Photovoltaic today DIY

At the moment, both for the generically green pressures, both for the increases in the electricity bill, both for the problems with fossil fuels, and the government subsidies, photovoltaic systems are on the agenda, in Italy and throughout the world.

As a result, they stick with offers and commercial proposals, which are often smoky and difficult to evaluate.

I try to clarify, sharing both the various analyzes, the projects carried out, and the results obtained, I hope they are useful as a starting point for those who want to try their hand at DIY, and for those who want to evaluate commercial offers.

1. This document is initially a fact-checking, for a correct setting of the problems.
2. Followed by DIY projects of photovoltaic installations less than 350 Wp (**plug and play**).
3. The next document “photovoltaic > 350 Wp” contains more DIY projects.

Preamble: simulations

An online simulator can be used to evaluate the potential of photovoltaics.

There are many, the most used is the European Union's PVGIS Photovoltaic Geographical Information System. I use it often, both in the design phase and in the test phase.

Another good simulator is PVWATTS (NREL-National Renewable Energy Laboratory, USA), analogous to PVGIS. With PVWATTS you get lower kWh per year than PVGIS (they use different weather data), on the plus side it has an editable satellite map and the ability to analyze the losses in detail.

For an immediate first test, using the optimized values with PVGIS:

1. Choose the *location on the map*, or enter an *address*, or the *Lat / Lon* values
2. For now, select *Calculated horizon*

Using the 'GRID CONNECTED' tab:

1. Let's set a reference value of 1 (1 kWp) as ‘*Installed peak PV power [kWp]*’.
2. We select ‘*Mounting position*’ = ‘*Free-standing*’ (i.e. with circulating air in the back).
3. We also check the ‘*Optimize slope and azimuth*’.

Then the button: *Visualize results*, and then PDF.

The following result is obtained (the location is Rome. Italy):

Performance of grid-connected PV

PVGIS-5 estimates of solar electricity generation:

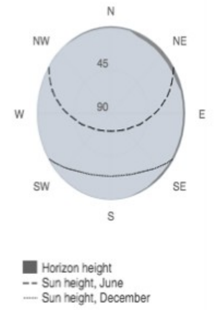
Provided inputs:

Latitude/Longitude:	41.927,12.437
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed:	1 kWp
System loss:	14 %

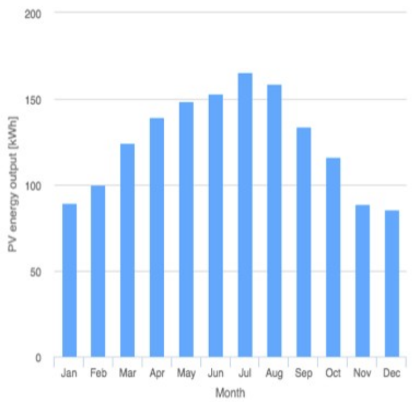
Simulation outputs

Slope angle:	37 (opt) °
Azimuth angle:	-1 (opt) °
Yearly PV energy production:	1503.34 kWh
Yearly in-plane irradiation:	1925.5 kWh/m²
Year-to-year variability:	54.94 kWh
Changes in output due to:	
Angle of incidence:	-2.65 %
Spectral effects:	0.97 %
Temperature and low irradiance:	-7.64 %
Total loss:	-21.92 %

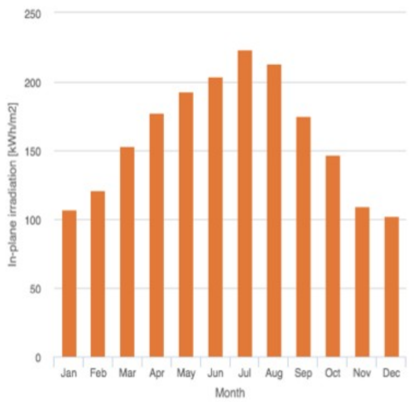
Outline of horizon at chosen location:



Monthly energy output from fix-angle PV system:



Monthly in-plane irradiation for fixed-angle:



Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	89.4	106.8	14.0
February	99.8	120.9	13.4
March	124.2	153.5	16.2
April	139.1	177.3	8.9
May	148.9	192.7	15.8
June	153.2	204.0	6.2
July	165.7	223.7	4.7
August	158.9	213.6	7.2
September	133.7	175.0	7.8
October	116.1	146.9	12.7
November	89.0	109.0	12.1
December	85.4	102.2	11.8

E_m: Average monthly electricity production from the defined system [kWh].

H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].

SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

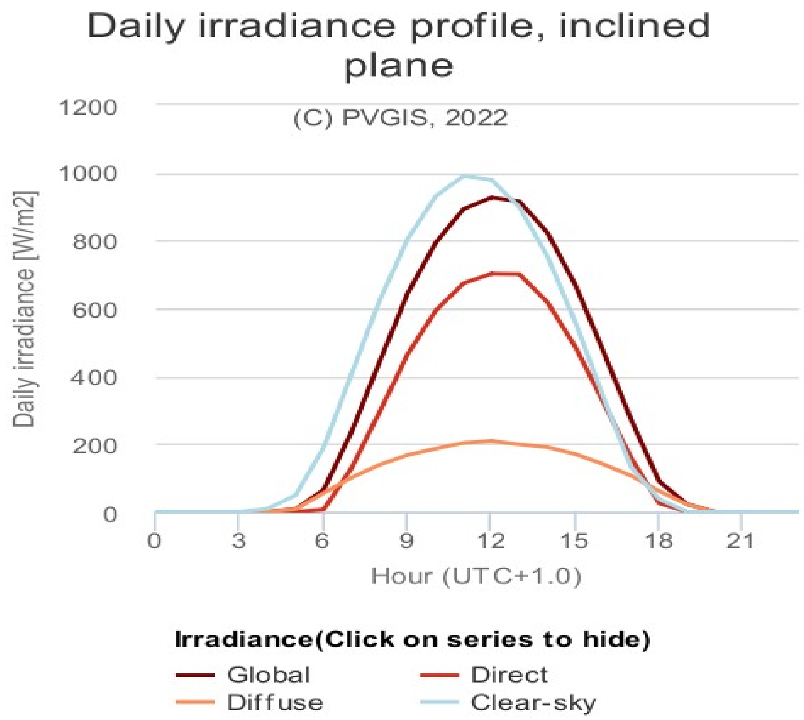
Joint Research Centre

Report generated on 2022/07/02

Let's analyze some results we get from the simulation:

1. The optimal inclination (slope) of the panel from the horizontal is 37°
2. The theoretical orientation (azimuth) is SOUTH (0°) or noon, but the optimal in this case is 1 ° towards WEST.
3. The calculated horizon, which takes into account natural obstacles, such as mountains and hills, is practically clear: only a small hill at E delays the sunrise (hence the 1 ° correction of the Azimuth).
4. Going with the mouse on the Sun Heigth curves, we find the height of the sun at noon: in June (71°) and in December (24°). From these values derives the optimal proposed value of 37°.
5. In one year the (average, optimal) production of electricity is estimated to be 1503.34 kWh per 1 KWp installed.
6. The month of maximum production is July (165.7 kWh) while the minimum is in December (85.4 kWh).
7. The standard deviation (`SD_m`) is also indicated for each month, which is a measure of variability. It can be simplified as follows: *based on the data of previous years there is a 95% probability of observing an energy production between* (`E_m - 2*SD_m`) *and* (`E_m + 2*SD_m`) *for the month considered* (see [68- 95-99.7 rule]).

