Flexible photovoltaic panels
for road transport

state-of-the-art technology
for saving money
and increasing battery life

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INDEX

Introduction

Introduction

In recent years, policies adopted by the European Union to reduce greenhouse gas emissions have imposed binding targets for **CO2 levels**, which have led to an increasingly stringent legislative framework also for road transport.

There has been a shift from a 'passive' approach, thus concerning the improvement of engines and optimization of journeys, to a more 'active' one with **electrification as a viable solution** to achieve the objectives established in 2015 with the Paris Agreement. Indeed, this pact foresees a global average temperature increase **below 2 degrees Celsius by 2050** compared to the pre-industrial period, aiming for a maximum increase of 1.5 degrees.[1]

Achieving this result is undoubtedly challenging, but it is a matter that concerns everyone and can be accomplished by adopting a cross-sectoral approach to electrification. This approach should begin with road transport, which alone accounted for **77% of greenhouse gas emissions** in the European transportation sector in 2020.[2]

The EU has implemented a strategic action plan, the **Green Deal**, aimed at reducing its environmental footprint. The primary objective is to make Europe the **first climate-neutral continent by 2050**[3] and this plan has outlined specific targets for the transport sector, which include:[4]

- **90% reduction in transport emissions** by 2050;
- Investments in **cleaner mobility**;
- A new directive on **renewable energy** to increase its share in the transport sector;
- A **13% reduction in greenhouse gas** emission intensity in transport by 2030.

As we strive towards a low-carbon future, the adoption of **Vehicle-**

Integrated Photovoltaics (VIPVs) is and will continue to be a crucial aspect of this transition. The International Energy Agency Photovoltaic Power Systems Programme (PVPS) has dedicated its "Task 17" working group specifically to researching the **implementation of photovoltaics in transportation**, highlighting its significance. This underscores the program's objective and urgency to foster a worldwide collaborative effort in this area.

Following preliminary analyses that demonstrated the feasibility and convenience of electric vehicles operating independently of charging stations, the IEA's PVPS recognized the **transport sector as a promising area for the implementation of photovoltaics**. As the electrification of vehicles becomes more widespread, the electricity produced by solar panels and other renewable energy sources is essential to achieve a significant reduction in CO2 emissions.[5]

With electric vehicles now looking set to become the main form of transport for people and freight, **the integration of solar is a natural, cost-effective, and high-potential choice to transform this sector**.

Sources:
[1] Paris Agreement
[2] Greenhouse gas emissions from transport in Europe
[3] A European Green Deal
[4] Make Transport Greener
[5] State-of-the-Art and Expected Benefits of PV-Powered Vehicles (2021)

01

The advantages of flexible solar panels for road transport

The advantages of flexible solar panels for road transport

In view of the above, it is not surprising that fleet operators are becoming ever more interested in solar panels. Whilst trucks are becoming more technologically advanced and have higher energy requirements, batteries have not kept pace with these advancements, necessitating more frequent maintenance and replacements.

In this context, the solar panels **designed for the trucking industry offer a perfect solution, being flexible, thin, lightweight, and highly adaptable to the varying surfaces and spaces** available on different types of vehicles, including vans, trucks, and trailers.

FOCUS

By producing free energy during the day, the flexible solar panels significantly extend the vehicle's electric range. What's more, by preventing the battery from discharging completely, they also help to **prolong its lifespan**, thus reducing the need for frequent replacements and associated costs.

In addition to this, there is also a fuel-saving benefit: while driving, a lighter load on the engine **reduces fuel consumption**, and during stops, energy from photovoltaics avoids having to keep the vehicle idling to generate electricity. With the engine, alternator, and battery under less stress, the savings come from both **lower maintenance costs** and the ability to avoid forced stops, thereby addressing the costly issue of missed deliveries.

