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Techno economical study of photovoltaic energy installations within DCNS

Master of Science Thesis in the Master Degree Programme, Sustainable Energy Systems

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Opportunity of installing photovoltaic panels on the roofs of a big industrial company having facilities in different parts of France.
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Cover:
[The photovoltaic modules on the buildings of the company "Pommiers", Bagnères-de-Bigorre, France, photo Diane Dhomé,, 06/12/2010]

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ABSTRACT

Concerns have risen in the last few years about global warming. It has been shown that energy is responsible for a big share of CO_2 emissions, and new ways of saving and producing energies are being investigated. Renewable energies are expected to play a major role in the world's energetic future, and photovoltaic – a technology converting sunlight into electricity – could be one of the important components.

These concerns have also started to get integrated by companies and industries. They start to realise that the way they produce is not sustainable, and want to diversify their energy sources. This is also at the same time a way of saving money and developing a better and cleaner image for customers.

DCNS is a leading company in the field of naval defence systems and is implanted at ten different places in France. After having achieved a group-wide ISO14001 certification and carried out a complete carbon accounting, DCNS is getting interested in different renewable energies, and among them photovoltaic electricity. The project is managed by the environmental service for the whole group, and the aim is to install as many photovoltaic panels as possible.

It has been shown that photovoltaic energy would be technically interesting, and using it on DCNS' industrial centres could cover between 5 and 10% of the whole group electricity consumption, and up to 20% of the sites it is installed in.

However, it is economically and juridically not as simple. Feed-in tariffs were launched in France in 2006, and the sector saw a big increase between 2006 and 2010, but in March 2011 all the incentives were decreased a lot. For big projects such as DCNS', companies need now to answer to call for tenders published by the state. Moreover, the sector does not seem to be mature yet; it is for example difficult to find serious and experienced companies, and consulted companies gave very different offers. There are also difficulties inside of DCNS, with reticence from several services such as the juridical or the infrastructures ones.

It has also been shown that environmental parameters are very important. In all cases photovoltaic panels are beneficial and avoid CO_2 emissions over their life cycles, but they are even more interesting if they are produced close to where they are installed, using low-carbon electricity, and transported by trains instead of trucks.

To conclude, the project could be interesting in the future for DCNS, but more work needs to be done to answer to call for tenders, with special importance to environmental and aesthetical parameters. More internal communication needs also to be done so that all concerned persons feel involved in the project.

Keywords: renewable energies, solar energy, photovoltaic, industry, France.

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INTRODUCTION

In the last few years, environment has taken a bigger and bigger place in people's minds, but also in company's world. Environmental questions and problems, that were totally ignored a few years ago, are now becoming part of companies' strategies. This is often due to stricter regulation and incentives, for example with the EU ETS, the coming obligation in France for companies over 500 employees to calculate their carbon footprint, or the probable future carbon tax. These policies also had the advantage of increasing environmental consciousness, which brings a higher number of companies to use self regulation. This is of course usually not only because of own conviction, but has several advantages for companies. It is indeed cheaper for them to reduce their pollutants emissions before it is compulsory. Developing environmental projects can also save money, for example with energy efficiency measures, but also directly bring money, for example through electricity production sold to the national grid. It also allows them to develop a "green" image, which can be extremely beneficial, except if it falls into "greenwashing".

Unfortunately, all governments have not really understood how important this movement can be, for their people, for the environment, but also for economy and for politics reasons. This can be seen in France with constant governmental changes of mind, which prevents from developing tong-term strategies and projects. Regarding photovoltaic industry, after two changes of feed-in tariffs in 8 months, the government decided in December 2010 to stop everything and set up a 3-months moratorium, before changing the whole incentives system.