The *DAILY DATA* option, chose a month, provides the average daily irradiation profile.



Clear-sky: does not take into account atmospheric absorption (dust and clouds).

Note: *Does not take into account daylight saving time (DST).*

These are the starting data for the chosen location (in the example, Rome) in optimal conditions.

In practice, what are the factors to be taken into account in the project?
The same as required by the simulation:

- Latitude and longitude of the installation.
- Surface (i. E. KWp) of solar panels, type.

- Mounting system with circulating air (preferable, '*Free-standing*') or on a surface ('*roof adding*') as required in some cases: the efficiency of the panel decreases with the increase in temperature.
- Shadows and geographical and local obstacles, e.g. buildings and trees: are considered by building a custom 'horizon file' (click on '*Upload horizon file*' for info) for a given location.
- Slope, or horizontal angle (if fixed)
- Azimuth or orientation (if fixed)
- As an alternative to fixed angles, you can also consider the '*TRACKING PV*' option, which is a mechanical tracking system, which transforms the solar panel into a sunflower.

Another fixed point: with standard monocrystalline panels (the most efficient, efficiency >= 20%) the equation applies:

1 square meter = 200 Wp

Use this formula as a litmus test to evaluate offers for solar systems and panels: if an offer promises 1 kWp (1000 Wp), the panels MUST be at least 5 m^2!

Notes: *a simulator is simply a sophisticated calculation system based on some assumptions. The results obtained must be verified.*

balcony solar panel.

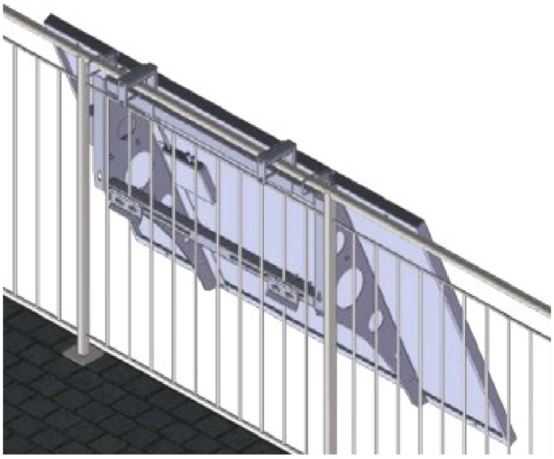
This type of photovoltaic system (called also ***plug-and-play***) is designed for urban users, who live in apartments in the city. The system is very simple and must be thought of as any household appliance: the panels can be installed by the end user in many ways, and they can also be moved. The presence of a plug is essential: these devices do not have to be hard-wired.
These installations aim to reduce the cost of the electricity bill.

Example 1: Flexible panels are attached directly vertically to an existing railing.

Example 2: Balcony and window: use of supports to improve the angle of inclination.

Example 3: self-supporting for terraces.

Italian commercial example: Enel-x-sun plug-play



Kit:

1 * rigid solar panel 196 cm * 100 cm, 340 Wp, 1.9 m^2, weight 19 Kg (datasheet)
1 * holder, 3 options, weight 7 Kg (see the manual in Italian).
1 * inverter, 380 W MPPT TSUN TSOL M350
1 * switch + power meter.
Independent video.

Price: **649 €**

Cost per kWp: **1900 €**

Italian commercial example: LaCasaDelSole

Kit:

1 * panel 169 x 99 cm. = 1.6 m^2, 340 W
1 * inverter TSOL-M350 (certified CEI 0-21)

Price **650 €**

Cost per kWp: **1’900 €**

Commercial example: German startup We Do Solar

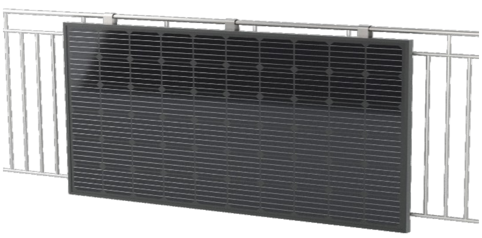
Kit :

8 * flexible solar panels 90 cm * 54 cm (80 Wp), total: 3.8 m^2, 640 Wp (datasheet)
1 * Inverter 600 W MPPT

Price: **1’299 €**

Cost per kWp: **2’170 €**

Italian business example: eet-solare.



Kit::

1* Photovoltaic Panel 166 x 100, 370 Wp (MaySun)
1* Inverter Envertec EVT300 MPPT
Mounting accessories

Price **539 €**

Cost per kWp **1’457 €**

Analyses

A series of factors intervene to reduce performance, especially in this type of installation:

1. **Shadows**
   Even a small shadow (a leaf) can drastically reduce the performance of a solar panel: this depends on how topologically the individual cells of the panel are connected. If, for example, they are connected in 3 groups, a single cell in the shade leads to a 33% drop in the production of the panel.
   The panels connected in series are all affected by the same decline. However, it is possible to use 'power optimizers' which substantially decouple the panels from each other.
   Similarly, if more panels are connected in parallel, they can be decoupled with protection diodes.

   Note: For an evaluation of the shadows of the nearest obstacles (buildings, chimneys, trees, etc.) at various hours and various months, it is possible to use, in addition to the custom definition of the horizon in PVGIS, also a 3D model made with *SketchUp-free*, as recommended by *milliWatt*.

3. **Azimuth**
   The optimal orientation is the SOUTH, but it is not certain that it is available. Fortunately, the losses are limited: to get an idea of the problem, here is a simple table obtained with PVGIS.
   Percentages of annual production (slope = 37°):

SUD 0°	100%
10°	99%
20°	98%
30°	97%
40°	95%
50°	92%
60°	91%

Note: as the orientation changes, the direct and diffuse irradiation changes during the day, which can be seen in PVGIS, DAILY DATA tab.