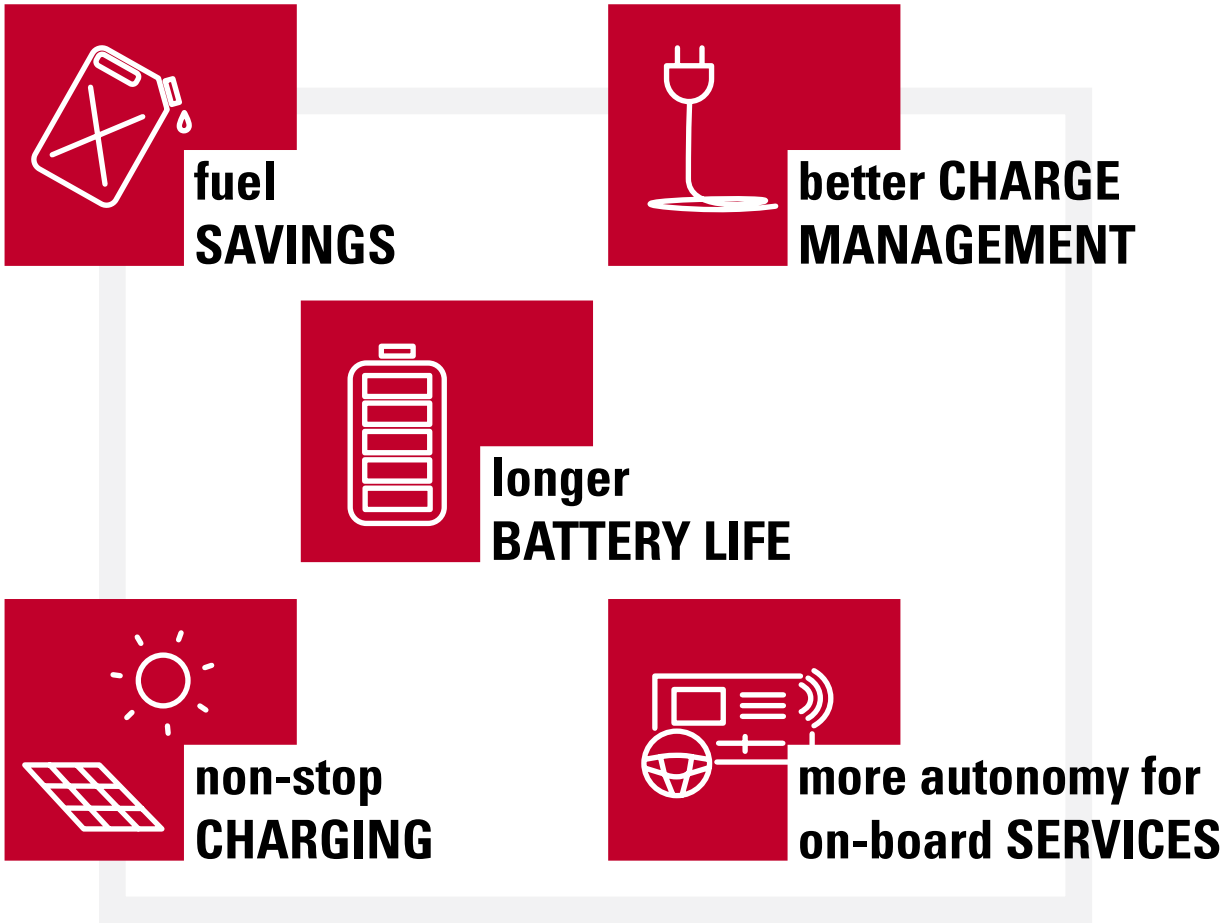
This advantage is not merely conceptual but also tangible and measurable through specialized analysis tools that enable fleet managers not only to estimate both the total savings and the return on investment but also to monitor consumption during usage, allowing for precise calculation and assessment of efficiency.

FOCUS

In refrigerated trucks, the photovoltaic system has the potential to **replace up to 85% of the diesel fuel consumed by the refrigeration unit** to maintain the trailer's temperature at -18°C. This could lead to significant savings in both economic and emission-related aspects.[6]

Regarding the advantages of integrating photovoltaics, the reduction in energy consumption and emissions, coupled with the prolonged battery life, are accompanied by **enhanced comfort in the workplace for the driver,** who no longer has to worry about conserving energy to prevent the battery from depleting entirely. With emergency calls to roadside assistance becoming a thing of the past, **the driver can concentrate** more on driving, without additional sources of stress.

More energy on board means optimized utilization of all services requiring such energy, primarily heating and cooling the cabin whilst stationary, along with the charging and operation of all electronic



Sources: [6] Elliston, B.; Dennis, M. Feasibility of Solar-Assisted Refrigerated Transport in Australia. In Proceedings of the 47th Conference of the Australia and New Zealand Solar Energy Society (Solar 2009), Australian and New Zealand Solar Energy Society (ANZSES), Townsville, Australia, 29th September - 2nd October 2009.

02

Which flexible solar panels are best?

