Flexible photovoltaic panels
Examples of application

State-of-the-art technology applied
to road transport, refrigerated vehicles,
ambulances and other vehicles.

SOLBIAN
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Contents

Introduction

Introduction

It is evident that electric vehicles are set to become the main form of transport for people and freight. For this reason, the integration of photovoltaic systems in transport vehicles is a natural evolution.

The first studies on this topic are several decades old, and engineering teams have long been researching, testing, and applying this technology to evaluate and optimize its results. Today, it can be confidently stated that **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.**

However, to attract investments, quantitative data is also necessary. This is the purpose behind the creation of this collection of real Case Studies, monitoring the operation of Solbianflex technologies on the vehicles that have been serviced over the past two years.

CASE STUDY
Application on trucks

Installations for battery maintenance

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.

Photovoltaic modules help maintain a constant and daily charge of the battery, avoiding voltage spikes or deep discharges that lead to premature battery replacement or unexpected vehicle stops (resulting in 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

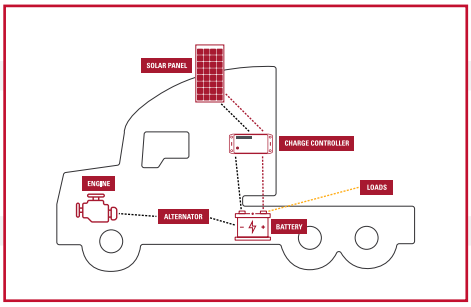

FIG.3

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

Typical daily trends in battery voltage and current produced by the solar system (and fed into the battery) are visible in Fig.4.
One can see how 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 to avoid over-discharge.
Going into more detail, it can be seen that during the night (from

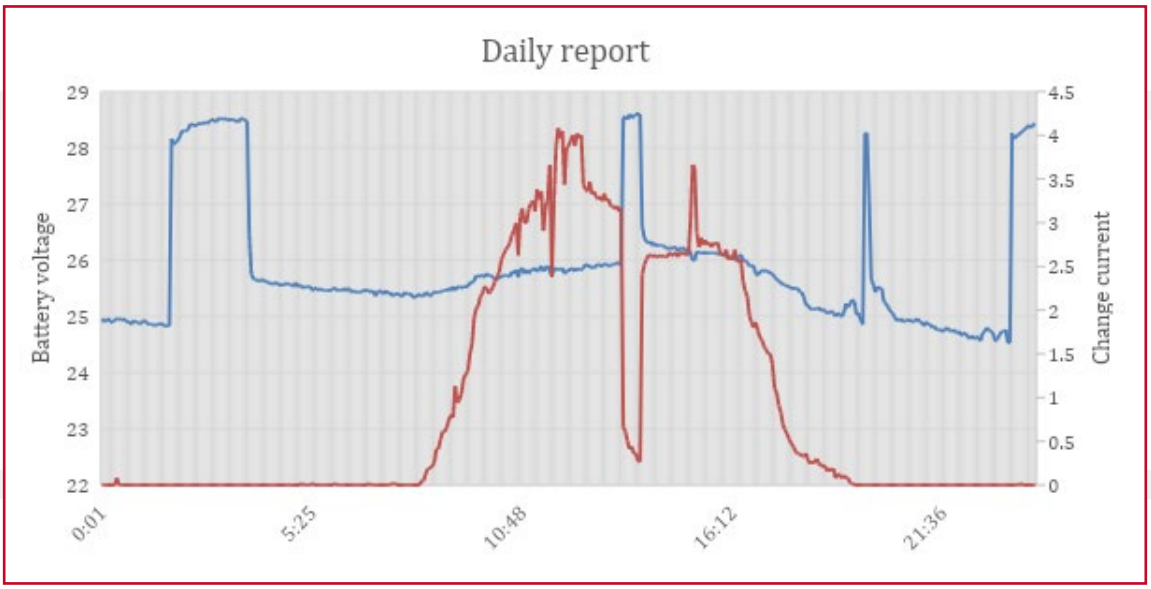

FIG.4 Daily trend of battery voltage (blue) and charging current due to the solar panel (red).

2:00 am to 4:00 am), the vehicle was in operation, as with the engine running, the alternator raises the voltage above 28 V.