3. **Slope**
   The optimal slope for our example is 37°. Other inclinations can also be used, for example horizontal (0 °) or vertical (90 °), but with high costs, as shown in the table:
   Percentages of annual production (azimuth = 0°):

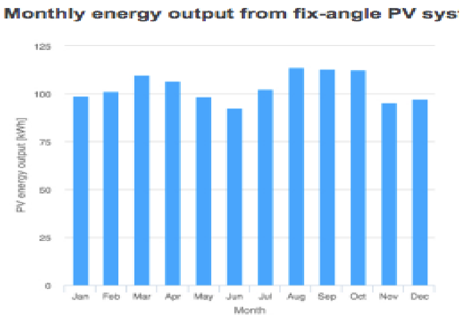
0°	84%
30°	99%
60°	93%
90°	66%

Sometimes we are forced to use sub-optimal values: for the exposure of existing roofs, for other architectural constraints, for shadows.

In Italy building permits are not required as long as the panels are mounted adherently on pitched roofs or walls. See GSE guide.

Note: a minimum inclination (eg 5%, equal to 2.8 °) favors the self-cleaning of the panel in case of dry leaves, snow, etc.

Note: as the inclination changes, the powers generated in the various months change, as can be seen in PVGIS. Example:



Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	99.0	118.3	17.0
February	101.1	122.3	14.7
March	109.9	135.9	15.6
April	106.7	136.8	7.0
May	98.6	129.7	9.6
June	92.4	126.1	3.1
July	102.4	141.3	2.3
August	113.8	154.5	4.8
September	112.7	147.7	7.0
October	112.7	142.4	13.1
November	95.5	117.0	14.4
December	97.2	116.3	14.3

E_m: .
H(i)_n
of the
SD_m

With an inclination of 75 ° there is a more limited monthly production (min 95.5 kWh, max 113 kWh), but more homogeneous than the optimum.

From the comparison with the monthly results at 37 ° (min 85.4 kWh, max 165 kWh), it can be seen that winter production increases (+ 12%) while production in the summer months is drastically reduced (-31%).

Optimization can be achieved by manually changing the inclination of the panels twice a year, in spring and autumn, in conjunction with standard maintenance.

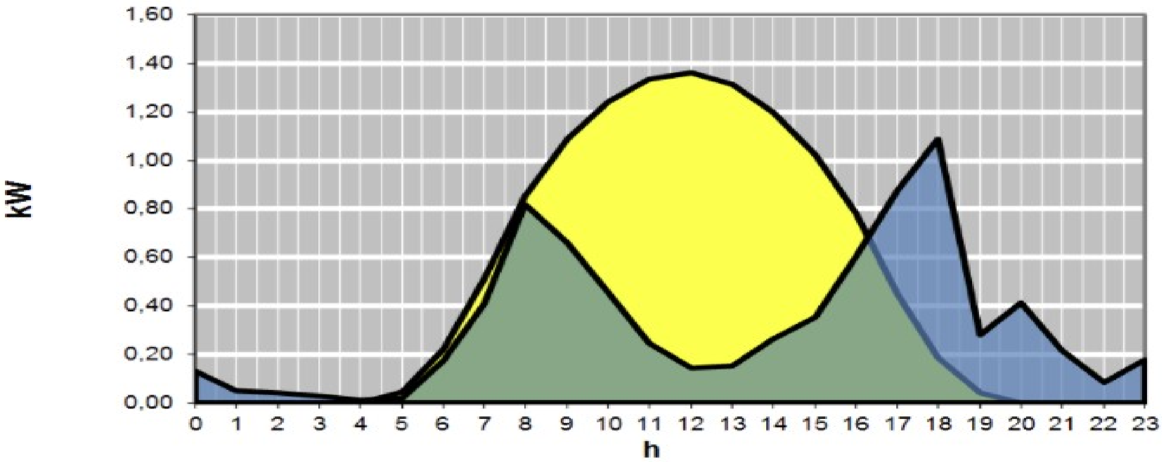
4. Hourly distribution

With this type of plant, the energy not used in self-consumption is lost, because the excess energy is not remunerated by the electricity companies.
But there is a physiological mismatch between the production and consumption of a family: the hours of maximum production are the central ones of the day, while the hours of maximum consumption are those in the evening.

The following figure schematically represents the typical consumption of a private user: there is a peak in the morning and a second peak in the afternoon-evening.
Compared with the energy produced by the photovoltaic system, the yellow area is the excess energy, the blue one is the energy supplied by the grid, in green we have self-consumption.

Note: the figure refers to a plant of at least 1.5 kWp, but even after reducing the yellow peak, the substance does not change.

In reality, the consumption curve is very variable: it obviously depends on the appliances installed, for example, water heaters and air conditioning are very energy-intensive. Ditto for electric ovens and induction hobs. Furthermore, the curve also depends on the habits of the users.



In practice, action must be taken on two fronts:

- Obtain experimental graphs for hourly consumption.
- Try to shift consumption towards daytime, for example by timing the switching on of the storage water heater, or by changing habits and using the washing machine at 2 pm, etc.

The goal, all in all simple to achieve for small powers, is to have *consumption, during the day, higher than the power generated by the photovoltaic system*. In this way, all the energy produced for self-consumption is used, without waste.

Notes: it is evident that, with systems with this strategy, it is never possible to cancel the electricity bill: there will always be consumptions out of hours.

But you can achieve the goal of producing and using solar energy with reduced waste, maximizing the reduction of billed electricity consumption,

Annual consumption per family

Nazione	1 person	2 people	3 people
Italy (ENEL)	1434	2081	2581
Italy (ISAE)	2168	2694	3134
Austria	2226	2910	4187
Malta	1400	1850	2175
Spain	1415	1924	2299
Netherlands	2220	3095	3875
Belgium	1575	2200	2705

(*font KiloWattene*)

For each *kWp* installed, the maximum theoretical photovoltaic production is ***1500 kWh/year*** (Rome, see initial simulation).

For comparison:

- The *350 Wp Enel plant* will produce 525 kWh/year (maximum) in Rome
- The *640 Wp We Do Solar plant* will produce 960 kWh/year (maximum) in Rome

These 'average' values must always be verified on a case-by-case basis, for example using the electricity bills of previous years.

DIY Plug and Play solar panel

A1 project (200 W):

2 * flexible solar panel 105 cm * 53 cm, RG-MN-100	**176.34 €**
1 * multipurpose holder, made of iron profile.	**12.00 €**
1 * inverter , 300 W GMI -300	**53.06 €**
1 * switch + meter 20A EU Tuya	**16.36 €**

Cost: **258 €**
Cost per kWp: **1280 €**

This project was developed and implemented mainly for experimentation and verification of simulations. Low cost and in a concrete case.

