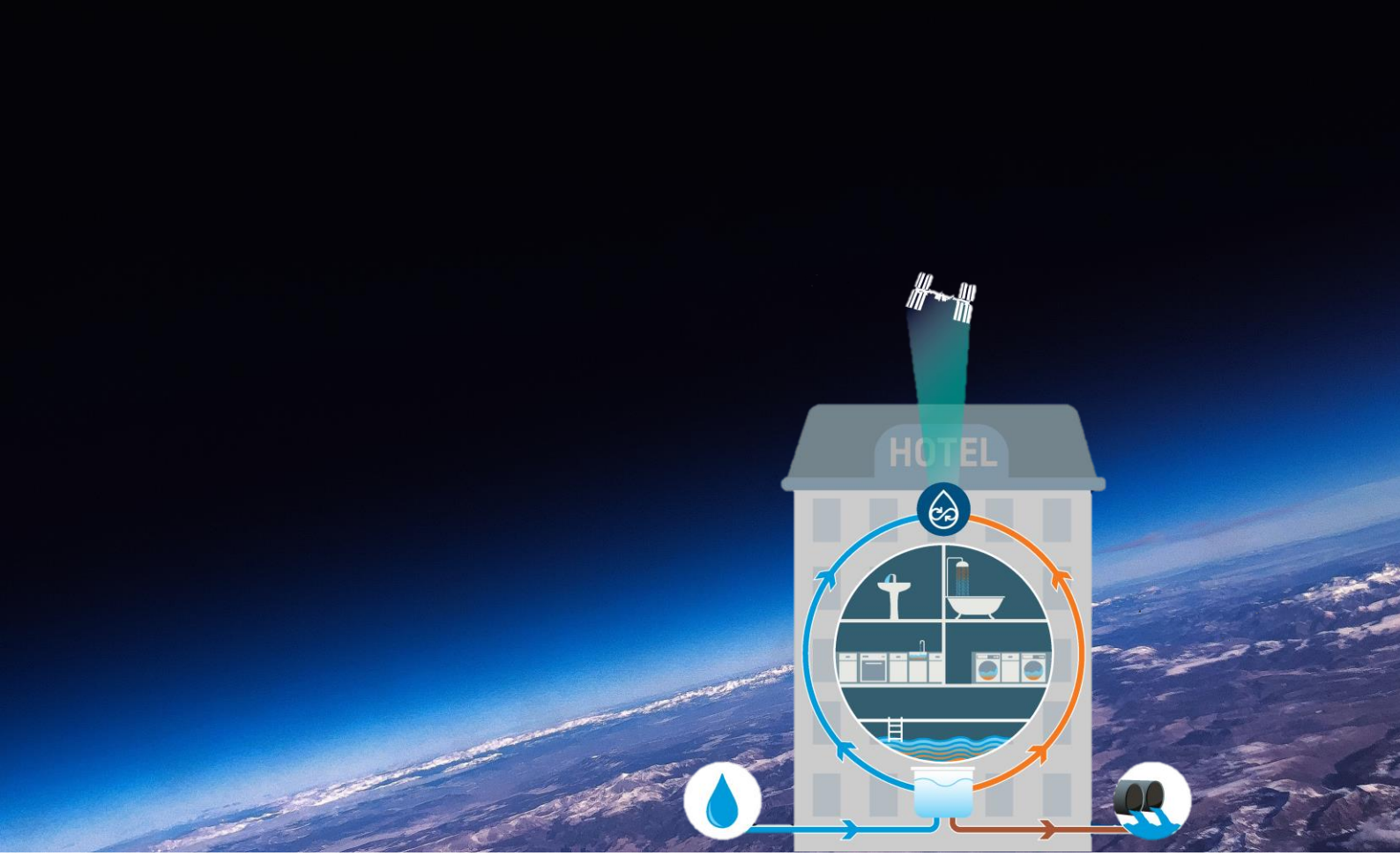

Socio-economic benefits from ESA Technology Transfers

A report for esa

CASE STUDY: Firmus Grey Water Recycling System (FGWRS)

know.space

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Closing the loop: how space technology could relieve water scarcity on Earth

Today 3.6 billion people, nearly half of the global population, are living in potentially water-scarce areas at least one month per year[1]. In the future this problem is only set to worsen as population growth continues, alongside GDP growth and increases in water demand, whilst surface water resources at a continent level remain fairly constant. By 2050, this figure is therefore predicted to increase to 4.8-5.7 billion people[2].