From 4:00 am, the vehicle is at a standstill but after 7:30 am, the solar contribution prevents the battery from being further discharged so that the engine is only switched on briefly at around 2:00 pm and then again for a longer time close to midnight when the rapid decrease in voltage indicates a probable use of a heating system on board. Another aspect to note is the reduced contribution of solar when the alternator charges the battery, as the current produced by the former inhibits the panel. A very visible effect in this case where the solar source is small and makes its contribution especially when the engine is switched off.

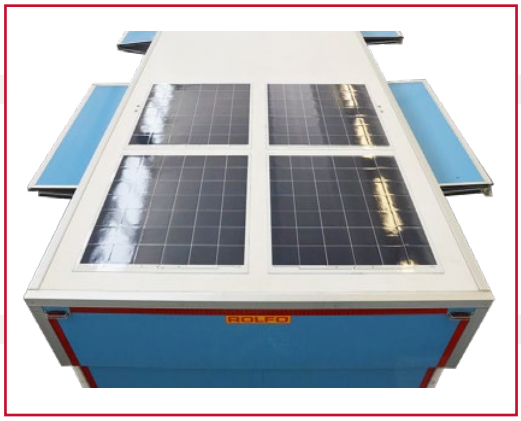

FIG.5

A similar installation but with more solar power, was carried out on a closed car transporter of the Rolfo company. Fig.5 shows a detail of the system and Fig.6 the daily trend of the electrical parameters. This is a system of about 700 W, used to charge the vehicle's auxiliary battery, the one that handles the loading and unloading sides of the car transporter.

In this case, the solar contribution is more substantial (charging currents of over 13A are reached) and the use is different, characterized by consumption peaks (sudden voltage drops) during loading and unloading operations and intervals when the system is charged by the sun. Again, the most important and most easily quantifiable contribution is the reduced stress on the battery, which extends its life.

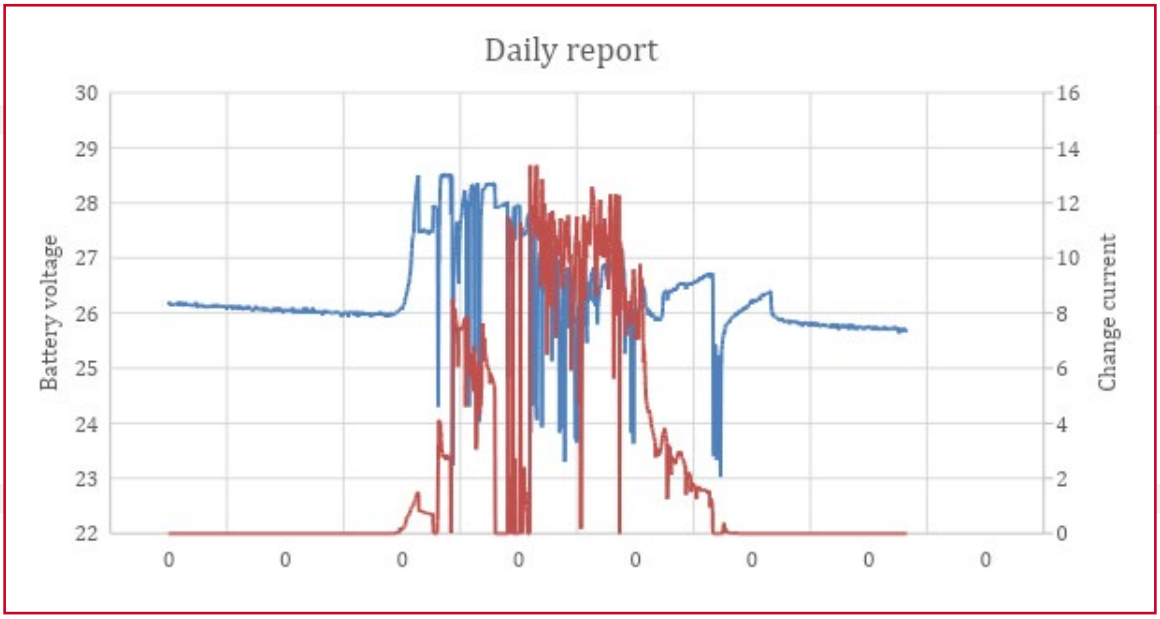

FIG.6 Daily trend of battery voltage (blue) and charging current due to the solar panel (red).