Note: *The prices indicate the amount I paid, including shipping (June-July 2022). Prices can obviously vary: carefully select the supplier*

Project criteria

The final goal is to reduce the amount of the electricity bill, therefore the objectives of the installation are:

- Cost per kW as low as possible
- Containment of the inevitable losses due to non-optimal orientation and inclination, presence of shadows, etc.
- I use, where possible, Tuya-compatible control and measurement devices, to have automation and remote control at no cost. For the most demanding users, it is available TuyaDeamon, a development environment open-source for IoT.

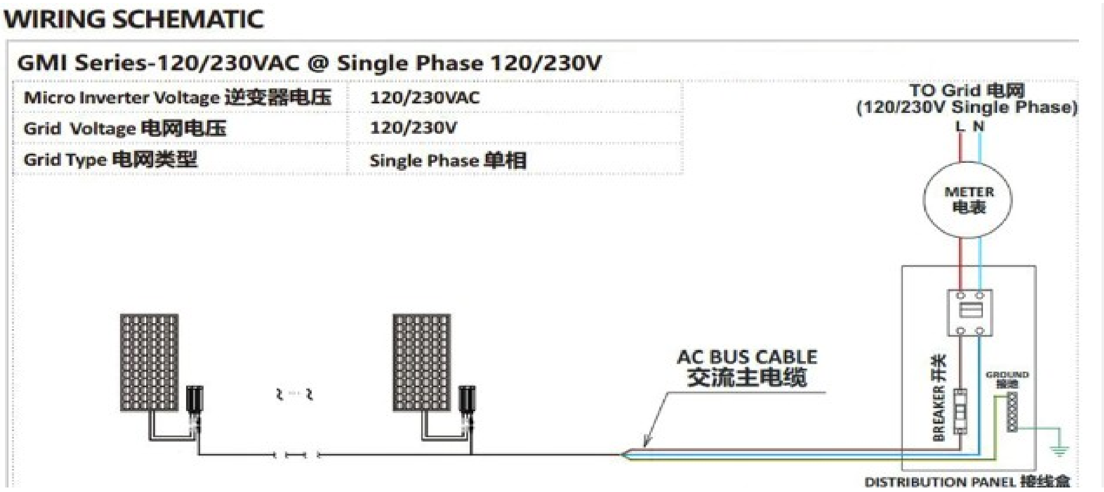
  I do not want to use proprietary clouds, and therefore not even the proprietary remote control WiFi APPs, apart from Tuya devices and the smartLife APP. Already deciding to use Tuya and its cloud was a difficult decision, justified by the high-security systems, the high performances, and the peculiar commercial position of Tuya as a provider of services to third parties - see 'why TuyaDAEMON' (in Italian: 'perchè TuyaDEAMON').

Modularity

I believe it is valid to design and use identical autonomous modules, to be multiplied if more power is required.
The advantages are as follows:

- *Greater flexibility:* when, for reasons of space, you want to use two different orientations (see the previous photo of the balcony), there is greater efficiency if each group of panels has its own MPPT controller.
- *Greater resilience* a failure causes less damage and is cheaper to repair. With little expense,

you can stock spare parts: a panel and an inverter.
- *Ease of later expansion* for example, if you add new appliances to your home.



Photovoltaic panels

Flexible panels have several advantages over those with frame and glass, especially in the DIY case:

- Reduced weight, the problems of transport, installation, supports, etc. are simplified.
- Small size (½ m^2.): Greater positioning possibilities
- Great reusability, multiple fixing and use options (on vehicles, boats etc.)
- High performance and low cost.
- In these months the rigid panels have very long delivery times. The flexible panels are ready.

The selected RG-MN-100 model has these characteristics:
power 100 Wp, dimensions 1050x530x2.5mm, weight 1.9 kg, open circuit voltage 19.2 V, DC current 6.87 A, efficiency 20.5%, life 25 years
It has 6 stainless steel eyelets on the perimeter for fixing. The length of the cables allows the connection of two panels in series and an inverter without the need for extensions or other accessories.
Fast delivery to Europe via Aliexpress from a warehouse in Poland.

There is also the possibility, if you are lucky, to find second-hand solar panels at very attractive prices (see example).

Inverter

Many Italian plug-and-play kits use Zucchetti blue *as inverter, or the* TSUN TSOL M350, *with CEI 0-21 certificate.*

For the initial plug-and-play photovoltaic project, I preferred a very simple and low-cost inverter, GMI300 slightly oversized (300 W) to reduce overheating problems (see datasheet and CE certificate) even if this involves a decrease in yield.
This inverter has two automatic shut-down levels in case of high temperatures: 50% and OFF.

If you mount the inverter close to the panels, (preferable solution) it is necessary to ensure that it is at least under the panels, in the shade and sheltered from the rain, connected to a metal structure to improve dissipation, while the solution of mounting the inverter to the internal, on a panel, can be valid in particular cases, but has the following defects:

- Reduction of modularity and portability

• Increased costs and losses for long large diameter DC cables (current 7 A).

The problem of overheating must be felt if the manufacturer also offers two spare parts kits, see instructions on the video (this was also a positive factor of choice).

Users presented various dubious solution hypotheses, such as holes, fans, etc.

The most valid, in my opinion, and which does not compromise the P55 specification, is to mount the hottest side (the bare aluminum one) in contact with the supporting metal structure, which will act as a heat sink.

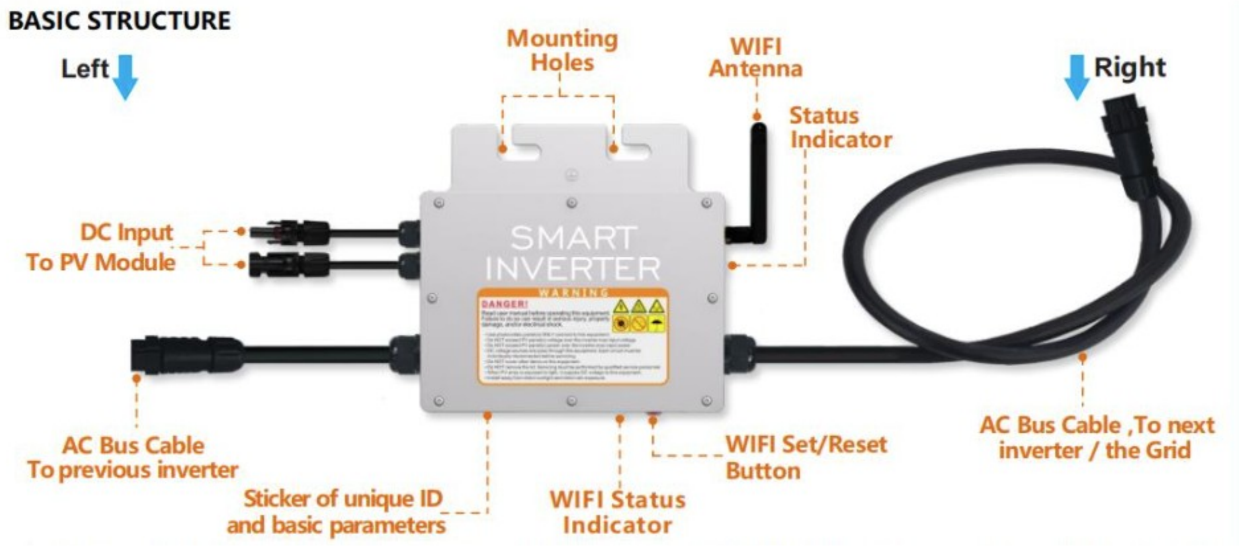
It is also possible to add an external finned heatsink (in the photo, a user's oversized solution).