In France, the average household of 2.5 people uses a huge 329 litres of water a day, which equates to an annual use of 120 cubic metres[3]; many developed countries, particularly the US, use substantially more water[4]. Of this figure, nearly 40% is used for baths and showers, 20% for flushing toilets, 12% for washing clothes, 10% for cleaning and the remainder for cooking, drinking and gardening[5]. This means **most daily wastewater is greywater[6], which is domestic wastewater from all streams except toilets** (showers, baths, sinks, swimming pools etc.).

A typical household plumbing system mixes greywater with toilet wastewater (black water) and together these streams are sent to centralised wastewater treatment plants. Meanwhile, **the water we use to flush out toilets is high quality drinking water**, since all household water comes from the same source. **As water shortages become an increasingly pressing issue, there is an urgent need to rethink how water as a resource is addressed**.

'Necessity is the mother of invention'

Whilst on Earth attempts to rethink how our water systems operate are in their infancy**, in space the scarcity of water has always been a pressing issue and a subject of research for many years**. At present, up to 80% of water on the International Space Station (ISS) is recycled, with condensation on the space station's walls recycled into drinking water[7]. The remainder of the water demand is addressed by regular resupply missions to the ISS. These are highly expensive - transporting anything to space requires huge amounts of energy and water in particular is heavy and bulky. Moreover, the more room taken up by water, the less room there is for important scientific equipment. **With ambitions for humans to reach Mars and the long journey times associated, in the future it will become vital to recycle all water in space**. **In this context, ESA has ambitions to create a closed-loop system, where water and other resources are recycled**,

[1] UN Water, 2018. *The United Nations World Water Development Report 2018*. Available at: https://www.unwater.org/publications/world-water-development-report-2018/
[2] UN Water, 2018. *The United Nations World Water Development Report 2018*. Available at: https://www.unwater.org/publications/world-water-development-report-2018/
[3] Le Centre D'Information sur L'eau, n.d. *What is the average water consumption per household?* Available at: https://www.cieau.com/le-metier-de-leau/ressource-en-eau-eau-potable-eaux-usees/quels-sont-les-usages-domestiques-de-leau/
[4] Statista, 2021. *Water withdrawals per capita worldwide as of 2019, by select country*. Available at: https://www.statista.com/statistics/263156/water-consumption-in-selected-countries/
[5] Le Centre D'Information sur L'eau, n.d. *What is the average water consumption per household?* Available at: https://www.cieau.com/le-metier-de-leau/ressource-en-eau-eau-potable-eaux-usees/quels-sont-les-usages-domestiques-de-leau/
[6] FGWRS, n.d. *Grey waters recycling*. Available at: https://www.fgwrs.mc/en/grey-waters-recycling/
[7] ESA, 2019. *Water in space*. Available at: https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/Water_in_space

so humans can survive for years aboard a spacecraft without external assistance. For over 30 years, the **MELiSSA project** has been developing the key components of this loop.

MELiSSA (Micro-Ecological Life Support System Alternative) is a European project within the European Space Agency (ESA), bringing many research institutes and organisations together to develop circular life support systems for the ISS and beyond.

Membrane specialists **Firmus have been involved in the MELiSSA project since the early 2000s, developing the Firmus Grey Water Recycling System (FGWRS).** The system uses organic and inorganic membranes to purify greywater, and is capable of producing drinking-grade water for full recycling, without the use of chemical treatment.

FIRMUS is a French company specialising in membrane-based water treatment technologies. The company has a long-running relationship with ESA (since the 1990s).