2.1

The most influential aspects in the selection process

Flexible photovoltaic panels are valued for their lightweight, comfort, and durability. However, the key factors that should influence the purchase decision are undoubtedly the quality and high level of customization, which allows them to be **adapted to any situation and need.**

Solbian, an Italian company that has specialized in producing this type of product for 15 years, has been closely monitoring **developments in the mobility sector** with great interest. They offer modules (the Solbianflex panels) with different power ratings to best support each vehicle and its operational and energy storage needs, as well as different **variants of crystalline silicon cells** - the most efficient technology on the market - capable of peak performance even in the harshest environmental conditions and with the most intense mechanical stresses.

Credits: Alexander Brown

2.2

Efficiency and power

One of the most intriguing technological advancements in the industry is the use of **flexible solar panels** incorporating solar cells that can convert **over 25% of sunlight into electricity,** which is a record level of efficiency for a flexible module. This achievement is the result of over a decade of collaboration between Solbian and Maxeon, a leading technology company in the field of solar cells and the same company that offers Sunpower modules to the market.

Thanks to this advancement, a **high level of power can be achieved even in small spaces** due to the dense concentration of power per surface area.

2.3

Durability and resistance to climatic conditions

The panels most suitable for this type of application must be **robust and durable over time**, especially in view of the constant environmental stresses of temperature changes, rain, salt spray and accidental impacts.

Developed for the nautical sector, Solbianflex modules have been extensively tested in the harshest climatic conditions by numerous navigators and are characterized by their high resistance to degradation.

2.4

Dimensions (thickness and weight)

Flexible solar panels also have the advantage of being **impressively thin,** at less than 2 mm (for Solbian modules), which is another key aspect in the choice of panels, since the thinner and more flexible the panel, the easier it is to integrate it into different contexts and to create complex geometries and aesthetic customizations. The possibility of bending down to radii of less than one meter then facilitates all kinds of applications, from **car bodies to truck spoilers and even boat hulls**. Heaviness is also particularly influential.

FOCUS

Solbianflex panels weigh less than 2.5 kilograms per square meter, compared to 12 kilograms or more for conventional panels.

2.5

Price

How much does a solar system cost? This is a legitimate question, the answer to which varies on a case-by-case basis depending on the **level of customization and configuration** of the entire system, including the electronic component that affects the installation price.

Prices are always customized. However, some considerations can be made. For instance, in the last decade, photovoltaic production capacities have increased considerably as prices for the technology have fallen, offering opportunities for applications that in the past would have been economically unfavorable. As an example, a solar system can now save a truck more than 5% of fuel on a standard day.[7] On a fleet of 100 trucks, this translates into **savings of about 210,000 liters per year.** Investments can therefore certainly be planned in an advantageous environment.

Sources: [7] State-of-the-Art and Expected Benefits of PV-Powered Vehicles (2021). 2.5 Case study on PV-powered truck trailers in the Netherlands: PV electricity production on trailers, p. 93.

03
How flexible solar panels are installed

3.1

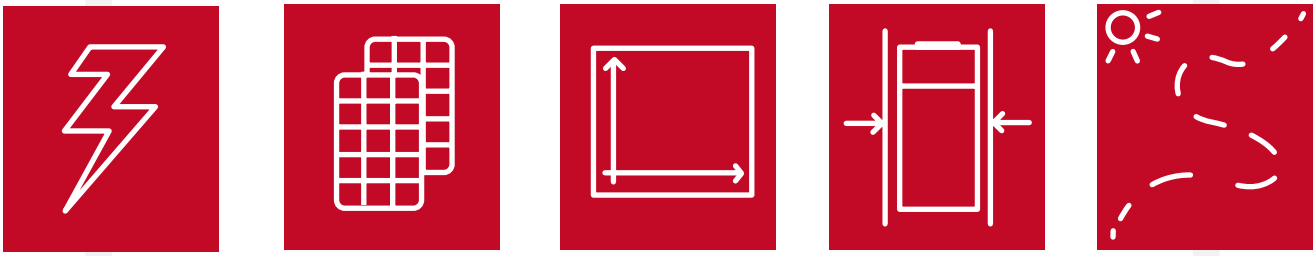
How flexible solar panels are installed

Panel, charge controller, battery - these are the components of an off-grid photovoltaic system.

The operational concept is straightforward - the panel **converts light into electrical energy**, the battery stores it and the charge controller optimizes the battery power.

However, the installation process starts with a consultation where specialized technicians assess the specific requirements of each vehicle to design the most appropriate solution.

