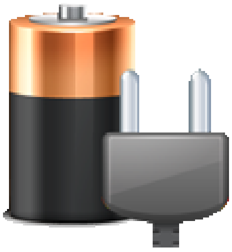
# PHOTOVOLTAICS IN FRANCE

## ENERGY, RISKS, ENVIRONMENT, TECHNOLOGIES, INVESTMENT

September 2010

# I. Photovoltaics and Electric Energy

## *I.1. What do kW and kWh mean ?*



In physics, one has to clearly distinguish the power, the time and the energy :

**Energy = Power x Time**

The respective units are : the Joule (energy, J), the Watt (power, W) and the second (time, s)

But for the consumptions of a house, it is usual to measure

* the power in kilowatt (kW) with 1 kW = 1000 W,
* and the time in hours (1h = 3600s).

The multiplication of the power in kW by the time counted in hours is an energy expressed in kilowatthour (kWh) : the role of the electricity meter is to measure in kWh the consumption or the production of this electric energy.

Note : one kWh, it is too 3 600 000 J = 3,6 MJ

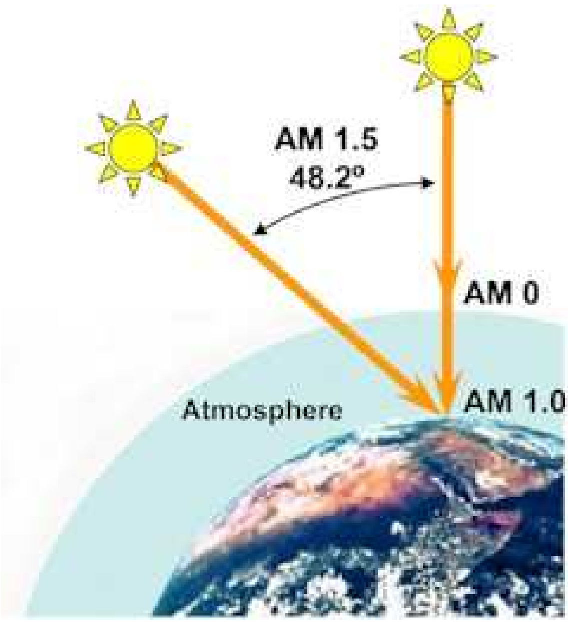
## *I.2. What represents very concretely 1 kWh ?*

It is the necessary energy to make shine a light of 100 W during 10h,

or to heat a oven of 1000 W during one hour.

## *I.3. What is a kWc ?*

This is one kilowattcrete. One meets also the anglosaxon kWp (kilowatt peak). This is the peak power produced by a plant and this notion isn't specific to the photovoltaics.




But the notion of peak power has to be normalized, notably for the photovoltaic panels. Thus a 100 Wp panel (one hundred wattpeak) will supply a power of 100 W while respecting the following conditions:

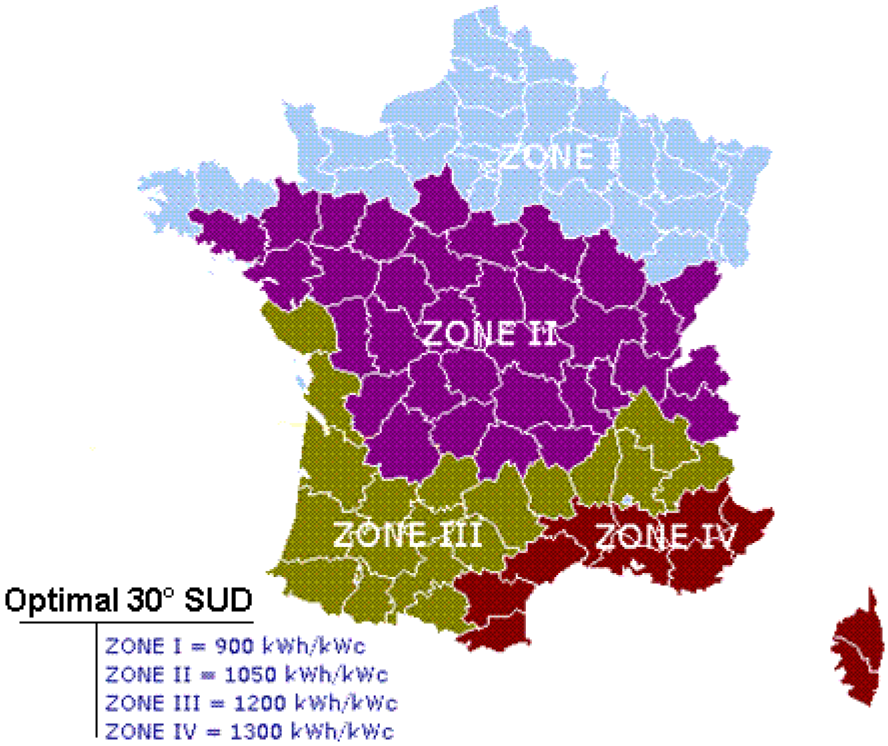
1) orientation orthogonal to the sun's rays, at a temperature of 25°C,

2) exposed to a radiance AM1.5 : a solar flux of 1000 W/m² received on the ground after having crossed an air mass of 1,5 atmospheres (what reduces the flux and its spectral content (the colors))

Note : AM0 corresponds to the space radiance (1360 W/m², solar spectrum with zero absorption), AM1 to the solar radiance on the ground with the shortest crossing of the atmosphere (1000 W/m², solar spectrum with absorptions).

## I.4. And the kWh/kWc ?

The kWh/kWc are giving the waited energy per installed kWc. In fact, this is a very imprecise notion because it depends both on the area where the plant is built, also on the working duration and on the weather. The notion of kWh/kWc is often the typical energy produced by a 1 kWc plant for one year.




**Slant of the modules to the horizontal**
**Neigung der Bauelemente zum Waagerechten**
**Pendiente de los módulos para la línea horizontal**

| | Inclinaison des modules PV par rapport à l'horizontale | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0° | 15° | 25° | 30° | 50° | 70° | 90° |
| EST | 88% | 87% | 85% | 83% | 77% | 65% | 50% |
| SUD-EST | 88% | 93% | 95% | 95% | 92% | 81% | 64% |
| SUD | 88% | 96% | 99% | 100% | 98% | 87% | 68% |
| SUD-OUEST | 88% | 93% | 95% | 95% | 92% | 81% | 64% |
| OUEST | 88% | 87% | 85% | 82% | 76% | 65% | 50% |

**Facteur correctif / Corrective factor / korrektiver Faktor / Factor correctivo**

The kWh/kWc is evidently depending on the geographic area, but also on the orientation of the plant and on possible shadings. Therefore, while keeping to be the most rigorous, we should to talk about kWh/kWc/year with an optimal orientation and no shading.

The opposite array is showing the optimal kWh/kWc in France and the corrective factors to apply in the case of imperfect orientation.

<u>Note :</u> there are plants with solar tracking (orientation follows the sun's motion and is always optimal) which increases by 30% the kWh/kWc in comparison with the production of ideally inclined static panels.