Another daily trend in Fig.7, shows how the solar contribution helped to contain the voltage drop so that in the evening, the vehicle goes to rest with the battery charged more than in the morning.

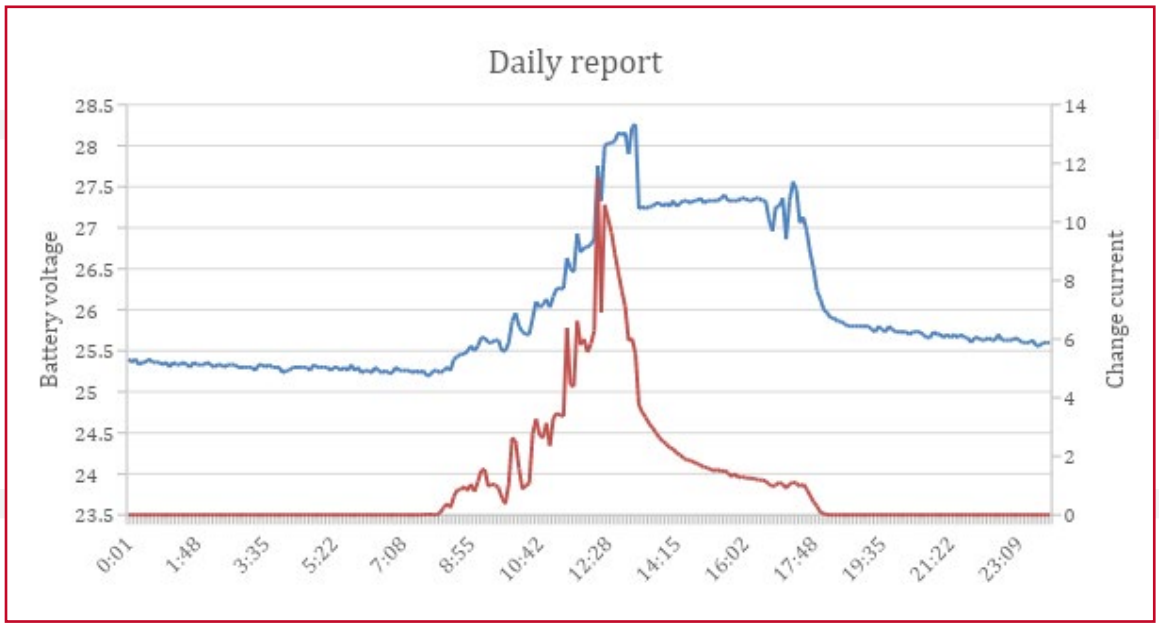

FIG.7 Daily trend of battery voltage (blue) and charging current due to the solar panel (red).

CASE STUDY
Application on ambulances

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.8 a diagram of an installation on a Red Cross ambulance vehicle.

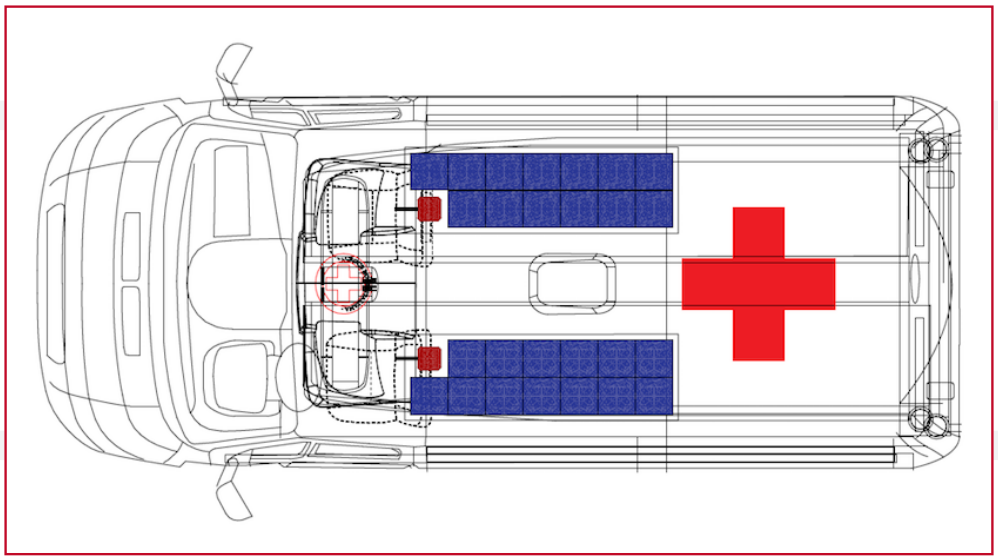

FIG.8

Objective

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

Operation

Installation of two Solbianflex SX 52 ALLinONE photovoltaic modules, totaling 104 Wp.
Further examples in Fig.9-10 show a Green Cross ambulance and an installation by an Irish partner.