VARIABLES INVOLVED IN THE DESIGN



Energy requirements

Number of panels

Usable vehicle surface

Space available for battery installation

Vehicle routes and average exposure

3.2

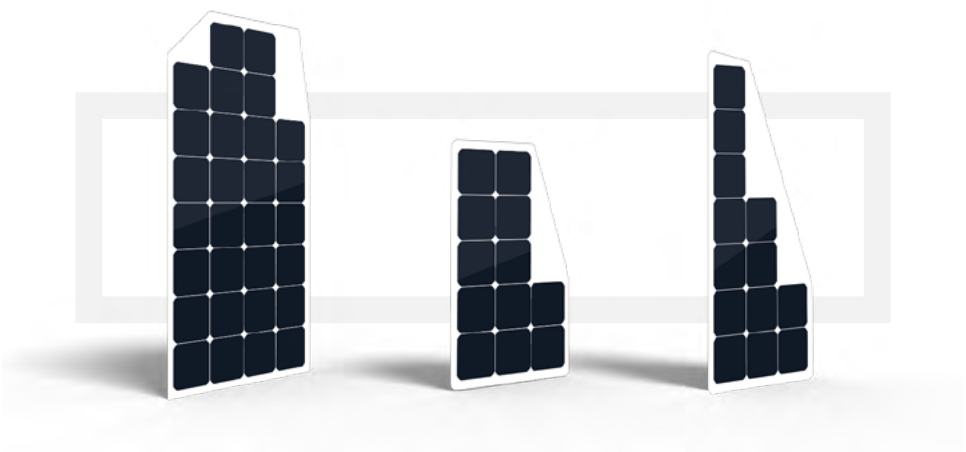
Do you need to recharge a 48-volt battery but have little space available?

The regulator and battery should be chosen according to the installation conditions. The assessment of a technical division, such as that of Solbian, is crucial. The use of advanced charge controllers with the MPPT (Maximum Power Point Tracking) algorithm is the most efficient method of obtaining as much energy as possible on moving vehicles. These regulators are capable of quickly responding to changes in lighting conditions while the vehicle is in motion, and can adjust the voltage of the panels independently of the size of the photovoltaic system, lighting conditions, and battery voltage.

3.2

Design and customization

Before proceeding with the installation of the flexible solar panel, it is possible to opt for further customizations, such as shape, background color, or surface finish.



Once the customized product is technically ready, we proceed with the electrical connection which can also vary according to taste and needs.

Solbianflex panels can be supplied with junction boxes or monopole connections applied to the front of the panel to allow connection to the charge controller. Alternatively, Solbian's Surface Mounting option is particularly suitable for structural integration with adhesives, where two silicone-insulated cables and a plastic grommet on the back make the electrical connection invisible.

04
Application examples

CASE STUDY: installations for battery maintenance

As mentioned in the introductory chapter, the use of photovoltaic modules on commercial trucks is a very advantageous and viable way of reducing fuel consumption and thus carbon dioxide emissions in the road transport sector.

4.1 On trucks

For small power installations involving the vehicle's tractor unit and thus with limited space available, the reduction in vehicle maintenance costs is more significant than the fuel savings. The photovoltaic modules help maintain a constant, daily battery charge that prevents voltage fluctuations or heavy discharges that can necessitate premature battery replacement or unexpected vehicle stoppages (meaning missed deliveries).

Amongst the first to embark on this path with Solbian was a well-known transport company, which has been putting its fleet and professionalism at the service of freight handling for over 50 years.

FIG. 1

FIG. 2

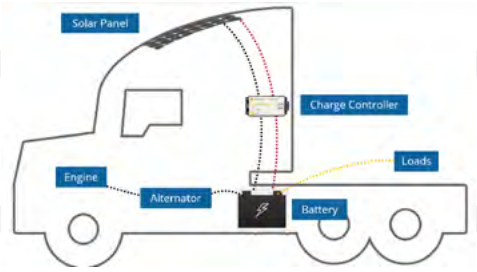


FIG. 3

Motivated by its innovative nature plus the desire to reduce fuel consumption and the number of battery replacements, the company decided to equip three vehicles in its fleet with Solbian flexible solar panels for a pilot project to evaluate and monitor the data.

The choice for installation on the vehicle spoiler was the ALLinONE model, which is a photovoltaic panel with integrated electronics. Furthermore, the system was equipped with remote monitoring to collect data on solar production and battery charge status.

Installed system

A Solbianflex SX 114 ALLinONE module, based on polycrystalline silicon cells, with an integrated MPPT charge regulator capable of raising the voltage to charge the vehicle's battery pack (24 V and 200 Ah) was applied to the vehicle's spoiler using double-sided adhesive tape. (Fig.1-2-3)

Results achieved

The solar input immediately raises the battery voltage in the morning, helping to keep the battery charged throughout the day so that in the evening, it can handle a longer-than-usual rest period without having to start the engine.