### I.5. And the kWp/m² ?

The kWp /m² give the peak power waited by installing 1 m² of photovoltaic panels. One takes place again in the normalized conditions for the peak power and the criterias for optimal exposure of the kWh/kWp.

The solaro-electric outputs are slowly raising and one admits that for panels mounted with their frames, it requires about :

- 7 to 10 m² of crystalline modules (mono ou polycrystalline) to get 1 kWp,
- 11 to 13 m² of thin film cells (CCM ou thin film)
- 16 to 20 m² amorphous modules to get 1 kWc,

In other words :
- between 100 to 140 Wc/m² for Silicium crystalline panels (with the advantage for the monocrystalline cells)
- between 75 to 90 Wc/m² for the modules with thin film (or CCM : cellules à couches minces)
- between 50 to 65 Wc/m² for the amorphous panels.

There are "record" outputs of laboratory, much higher, but in general, it breaks the reliability and increases dramatically the cost. Moreover they are often obtained by keeping artificial conditions and are not on the market.

Note : the last (2010) solaro-electric outputs of manufactured panels and computed for the real surfaces of productive photovoltaic materials are typically 20% for the monocrystalline panels, 16% for the polycrystalline, 6 to 10% for the thin films and 4 to 7% for the amorphous modules.

### I.6. Is the photovoltaic electricity adapted for the ways of consuming energy ?

The solar energy is intermittent, but it also respects the days / night cycles of the demand in electricity. Thus, it is not fundamentally incompatible with the human activities, even economic or industrial.

**However there isn't a definitive answer to give. One has to consider 2 types of energies :**
* The *"on demand" energies* : available at any time in any wanted quantity. These are essentially the chemical energies of combustions with hydrocarbons (wood, biomass, coal, gas, petroleum, hydrogen...), the stored energies (hydraulics, pneumatics...) or much rarer the thermal natural energies (geothermy, thermal energy from the seas/oceans)
* The **"not on demand" energies** : more or less temporally foreseeable and in non chosen quantity (nuclear, wind, tides...), they require to be immediately consumed or stored for an ulterior consumption.

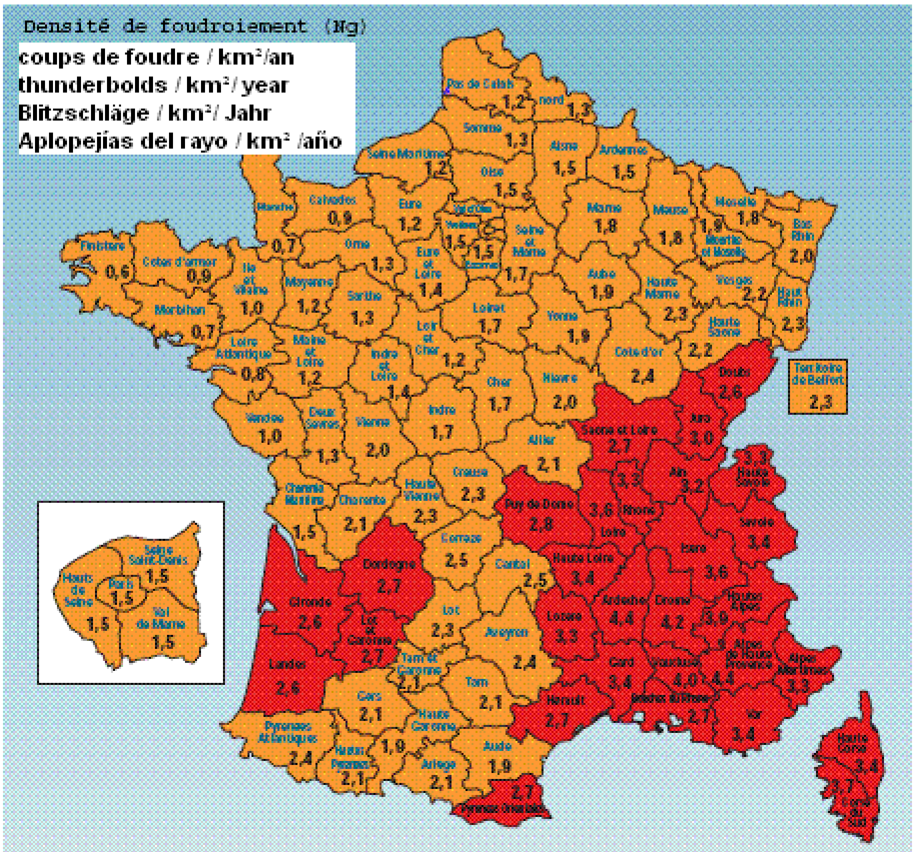
The balance of the electric grid ( production=demand ) entails a complex management and heavy investments granted by the big national providers of electricity : in France, it is d'EDF RTE (Electricité De France / Réseau de Transport de l'Electricité) which has the monopole about it. There are even agreements on international regulation of the grids because synergies generally appear through the temporal, geographic and energetic diversity or the different sources.


Among the "not on demand" energies, the photovoltaic electricity doesn't bring serious problem. It is often injected on the grid and/or locally self consumed (with in line losts nearly zero). It has the incontestable asset to be accessible anywhere for everybody, and if necessary easy to store with low cost batteries of accumulators (for example : plomb/acid) and with great environmental advantages.

## II. Photovoltaics and Natural Risks

### *II.1. Can a thunderbolt destroy a solar plant ?*

Of course, a thunderbolt can destroy a solar installation.



Nevertheless one has to notice that a photovoltaic solar plant has no influence about the probability (1 to 4 occurences / 10 000 for a house of 100 m²) that a thunderbolt hits the building (see opposite). On the contrary, the thunderbolt induces overvoltages and super amperic currents against whom it is possible to fight efficiently :

1) to build the wiring of the panels with small surfacic loops of current,
2) to foresee devices for anti-overvoltage to protect the inverters,
3) to take care about the connections towards the earth for the entire plant.

Close to the photovoltaic field, the presence of lonely high trees, a fortiori the build of a lightning conductor is to avoid.

It is also advised to assure the photovoltaic installation with a contract which multiriskly protects the dwelling.