I tested the inverter in July 2022 (35 ° C) without a heatsink and without problems, measuring an external temperature of 55 ° C. The panels reach 61 ° C.

However, here is an example of an additional heatsink: 100x60x10, 4.09 €, to be connected not with nylon ties, but with parker screws and a lot of heat-conducting paste.

A2 Project

In this sector there is a continuous evolution. While I was testing the A1 version, a new series of inverters appeared on the market, with some advantages. Obviously, I bought one and immediately tried it:



An advantage of the Y&H SG-300W is the better connectivity (at 220 and DC) which offers simplicity and savings of accessories (cables, diodes, joints). Another is the Tuya/SmartHome compatibility, which allows for easy control.

A2 project (300 W):

3 * flexible solar panel 105 cm * 53 cm, RG-MN-100	**264.51 €**
1 * multipurpose holder, made of iron profile.	**15.00 €**
1 * inverter , 300 W SG300MS	**104.65 €**

Cost:	**384 €**
Cost per kWp:	**1280 €**

Similar to the *A1 version*, it uses a different inverter and does not require the '*switch + meter 20A EU Tuya*', as the WiFi function is present in the SG300 inverter.

DIY Plug-and-Play solar panel: realization

Step 1: analisi consumi

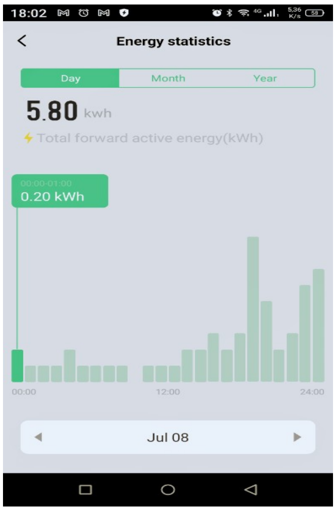
The first step I took was the replacement of the lifesaver in the electrical panel of the house with a compatible Tuya life saver + wattmeter, for a better analysis of domestic consumption (optional).

2P 63A TUYA APP WiFi Smart Energy Meter OPWT-63 (https://www.aliexpress.com/item/1005002361164427.html, **€ 33**)

In addition to the measurement function (V, I, W, kWh) visible on the display, this switch has adjustable protections for:

- Leakage (10-100 mA) (same as lifesaving)
- Overcurrent (1-63 A) (same as magnetic)
- Overvoltage (250-300 V) 0.5 s delay
- Undervoltage (150-190 V) delay 0.5 s

Among the many devices available, I chose this model because it has the same dimensions as the existing life-saver breaker, so the replacement into the home switchboard is very simple.



This meter provides (with the SmartLife App) a daily graph, which is exactly what you need to evaluate electricity consumptioni.

Note: in Italy, the e-distribution APP *offers similar 'load curves'.*

We see how the consumption of a day (July 8) is mainly evening-night, while the basic value (about 100 W) is the sum of the standby of TV, WIFI, PC, irrigation etc.

Note that hourly integral values are indicated in the graph: peak values can be greater (up to 3.3 KW).

The data provided by the OPWT-63 Meter can also be used in rt with tuyaDAEMON: here is the consumption of 24 hours

Notice:
- minimum < 100 W
- evening 300W
- peaks due to household appliances.

The biggest peak is caused by the storage water heater (boiler 1300W)

Step 2: supports

Taking [commercial models]() as an example, as in the figure, the mobile support was made with perforated L-shaped iron profiles (the type for shelves) mainly because they were available!

It can be made in wood, or, better using aluminum - this presents welding problems for me - always bearing in mind an assumed duration of 20 years.

In reality, there are only two welding points at the vertices of the main rectangle, to provide rigidity: the assembly is all done with 8 mm bolts, with nuts or butterflies.

The railing brackets are made by joining two 'L' with rivets and creating an 8mm hole.
The only critical measurement is the vertical side of the frame, equal to the length of the panels (105 cm).

This support is universal, it can be used on railings, windows, walls... The inclination is easily adjustable to carry out all tests.

