for integration into other crop management tools.



The solution was used on a 6 hectare farm in France, reducing water costs by 20% and electricity use by 16%.

Solutions operating in Scotland

Solar Impulse

Labeled Solutions with Activities in Scotland

Labeled Solutions based in Scotland

ArbnCo
Arbn Well is a high-density indoor Environmental Quality sensing service to track health and well-being in buildings. The company ArbnCo is based in Glasgow and has started selling its product generating a return exceeding 60% gross margin on hardware costs.

SolarisKit
SolarisKit is a company based on the outskirts of Edinburgh who have designed an affordable and easy to deploy solar thermal collector capable of converting sunlight into hot water for homes, business, and industry.

Sunstore Powerpanel XL
Edinburgh-based Sunstore Technologies have designed an integrated solar tracking, food processing, water purification and electricity generator for off-grid communities.

Solatube
Solatube Tubular Daylighting Devices are high-performance, green building components that bring daylight into interior spaces where traditional skylights and windows cannot reach. Solatube Scotland has been installing Solatubes throughout mainland Scotland and the islands including in schools, hospitals, supermarkets and even in the V&A Museum in Dundee.

Labeled Solutions with clients in Scotland

MWLC – Autonomous Freight Transport

MWLC transport goods through their autonomous electric vehicles and have been commissioned by the Scottish organisation, HiTrans (Highlands and Islands Transport Partnership), to deliver a pilot using small autonomous vehicles for freight transport tasks in the North of Scotland. Parallel to this project, they are also working with the Orkney Island Council and Robert Gordon University.

TwingTec

TwingTec have a containerized mobile wind energy system to harness wind from higher altitudes. Their main strategic partner is Scottish company Aggreko, one of the leading rental power companies. This partnership has the shared goal to start implementing the solution in Scotland and introduce it to the rental power market.

Hamwells

Hamwells has created Blue, a heat recovery shower system from wastewater to preheat the cold water supply. This energy saving device is commercialised all over the UK, reducing emissions associated with showering by 50%.

DPM Mashel

DPM Marshall has created an ecological interior paint called Farnovo. This new paint is distributed around Scotland (through UK distributor Mighel Hurtig). It offers a sustainable paint alternative, creating a 100% emission and pollution-free room environment. This sets new standards for the construction and paint industry in Scotland.

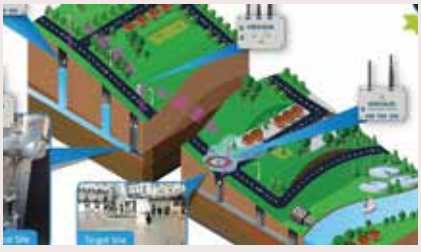
Labeled Solutions with clients in Scotland

Sabella
Sabella builds leading tidal turbines and have a strong partnership with Scottish company Nova innovation in the same field. This collaboration will accelerate the development of tidal energy in Scotland and France. Both companies share knowledge to provide predictable and clean energy to both countries.

Pinovo AS
Pinovo AS has been active in the Scottish market since 2014. They produce the Pinovo Circular Blasting Technology, a clean sand blasting solution to prevent paint microplastics. In Scotland this Labeled solution is used in nuclear power, Defence, infrastructure and the Oil and Gas industry. This company is currently seeking to develop into the offshore wind industry, where Scotland is an international force.

BHSL Waste solutions
BHSL has designed a solution which converts various organic waste products such as manures, sludge or MBM into energy. This Labeled Solution has Free Range Eggs of Britain as a client in Scotland using the BHSL FBC system.

Centaur
Centaur, developed by EM-solutions, is an IoT system for wastewater operators who want to reduce urban flooding and overflows to the environment in the face of urban growth and more intense storms. This technology is being installed and used by Scottish Water to support flood control.



Etrel
Etrel have created an interactive charger for electric vehicles that talks with the user and responds to the grid, thus balancing charging power for more efficient charging. Etrel currently have two distributors in the UK and are listed in the UK OZEV list of chargers eligible for financial reimbursement.