DCNS is an example of a company that has integrated these questions. Environment has been taken into account to a quite big extent for such a company in the last few years, which can be seen for example with the group-wide ISO14001 certification or the carbon accounting carried out in 2010. DCNS, big old naval industry company, is now expanding in new activities, such as marine renewable energies. In parallel, it wants to develop renewable energies for its own buildings. One of these projects is to install photovoltaic panels on the roofs.
The subject of this thesis enters in this scope. The aim is to study the feasibility of such a photovoltaic project, both from a technical point of view and regarding economical aspects. Other criteria, such as environmental or social impacts, should also be included in the study. The aim is to investigate the possibility of installing photovoltaic panels on the roofs of all production sites of DCNS: one in Normandy, three in Brittany, one in South-West of France and two on the French Riviera. These centres have very different characteristics that should be taken into account.

First, the background of this thesis will be explained, including a presentation of the company DCNS, a state of the art of photovoltaic energy, and specific context in France. Afterwards, the method used will be explained. The work has been divided into three main parts: own estimations of the potential for DCNS buildings, follow-up of the project at DCNS and consultation of design offices, and CO_2 life cycle assessment; economical calculations have also been carried out. Main results of this work will then be presented. These results will next be analysed. Finally, the project and its future will be discussed.

BACKGROUND

Presentation of DCNS

A long history in naval defence systems

DCNS is a leading company in the field of naval defence systems. Historically created in 1631 with the construction of the first arsenals, it was totally state owned until 2003, when it became a private company. Today, the French state still holds 75% of the company; a large part of the rest being owned by another defence company (Thales). It employs 12239 persons, has 2.3 billion euros order intake and generates around 2.5 billion euros in revenue.

DCNS designs, builds and supports naval defence systems, such as frigates, torpedoes, nuclear-powered submarines, aircraft carriers… Since it has been privatised, it has also expanded its activities to new markets, especially industrial services, civil nuclear energy and marine renewable energies. In 2009 an "incubator" was created in order to develop marine energies, especially marine current turbines, floating offshore wind farms, wave energy and ocean thermal energy conversion.

The company was historically based in France around the coast. It has 10 implantations in France, with different specialties, that can be seen on France's map in Figure 1. There are three tertiary offices: the headquarter and the civil nuclear department are based in Paris, the surface ships and naval systems department is in Bagneux, next to Paris, and in Le Mourillon, next to Toulon. The submarines are built in Cherbourg and Nantes-Indret, the surface ships and naval systems are constructed in Lorient, underwater weapons are built in Saint-Tropez, the equipments are designed and constructed in Ruelle, and the sites of Brest and Toulon are dedicated to maintenance of and services to the products.

Figure 1: Implantations of DCNS in France

Today, DCNS is expanding a lot abroad, with implantations in various countries such as South Arabia, Bulgaria, Greece, Italy, India, Malaysia, Singapore. It recently signed a 7 billions euros contract with Brazil for four conventional submarines, help to design nuclear-powered submarines, assistance to the design and construction of a naval base, and a school to learn designing submarines to Brazilians.

A recent commitment to the environment

DCNS was one of the first companies in its field to take the environment into account. In 2009 it obtained a group-wide ISO 14001 certification. It also develops eco-conception and realised a carbon inventory of the whole group in 2010, a little bit in advance with the French law which makes it compulsory before 2012.

In 2009, the “Championship” program was launched, with the objective of increasing sales by 50 to 100% within 10 years, through an increase in productivity of 30%. The program is divided in several axes. One of them is called “working differently” and includes a workshop “Energy”. This energy workshop is divided itself into four workshops:

- Energy savings
- New energies
- Financial aspects, carbon trading
- Electricity and gas purchases

championship

Figure 2: Championship program logo

This thesis enters in the scope of the second workshop, “new energies”. DCNS aims at developing renewable energies on its buildings, and has different projects for that. One of them is to install photovoltaic panels in all of its locations, everywhere it is possible and profitable. In addition to the environmental commitment, this project would have the advantage of improving the image of the company, and bringing additional earnings, which could be used to finance other energy projects. Other projects in this workshop include for example a wind turbine in Nantes-Indret, a biomass boiler in Cherbourg, a hydro turbine in Ruelle…

Social Responsibility

DCNS environmental involvement is part of a CSR commitment. Next to that, a program of knowledge transmission has been started.