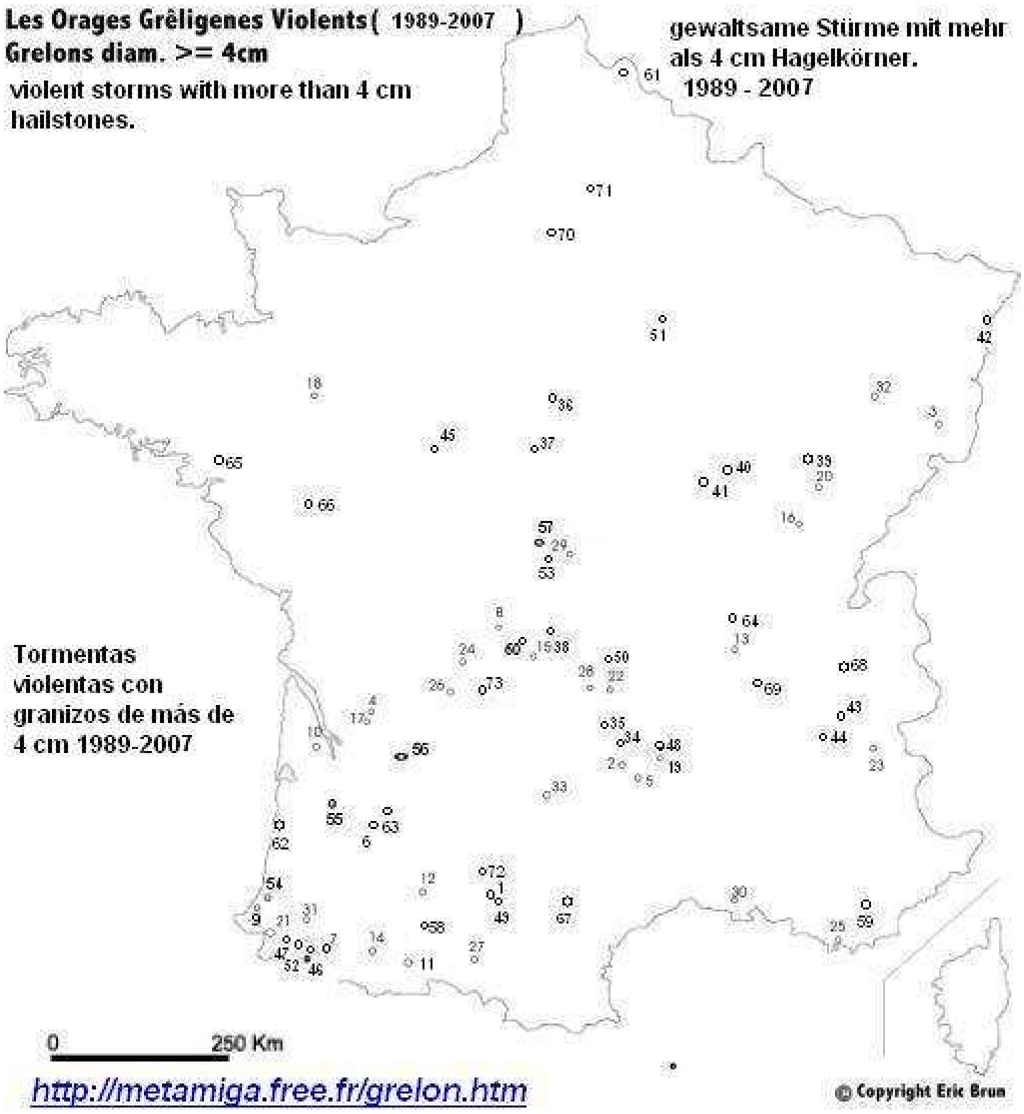
### II.2. Do the modules resist against the hailstones ?

The modules have generally been designed according the IEC 61215 norm (crystalline) or 61646 (thin film) to be sold in France. This norm defines many mechanical physicochemical resiliences for the panels, of which a faculty to support strong and moderate hails.

The panels achieving the IEC 61215 or IEC 61646 faced with success the simultaneous impacts of 11 hailstones of diameter 25 mm thrown vertically at 80 km / h against the panel.

Other tests are made with iceballs until to 75 mm of diameter or higher speeds until 140 km/h, but the shocks combining the highest speeds and masses can pass the limits of the panel. The IEC61215 panels resist hail in general better that of the tiles in terra-cotta.

The risk of violent hail is statistically a lot weaker than the risk of the thunderbolt. Although if it takes place, it is very difficult to preserve the photovoltaic field. Here is opposite a map of the violent hail events in France. The most exposed areas are Aquitaine and the South / West of the Massif Central.




Source *Observatoire Méteo en Provence* by *Eric Brun*

To increase the slope (50° and more) of the photovoltaic system is favorable to fight against the impacts because the hailstone rebounds on the field while keeping the essential of its energy which will be going to vanish on the ground. On the other hand, to increase this slope is unfavorable for the solar production, and one often cannot choose the slope of the roof. Like for the thunderbolt, an insurance is strongly recommended for the haily risk.

### *II.3. What happen in case of shut down of the electric grid ?*

The tension of wires coming from the network can disappear in case of maintenance or failure of the grid. In this case, the inverters lose their synchronization and automatically switch off. Thus the solar energy is not converted anymore in electricity thanks to an internal unplugging organ inside the inverters (in accordance with the requirements of EDF concerning security of goods and people). It allows the EDF workers to repair the lines in the absence of "electric islands", that is to say without local and unknown injections of electricity. When the tensions come back, the inverters resets themselves and the production takes place again in optimal and secured conditions.

Note : it means that in case of shut-down of the grid, a classic photovoltaic installation is not of any help. However, some specific inverters exists (“island” inverters); additional devices that permit to recreate a local wire under tension inside the system and to inject the energy solely in the network of the house even in case breakdown of the outside grid. The overcost of this option and its very rare use make that it is hardly ever not chosen.

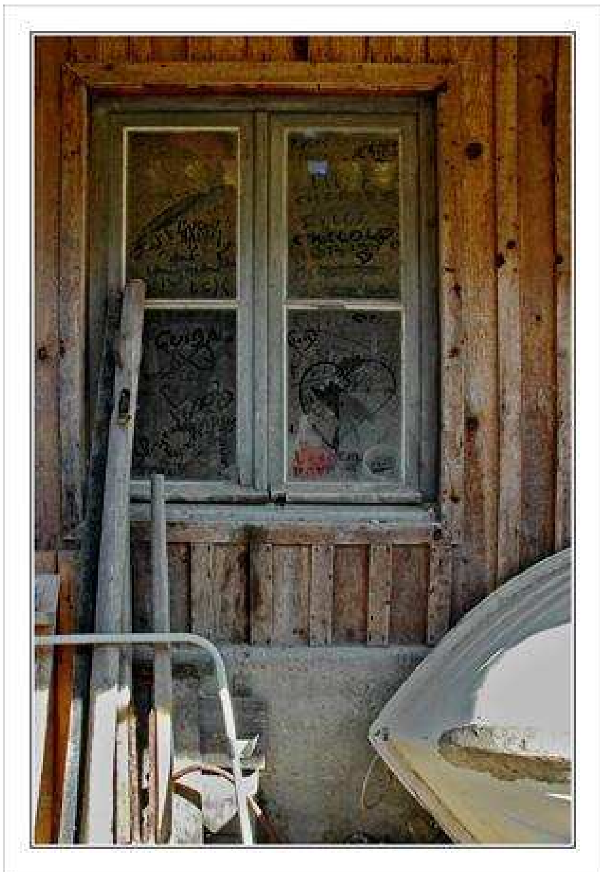
### *II.4. Has the photovoltaic field to be regularly cleaned up ?*

The cleaning of the panels is not obligatory, but it is absolutely necessary to maximize the production. It is indeed necessary to know that the serial connection of the photovoltaic panels (called "strings") *make that the weak link of the string imposes its current to the others even though all the other panels are stronger* (analogy with the mechanical strength of a chain limited by its weakest link). Therefore, the panels are sorted out by power while manufacturing and the tolerance is strict enough so that a weak panel doesn't slow down any more powerful panels.