SageTech Medical
95% of anaesthetic gas is released unused into the atmosphere where it is hugely damaging to the environment. SageTech Medical has developed a technology to capture waste anaesthetic gas in hospitals, purify it so it is ready to be reused again in those same hospitals. The company based in the UK is in advanced discussions with a group of hospitals in Edinburgh to trial the technology.

Labeled Solutions that will be showcased at COP26

SwissVault, Smart Green Shipping, Dryad and Tocardo in the #26ForCOP26 Greenbackers cohort

The Solar Impulse Foundation partnered with Greenbackers Investment Capital on their #26ForCOP26 initiative: a cohort of 26 cleantech ventures, chosen from hundreds of applicants, who have been deemed "investment ready" by the Greenbackers team. The pledge of this initiative: let's walk the talk and have those 26 startups secure growth funding by the end of COP26! As of today, 17 of these 26 solutions are in the process of being labeled as Efficient solutions by the Solar Impulse Foundation, 4 successfully passed the evaluation process proving they were protecting the environment in a profitable way. Congratulations to SwissVault, Smart Green Shipping, Dryad and Tocardo.

EcoCore (TBC)

EcoCore® plastic moulding technology creates more sustainable packaging with skin-foam-skin walls. It is used for reusable, as well as recyclable single-use packaging, that is low-cost, lightweight, insulated, strong and very durable. This solution will be a provider of reusable cups at COP26 and is additionally being trialled by the National Health Service Scotland in their battle to reduce waste.

Brainbox AI

Brainbox AI, offering artificial intelligence to combat climate change by making commercial buildings smarter and more efficient, got selected to showcase their solutions on the international stage at COP26 as part of the Tech For Our Planet challenge – initiative run by the Cabinet Office.

Labeled Solutions that partner with Scottish stakeholders

Holcim

Holcim is partnering with the Scottish NGO, Classrooms for Malawi, who construct and repair education facilities in areas of poverty in collaboration with local communities. Two of Holcim's Labeled Solutions, Durabric and 3D Printing, will be used in a current construction project and another next year.

Corporate Case Study

Energy at the core of The Glenmorangie Company's Transition

SOLARIMPULSE FOUNDATION | LVMH OFFICIAL PARTNER

SOLARIMPULSE
FOUNDATION

A shared vision

The LVMH & Solar Impulse Foundation Partnership

Bertrand Piccard and the Solar Impulse Foundation have identified and assessed over +1000 clean and profitable solutions that can be implemented today to address environmental challenges without compromising economic growth.

The selected solutions are products, processes, or services coming from companies ranging from start-ups to large corporations. They benefit both the environment and the economy, and cover the sectors of water, energy, construction, mobility, industry, and/or agriculture.

Since 2019, LVMH and the Solar Impulse Foundation have partnered to find and promote innovative and clean technologies to build a more sustainable world.

Concretely, the Solar Impulse Foundation provides LVMH and its Maisons with certified solutions regarding diverse topics such as energy consumption, renewable energy, alternative ways of transport and more.

LVMH AND THE SOLAR IMPULSE FOUNDATION HAVE PARTNERED TO FIND AND PROMOTE INNOVATIVE AND CLEAN TECHNOLOGIES TO BUILD A MORE SUSTAINABLE WORLD.

This present document is a representative example of that joint effort.

In the context of the COP26 in Glasgow, the Solar Impulse Foundation (SIF) is producing a Solutions Guide whose overarching purpose is to propose a selection of SIF-labelled solutions to support Scotland as it tackles its various environmental challenges.

The Glenmorangie Company, the Single Malt Scotch Whisky company within the LVMH group, is based in Scotland. It makes for an ideal case study for assessing how an environmental transition within this industry can effectively take place.

To this end, the Glenmorangie Company and Solar Impulse teams have worked together and identified a selection of technologies that could potentially contribute to the Company reaching its environmental objectives, in line with the Scotch Whisky Association's *Climate Strategy*.