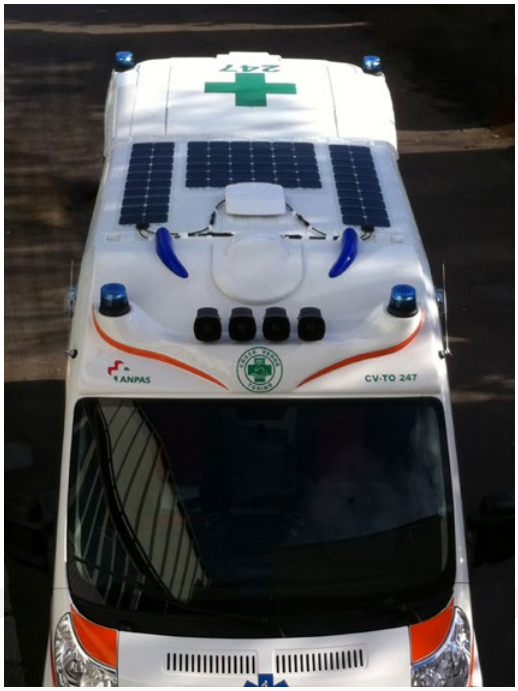

FIG.9

FIG.10

CASE STUDY
Application on refrigerated trucks

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**. 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[1], 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[2], 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[3].

In fact, 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.

[1] 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

[2] Solar Powered Refrigeration for Transport Applications. (2001) SAND2001–3753

[3] Christoph Kutter, et al. (2021) Presented at the 38th European PV Solar Energy Conference and Exhibition

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.