This precaution guarantees almost-identical panels once delivered and mounted up, except if one of them comes to be clogged. In fact if its individual power lowers 15%, the whole chain where it is will also lower 15% even though the other panels of the string are perfectly clean !

The clogging of the panels comes from 4 main causes :
- the artificial dusts : atmospheric pollution, particles of soot, of tires, asphalt...
- the natural dusts : biomass particles, dust of earth, sand or stone,
- the adhesive inorganic deposits: the limestone, various chemical solid adherences,
- the adhesive organic deposits: mosses, lichens (rare), various excrements (frequent)...

In France, the natural precipitations of soft water make that the cleaning of the dusts is good enough without intervention. But in some very exposed areas (sandy rains of the Sahara, polluted cities, sea coasts, proximity of dusty activities (mine, stones' extraction, heavy industry, highways, agriculture...), it will be preferable to achieve a cleaning with soft water, or even slightly acidic to dissolve the deposits inorganic, or slightly alcoholic to dissolve the organic deposits. Cleaning can make itself by flowing, or by rubbing



with a perch / scraper and a adequat liquid, both can be combined. The frequency of cleanings can be monthly, yearly, multi-yearly according to the observation of the state of surface of the panels : it has to be done case by case... A decrease of the electric production is often the sign of a clogging.

Note : In the regions where water is chalky, it is strongly advised not to use this water for cleaning. An ideal installation will recover the rainwater in a cistern to cleaning aims. It is also advised not to walk on the panels.

## III. Photovoltaics and Cycle of Life

### *III.1. Are the photovoltaic panels recyclable ?*

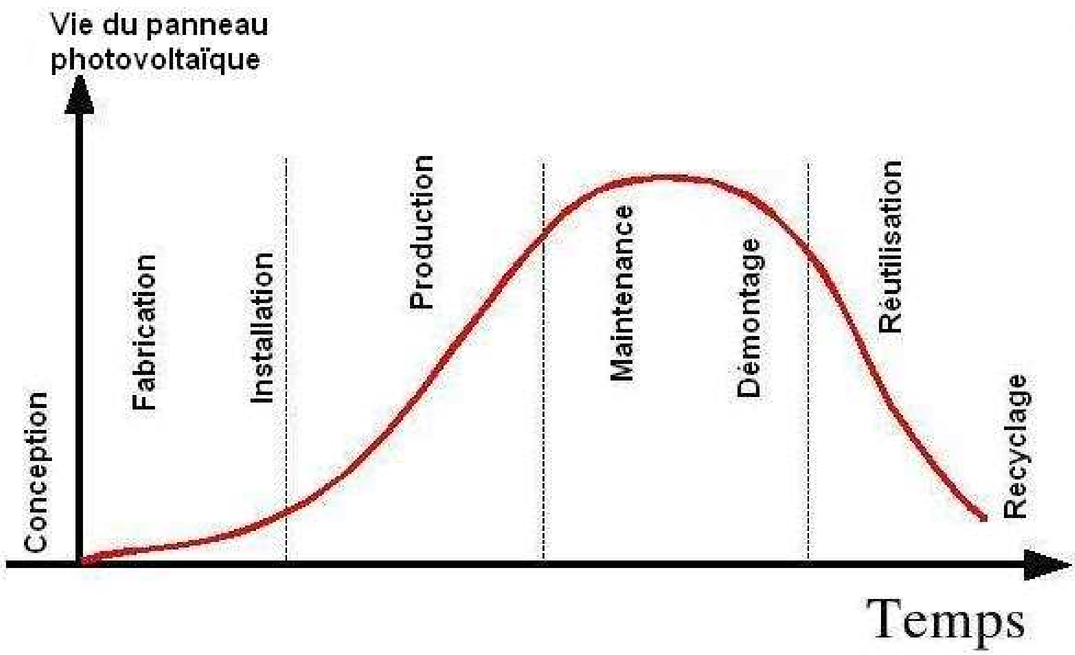
All components of the photovoltaic solar panels are recyclable. It is about separating the structures in alloy of aluminum of the photovoltaic parts. Then, metals are separated by physico-chemical processes to manufacture some new products, notably containing sicilicium.

### *III.2. How long will work my photovoltaic plant ?*

The panels are submitted to cycles of temperatures, of hygrometries, of physico-chemical aggressions foreseen by the IEC61215 norm. Thus the solaroelectric output decreases. But the manufacturers impose to their panels some accelerated ageing tests and the electric performances maintain themselves remarkably because they generally grant :

* at least 90% of the initial performance at the end of 10 years
* at least 80% of the initial performance at the end of 25 years
* in case of breakdown, the free supply of replacement modules during 20 years.

**Life of a photovoltaic panel**




From left to right : Design, Manufacturing, Installing, Working, Maintaining, Disassembling, Reusing, Recycling

## *III.3. Do the photovoltaic modules lose their power while aging ?*

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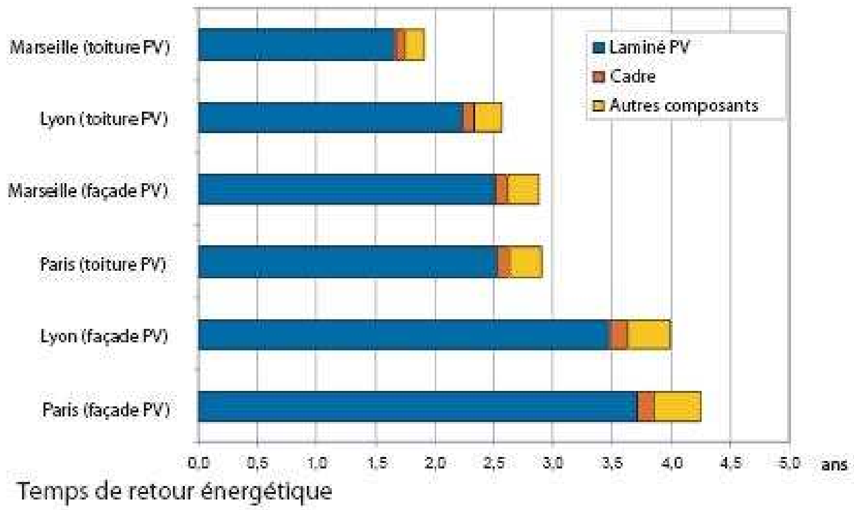
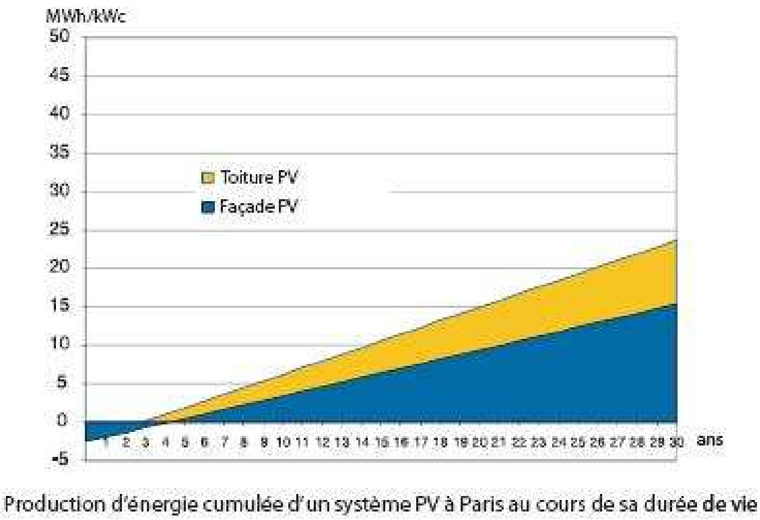



