Noise Barriers Integrated with Photovoltaic Panels

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As a result of the incentives provided for under Italian law, the application of solar panels integrated into both buildings and infrastructure is attracting interest. This article describes the first solutions made in Italy that integrate sound-proof barriers into photovoltaic modules

The negative consequences that the worldwide energy industry is having on the delicate balance of the earth's ecosystem are still there for all to see; to try to alleviate the problem, governments around the world, by means of the Kyoto protocol, have taken steps to, among other things, provide incentives for the development and diffusion of renewable sources of energy.

It should be stressed moreover, that the Italian economy can no longer depend on an energy system in which it is not even a player, being unable to boast of any production capacity of its own nor of any ability to accumulate energy, and that is being consumed irreversibly.

In the Official Gazette No. 181 of 5th August 2005 the Decree (Ministry of Productive Activities and Ministry of the Environment) was published under which Italians also can produce photovoltaic electricity, download it into the grid and be paid a price in remuneration. This is the kind of "energy account" funding that has made Germany the leading country in the world in wind power and almost level with Japan in photovoltaic energy.

Following the Decree of 19.02.2007 on the criteria and means for providing incentives for the production of electrical power through photovoltaic conversion of light from the sun, some studies were started into the integration of noise barriers with photovoltaic panels in order to abate road and rail noise. The decree addresses this problem and the financial advantages that the transport infrastructure management bodies can enjoy from the systematic production of energy derived from renewable sources having a minimal environmental impact.

Regulatory Aspects

The financial-environmental policy has been supported for some time by the European Community through various directives implemented by member states. On the question of solar energy in particular, an important step forward was certainly taken with directive 2001/77/EC, implemented by the Italian Parliament with the approval of Leg. Decree 387/2003. Thereafter, a series of legislative steps resulted in a detailed definition of the means for accessing the "Energy account" which, in addition to the development of the technology for the production of clean energy, made it possible to realise a financial benefit from the sale of this energy to the major national suppliers.

As mentioned the Ministry for Economic Development issued a new decree (19/02/2007) on the criteria and means for providing incentives for the production of electrical power by means of the photovoltaic conversion of light from the sun, in implementation of article 7 of Legislative Decree 387 of 29th December 2003. The guidelines of the new decree are as follows:

- simplification of the procedure to obtain the incentive payments;
- simplification of the application procedure;
- sub-division of the tariff by type of application as well as by class of plant;
- privileges arising from architectonic integration;

Nominal power of the plant (kW)	Non-integrated photovoltaic plant	Partially integrated photovoltaic plant	Photovoltaic plant with architectonic integration
$1 \leq P \leq 3$	0,40	0,44	0,49
$3 < P \leq 20$	0,38	0,42	0,46
$P > 20$	0,36	0,40	0,44

Table 1 - Financial incentives provided by the "Energy Account" for the installation of photovoltaic energy systems

- revision of the annual power limits for incentive payments;
- provision of a concession for photovoltaic systems and for energy saving measures.

By the approval of these decrees in line with Community environmental directives, the use of photovoltaic panels can be considered to have become part of daily life and their spread across the country is just a matter of time. Even the transport infrastructure operators can take advantage of the financial benefits of this decree by the adoption of photovoltaic panels integrated into the normal noise barriers at the sides of the roads and railways.

It is not possible at this moment to define the unit costs of a project involving sound absorbing panels integrated with a photovoltaic system (that today, for plants sized for private use, run to about 6000/ kWp required), but more information is available in the regulations on the "Energy Account" that encourages the installation of these energy systems by providing the financial incentives shown in ***Table 1*** (expressed as €/kWh).

The shown incentives range from 0.36 /kWh for the largest plants up to 0.49 /kWh for small domestic systems. To these incentives can then be added the consequent savings from the consumption of the energy produced and the income from the sale of the same energy, delivering it directly into the national electricity grid.