The FGWRS is a multistage process, and in order to operate, the greywater must be kept separate from dirtier streams of water (coming from toilets). This requires separate plumbing, which is easy to install in new buildings, but involves adaptions to buildings with existing plumbing systems. Greywater is directed to the FGWRS system, which is comprised of two tanks, one for untreated and one for treated water. This means that the FGWRS is implemented as a local water treatment unit, adapted to the building, venue or specific location needs. The **greywater is pre-filtered, before passing through two carefully designed membranes.** At this stage, the water is fully clean. The technology can recycle between 75 and 85% of greywater[8]. By lowering the load of greywater to be treated, this local treatment can also reduce pressure on centralised treatment plants.

15 years of use on 'White Mars'

In cooperation with ESA, the **FGWRS was installed at the French-Italian Concordia station in Antarctica in 2005.** Antarctica is sometimes referred to as 'White Mars': scientists living there are completely cut-off from the outside world for winter, creating an isolated community, which is a useful testing ground for potential space technologies. The system installed is capable of treating nearly 3,000 litres of water a day, enough to serve around 25 people. Since its installation, it has successfully operated without any technical or sanitary failures and has received widespread approval from over 1,300 users so far. **Firmus hope that in the future FGWRS will be tested in space and will form a building block of the MELiSSA loop.**

Space technology brought down to Earth …

When MELiSSA started in 1989, interest in sustainability and closed-loop systems both inside and outside of the space sector was limited. Yet, in recent years interest in recycling water has grown greatly, as climate change becomes an ever more pressing issue. Firmus recognised the potential for terrestrial applications of their greywater recycling system, particularly as water shortages are expected to worsen, founding a spin-off company named after their technology, FGWRS.

[8] Firmus, n.d. *Grey Water Treatment*. Available at: https://www.firmus.net/en/grey-water-treatment/

Monaco-based FGWRS was founded in 2017 as a FIRMUS spin-off, with the aim of commercialising the greywater treatment technology developed by FIRMUS.

Potential for significant socio-economic benefits

FGWRS have begun to commercialise the technology, with several high-profile customers, yet the technology is still very new. As such, though some socio-economic benefits have begun to emerge, the majority of impacts are potential, with wider benefits expected to materialize as FGWRS further commercialises their product.

Developing a greywater recycling system

Commercial opportunities

FGWRS have already secured several **high-profile clients** and are in discussions with a **variety of potential users**

Firmus recognised the commercial potential of their greywater recycling system, founding **spin-off company FGWRS** in 2017 in Monaco. Since then, despite the challenges associated with the global pandemic, FGWRS has successfully trialled their solution in a number of locations, including the changing rooms at the Roland-Garros tennis tournament (using water from players' showers to flush the changing room toilets), the Monaco Pavilion at the Dubai 2020 Expo, the Océanographic Museum in Monaco and several private residencies in Monaco. FGWRS is currently in discussion with a number of potential clients across France, including swimming pools and hotels.

Despite the successful operation of greywater recycling technology for over 15 years in Antarctica, **domestic greywater recycling is not authorised in France**. For the Roland Garros tennis tournament, FGWRS was granted a **special exemption**, supplying the authorities with regular updates to demonstrate the safe functioning of the system. Though FGWRS is based in Monaco, the firm hopes that France will soon recognise the potential for greywater recycling, particularly in drought-prone regions, opening up a much larger market to FGWRS. Different European countries have different regulations, but successful demonstrations such as this are key to highlighting the importance of advancing the regulatory landscape.

The project is already providing **skilled jobs** in Southern France and Monaco with 3 employees at Firmus (not exclusively involved in greywater recycling) and 2 employees at spin-off company FGWRS in Monaco.

New partnerships

FGWRS had originally developed their technology for terrestrial applications as part of a consortium of firms. In the future, FGWRS hope to make their technology available globally through partnerships with local companies, who are well-versed on the laws on greywater recycling in their country.

Currently, the FGWRS and Firmus are looking for investors to help develop the companies, so that they can continue growing and focussing on commercialisation.

User profile

GL Events is a major player in the global events industry, with more than 40 years' experience and an international network of 50 events venues. The firm successfully proposed the use of the FGWRS system to the French Federation of Tennis for use at the Roland-Garros tennis tournament.