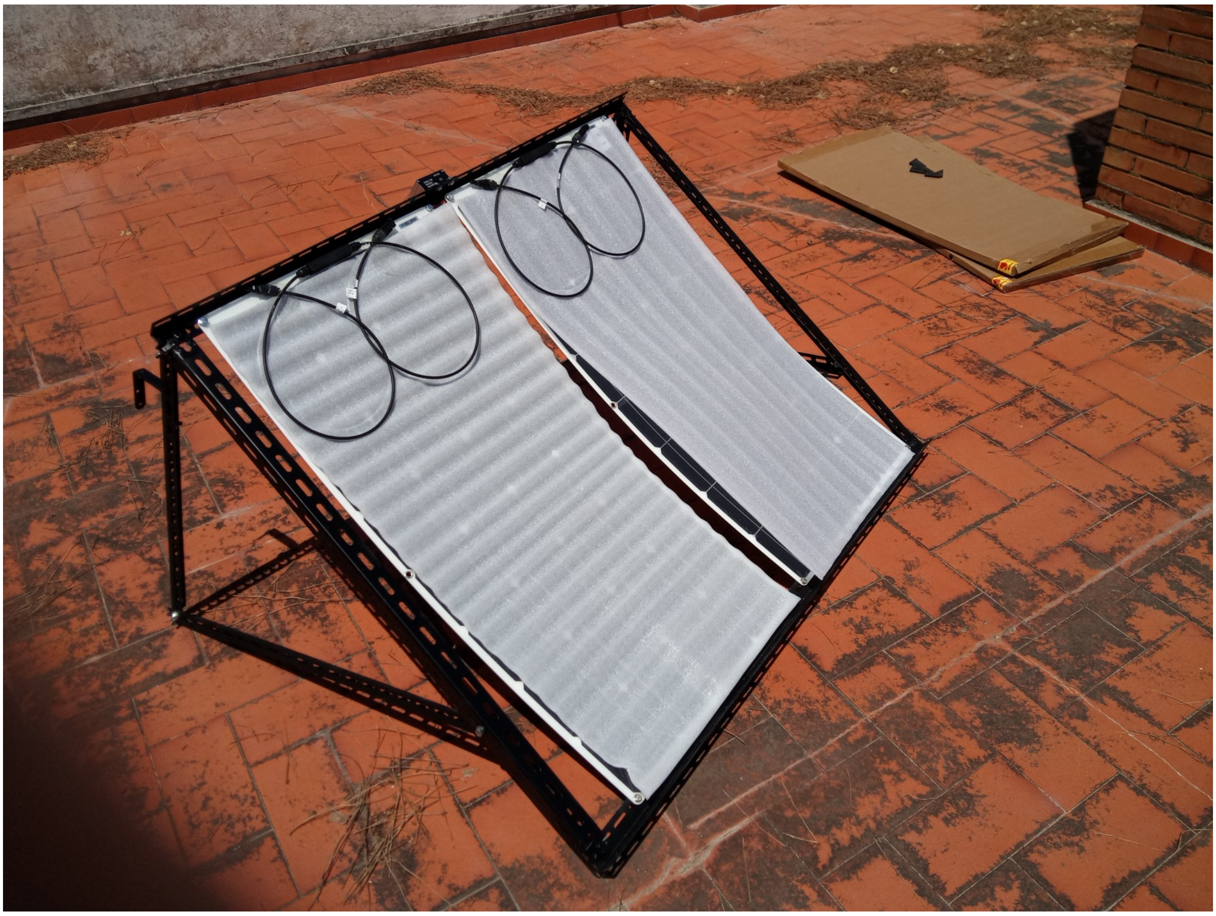
Total weight **14 kg**:

support	9,7 kg
panels	3.8 kg
inverter	0,5 kg

notes on fixing: *DIY does not mean unsafe: provide stability in case of strong winds (at 40 m / s the pressure is 190 kg / m2), on railings also use a lower fixing, and use a second safety system (e.g. with nylon ropes) anchored to the frame, to avoid accidental falls (see Enel instructions).*

On a flat surface, weights (TSUN recommends at least 20 kg.) and safety cables should be used so as not to puncture the flooring.
Here is another example, but we can use flower pots or cheap umbrella bases filled with water or sand (€ 9).

Step 3: fixing panels



Flexible solar panels can be installed using various systems:

- On an existing surface (walls, vehicles and campers, boats, etc ...) you can use simple double-sided tape!
- Or even self-adhesive velcro, if you want to move them quickly.
- Even using zips 'sewn' to the edges of the panels (for boating).
- They can also be fixed with ropes passed through eyelets (e.g. on balcony railings).

To fix the panels to the frame I simply used 4 6 mm stainless steel bolts with self-locking nuts.
If you want to increase the rigidity, you can add a sheet of alveolar polycarbonate under the panels, increasing however the costs and worsening the ventilation.

Step 4: connection

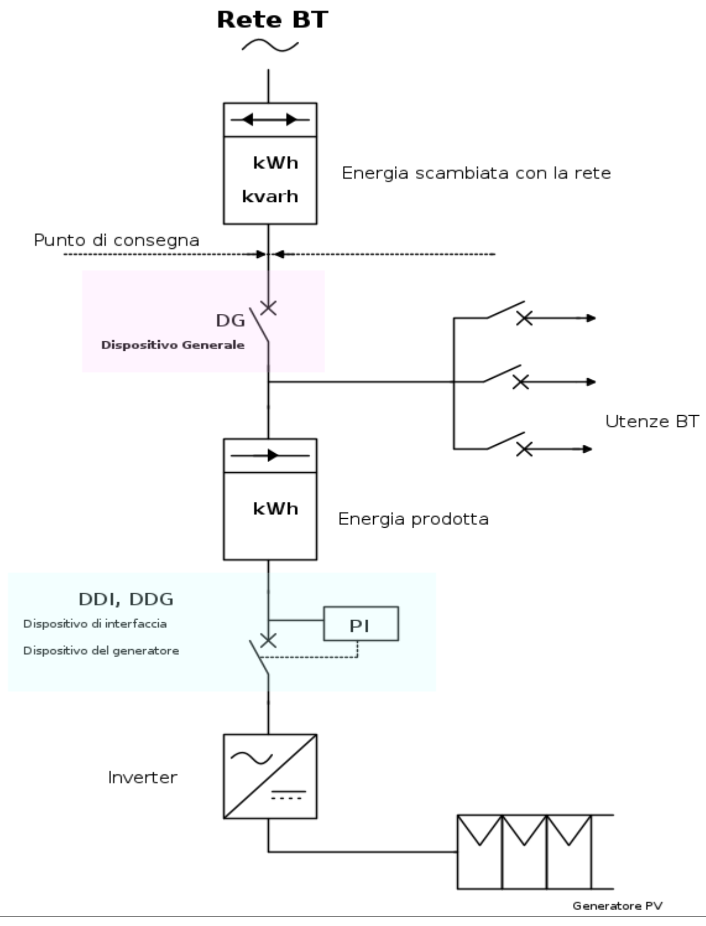
To work, this inverter must be connected to the 220 grid: it cannot, therefore, be used as an uninterruptible power supply (UPS).

It is safe to use any socket in the existing system because if the socket is not live the inverter stops working, eliminating any risk.

The rules vary from country to country: comply with current regulations.

In Italy, according to resolution ARERA 315/2020/R/EE, the generator must be connected to a 'dedicated socket', connected between the DG and the other users (see diagram, source https://electroyou.it/admin/wiki/schemes-photovoltaic-in-bt) or even this.

A DDI device must allow the protection of the users and the disconnection of the generator.



As DG (on the home panel) I used the 'WiFi Smart Energy Meter' (see above), which, in addition to acting as a switch, integrates some protection and WiFi functions.

As DDI + DGI, you can use a circuit breaker with protection, or a second Smart Energy Meter (see above), with breaker and differential and magnetothermic protection functions, in a small distribution box (e.g. enel-x-sun).

Many commercial kits simply use a smart switch (€ 16.36), to ensure mobility, which performs multiple functions:

- The button on the body acts as a manual switch for the solar panel
- With the SmartLife application it is possible to remotely control the ON / OFF function
- With SmartLife it is possible to read V, I and W snapshots remotely.
- With Smartlife you also have the daily kWh with both monthly and annual totals and graphs.