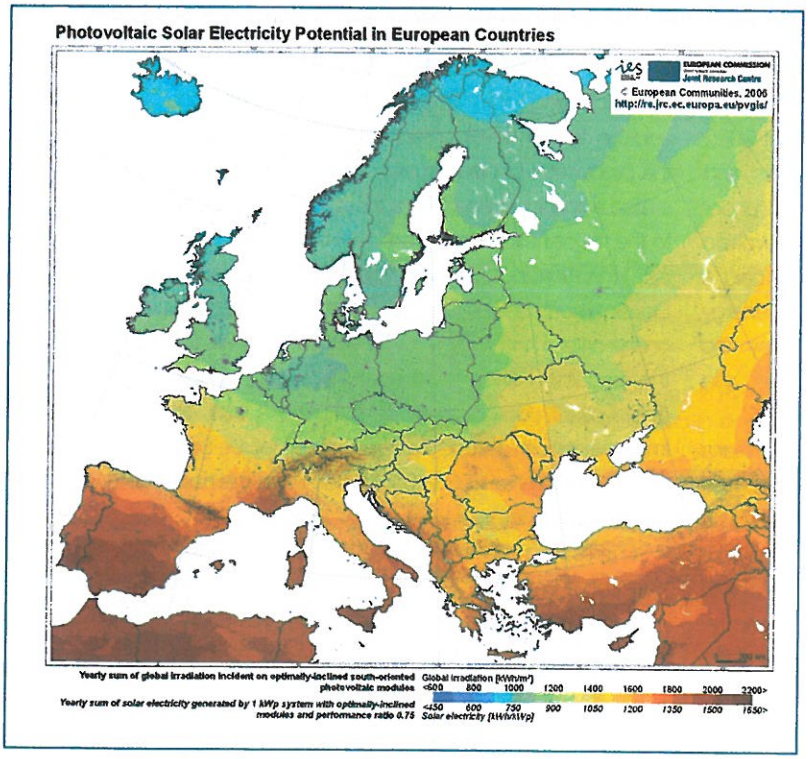


Fig. 1 - Thematic chart of photovoltaic solar energy potential in Europe (Source: Common Research Centre of the European Commission)

Photovoltaic Systems in the European Union

A development parallel to this politico-environmental trend is what is taking place in the architectonic-engineering sector in relation to the design of solar panels integrated into both building and infrastructural works. This development makes it possible to adapt engineering solutions to aesthetical-functional solutions.

A recent sector taking an interest in this innovation is that of anti-noise barriers. There are kilometres of works that could be used, not just for their principal function of limiting the propagation of noise, but also for the production of clean electrical power by means of the integral installation of photovoltaic panels (Photo Voltaic Noise Barrier, PVNB). In fact by varying the orientation of the photovoltaic panel in accordance with the geographical location and integrating it into the sound absorbing structure, the original primary function required of abating the noise created by the sound source would remain unaffected, and in addition a significant financial and environmental benefit would be gained by making available clean energy that could be used as needed or sold by delivering it directly into the national electricity grid.

The solutions currently available on the market are capable of optimising any geographical situation that may be encountered, as a result of which countries that experience high average levels of solar radiation, such as for example Italy, enjoy a not insignificant advantage. That notwithstanding, it is the countries of central Europe, such as Switzerland, Austria and Germany, that years ago began the first experimentation in the field. In these countries various solutions of anti-noise panels integrated with photovoltaic panels have been positioned on the principal communications arteries, and are demonstrating their efficiency both as anti-noise barriers and as renewable sources of energy.

The delay in implementing these applications is even less forgivable when one understands the enormous thermal potential that a country such as Italy is able to boast. A new thematic map (***fig. 1***), the work of the Common Research Centre (CRC) of the European Commission, identifies the photovoltaic solar energy potential of all of the regions of Europe. To comprehend this resource merely requires understanding the simple mathematical formula that illustrates the power of a single photovoltaic module:

$$P = \eta \times A \times W$$

where:
η is the yield of the photovoltaic module
A is the area of the module
W is radiated power (W/m²)

From the map (***fig. 1***) it is evident that with the same device it would be possible to produce twice as much energy in the southern areas of Europe as in the northern regions. From the cited study it can be seen that the countries of Central Europe, such as Germany for example, record an average annual solar radiation of around 1200 kWh/m2, much lower than the value measurable along the Italian peninsula, that on average achieves values of about 1500 kWh/m2. But it is important also to add that within Italy itself, that is already advantaged in comparison with other European countries, there is an enormous difference in potential as one moves down the peninsula; from the least radiation in the northern regions, that have average values similar to those of Germany, in Sicily for example (***fig.2***), radiation values can be measured totalling 2000 kWh/m2 annually.