One part is within the company, with young people coming to learn a new job; another part stands in the DCNS Imoca 60 feet boat, which was first skipped by an experienced skipper (Marc Thiercelin) who then transmitted his experience to a young skipper (Christopher Pratt), selected through a special program of sailing races.

Figure 3: "DCNS 1000", 60 feet Imoca boat sponsored by DCNS

DCNS specificities

Even if DCNS is now a private company, it has some particularities due to its activities and links with the army.

First, a lot of documents are confidential and cannot be given away because it is supposed to be part of France’s defence. For the same reason, access to the buildings of the company is a bit complicated: when someone comes, his identity card must be sent a few days in advance, and even a few weeks if the person is not French.

In Toulon and Brest, the situation is even more complicated. DCNS in these cities is indeed located inside of the arsenals. It means that the rules of the French defence apply, and the security rules are very demanding. In these two places, DCNS is not owner of the buildings, but rents them to the state, through “COT” (temporary occupation convention) of thirty years and “AOT” (temporary occupation agreement) of a few years.

Photovoltaic energy

Solar energy

Energy from the sun is spread over the whole planet in huge quantities. Sun is at the origin of most of the energy sources that are currently used by humans: hydroelectricity (through the water cycle), wind energy, biomass but also coal or oil (through photosynthesis)…
The energy the earth receives from the sun every year is more than 10 000 times the total world energy consumption, all kinds of energy types and usages included! *(*Association Hespul 2010b*)* Moreover, the sunlight has been here for more than five billions years, and is going to be still here for more than five billions years. Covering only 0.3% of deserts surface with solar thermodynamic devices would cover the electricity needs of the entire humanity! (Syndicat des Énergies Renouvelables 2010a) This is of course purely imaginary as it would bring the problem of electricity transportation over long distances. However, this potential is still huge but very poorly used today.

Solar energy can be used in several different ways.

First it can be used for **heating**. Sun radiation is directly converted into useable heat. Solar sensors are placed either on roofs or on walls, and a fluid (usually air or water with an antifreeze product) goes through these sensors and then into the house. These systems can be either passive (there is no pump in such a system, the fluid naturally circulates due to the density difference through a thermosiphon flow), or active (a pump forces the fluid circulation). Solar heating can be used for heating houses or buildings or for domestic hot water, for private individuals or in companies for the locker rooms. (Liébard & De Herde 2005)
Figure 4 shows how an active system for domestic hot water works.

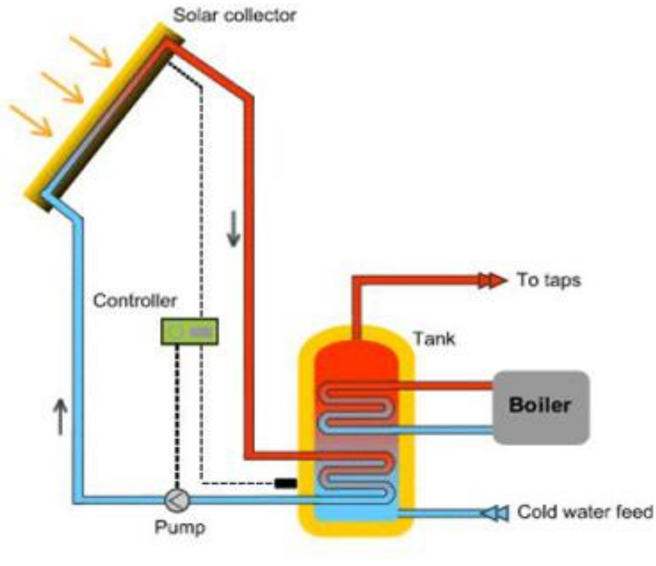


Figure 4: Solar heating installation
(The Renewable Energy Centre n.d)

Moreover, sun can be used to produce electricity using **photovoltaic** devices. This technology is the point of this report and will be explained in more details further.