## *III.4. What is the carbon balance of the photovoltaic panels ?*

As all manufactured product, a photovoltaic panel imposes to consume some hydrocarbons (oil, coal, gas) for its manufacture, its installation and its retraining/recycling. The carbon balance of a photovoltaic panel is always very positive, in other words, the energy that it produces permits to save a quantity of hydrocarbons much



bigger than the necessary hydrocarbons' quantity during its cycle of life. One argues here in "CO2 Payback time" or time of return on carbon investment. The most recent surveys (2005/2010) studied by the ADEME and Hespul for the account of the International Agency of Energy (IEA) show that in France, this back time doesn't pass 4 years even for panels placed in facade in Paris.

## IV. Photovoltaics and other ways to convert solar energies

*The solar energy is an energy radiative covering 10 000 times the human needs*. One can exploit it according to various methods depending on the sought-after goal. 3 ways essentially exist :
- the thermal solar panels intended to the get sanitary hot water, with different variants,
- the photovoltaic panels to produce electricity with efficiency of 10 to 20%, also with different variants,
- the solar thermodynamics for the solar electricity with high output (20% and more) that requires the concentration of light, there are also varied technological choices in this domain.

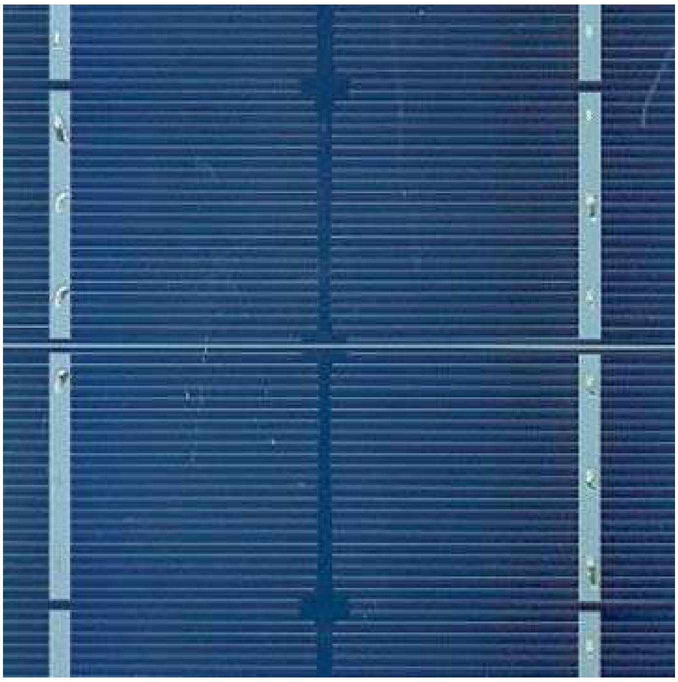
Let notice that there are marginal ways of research hybridizing the luminous concentration and the photovoltaic cells for example, or mixed solar panels (electricity + hot water)..

*The photovoltaics stays the only technology which can produce electricity from the diffuse solar radiance* (when the sky is cloudy). But for very sunny countries, the direct solar radiance can valorized with a better output with the concentrating solar thermodynamics. One will find here some precisions about these topics : http://sycomoreen.free.fr .

## V. Photovoltaics and Technologies

### *V.1. Can one plug and install himself any panels on any inverter ?*

The answer is clearly No. Every solar plant is specific and require a survey. Expertises in photovoltaic engineering (that Sycomoreen has) are necessary to size and to wire an installation in an optimal manner. Every case is to study with a great care : surface of the roofing, slant of the roof, environment of the installation, output of the panels, limit of the inverters, budget... In the same way, the installation requires expertises in framework / roofing and in electricity. Some photovoltaic administrative recognitions exist in France for the craftsmen carpenters and electricians about solar photovoltaics (QualiPV, QualiSol...).



### *V.2. What are the monocrystalline, polycrystalline, thin film and amorphous modules ?*

There are currently 4 industrialized technologies on the market :

#### *V.2.a) The monocrystalline Silicium*

While cooling, the melted silicium becomes solid by creating only one big sized crystal. Then the monocrystal is cut in fine slices that will give the cells. These cells appear in general with an uniform, intense and brilliant blue. They are used, but are not the most chosen, on the market of the photovoltaic energy.

<u>Advantages :</u> the best output, de 15% à 20% , the best ratio Wc/m² (until 180 Wc/m2) , life span of over 30 years.

Drawbacks :high cost, mediocre rate power/price, often rounded corners of the cell (lost of productive surface), the output decreases significantly with heat. Important grey energy (it requires a very pure silicium).

Applications : those where the top criteria is the electric power with minimal clutter : space probe, terrestrial plants with limited area and/or for high budget...

### *V.2.b) the polycrystalline Silicium (or multicrystalline)*

While the cooling the silicon in a ingoting device, it forms several crystals. The photovoltaic cell gets a blue aspect, but not uniform ; one distinguishes geometric shapes created by the different crystals which join themselves to form an intense blue with multiple reflections. They are used very extensively on the market of the photovoltaic energy.

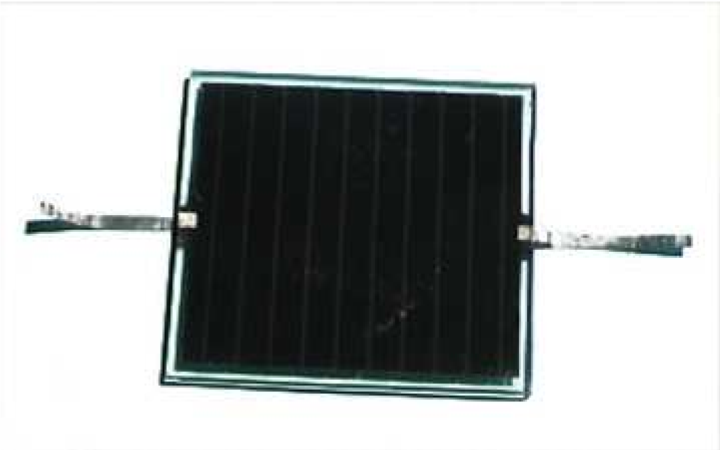
Advantages : good life span over 30 years, square cell allowing a perfect paving on the module, diffuse radiance better converted into electricity, good output (12 à 16% and about 140 Wc/m²), ingot much less expensive to produce than the monocrystalline which give the best rate power/price.

Drawbacks : lower output with weak lighting or heat.

Applications : those where the top criteria is the rate power/price : houses, photovoltaic plants, ground facilities with quite limited space...