The most important and most easily quantifiable contribution is the reduced stress on the battery, which extends its life.

4.2

On ambulances

Trucks are not the only vehicles with high electrical consumption, another typical case where solar energy makes an important contribution is in fact ambulances. Indeed, these vehicles increasingly contain sophisticated diagnostic and emergency instruments, which have a significant power consumption. To avoid over-discharging the batteries, one method is to turn the engine on often, which not only increases consumption but is also anti-ecological and even annoying when the ambulance makes long stops, such as during sporting events. This is where photovoltaic modules can come to the rescue. By way of example, in Fig.4 a diagram of an installation on a Red Cross ambulance vehicle.

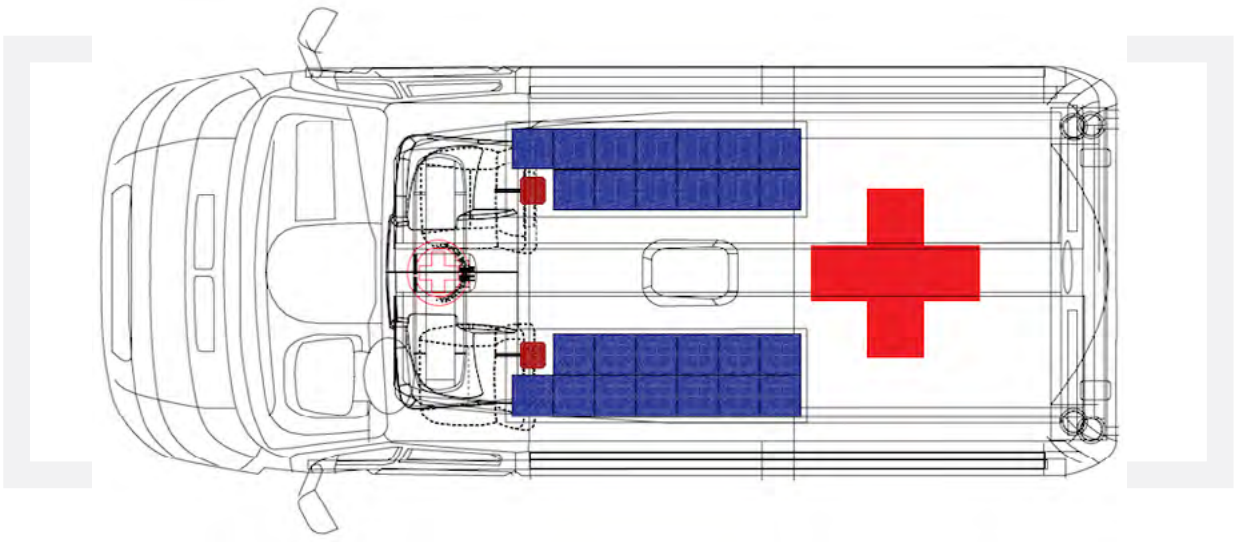


FIG. 4

Objective

Installation of maximum photovoltaic power in the available area, to power on-board services.

Operation

Installation of two Solbianflex SX52 ALLinONE photovoltaic modules, totaling 104 Wp.
More examples in Fig.5-6 show a Green Cross ambulance and an installation by an Irish partner.

FIG. 5

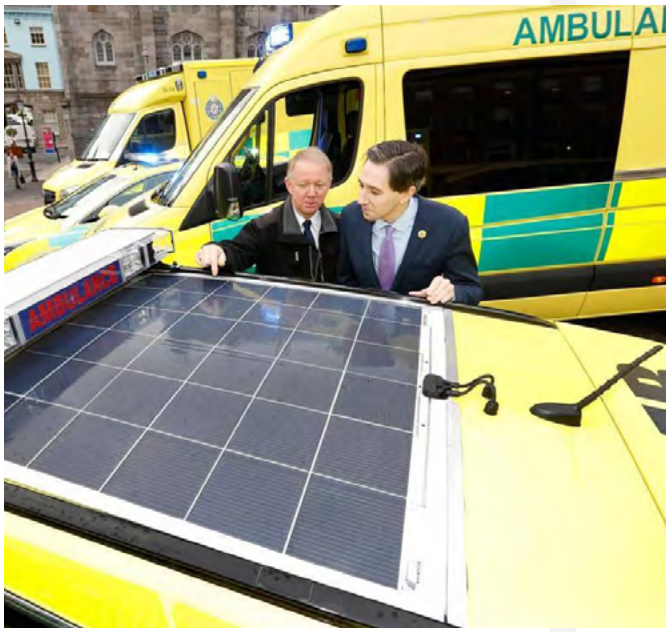


FIG. 6

4.3

CASE STUDY: Application on refrigerated trucks

Refrigerated trucks are a type of vehicle that can benefit most from the installation of flexible solar panels given that, not only do they have high consumption for maintaining ideal cold storage conditions, but they also have considerable space available for installing the solar system.