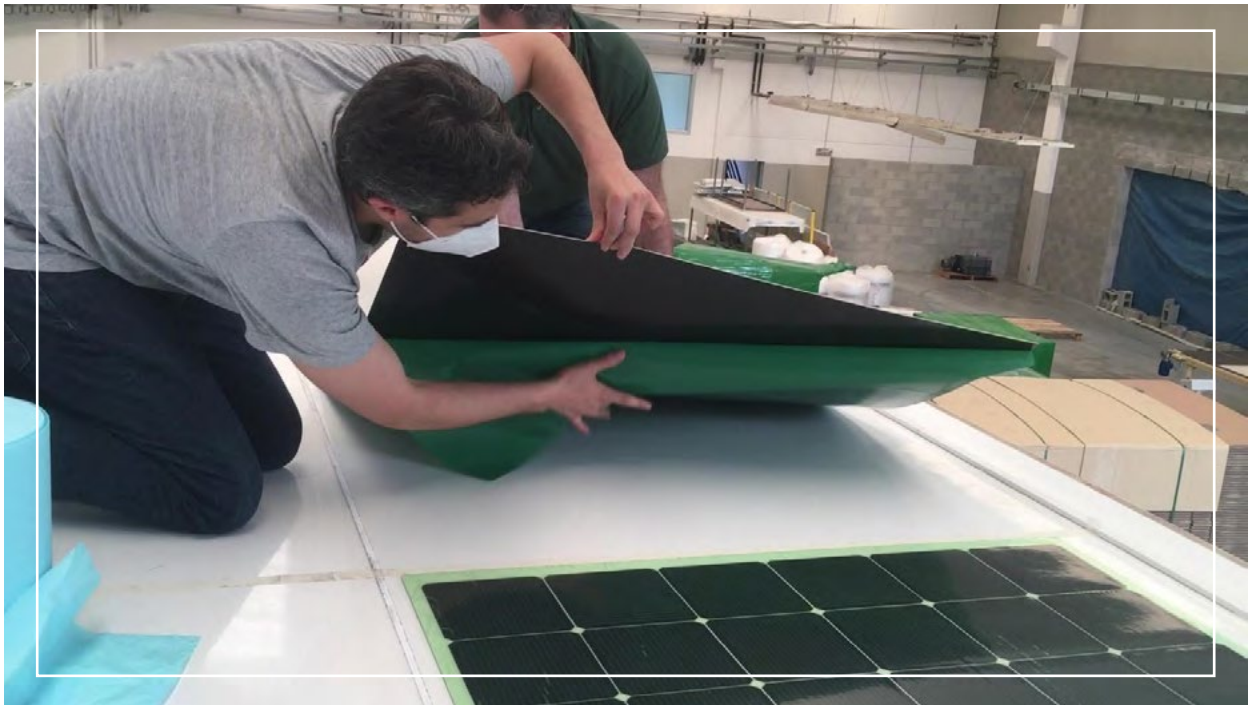

FIG.11 Installation of flexible photovoltaic modules on the roof of a trailer. The protective film is removed from the rear adhesive before attachment.

Results achieved

The final result, in this case, led to an installation with a peak power of 3.5 kW, but by optimizing the space and using more efficient solar cells, up to 5.5 kW 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, so-called because it powers the thermal machine with both electrical energy supplied by a diesel generator and that supplied by the sun, all with the contribution of a battery acting as a buffer.

One of the aspects still to be standardized for the use of solar energy in refrigerated trucks is the interface between the solar system and the battery. There are actually various solutions using batteries at different voltages, both low (24–48 V) and high (over 700 V). Therefore, the solar system must also include a charge controller that can convert the voltage to match that of the battery.

FIG.12 The ADDVOLT system is positioned under the trailer.

An example of smart retrofitting is the use of the ADDVOLT system (https://addvolt.com/), which involves adding a lithium battery that is recharged by harnessing the energy generated during vehicle deceleration, known as regenerative braking. Associating a solar system with a product from ADDVOLT is an obvious step. Energy recovery during braking and the sun's contribution work to charge the battery in a coordinated manner, with the former more effective during vehicle motion and the latter always active, even during stops. As the battery is high voltage, the connection between the solar system and the battery was made using a DC/DC converter, capable of raising the voltage up to over 700 V to recharge the battery. Communication between the converter and the battery occurs through CANbus, ensuring safe and optimized recharging.