### *V.2.c) The « thin films » cells without Silicium (CCM CIS or "Thin film CIS")*

These cells represent the new generation of solar cells as thin films, of type copper-indium-selenium (CIS) or Cadmium Tellurium (CdTe). Nowadays, the raw materials necessary to the manufacture these cells are easier to obtain than silicium used in the classic photovoltaic cells. Besides, their efficiency of energizing conversion is the best among the technologies to thin layer.



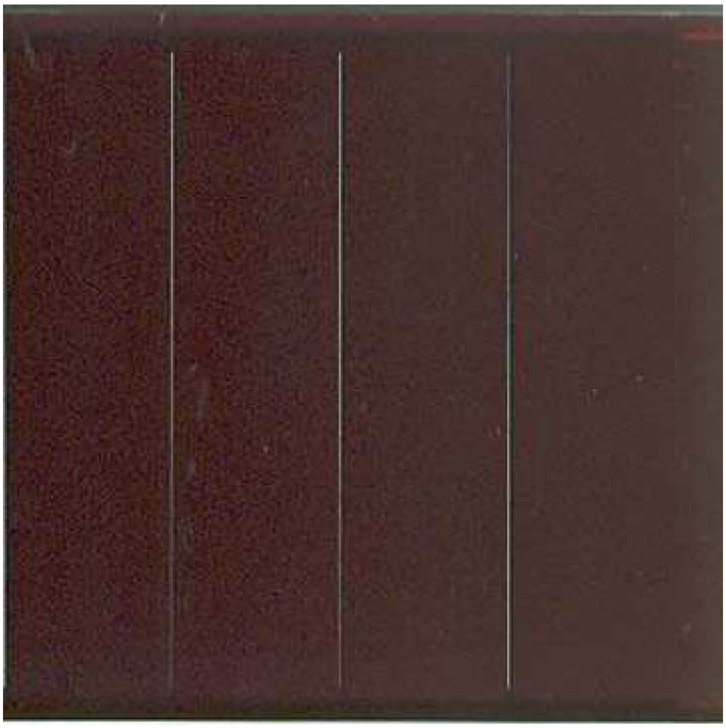
Advantages : medium output of the thin films CIS or CdTe in comparison with the amorphous thin films with Silicium ; allows not to need silicium, possibly flexible panels

Drawbacks : Because of a quite weak output, (6 to 10% and roughly 80 Wc/m²), the thin film cells (0.01 mm) require a wider area to attempt the same power as the thick cells (0.2 mm) that they are poly or monocrystallines.

Applications : those where the top criteria is the rate price/Wc while worrying a little about the powere/m² and without to be limited by the surface. Roofs of factory and supermarket, installation on the ground with big areas.

Note : the thin film research without Silicium is active and other combinations metals/semi-conductors will be used (Gallium, Indium, Phospore, Arsenic, Germanium...). Another way is the crystalline silicium in thin film while hoping to get the advantages of the 2 technologies without the drawbacks...

### V.2.d) The amorphous cells of Silicium in thin films (CCM Si "Thin film Si")



The Silicium while transforming produces a gas which is projected on a leaf of glass. The cell is gray very dark or brown with a mat aspect. It is the cell of the "solar" calculators and watches (in fact it reloads a chemical accu).

Advantages : Working with low radiance, quite good in diffuse light, low cost in comparison to other types of, less sensitive to the high temperatures, possibly flexible panels.

Drawbacks : Very weak output (4 à 7% and roughly 60 Wc/m²), the thin film cells require a more important area to get the same productions as the thick cells, short life span ( + / - 10 years), performances which meaningfully decrease with time.

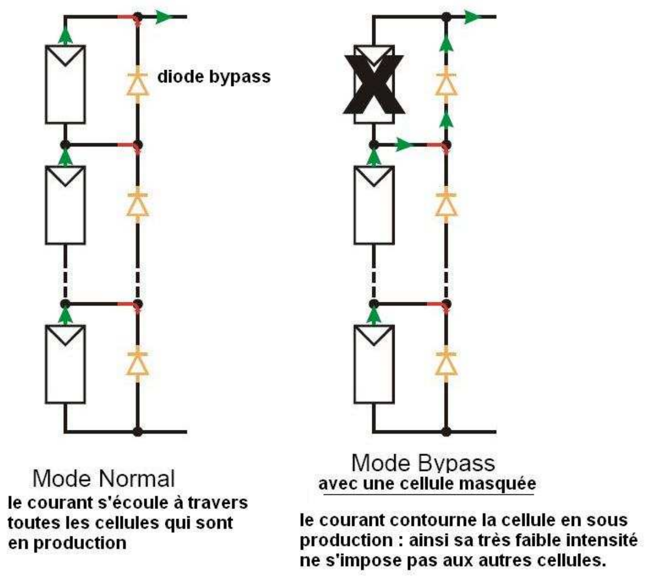
Applications : those where the top criteria is the rate price/Wc without wondering about power/m² or being limited in space. Very used for portable electronics or for the low cost solar plants with big areas.

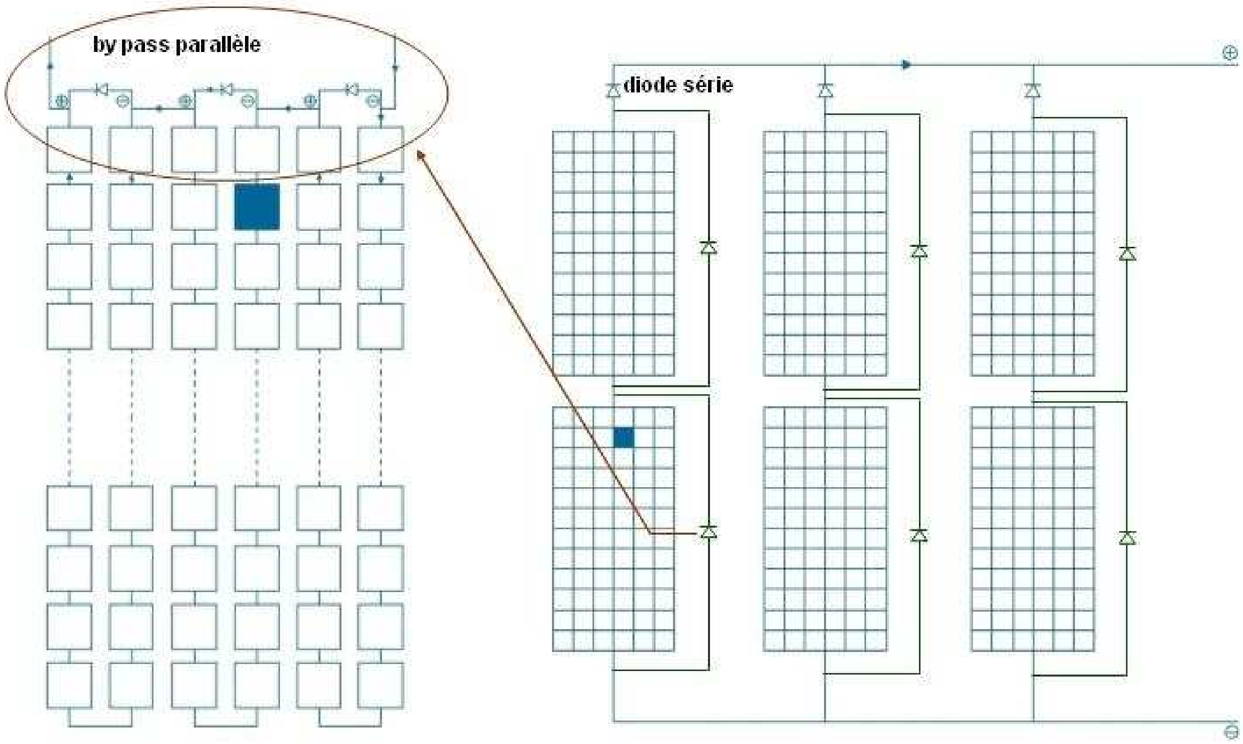
Applications : celle où le critère prioritaire est le prix/Wc sans se soucier de puissance/m² ou être limité en surface. Très utilisées pour l'électronique portative ou les installations solaires "low cost" à grande surface.