THE SCOTCH WHISKY INDUSTRY IN SCOTLAND IS OF PARAMOUNT IMPORTANCE TO THE COUNTRY.

Industry Context

The Scotch Whisky Industry Pathway to Net Zero

The Scotch Whisky industry in Scotland is of paramount importance to the country. According to the Scotch Whisky Association (SWA) of which The Glenmorangie Company is a member, exports from the 134 operating distilleries in the country amounted to £3.8 bn in 2020 – 75% of all Scottish food and drink exports. Furthermore, the industry directly employs over 10,000 people in Scotland, with 7,000 located in rural areas, providing crucial employment opportunities and investment to local communities. Recognising its economic significance, the industry has pledged to put sustainability at its core by setting itself on a pioneering path: reaching net-zero by 2040 (-40% by 2030 relative to 2018) – 5 years before the Scottish Government's already ambitious country-wide target to be carbon neutral by 2045. Identifying means to power the distilleries' activities through clean and renewable energy is central to reaching the stated goals given the preponderance of these emissions in the overall environmental footprint.

Indeed, in order to properly end its reliance on fossil fuels, the biggest challenge the industry must tackle is that of industrial heat generation. Distilleries countrywide will need to set a clear focus on finding clean-energy alternatives for heat production, which was responsible for 82.7% of industrial fuel consumption in 2018. Delving deeper, it appears that distillation heat is the main source of the sector's GHG emissions and is responsible for 91% of the industry's heat-related fuel consumption (2018). Ideally, and as identified by the Scotch Whisky Association, the goal is to see more and more self-sufficient distilleries valorising their waste and by-products into energy, reusing the waste heat, continuing to improve energy efficiency and investing in renewable energy. Some of the principal technologies that have been identified to do so are heat pumps, biomass cogeneration plants, anaerobic digestion, hydrogen and energy efficiency solutions that can be retrofitted to optimise the energy management.

Industry facts and figures came from the SWA. More information can be found on their website scotch-whisky.org.uk

Leading the Way

The Glenmorangie Company's Ambitious Energy Journey

The Company is aligned with Moët Hennessy's commitment to reduce carbon footprints by 50% by 2030.

Sustainable solutions selected through the present collaborative effort between the Glenmorangie Company and the Solar Impulse Foundation may also contribute to the rest of the Scotch Whisky Industry in its strive for net zero. The Company has also joined forces with the SWA working on other aspects of the value chain such as, malted barley, packaging and transport.

The Company operates two Single Malt Scotch Whisky Distilleries: Glenmorangie Distillery located in Tain in the Highlands and Ardbeg Distillery on Islay.

In Tain, Glenmorangie will use 100% renewable energy in future. Today, part of the Distillery's energy requirement (c.15%) is already supplied on site by biogas from anaerobic digestion derived from distillation effluent. This complements the rest of the energy which is today mostly from compressed natural gas (CNG), used to create the steam which helps to power the Distillery. Additionally, the Company is transitioning to bio-CNG which is currently being implemented.

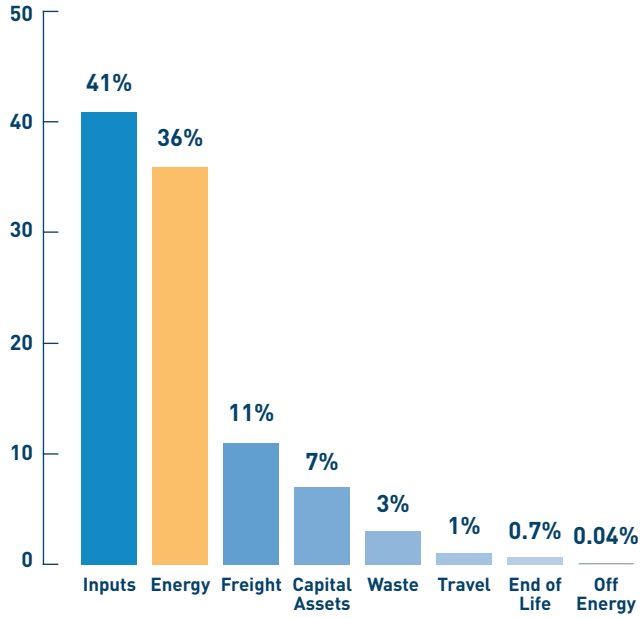
The use of hydrogen as a source of energy for the Glenmorangie Distillery is also under consideration. The Company is involved in the North of Scotland Hydrogen project, a collaborative partnership with other leading whisky companies and the Port of Cromarty which plans to develop a state-of-the-art energy hub from offshore wind that will produce, store, and distribute green hydrogen across Scotland.