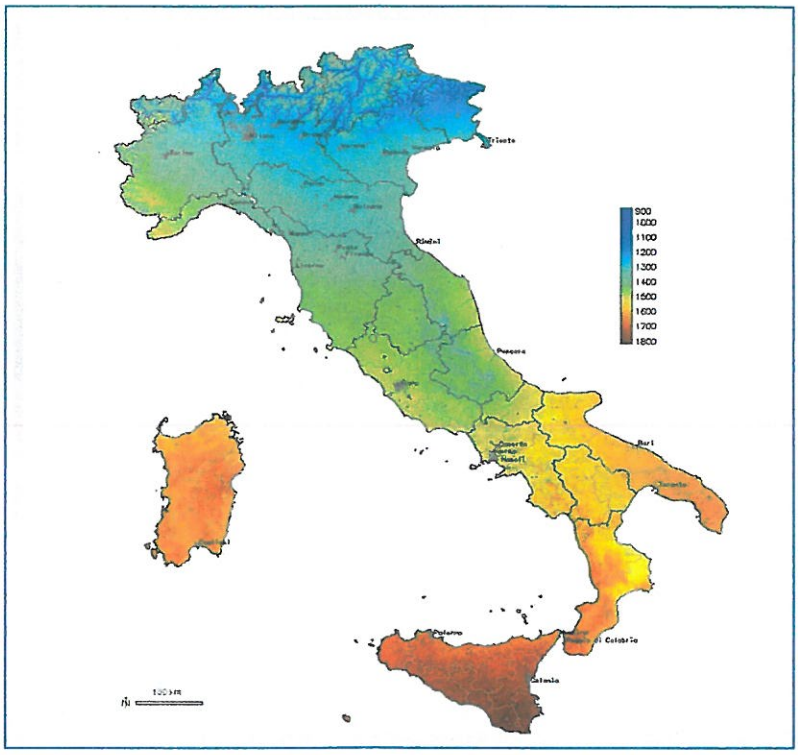


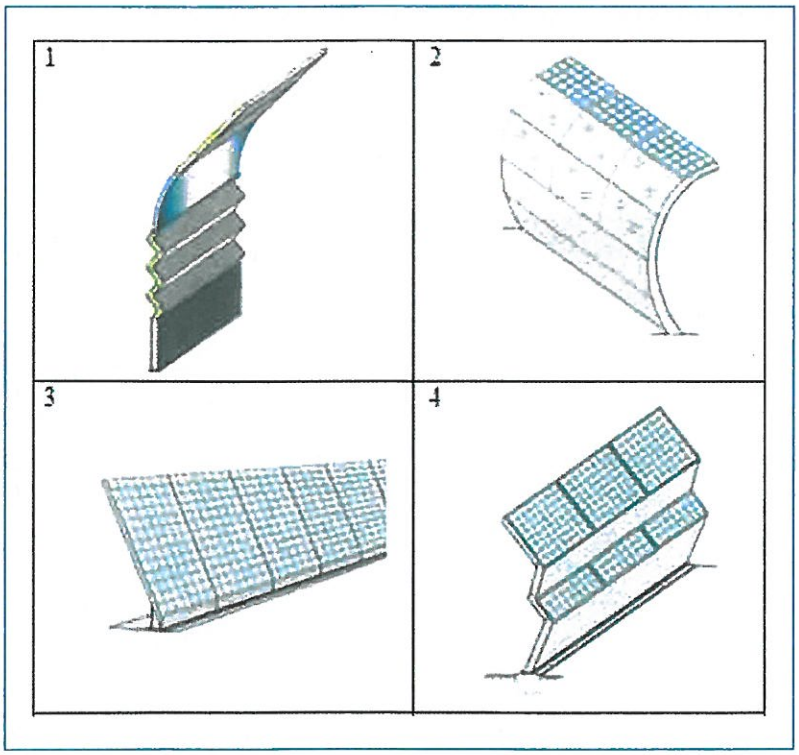
Fig. 2 - Thematic chart of photovoltaic solar energy potential in Italy (Source: Italian National Agency for New Technologies, Energy and the Environment)

Types of Sound Absorbing Barriers with Integrated Photovoltaic Capability

The different types of sound absorbing barriers integrated with photovoltaic panels meet the technical requirements of the specifications for the design of works to abate noise. In fact they are available in various forms and materials, giving the possibility of integrating the photovoltaic sound reflecting panels in such a way as to be able to satisfy any of the different design criteria that might be encountered.