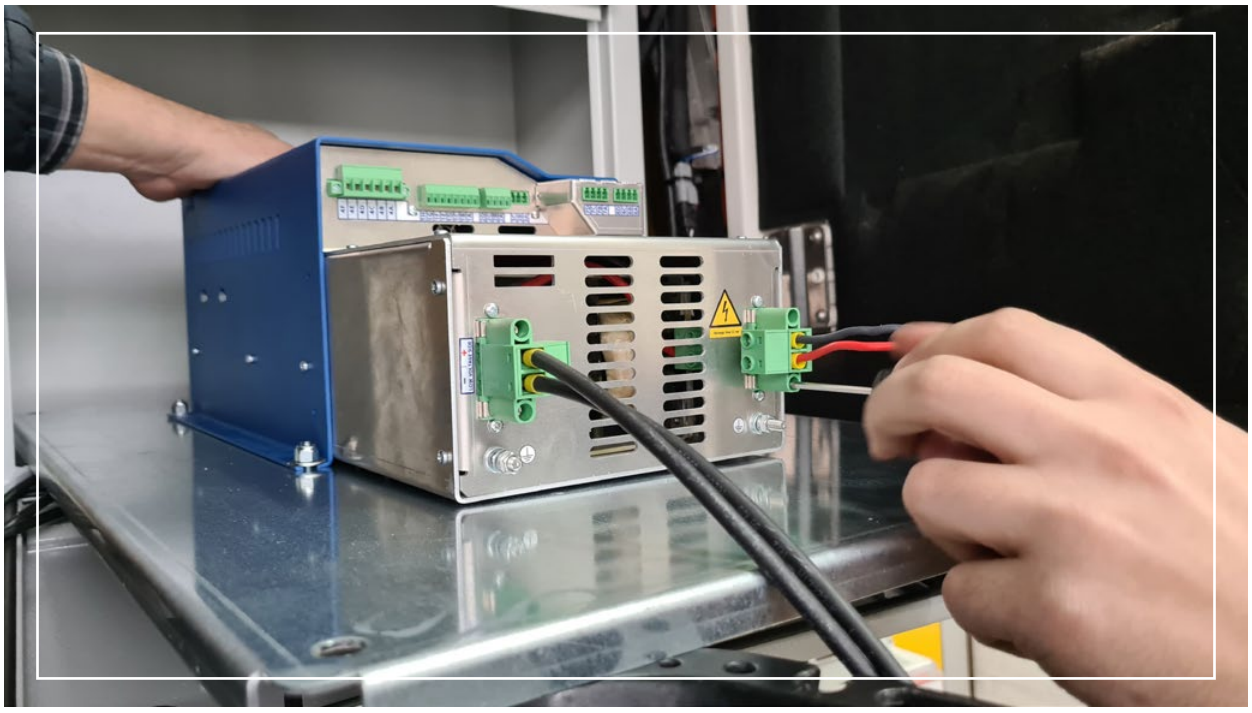

FIG.13

The overall layout of the system is visible in Fig.14.

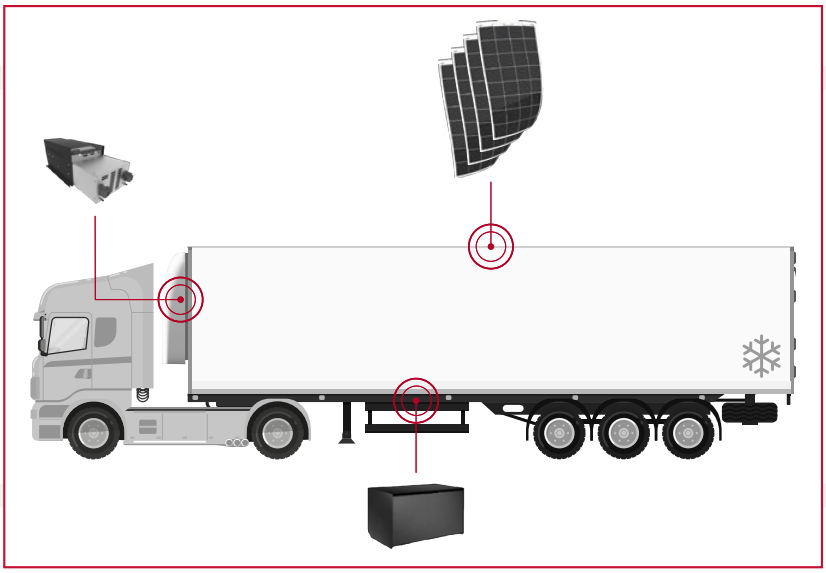

FIG.14

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.15 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.