Conventional refrigerated trailers are equipped with single- or multi-temperature cooling technologies for transporting, in the latter case even simultaneously, both refrigerated products from 0° to +7° C and frozen products that travel at -18° C.[8] Given that such trailers are detachable from the tractor unit, they must be autonomous in terms of refrigeration system operation thus they are typically equipped with diesel generators and electric refrigeration systems. The generator is started up via battery, just like a regular car.

Logistics companies are often offered vehicles that can operate at both temperature ranges to avoid the need for two different dedicated trailers. The diesel engine directly drives the refrigeration compressor, and fuel consumption varies depending on the temperature to be maintained. It goes without saying that the use of solar power, which can be exploited by means of a control logic that accompanies or suspends the diesel engine when sun-generated electricity is available, can represent a considerable economic and environmental advantage for this type of vehicle.

It is no coincidence that there have been several studies since the 1990s with specific reference to refrigerated trucks, starting with that of Sainsbury's supermarkets in 1998,[9] which showed how the application of photovoltaic modules on the roof of the trailer led to a reduction in diesel consumption, identifying a return on investment (including the cost of batteries) in around 15 years.

This was when both photovoltaic modules and batteries were considerably more expensive than today, whereas fuel was much cheaper. A similar conclusion was also drawn in a theoretical study carried out by the US Sandia National Laboratories in 2001,[10] which calculated the sustainability of the photovoltaic system in about 20 years. This was an interesting study because it also considered the excess weight due to the photovoltaic system, which at the time was made with much heavier modules than today.

Today, the costs of solar systems and batteries are significantly lower than twenty years ago. This is evident from the estimates of more recent works, which provide ROIs in less than four years, with further potential for decreases linked to entering into series production.[11]

Thus today, we can say that for a 5 kWp solar system, including charge controllers and accessories, the ROI is 4 years.

Let us, therefore, examine how a solar system for a refrigerated truck could be structured, taking as an example an installation realized in 2022.

Operation

The starting point was to apply the photovoltaic modules on the trailer, which with its 2.6x13.6 square meters of roof provides ample space.

The use of flexible photovoltaic modules for this type of installation is recommended for several reasons, starting with their lightweight which reduces the load of the installation by 80% compared to conventional photovoltaic modules with glass and aluminum frames. Furthermore, the flexible and thin modules do not substantially alter the aerodynamics of the trailer and can be easily attached by means of double-sided adhesive tape.