Fig. 3 shows some of the different sound barriers with integrated photovoltaic panels, to give an idea of the variety of the typologies that can be designed and produced. In solution No. 1 in particular there is a combined effect between the panels made of concrete and transparent material (poly-methylmethacrylate or glass) and the photovoltaic panels, whereas with solution No. 2 there is the exact same combination of materials but arched, used in specific aesthetic circumstances by the road operators. In solution No. 3 instead, almost the entire work is constructed with photovoltaic panels, resulting in an abatement of the noise on one side of the structure only since a barrier

Fig. 3 - Different acoustic barriers with integrated photovoltaic panel; 1) combined effect, 2) arched, 3) reflecting, 4) absorbent and reflective



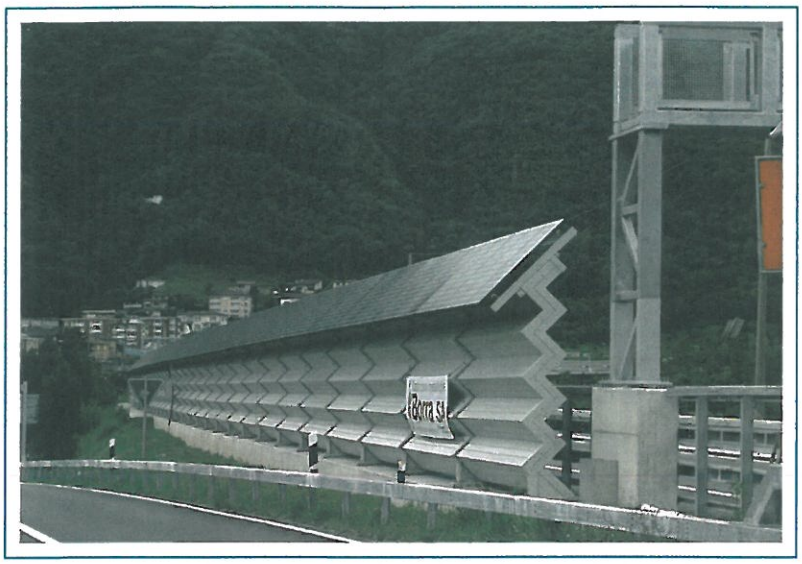


Fig 4 - Acoustic barrier integrated with photovoltaic panels alongside the A1 motorway close to Lugano, in Switzerland

produced in this way is totally sound reflecting, while with solution No. 4 there is an absorbent-reflecting combination recommended for situations where a road or railway faces buildings on both sides.

Hence, the difference in inclination of the panels and the different position occupied by the photovoltaic element within the sound absorbing structure make it possible, in each instance, to choose the most suitable solution, both on the basis of the characteristics of the noise pollution present and on the basis of the geographical characteristics of the site in which the structure is to be constructed.

A further type of structure, composed of a noise barrier integrated with photovoltaic panels positioned along the top and directed at an angle that favours the maximum acquisition possible of solar radiation, can be seen, for example, alongside the A1 motorway close to Lugano (***fig. 4***) in Switzerland (produced by Officina Borra SA). By means of this structure it has been possible to abate the noise, not just of the motorway itself, but of the adjacent railway line also (***fig. 5***).

Fig 5 - Acoustic barrier integrated with photovoltaic panels alongside the railway line that follows the A1 motorway close to Lugano, in Switzerland

In addition to the geographical position of the barrier itself, it is essential to give consideration to the orientation of the structure, in order to choose the correct type of integrated barrier. Leaving aside the latitude of the site, which may be more or less favourable, each photovoltaic panel must be oriented in the direction that will give the greatest exposure to solar radiation over the course of the day. As can be seen in the following schematics (***figs. 6*** and ***7***), depending on the orientation of the sound absorbing structures in relation to the daily path of the sun, it is possible to select noise barriers with different modules, so as to optimise to the maximum both the acoustic performance and the yield of energy.

The principle on which the technical choice for the implementation of photovoltaic panels is made, however, is dependent primarily on the need to design works for noise abatement and secondly on the decision to exploit this physical structure to produce renewable energy, through the application of photovoltaic panels positioned within it in such a way as to obtain the maximum yield possible.