The Glenmorangie Company has also commenced an onsite methanation feasibility study with MAN Energy Solutions and the Mabbett consultancy, supported by seed funding from the Scottish Government Industrial Energy Transformation Fund (SIETF). The purpose is to combine hydrogen and the CO_2 generated from fermentation to produce biomethane that can be used to part fuel the Distillery's activities.

On Islay, Ardbeg Distillery currently runs mainly on diesel. The Company's ambition here is to replicate what has already been fulfilled in Tain, in collaboration with other Islay Distilleries through switching to CNG and the creation of an anaerobic digestion plant. The smaller volumes of spirit created at Ardbeg and the lower amount of energy consumed make the transition more of a challenge. Despite this, the Company is working on solutions for its energy needs on Islay.

The Glenmorangie Company and the Solar Impulse Foundation are ready to work together to take sustainable innovation further. As such, the Company welcomes SIF's proposed solutions (see next section) and will investigate them as part of its overall Sustainability Strategy.

The Glenmorangie Company's carbon footprint data for 2019.



Solar Impulse Foundation's recommended solutions for The Glenmorangie Company

Clean and Efficient Technologies for Glenmorangie's Distilleries

Below are examples of 5 Solar Impulse Labelled Solutions identified to tackle the challenges of Glenmorangie's Distilleries' energy efficiency, high-temperature clean steam production, processes' thermal losses and finally sludge management.

Qpinch

Through a physical-chemical reaction on a cyclic closed-loop system requiring no additional water or chemical input, Qpinch captures waste heat and converts it back into reusable higher temperature heat for the production process. Applicable on a megawatt scale by all industries that use industrial heat, it requires only marginal electrical energy consumption and can pay for itself in less than five years.

- Up to 2,200 tons of CO_2 savings per year per MW of thermal energy output

MEVA – Renewable gas for industrial burners

MEVA is a gasification module which creates renewable gas from biomass residues to be used directly at the plants, enabling a local circular system. The biomass residues used include fine fraction biomass such as sawdust, rice husks and wood fibre, which many industries currently struggle to dispose of.

- Process heat is 19% cheaper
- Cost of combustion from 25EUR/MWh 50EUR/MWh depending on feedstock

METRON EVA

This platform aims to create energy efficient plants by detecting the types of energy used in real time (electricity, steam, etc.). Using this data, the platform simulates the factory by creating digital models allowing it to predict (through machine learning) the energy behaviour and continuously identify opportunities for optimisation and to reduce energy bills and environmental footprint.

- ROI in 1 year
- -15% energy consumption

Aqua assist

The Aqua Assist biocatalyst accelerates microbial activity and the degradation of organic matter through biological digestion – both aerobic and anaerobic. Biosolids reduction between 30% and 70% has been repeatedly observed along with nuisance odours and hydrogen sulphide reduction by up to 43% and 50% respectively.

- Up to 10% reduction in chemical costs
- Reduced methane emissions at landfills (0.43 kg/ton of sludge)

HP2 Steam Generation

HP2 is an integrated steam generator to prepare, condition and combust biomass and can be integrated with the rest of the power plant to produce renewable energy.
Compared to conventional furnaces technologies, HP2 presents an optimal complete combustion (+99%) and its burner reaches up to 92% efficiency compared to 80% for conventional fuel burners.

- 30–40% less raw material consumption
- Up to 98% CO_2 emissions reduction compared to fossil fuels

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The Scottish Context

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