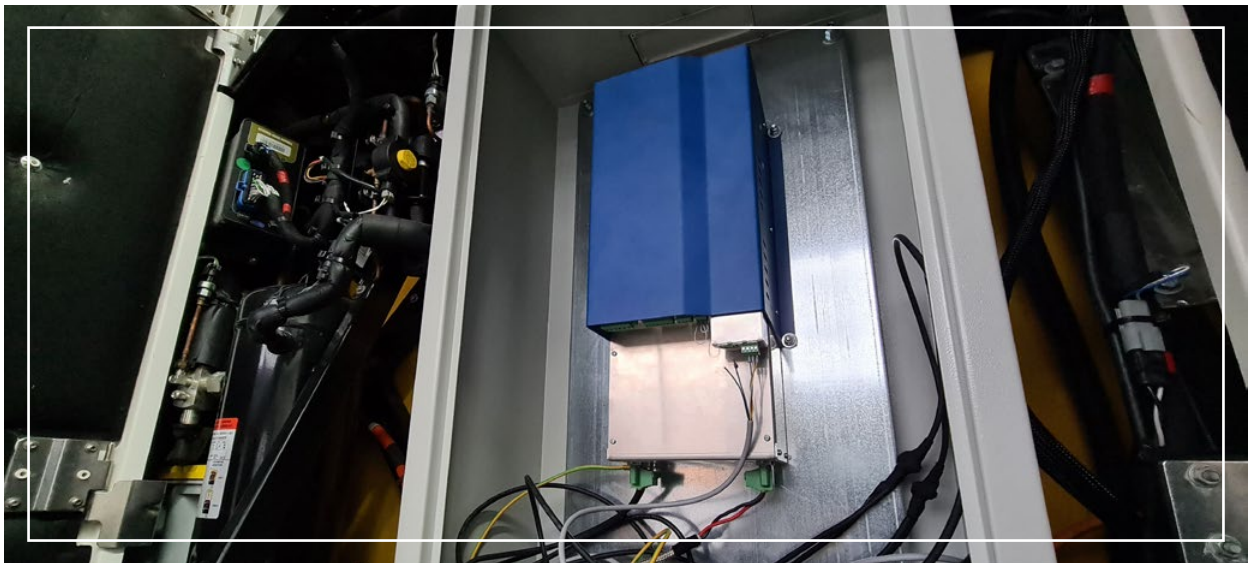

FIG.15 The MPPT converter takes the place of the diesel generator.

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.

CASE STUDY
Application on refrigerated vans

Application on refrigerated vans

Refrigerated vans with refrigerated isothermal boxes are used for medium-short journeys, with load capacities to the extent of a few tens of cubic meters. The refrigeration units are powered by the vehicle engine or by connection to the mains. Especially in the transport of frozen food, for very short journeys for deliveries to restaurants, coffee shops, and bathing establishments in the summer season, the frequent opening and closing of the unloading hatches requires the engine to be kept running, resulting in considerable consumption and pollution.

To assess the contribution of solar, a fleet of 15 vehicles, with different load capacities (40 m^3 and 20 m^3 refrigerated isothermal boxes), was studied. The refrigerated vans with 40 m^3 boxes were used for longer routes with fewer stops.

Fleet composition

10 vehicles with a 20 m^3 refrigerated box and a Zanotti SFZ238 refrigerating unit – maximum 3830 W/0° C – 2010W/-20° C. The internal volume is variable but generally, the proportions are ½ fresh, ½ frozen. The usable area for the installation of the photovoltaic panels is 3.7 x 2.1 m^2.
5 vehicles with a 40 m^3 refrigerated box and a Zanotti U600 refrigerating unit – maximum 6200 W/0° C – 3200W/-20° C. The internal volume is variable but generally, the proportions are ½ fresh, ½ frozen. The useful area for the installation of photovoltaic panels is 6.9 x 2.5 m^2.

Operation

20 m³ BOX

On smaller vans, 10 Solbianflex SX 137 Wp panels (683 x 1205 mm) were installed for a total of 1.37 kWp. The panels equipped with structural double-sided adhesive increased the weight of the vehicle by only 20 kg, thanks to a panel thickness of 2 mm and 20 mm along the mounting areas of the junction boxes which, complete with cables and MC4 watertight connectors, allow the electrical connection between the panels. The solar system was divided into two parts (2 strings) of 5 panels in series. Each of the strings was finally connected to a Victron SmartSolar 100/30 charge controller (maximum power 880 W when used with 24 V batteries).

FIG.16

A lithium battery (LiFePO4) with a nominal voltage of 24 V and a capacity of 150 Ah, provides 3.6 kWh of energy storage, increasing the weight of the vehicle by 35 kg.

Finally, an inverter was fitted with a continuous output power of 3 kW at 25° C, having a peak power of 6 kW, with dimensions of 485 x 285 x 150 mm and a weight of 19 kg.

Results achieved

The installed 1.37 kWp photovoltaic system is able to generate an annual production of 1557 kWh divided into the monthly fractions shown in Fig. 17-18.

MONTH	kWh
January	46.4
February	71.8
March	122.8
April	163.6
May	197.3
June	213.9
July	224.5
August	192.7
September	140.7
October	93.3
November	49.6
December	40.7