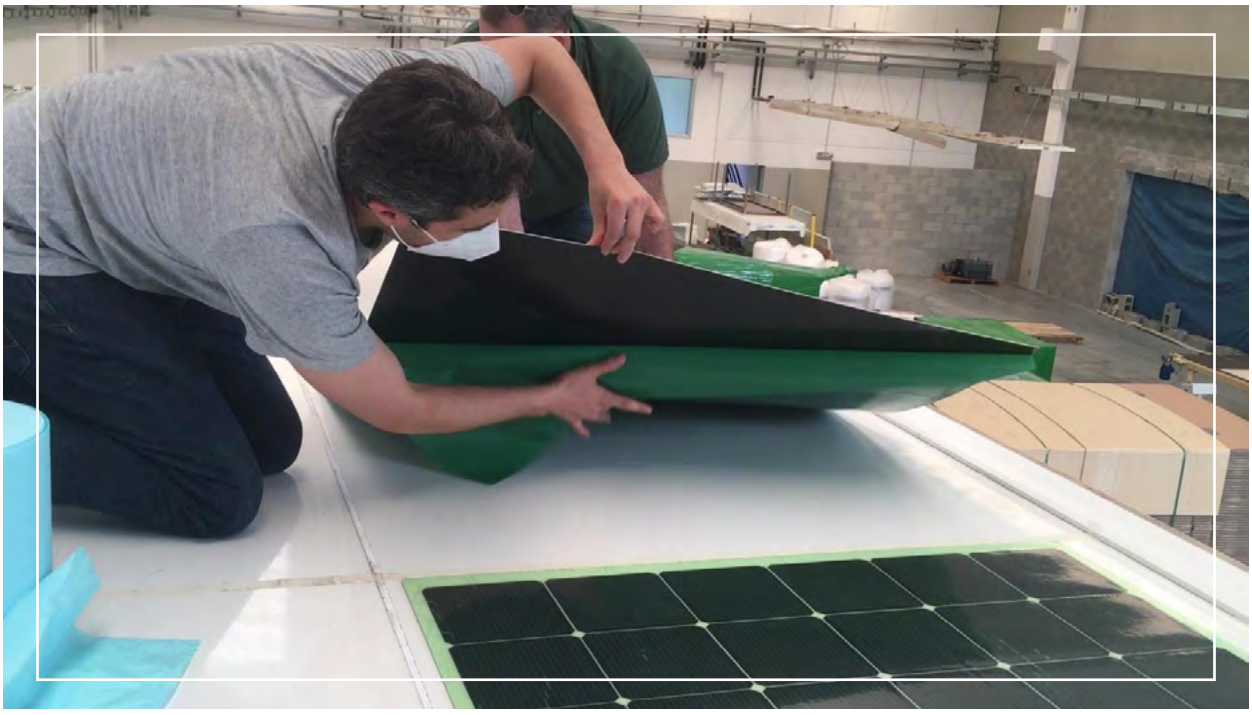


FIG. 7 Installation of flexible photovoltaic modules on the roof of a trailer.
The protective film is removed from the rear adhesive before attachment.

Results achieved

The final result, in this case, led to an installation with a peak power of 3.5 kWp, but by optimizing the space and using more efficient solar cells, up to 5.5 kWp can be achieved. The modules can then be electrically connected according to the defined layout characteristics and overall power, with corresponding output values of voltage and current. The solar system thus designed will power a hybrid refrigeration system.

This solution can be taken even further to achieve full electric refrigeration, as shown in the layout in Fig.8, which represents another

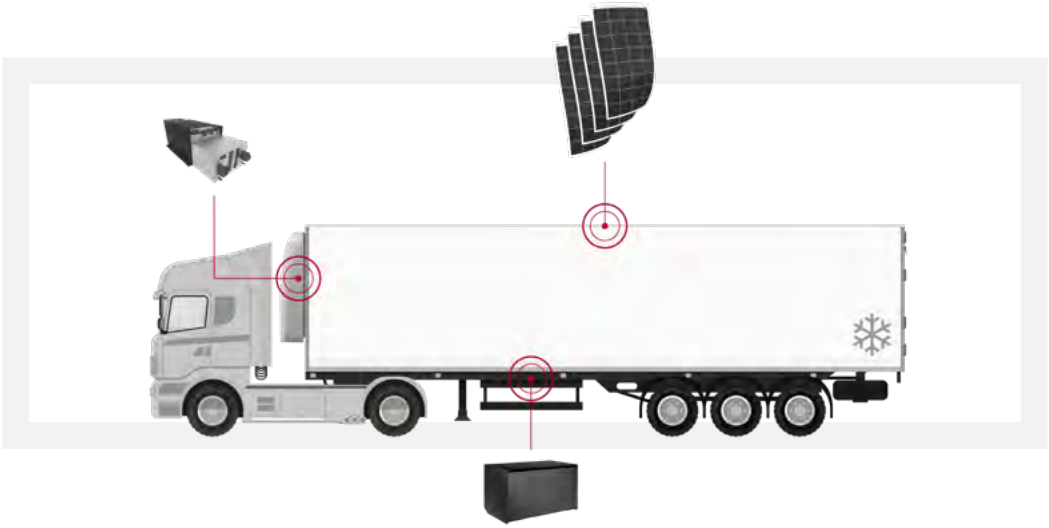


FIG. 8

In this example, by availing of the sun's energy and energy recovery in association with the vehicle's braking, this highly innovative solution has made it possible to completely eliminate the diesel generator that was previously necessary for cooling.

In Fig. 9 some details of the converter installation in the refrigeration system space that was previously dedicated to the diesel engine: a fully electric and sustainable refrigeration.