Finally, **thermodynamic solar energy** – also called Concentrated Solar Power – is more and more used. The principle is that big mirrors reflect and concentrate the sun rays. A receptor absorbs this energy and transfers it to a thermodynamic fluid. Then different kinds of systems can be used to convert this energy into electricity: gas turbine, steam Rankine cycle, Stirling engine… Rankine cycles are the most widely used today. (Syndicat des Énergies Renouvelables 2010a) An example of a parabolic sensor plant is shown in Figure 5.

Figure 5: Thermodynamic solar installation (Syndicat des Énergies Renouvelables 2010a)

Photovoltaic energy

The photovoltaic effect, which has been discovered by Antoine Becquerel in the late XIXth century, is the effect that enables direct conversion of sunlight into electricity. (Syndicat des Énergies Renouvelables 2010b) The word photovoltaic comes from the Greek word “photo” which means “light” and “Volta”, the measure unit for electromotive force.

A photovoltaic device is made of several components. The photovoltaic cells are interconnected to form a photovoltaic module. Several modules are then connected together to form an array.

The whole installation

Photovoltaic modules produce direct current electricity. Electricity produced can be either used for the owner’s own electricity consumption (off-grid system), which can be very useful especially for isolated places, or connected to the national electricity grid. In the latest case, the direct-current electricity needs to be converted into alternating-current electricity through a DC to AC inverter.
A typical on-grid electrical installation is described in Figure 6.

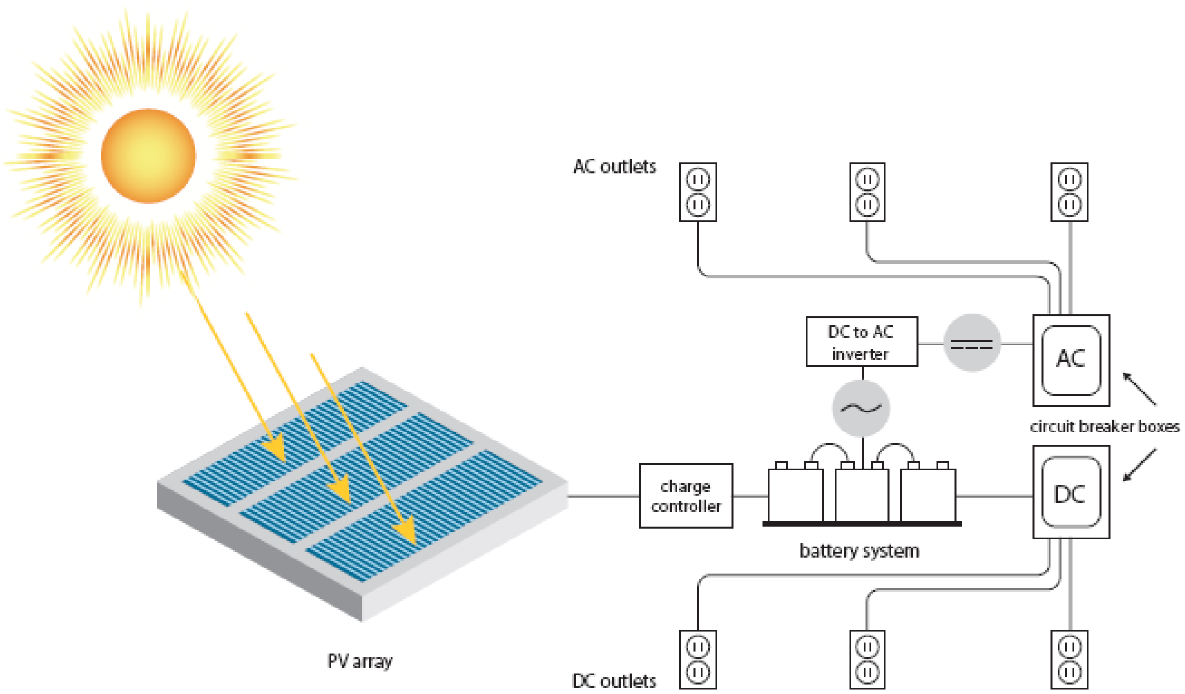


Figure 6: Photovoltaic electrical installation (European Commission 2009)