Since October 2020, FGWRS has been used in the temporary infrastructure at the stadium[9], after a special exemption from French Regional Health Agency (ARS) to recycle greywater was secured in August 2020. The project benefitted GL events, opening the company up to new opportunities in sustainable events management and allowing the firm to make interesting new contacts in the process. For GL Events, it was important to be the first movers using this technology in the industry; they believe that what is 'innovative today' will be 'required tomorrow', so getting on board early is hugely beneficial.

The current contract has already been extended by a year (until 2022) and it is hoped that another special exemption can be secured, and the technology will remain in place for the next few years, when it can be further developed and adapted to the specific needs of the events industry.

Generating momentum in the sector

The work of private firms, such as Firmus and FGWRS, on circular economy concepts helps to generate momentum around the wider circular economy, which in turn benefits the MELiSSA project and society in general.

MELiSSA is now part of a much wider and larger network than when the project first started and, just as ideas spin-out from MELiSSA, they have the potential to spin back to the project also. MELiSSA benefits from non-space interest in the circular economy and the larger catalogue of intellectual property available.

Protecting the environment

Water savings

FGWRS can **recycle up to 80% of greywater**

Since FIRMUS developed FGWRS in the early 2000s, and as population and income growth alongside changes in our climate have worsened water shortages on Earth, the need to rethink how we use water has become ever-more pressing. Indeed, over 2 billion people live in countries where the water supply is inadequate, and this is forecast to worsen even in the next 5-10 years[10].

In developing countries, the effects of drought and water shortages are already severe. Limited access to safe drinking water and water for basic hygiene threaten people's health, whilst women and children walk long distances every day to collect water, including taking the children

[9] FGWRS, 2020. *Recycling grey waters of the Jean Bouin tennis courts, arranged by the French Tennis Federation for the 2020 Roland Garros Championship*. Available at: https://www.fgwrs.mc/wp-content/uploads/2020/10/FGWRS_CP_Roland_Garros_EN-1.pdf

[10] UNICEF, n.d. *Water Scarcity*. Available at: https://www.unicef.org/wash/water-scarcity

out of school for this purpose, which damages their education. Moreover, by 2030, it is estimated that severe water shortages will lead to 700 million people being displaced[11].

Whilst the most severe water shortages are expected in the developing world, developed countries are not immune either; 2018 and 2019 saw two **exceptional droughts in Europe**, with some parts of central Europe receiving less than half of their usual rainfall in the 2018 drought[12]. This could have severe economic consequences, with research suggesting that the economic damages from droughts in the EU and UK could increase by a third by the end of the century, even if global warming is limited to 1.5 degrees[13].

In this context, greywater recycling may prove to be an important tool in tackling water scarcity. The FGWRS can **recycle up to 80% of greywater**, which constitutes the majority of household water consumption. The system can operate in a variety of contexts, including hotels, museums, swimming pools, laundries and large domestic buildings, e.g., apartment blocks or large private residences. Where there is scale, the system is cost effective and can operate as an impactful solution. FGWRS believes that their technology has global potential and hopes to see their technology used outside of Europe, with the help of local partnerships.

Energy savings

50% of thermal energy recovered from the showers at the Roland-Garros tennis tournament, with the help of a partner company

The FGWRS technology can be combined with heat recovery systems to **recover thermal energy from greywater** (e.g., from warm showers), which would otherwise be wasted; for example, when the FGWRS and a complimentary heat recovery system were installed at the Fairmont Hotel in Monte Carlo, the average temperature of greywater collected was 26.7 °C.

A heat recovery system in combination with FGWRS can recover much of this heat; in the Fairmont Hotel, the average temperature of treated water was less than a degree Celsius below that of the greywater recovered, at 25.8 °C. Recently the company worked with EHTech, a firm specialising in heat recovery systems, to recover thermal energy from the showers at the Roland-Garros tennis tournament. In partnership with FGWRS, EHTech successfully recovered 50% of the thermal energy used[14]. By preheating, less energy is needed to heat water to the desired temperature and the overall energy consumption of buildings is reduced. This clearly has a positive environmental benefit, reducing fossil fuels use and greenhouse gas emissions, but also implies cost savings for users.