Sound Absorbent Barriers with Integrated Photovoltaic Capability in Italy

It is only recently that Italy has availed itself of innovative integrated systems of noise abatement and exploitation of renewable sources of energy.

The first example of this was completed in July 2006 in the town of Trento, at the southern end of the Roncafort intermodal terminal (***fig. 8***).

This experimental application combined the two systems (sound absorption + photovoltaic), to obtain a mixed panel capable of producing electrical energy while at the same time guaranteeing the maximum performance required by the standards for acoustic panels (sound absorption class A4 UNI-EN 1793-1, sound insulation B3 UNI-EN 1793-2).

Noise barriers typically are set at an angle of 90 degrees to the horizontal, which, from a photovoltaic point of view is a highly limiting factor; instead, to exploit to the maximum the solar radiation characteristic of the site, the photovoltaic modules have been fixed with an azimuth not greater than 20 degrees south along the entire extent of the sound absorbent barrier and at an angle of 45 degrees to the horizontal. Constructed in this way, the installation, composed of 49

photovoltaic modules, is capable of guaranteeing a peak power of 6076 Wp.

Instead, the first example in connection with a motorway infrastructure will be seen in Trentino on the Brennero motorway (the Municipality of Isera Project), where, along the south lane of the A22, an anti sound barrier will be installed that, as well as limiting the noise pollution that has been monitored in the built-up area of Marano (Trento), will guarantee a constant production of electrical power, that will go towards satisfying a part of the energy needs of the nearby town of Isera. In particular, the barrier will be made up of sound absorbing panels with aluminium frames onto which the photovoltaic panels will be affixed.

The whole barrier will be about 1240 m long, and about 5 m high with a photovoltaic area, made up of monocrystalline silicon cells protected externally by very high transparency tempered glass, that will therefore be of about 5000 m².

To exploit to the maximum the incident solar radiation, the designers have chosen to use a transversal section of the barrier made up of two lengths at different inclinations, of 60 and 35° in order to improve considerably the energy efficiency, while still maintaining the performance from the acoustics point of view. The planned barrier is divided into segments 3.41 m long, inside of which are placed the photovoltaic modules for a total of 3500 panels, each of which, in standard conditions (radiation 1000 W/m², and a cell temperature of 25 °C) is capable of producing a maximum nominal power of 210 W. The total installed power is therefore 735 kWp.

Another national example of this, is the requirement that has arisen in Sicily, on the part of the Ministry of the Environment and Protection of the Territory in concert with the Ministry for Heritage and Cultural Activities, to create acoustic screening integrated with photovoltaic panels in connection with the project to double the Fiumetorto-Cefalù-Castelbuono section of the Palermo-Messina railway line. With decree No.724 of 28/11/03, the EIA (Environmental Impact Assessment) Commission of the Ministry of the Environment gave a favourable decision on the environmental compatibility of the project under consideration, with the following necessary conditions to enable it to go ahead: "[...] for the planning of the acoustic screening the solar energy must be converted, by means also of photovoltaic panels to be inserted

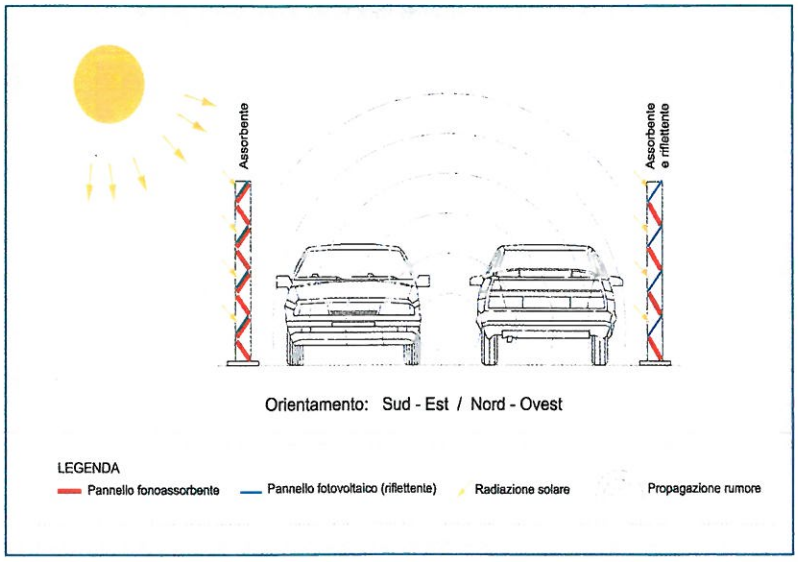


Fig. 6 - South-east / North-west orientation of the sound absorbing structure in relation to the daily path of the sun