The solar cell

The solar cell is the component in which the conversion from sunlight into electricity actually takes place. It is usually made of semiconductors materials, such as silicon. The principle is explained in Figure 7. The material is made of two parts. One of them called type “n” has too many electrons (in orange in the figure) whereas the other one – called type “p” - has not enough electrons (in blue in the figure). These two types of material are usually created by adding phosphorus (n-part) and boron (p-part) to the silicon. (Vériot & Firon 2004)
When photons from the sunlight strike the solar cell, they can be reflected, absorbed or pass through. When one of them is absorbed, its energy is transferred to an electron, in the “n-zone”. This electron moves to the “p-zone”, which creates a “hole” behind him, and an “electron-hole” pair is created. In order to create an electrical power, electrons and holes need to be separated, which is done thanks to the electrical field at the p-n junction. Electrons can then move to the n-zone, whereas the holes move to the p-zone. Finally, an electrical current is created, which can be used in an electrical circuit.
(PVResources 2010b) (Lincot et al. 2010)

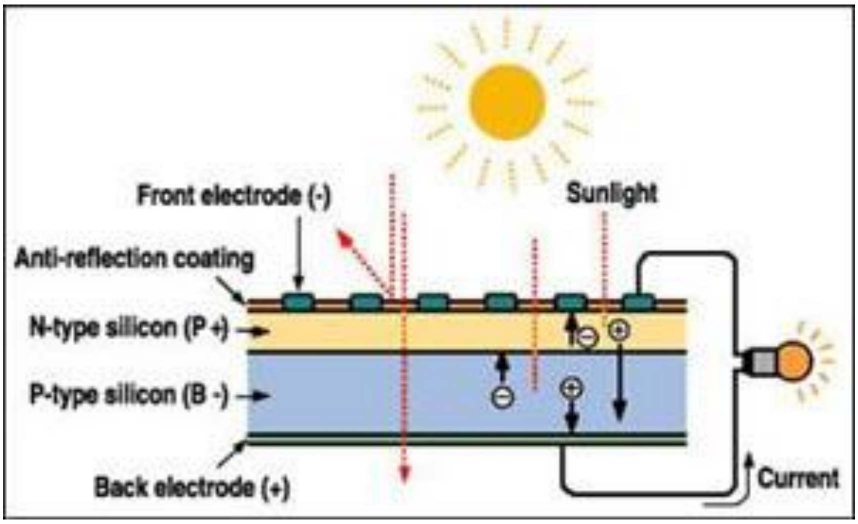


Figure 7: Physics of a solar cell
(University of Hartford's Engineering Application Centre n.d)

These cells can be made of different materials, but more than 90% of cells built today consist of wafer-based silicon cells. (European Commission 2009) The production chain can be seen in Figure 8.

Figure 8: Photovoltaic system fabrication
(European Photovoltaic Industry Association n.d.a)

The performance of a solar cell can be described with the efficiency at turning sunlight into electricity. Two main technologies of solar cells are used today, but a lot of others are under development, with very different efficiencies.