Offering significant user value

Cost effective

A targeted **cost payback of just 5 years**

[11] UNICEF, n.d. *Water Scarcity*. Available at: https://www.unicef.org/wash/water-scarcity
[12] Carbon Brief, 2021. *Increasing droughts will drive 'billions' in economic losses in Europe*. Available at: https://www.carbonbrief.org/increasing-droughts-will-drive-billions-in-economic-losses-in-europe#:~:text=In%202018%20and%202019%2C%20Europe,their%20usual%20rainfall%2C%20research%20shows.
[13] Naumann, G., Cammalleri, C., Mentaschi, L. et al. Increased economic drought impacts in Europe with anthropogenic warming. *Nat. Clim. Chang.* 11, 485–491 (2021). https://doi.org/10.1038/s41558-021-01044-3
[14] FGWRS, 2020. *Recycling grey waters of the Jean Bouin tennis courts, arranged by the French Tennis Federation for the 2020 Roland Garros Championship*. Available at: https://www.fgwrs.mc/wp-content/uploads/2020/10/FGWRS_CP_Roland_Garros_EN-1.pdf ; FGWRS, 2022. *Preserve drinkable water resources for future generations.*

For commercial users, where there is a high volume of greywater generated, the FGWRS system is cost effective over a number of years. Indeed, **the larger the scale, the less expensive** the system becomes, making large hotels or laundry services ideal end users. The company is targeting a cost payback period of just 5 years. Furthermore, there is evidence to suggest that **sustainable credentials confer a price premium**. A recent survey found that globally, 34% of consumers self-reported that they are willing to pay more for sustainable products or services[15].

Commercial users benefit from **reduced water bills after installation**, as greywater is recycled. As a reference, for a hotel with 100 rooms and 100% occupation ratio/year, FGWRS will save **7913m³ of drinkable water** and **209 MWh of energy**[16]. Further savings can be made if FGWRS is combined with a heat recovery unit, allowing users to save on energy bills.

Easy to use

A key advantage of FGWRS over other greywater recycling systems is their **simple user interface**, developed by Sherpa Engineering. The platform operates on a webpage and connects to the greywater recycling system via wi-fi. Users can easily change input settings and benefit from **real time display of water and energy savings**, all in an easy-to-use format.