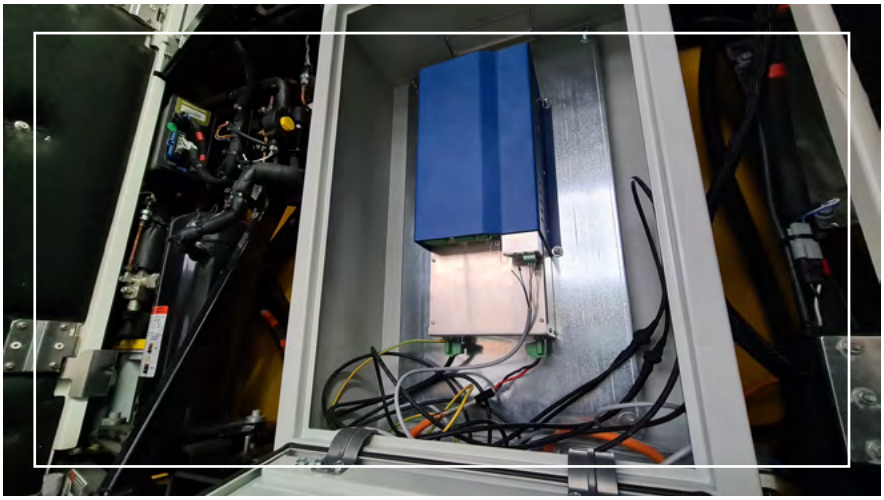


FIG. 9 The MPPT converter takes the place of the diesel generator.

The photovoltaic modules, MPPT converter, batteries, and regenerative braking axis are currently in operation. The trailer can transport refrigerated goods without any diesel generator being installed.

Sources: [8] ATP HANDBOOK (2016), pages 91-100
[9] Bahaj A.S. and James P.A.B. (2002) Economics of solar powered refrigeration transport applications. Proceedings of the 29th IEEE PV Specialists Conference, New Orleans, USA, 21st-24th May 2002, pages 1561-1564
[10] Solar Powered Refrigeration for Transport Applications. (2001) SAND2001-3753
[11] Christoph Kutter, et al. (2021) Presented at the 38th European PV Solar Energy Conference and Exhibition

05

Other applications of flexible photovoltaic panels in transport

5.1

Other applications of flexible photovoltaic panels in transport

Flexible photovoltaic panels can be used on a wide range of wheeled vehicles, from trucks and vans to motorhomes and ambulances. In fact, any vehicle that requires electricity for activities beyond just transportation is a potential application.

Additionally, the panels can even be installed on two-wheeled vehicles, such as e-bikes and cargo bikes, which are commonly used for transporting goods, people, and animals in Northern Europe.

FIG. 10 Sunrider's cargo bike (sunrider.bike)

FIG. 11 The solar-assisted bicycle (which has three wheels) from IFEVS (www.ifevs.com)

In cargo bikes space is limited and it's crucial to keep maintenance costs low. By incorporating photovoltaic modules into them, a consistent daily battery charge can be maintained, preventing voltage fluctuations and deep discharges that can lead to premature battery replacement or unexpected stops during deliveries. With the help of solar power, riders can avoid missed deliveries and improve their overall efficiency while reducing their impact on the environment.

Solbian's lightweight and efficient flexible solar panels have made them a great choice for cargo bikes, resulting in collaborations with companies such as Need The Globe and I-FEVS for the development of solar-powered solutions.

Launched by the Dutch company, Need The Globe, SunRider (Fig.10) is a solar cargo bike that enables seamless and green delivery by reducing charging time and labor costs. By charging on the move SunRider has up to an additional 100 km of range per day, reducing dependence on the power grid. The e-bike features a Euro pallet-sized cargo box that can hold up to a 150 kg payload

I-FEVS e-bikes (Fig.11) serve multiple uses, including commuting, urban delivery, and day-to-day family travel. Solar panels encase the e-bike's high-strength nanostructured steel square-tubed frame, charging the onboard electric motor as the rider drives. The high-efficiency solar panels perform active balancing of the battery pack.

ABOUT SOLBIAN

Solbian was born from the shared vision of Giovanni Soldini, the renowned Italian sailor, and Marco Bianucci, an accomplished physicist. Their goal was to revolutionize competitive sailing boats by integrating photovoltaic technology.
The journey began in the nautical world, where they aimed to develop flexible solar panels capable of withstanding the dynamic movements of the boats. Over time, Solbian expanded its horizons, leveraging industrial resources and harnessing the expertise of talented individuals. This multidisciplinary approach fueled the continuous technological advancements in module design and control electronics, paving the way for diverse applications.
Through unwavering dedication, Solbian has solidified its position as a prominent player in the photovoltaic industry. Building on this success, the company has set its sights on a new aspiration: promoting sustainable mobility powered by solar energy. Their focus extends beyond sailing to encompass areas such as transportation and refrigerated vehicles, aiming to drive positive change for a greener future.

Headquarter:

Viale Gandhi 21b,
10051 Avigliana (TO)
ITALY

Phone: +39 011.966.35.12

e-mail: sales@solbian.eu

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