Note : Note : the research is active too and is trying to combine several technologies : multilayers cells (ou multi junctions) to better convert each color of the solar spectrum. But it entails difficulties to manufacture and the solaro electric output often stays at 30% in the laboratory.

### *V.3. Why to use some bypassing or blocking diodes ?*

The diodes are put inside a photovoltaic panel in serie or in parallel for cells or strings which are internal to this panel. Their goal is to **avoid the phenomenon of hot spots** which occurs when an internal cell or a string are not producing, generally because of a shade (by a leaf, shading deposit). This under irradiated part is indeed likely in reverse polarisation. It means that it doesn't work as an electric generator, but as a receptor which converts the energy sent by the other well irradiated cells into heat. It may entail the destruction of the cells. *To forbid this thermal effect, the diodes can be placed in a parallel way* (**bypassing of the current**) as shown on the opposite picture for the cells.. *The hot spot for a string can be avoided too with a diode put in serie* (**blocking of the current**). The combination of the diodes serie/parallel is possible as illustrated below for an example among others :




To protect the cell, the bypassing diode starts its conduction while the polarisation is reversing. For a string, the serial diode is blocking while the current on the string becomes negative. In the both cases, the current comes to zero in the under irradiated cells or strings in order to protect them. **The bypassing way has also the advantage not to collaps the current on the whole string while only one cell is shaded**. However, as soon as a diode is protecting a cell or a string, a part of the solar plant is not producing and *the power can strongly decrease*. Moreover, according to specifications about voltages and currents of a panel, the design of the module intends **to find the best compromise protection / power** … because if the diodes are protective, their numerous implantations are harmful for the output of the panel although it is normally irradiated …

## VI. Photovoltaics and investment

In France, the photovoltaics keeps to be sustained by a policy of preferential tariffs while selling the photovoltaic kWh. **These tariffs justify themselves because the solar energy is a responsible energy that doesn't mortgage the future :** the hydrocarbons and the nuclear powers indeed offer the present generations derisory prices per kWh (1 to 2 cts €) while neglecting the heavy consequences that the future generations should assume (climatic global warming and nuclear garbage). The photovoltaic lately knew aggressive speeches that qualify it of "bubble for speculators costing billions of euros for the whole collectivity". In spite of a lot more fine situation than this simplistic argument, its objectives achieve themselves while finding strong partisans *via* powerful influences : *after having undergone a consequent decrease in March 2010 and a significant hardening of its administrative rules, the tariffs are amputated again of 12% since September 1st, 2010 for the least newcomers, except for the very small facilities until 3 kWc.*

During less than 8 months, in addition to administrative heaviness and complex tariff rules of eligibility, **these one-sided and sudden decisions officially emanating from the French government made the sector financially little attractive and volatile.** *The typical payback time of a photovoltaic installation is currently from 8 to 15 years* according to the surfaces, the region, the technicality of the project and its “eligible” tariff. Nevertheless, as regards to the lasting development and patrimonial side, ***for the very small facilities*** (of which the tariff to sell the kWh is saved temporarily, but not the relative credits of tax that have just been divided by 2), ***the photovoltaic remains an alternative*** *at the hour of the stock agitations and the waving moneys*.

In spite of all, while seeing the strategic aspect, the photovoltaic brings a clean energy every year, produced to the closer to the consumers in total independence of the value of the hydrocarbons or the uranium ores. It also creates many jobs by the activity it brings (local craftsmen and enterprises), while valuing the buildings of any type.

However, since September 2010, **the initial and uniform tariff of about 60 cts € / kWh has been buried definitely.** Compared to the rules that were valid until December 31, 2009, numerous variants and exceptions occur while generally *modulating the tariff per kWh with very significant decreases.* And since January 2012, the tariffs of basis will be amputated of 10%/year for the new contracts. Except if a “new unforeseen order” will be given again. **This big instability of the rules combines itself with a potentially slow decrease of the installation costs,** because big markets emerge worldwide (the demand) and the capacities of production of the photovoltaic cells progress slowly (the offer): **some massive divestitures are possible (wished ?) in the French photovoltaic field,** in spite of its already extremely important delay in comparison with Germany, Spain or Italy.

To conclude, let's recall that it is necessary to take care about varying the energizing investments which can be achieved in a house. The photovoltaics is producing electricity, but for the heating, the installation of thermal solar panels will be a lot more applicable, as all other works of thermal insulation… and maybe simply the reduction of the energy wastes.

*Written by*

**The Naturally Energetic Movement !**

http://sycomoreen.free.fr

## Annex 1 : tariff future of photovoltaics in France

| Implantation of the photovoltaic field | | *Until* 31/08/2010 | *Starting from* 01/09/2010 | Notice |
|---|---|---|---|---|
| Full integration to the roofing of the building : closed, covered and tightness | Residential <3kW | 58 | 58 | unaltered |
| | Residential > 3kW | 58 | 51 | -12% |
| | Schools & Medicine | 58 | 51 | -12% |
| | Other use | 50 | 44 | -12% |
| Simplified integration to the roofing | Any use Closed, covered, and tightness, specific | 42 | 37 | -12% |
| Put on the ground Modulated from the North to the South by the « R coefficient » | North of France | 37.68 | 33.12 | -12% |
| | South of France | 31.4 | 27.6 | -12% |
| | DOM (beside seas department) | 40 | 35.2 | -12% |
| *Granted Tariffs for 20 years and revalued with indexes and for a limited maximal yearly production* | | | | |

Important commentaries :