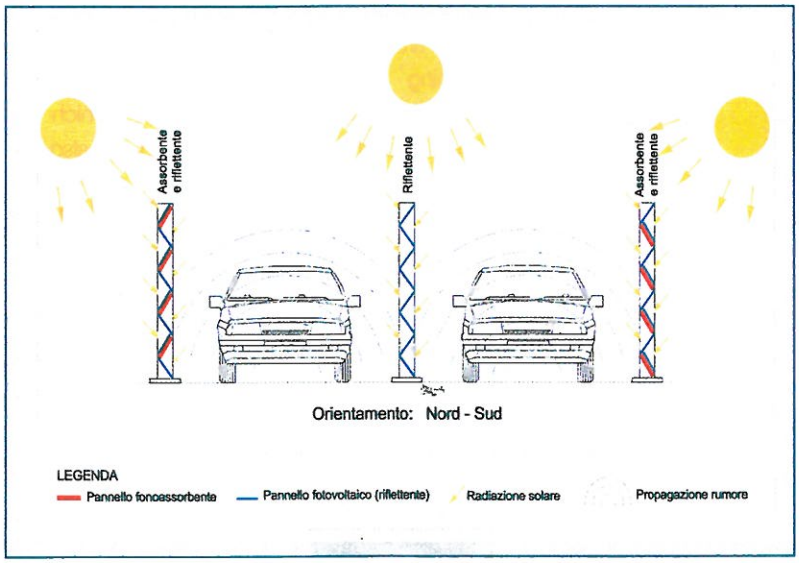


Fig. 7 - North-South orientation of the sound absorbing structure in irelation to the daily path of the sun

Fig. 8 - Integrated system of noise abatement and exploitation of renewable source of energy constructed in 2006 in the Municipality of Trento.

VDP SRL

VDP is an engineering company that has been working in the environmental field for more than twenty years with the objective of producing multi-disciplinary studies and assessments in systematic design aimed at the environmental compatibility of engineering projects. In particular, VDP has acquired great experience in the field of environmental impact studies, of innovative resources, of the design of environmental mitigation works, of environmental monitoring, of noise zoning and of reclamation plans.
Specialist units including engineers, physicists, chemists, geologists, naturalists, biologists, botanists, architects and graphic designers work under its technical direction.
VDP makes use of a Technical-Scientific Committee and also carries out research activities on its own account and on behalf of third parties that have enabled it to publish numerous articles in specialist magazines.
Through its organisational structure VDP is able to operate both domestically and abroad, addressing both large businesses and public and private bodies.

into the anti-noise structure in a position favourable to the collection of the said energy [...]".
There are several projects and studies for prototypes currently under examination in response to these particular requirements.
These are the first national examples as far as the planning of noise barriers integrated with photovoltaic panels is concerned, which will certainly be followed by others, given also the growing government commitment put into effect through financial incentives and building conditions, such as for example the above-mentioned railway case.
These types of anti-noise barriers with integrated photovoltaic capability can find major applications, for example in the plans for acoustic improvements relating to the existing road and railway infrastructure, on the basis of the Ministry of the Environment decree of 29/11/2000 that is currently being carried out.
In conclusion, it is clear how much the technological development of photovoltaic panels and their diffusion over the territory need to be supported, in order to give a start to the systematic production of energy derived from renewable sources with very low environmental impact. To that end we have tried to stress how the integration of these technologies into structural works, the need for which has already been established, such as the acoustic barriers for the protection of our roads and railways, can prove to be particularly advantageous. ■

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He is involved in aspects of atmospheric and noise pollution from fixed sources and from the transport infrastructure. In addition, as project manager of VDP, he is pursuing a series of research studies for eco-compatible solutions in the field of sustainable mobility: one case is that of alternative energy with the introduction, for example, of photovoltaic technology to mitigate/offset engineering activities.