FIG.17

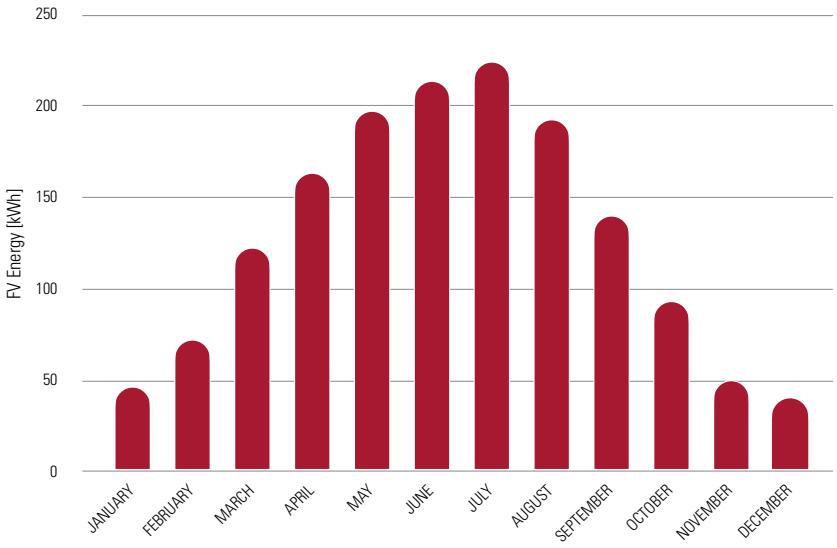

FIG.18

In the summer months, daily energy production will thus range from 6.3 kWh in May, to 7.2 kWh in July, which will more than compensate for consumption, allowing the vehicle's engine to be switched off even between one delivery and the next, thus achieving significant fuel savings, all whilst complying with legal temperatures.

Operation

40 m³ BOX

On the larger van, 20 Solbianflex SX 137 Wp panels could be installed, totaling 2.74 kWp. The panels equipped with structural double-sided adhesive increased the weight of the vehicle by only 40 kg, thanks to a panel thickness of 2 mm and 20 mm along the mounting areas of the junction boxes which, complete with cables and MC4 watertight connectors, allow the electrical connection between the panels. The solar system was divided into two parts (2 strings) of 10 panels in series. Each of the strings was finally connected to a Victron SmartSolar 150/70 charge controller (maximum output 2000 W when used with 24 V batteries).

The installed battery pack has a nominal voltage of 24 V and consists of three LiFePO4 batteries each with a capacity of 100 Ah, giving a total of 7.2 kWh of storage and an increase in vehicle weight of 81 kg.

To accompany the system, an inverter with a continuous output power of 5 kW at 25° C and a peak power of 10 kW, with dimensions 595 x 295 x 160 mm and a weight of 29 kg, was installed.

FIG.19

Results achieved

The installed 2.74 kWp photovoltaic system is able to generate an annual production of 3114 kWh divided into the monthly fractions shown in Fig.20-21.

MONTH	kWh
January	92.7
February	143.5
March	245.5
April	327.2
May	394.5
June	427.8
July	448.9
August	385.3
September	281.4
October	186.6
November	99.2
December	81.3

FIG.20

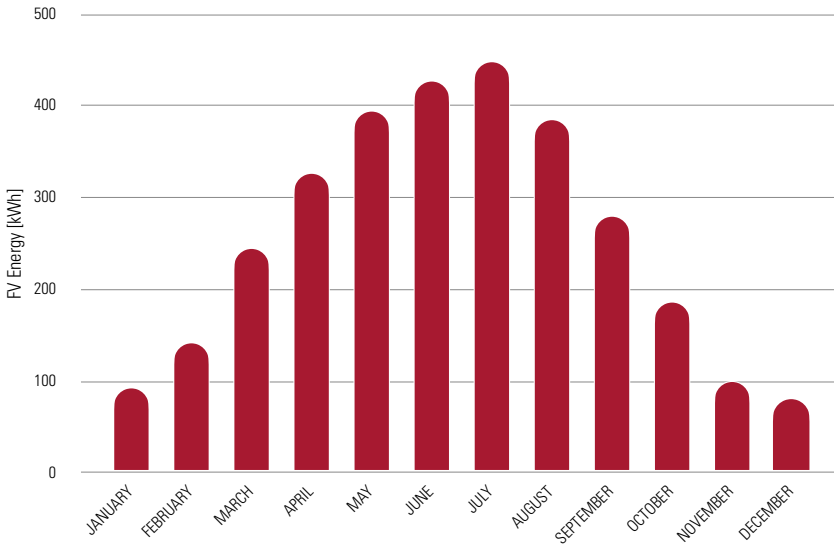

FIG.21

In the summer months, daily energy production will thus range from 12.7 kWh in May to 14.5 kWh in July, which will more than compensate for consumption, allowing the vehicle's engine to be switched off even between one delivery and the next, all whilst complying with legal temperatures.

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.

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