1) Before the 01/01/2010 , there was the « 2006 grid of tariffs » which gave about 60 cts€/kWh for every building or roofing surface and 35 cts€/kWh for the solar plants on the ground.
2) Since the 01/01/2010 (confirmed in march 2010), for the new buildings (except the dwellings, schools and medicine buildings), *to get the tariffs above needs to leave a minimal delay of 2 years between the ending of the building and the roofing of the photovoltaic field* : **in 2010, a big commercial, industrial or agricultural building must put a classical roofing, and then optionally replace it in 2012 by photovoltaics… to have at the best only the 2012 tariffs and…**
3) Since 2012, **all the tariffs of basis for all** the new contracts **are decreasing of 10%** per year. **Thus, since 2012, the following coefficients will apply on the whole grid of tariffs :**

| Date of full query to connect the plant or payment of the "proposition technique et financière (PTF) de ErDF" | Coefficient which applies on the whole grid of tariffs |
|---|---|
| 01/01/2012 to 31/12/2012 | 0.9 |
| 01/01/2013 to 31/12/2013 | 0.81 |
| 01/01/2014 to 31/12/2014 | 0.729 |
| 01/01/2015 to 31/12/2015 | 0.6561 |
| 01/01/2016 to 31/12/2016 | 0.59049 |
| 01/01/2017 to 31/12/2017 | 0.531441 |
| 01/01/2018 to 31/12/2018 | 0.4782969 |
| 01/01/20XX to 31/12/20XX | 0.9^(20XX-2011) ----(either ≈ 0 at long time) |
| ? Until the electric grid parity (price kWh elec = price kWh photovoltaics) ? | |

4) Since the decree of march 2010, ErDF doesn't let the connections of the electric grid anymore : it requires now to make the CONSUEL to come, or at least to get his validating visa which has to be given to ErdF in order to obtain the power from the grid and send the photovoltaic energy on it (start from the solar plant). It costs about 150 € and needs the conformity with the norm UTE C15-712. Any non conformity requires a counter inspection with about 200 € more.
5) **For any precision or additional legal sublety,** one has to read (or will have) the « *Arrêté du 31 août 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil* », its annexes and any other decrees and applying measures, current of future and relative to this question. ( http://www.legifrance.gouv.fr )

# Annexe 2 : references and sources

The text and the design of this booklet of information about photovoltaics have been adapted by SYCOMOREEN (SYstems for COnversion of MOtions and REnewable Energies) from the FAQ Sycomoreen's Photovoltaics : *http://sycomoreen.free.fr/syco_PV_FAQ.html* (french, german and spanish translations are available there). The following links give the references of the illustrations and scientific sources :

| Page | Description | Auteur / Source |
|---|---|---|
| 1 | Photovoltaic roof | http://www.sunlightelectricity.eu/upload/Image/photovoltaique.jpg |
| 2 | Batteries and electric wires | http://www.clipart-fr.com énergie |
| 2 | Tiny pictures of the EDF meters | http://t1.gstatic.com/ ( google search « image compteur EDF ») |
| 2 | Tiny pictures of the SAGEM meters | http://t1.gstatic.com/ (google search « image compteur EDF ») |
| 2 | Light | http://www.icone-gif.com/gif/lumiere/ampoules/ |
| 2 | oven | http://www.clipart-fr.com Micro onde |
| 2 | Normalized AM irradiation | http://www.eyesolarlux.com/solar_am1.5_graphic_sm.jpg |
| 3 | Corrective factor of orientation | http://www.per-energie.fr/per+energie+calculs+production+pv-108.html adapted by http://sycomoreen.free.fr |
| 4 | Photovoltaic solar field | http://www.whitehouse.gov/sites/default/files/imagecache/embedded_img_full/image/image_file/smartgrid1.jpg adapted by http://sycomoreen.fr |
| 5 | Smart Grid Thinking / Managing | http://www02.abb.com |
| 5 | Thunderbolts in France and keraunic risks | http://www.stielec.ac-aix-marseille.fr/cours/abati/foudre/foudre.htm http://www.stielec.ac-aix-marseille.fr/cours/abati/foudre/pdf/densite.pdf |
| 6 | Violent storms with hailstones | http://metamiga.free.fr/grelon.htm |
| 6 | Hailstones Test norm 61 215 | http://www.iec-normen.de/previewpdf/info_iec61215%7Bed2.0%7Db.pdf et la norme résumée http://www.arsenal.ac.at/downloads/pvst3.pdf |
| 7 | Electric shutdown | http://techno.branchez-vous.com/actualite/upload/2007/07/nno%20plug.jpg |
| 7 | Workers maintaining the electric net | http://www.ledauphine.com/__cache__/image/photoelement/pj/___857818.jpg[435x-1].JPG adapted by http://sycomoreen.free.fr |
| 8 | Clean panels on a roof | http://www.arkitekto.net/P2_solaire_fichiers/Capteur_photovoltaique_cristallin_5.jpg |
| 8 | Dirty windows | http://mb33470.fond-ecran-image.com/blog-photo/files/2007/10/blog-dsc_9908-fenetre-sale-coeurs.jpg adapted by http://sycomoreen.free.fr |
| 8 | Curly cycle of life of a photovoltaic panel | http://www.ellipsos.ca/site_files/Image/cycle%20de%20vie.jpg |
| 9 | Time of the lifecycle | http://www.daskoo.org/upload/images/strategie-liee-au-cycle-de-vie-du-produit.jpg adapted by http://sycomoreen.free.fr |
| 9 | Photovoltaic CO2 balance | http://www.hespul.org/IMG/pdf/Brochure-indicateurs_France.pdf et http://www.hespul.org/IMG/pdf/resume_rapport_IEA-PVPS_FR.pdf |
| 10 | Monocrystalline Silicium square | http://www.ecosources.info/images/energie_industrie/silicium_monocristallin.jpg |
| 11 | Polycrystalline Silicium square | http://www.ecosources.info/images/energie_industrie/cellule-polycrystalline.jpg |
| 11 | Thin Film Silicium square | http://www.ecosources.info/images/energie_industrie/cellule_photovoltaique_cis.jpg |
| 12 | Amorphous square | http://www.ecosources.info/images/energie_industrie/silicium_amorphe.jpg |
| 12 | Amorphous Silicium roller | http://www.arkitekto.net/P2_solaire_fichiers/Capteur_photovoltaique_amorphe_1.jpg |
| 13 | Working of the bypassing diodes | http://www.ibselectronics.com/pdf/ac/Diotec/applications/solardiodes.pdf extracted and adapted by http://sycomoreen.free.fr |
| 13 | Set of series and bypass diodes | http://photovolt34.free.fr/energie_pv.php adapted by http://sycomoreen.fr |
| 15 | Grid of photovoltaic tariffs in France | http://www.photovoltaique.info/IMG/pdf/100101_Tarifs_pv_HESPUL.pdf |

**International theses about the « CO2 Payback Time » of photovoltaics**
http://www.oilcrisis.com/netEnergy/EnergyPayback4PV_NREL.pdf (NREL, USA)
http://www.clca.columbia.edu/papers/Photovoltaic_Energy_Payback_Times.pdf (USA)
http://www.newenergyindia.org/Energy%20Payback%20time_Opinion%20Page.pdf (India)

**Database and solar simulations advised by Sycomoreen**
http://re.jrc.ec.europa.eu/pvgis/ (PVGIS : PhotoVoltaic Geographical Information System)

**French websites of information and tracking on solar energy in France**
http://www.outilssolaires.com/
http://www.photovoltaique.info/
http://www.hespul.org/
http://forum-photovoltaique.fr/