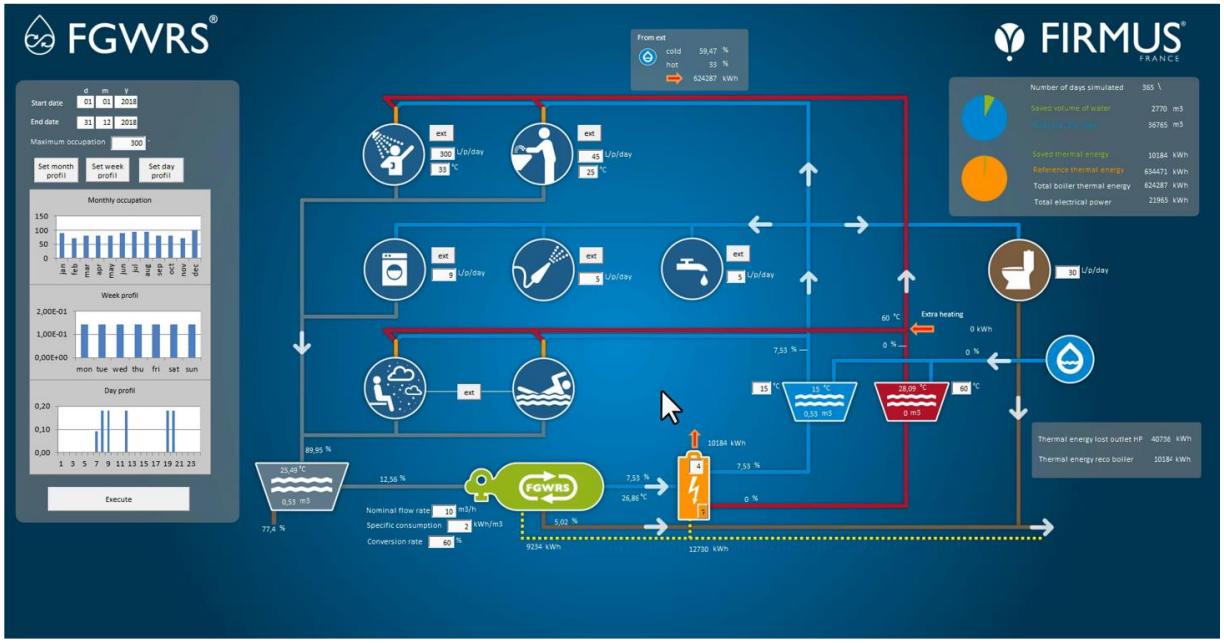

Image: FGWRS

Furthermore, FGWRS supply the appropriate parameters for a given building and can adjust these as part of a maintenance agreement with buyers, so they are supported throughout the lifetime of the system.

Requires no change in user behaviour

The FGWRS system requires separate piping for greywater and the dirtier water from toilets, but no further adjustments are needed, i.e., normal toilets, sinks, showers etc. can be used. This means that no change in user behaviour is necessary, making the system suitable for use in settings such as hotels and other places where the general public are end users.

[15] Simon Kucher and Partners, 2021. *Global Sustainability Study 2021*. Available at: https://www.simon-kucher.com/sites/default/files/studies/Simon-Kucher_Global_Sustainability_Study_2021.pdf .
[16] FGWRS and Monacotech, *Hotel 100 Rooms Case Study*

Promotes a sustainable brand image

The substantial water savings generated by the FGWRS system allows companies adopting the technology to promote a sustainable brand image. This should in turn generate real economic benefits to firms. A recent survey of over 10,000 people across 17 countries demonstrated that **sustainability is an increasingly important purchase criterion** for many customers; 85% of respondents reported shifting their purchasing towards more sustainable options over the last 5 years and 60% of consumers rated sustainability as an important criterion when making a purchase[17].

Indeed, Roland-Garros promoted their use of FGWRS as part of their World Environment Day celebrations in 2021, helping to promote a sustainable brand image through real commitments to sustainable technology in the stadium.

Would these benefits have been realised without ESA?

ESA have played an important role in developing the technology central to the FGWRS system today. The greywater recycling technology was developed by Firmus, with strong ESA support. Firmus first worked with ESA in the 1990s, before getting involved in the MELiSSA project in the early 2000s. **ESA then initiated the installation of the technology on the Concordia Antarctic station in 2005**, paving the way for terrestrial applications of the technology. This long-running project has been crucial for Firmus and FGWRS in demonstrating the success of their technology, particularly its reliability, to potential customers. **ESA were interested in circular economy technology, through the MELiSSA project, long before others recognised the potential of technologies like this for sustainability on Earth.**

"(FGWRS) is **ESA technology**…created from the knowledge transferred from ESA."

Pierre Magnes, Development Manager at FGWRS

… with further development and benefits to come

After 15 years of use on the Concordia station in Antarctica, it is clear that the FGWRS technology is stable and effective. FGWRS hopes to develop a smaller, domestic version of the system, but for the past few years, FGWRS has been focused on commercialising the technology for use in non-domestic buildings. Though the pandemic disrupted the commercialisation of the technology, **FGWRS has already rolled their solution out to a number of customers**, including the Roland-Garros tennis tournament, the Monaco Pavilion at the Dubai Expo and several large private residencies in Monaco. **The company is in discussions with many potential customers**, including laundries and swimming pools in France, and hopes to bring the technology to the hotel industry. To secure this expansion, FGWRS is also looking for investment.

At present, the tight legislation in France surrounding greywater recycling remains an obstacle, but FGWRS has successfully rolled the system out in Monaco and are in conversation with the French authorities. The Roland-Garros tournament exemption has provided a useful testing platform and the Ministry of Health are signalling that new legislation will be in place by 2025 to make it easier to use these systems, potentially opening up a large new market. The firm has **ambitions to expand internationally beyond their home markets of France and Monaco, potentially rolling the technology out on a global scale with the help of local partner companies.**

[17]Simon Kucher and Partners, 2021. *Global Sustainability Study 2021*. Available at: https://www.simon-kucher.com/sites/default/files/studies/Simon-Kucher_Global_Sustainability_Study_2021.pdf