The protection for extra voltages is entrusted to the WiFi Smart Energy Meter device upstream. In the ***A2 project,*** the *smart switch* is not necessary and the inverter can be directly connected to a home socket.

Automation: tuyaDAEMON

With this project, both the grid information (power, cumulative consumption) and the information relating to the solar generator (rt power, kWh generated) are available remotely via SmartLife. If desired, the solar generator can also be set to OFF.

Unfortunately, the automatisms available with smartLife are not advanced enough to be useful in the management of this photovoltaic panel, apart from the timed start and shutdown.
Also a simple ON / OFF strategy cannot be implemented in smartLife*: "insert the photovoltaic energy only when consumption exceeds the power produced, and disconnect when the energy consumed is less than the energy produced, so as not to send energy to the grid".*

Instead, this is possible with tuyaDEAMON, used with the function of a super-controller, which integrates the entire *Tuya ecosystem* - sensors, switches, photovoltaic - with a database, custom extensions, and high-level logic.

Step 5: performance

The default yield that the PGIS simulator uses is equal to 16.4% (from the ratio between annual kWh produced and annual irradiation).
The real yield is variable, as shown in the following table (a few hours for shade on the panels are excluded), where the 'irradiation' column comes from PGIS, 'daily data' tab. The 'power produced' data is read every hour by the Smart Switch.

Measurements (17 Sept.) clear day, inclination 37°, south orientation (0°)

time	Irradiation (Wh/m^2)	Power (W)	Yield (%)
9:00	570	78	13,7
10:00	730	99	13,6
11:00	813	120	14,7
12:00	837	124	14,8
13:00	787	123	15,6
14:00	686	100	14,6
15:00	516	80	15,5
Tot.	**4939**	**724**	**14,7**

The average yield is about 15%, lower than the expected value (16.4%) estimated by PVGIS.

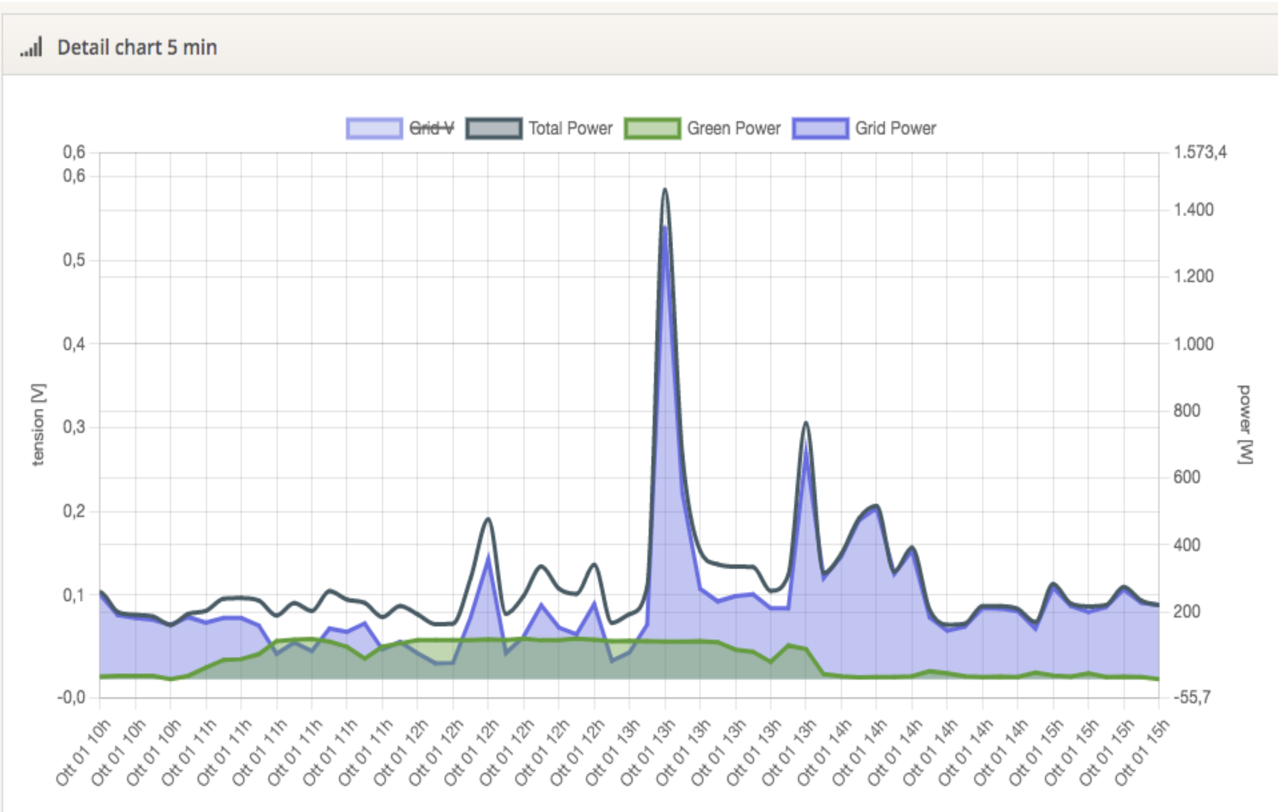
1. In inverters it is common to decrease the efficiency as the power decreases
(*inverter specifications: Pmax: 300W, CEC efficiency at 220V: 91.5%*).

2. Furthermore, the global irradiation data estimated by the PVGIS, which takes into account the clouds, may differ from the real values. I have noticed different values in at least one case.

3. Further investigation should allow us to pinpoint the exact cause of the discrepancy, but let's continue with the actual measured values.

In the PVGIS simulator, it is possible to empirically increase the losses (default 14%) to obtain a similar yield.

Graph of the **total power**, power from **photovoltaics** and power from the **grid** (10 October 2022, from tuyaDAEMON):



As you can see, the hours are reduced (from 11:00 to 15:00) both for clouds and for exposure.

Economic return

Starting data (Italy, third quarter 2022):

Cost of energy materials:	**33.08 c€/kWh**.
Energy cost in the bill (Source ARERA):	**41.51 c€/kWh**.
system cost:	258 €
annual cost (cleaning, spare parts, etc.):	20 €
annual production:	220 kWh (yield 15%)

Hypothesis 1: optimal position, total self-consumption: 100% (220 kWh/year)

Amortization: 3 years, 8 months
Investment Return: 17.21%

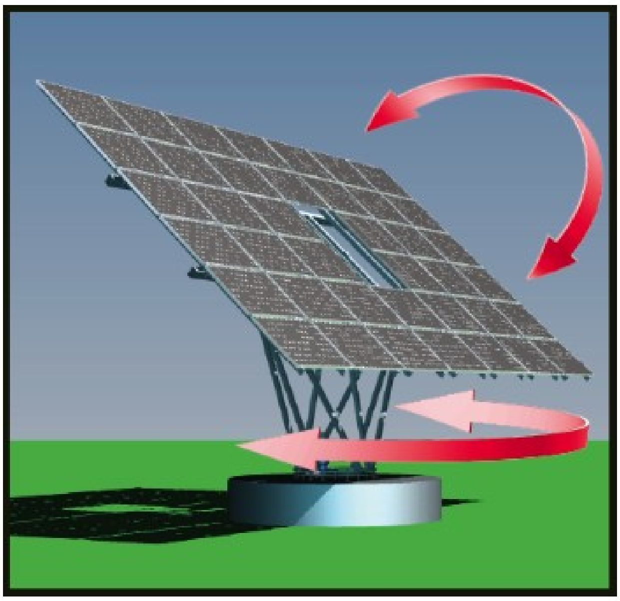
Hypothesis 2: not optimal position, partial self-consumption: 60% (132 kWh/year)

Amortization: 7 years, 7 months
Investment Return: 3.22%

font: https://www.sunearthtools.com/it/solar/payback-photovoltaic.php

note: Tracking systems

You can have systems with a single axis (normally parallel to the earth's axis) to point the sun from sunrise to sunset, or with two axes to also follow the height of the sun.



Benefits:

- PVGIS shows an increase in the energy produced by 31% (2088 vs 1586 kWh / year).

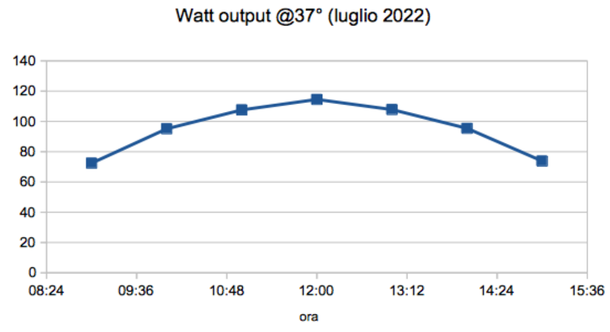
Disadvantages:

- Solar panels are quite heavy objects and the mechanics needed to move them safely are neither simple nor cheap.
- Electronic control systems, maintenance, consumption etc. must also be considered.
- With movement, each panel requires more space and generates shadows.

Conclusion:

Using normal monocrystalline panels, only by finding a simple and inexpensive system, which costs less than 20% of the installation, can the pursuit be considered. Not (at least for now) of DIY interest.
However, it is possible to evaluate the manual modification, twice a year, of the 'slope' of the panels.

Conclusions on plug-and-play DIY



The **plug-and-play DIY solar panel** has production shown between 9:00 and 15:00 (solar) in July, with a total between **0.6 and 0.7 kW/day.**

There is therefore a self-consumption of 100% if between 9:00 and 15:00 the electricity consumed is equal to or greater than the production *(70-120 W)*.

In this case, all the annual production (estimated 220 kWh) is used, with an annual saving (Italy, current prices) of 90.2 €. with a very short amortization period (about 4 years).

- *The panels degrade over time: the life of the solar panels is estimated 20-25 years.*
- *Ordinary maintenance required: every 6 months cleaning of the surface of the panels.*

The most favorable situation occurs when there is already constant electricity consumption during the day: public places, greenhouses or hydroponic crops, electronic equipment, fans, etc. Otherwise, it is necessary to shift the usual consumption to the hours of sunshine.

The importance of a tailor-made 'energy strategy', possibly implemented with the help of automatic IoT control systems, such as TuyaDAEMON, is evident.

Permissions and obligations (plug-and-play)

Warning: in standard conditions, the electricity meter counts the surplus of energy fed into the network by the user as consumption.
In general, a communication to the distribution company can allow the (modern electronic) meter to be enabled for bidirectional operation, but, usually, the energy transferred to the network is not remunerated: for the user it is lost.

The rules (and incentives) vary by country and by the supplier company.

In Italy a **plug and play** photovoltaic system (Wp <= 350 W) is facilitated:

1. can be installed by the end user
2. does not require permits, except for a possible 'communication' to the condominium, or an authorization in the case of historic center subject to 'landscape constraints' (information to the municipality, see also sentence of the Lombardy Tar No. 496/2018 on the visible/invisible problem).
3. must be communicated to the local network operator by completing and sending the "Comunicazione Unica per impianti di produzione di potenza inferiore a 800 W" form available on the ARERA website, at the following link: https://www.arera.it/allegati/docs/20/315-20.pdf or filling a form online on the e-distribuzione site ("iter semplificato") at no cost.

As a result, the meter is enabled (bidirectional) so that the user does not find the excess energy produced in the bill, but the energy transferred to the grid is not remunerated.

Note: *the "simplified" online e-distribution process is only apparently simple (see* guida*). The DIY user can make silly mistakes the first time just because some useful information is not easy to* find on the site*. For instance:*

- *The registered letter of adhesion (Form + photocopy of identity document, paper copy) must be sent to "e-Distribuzione, CP240, 00071 Pomezia, RM" and NOT to other addresses on the site. Keep the receipt!*
- *The same form must be submitted a second time electronically. together with another PDF copy of the doc. of identity and with a copy of the receipt of the registered letter (! sob). The form, in PDF format, must be complete (7 pages), even if signed only on the last page (!). As there is a 3Mb limit, the 7 pages must be sent as 7 separate files (!).*
- *Access to the various forms is compulsorily sequential, even if the page is counter-intuitively structured with tabs.*
- *If you need to perform a subsequent update action - called INTEGRA (integration)- you must always restart from the first step (even if the INTEGRA tab is present: you must not use it immediately): a lot of nonsense.*

When I communicated my plug-and-play A1 system *to* e-distribution *(indicating the brand of the inverter* Taozhong New Energy *and model* GMI300W*), the request of August 25th was processed on October 13th, because I make all previous 'blocking' mistakes.*

Note: In Italy there is an additional temporary incentive for the purchase of solar panels, inverters and batteries: 50% refund on future taxes (eco-bonus). Some large companies offer a discount on the invoice for the amount of the incentive.

Also in Italy, for systems with power greater than 350 Wp, but **less than 800 Wp**, the following documents are also required (see example), which can represent a difficulty in the DIY case:

- Single-line wiring diagram of the system
- Declaration of conformity of the production plant to the rule of the art in accordance with current legislation
- Declaration of conformity of any static conversion and interface devices installed
- Operating regulations signed by the manufacture