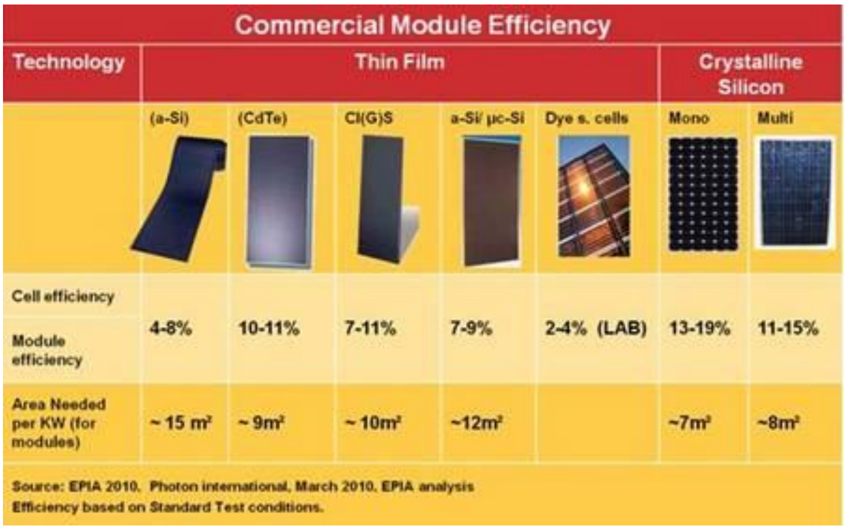
Crystalline silicon technology

Crystalline silicon cells are made of thin slices cut from silicon crystals. It can be either slices from a single crystal of silicon, it is then called monocrystalline, or from a block of silicon crystals, it is called polycrystalline. A third kind of crystalline silicon technology is made of ribbon sheets. Monocrystalline cells have a slightly higher efficiency (from 13 to 19%) than polycrystalline cells (from 11 to 15%). (European Photovoltaic Industry Association n.d.a)

Thin film technology

The second main technology of photovoltaic energy is the thin film technology. The modules are constructed by depositing very thin layers of photosensitive materials on a backing such as plastic, stainless steel or glass. The main advantage of this technology is its lower production costs. However, its efficiency is lower than with crystalline cells, ranging from 4 to 11%. Different materials can be used for this kind of modules: amorphous silicon, cadmium telluride, copper indium or gallium diselenide or disulphide. (European Photovoltaic Industry Association n.d.a)

Figure 9 summarizes the efficiencies of the previously described technologies. Another important criterion can be seen in this table: the area per kW. It can be seen that the area needed is much higher with the thin film technology than with the crystalline silicon technology, due to its lower efficiency.



Commercial Module Efficiency							
Technology	Thin Film					Crystalline Silicon	
	(a-Si)	(CdTe)	CI(G)S	a-Si/ µc-Si	Dye s. cells	Mono	Multi
Cell efficiency / Module efficiency	4-8%	10-11%	7-11%	7-9%	2-4% (LAB)	13-19%	11-15%
Area Needed per KW (for modules)	~ 15 m²	~ 9m²	~ 10m²	~12m²		~7m²	~8m²

Source: EPIA 2010, Photon international, March 2010, EPIA analysis
Efficiency based on Standard Test conditions.

Figure 9: Commercial modules efficiencies
(European Photovoltaic Industry Association n.d.a)

Today's world record efficiency for thin-film solar cells is 20.3% and has been reached in August 2010 in Germany by researchers of the Centre for Solar Energy and Hydrogen Research ZSW. (SolarServer 2010)

Other technologies are under development with a promising future.

Organic photovoltaic cells
One of these emerging technologies is organic cells, which are very promising for several reasons. It uses indeed much cheaper materials, so it could bring a big reduction in costs. Moreover, from an ecological point of view, organic materials, such as plastic, are degradable; it would then simplify the problem of photovoltaic cells recycling. They are finally flexible, and could be used for specific applications, for which classical photovoltaic cells cannot be used, for example photovoltaic tiles. However, this technology is not ready at all and has too low efficiencies so far. (Vériot & Firon 2004)

High efficiency multijunction cells
New generations of silicon technologies are also under development. An idea is to use several layers of semiconductors that are able to capture different parts of the solar spectrum. Today's solar panels can only absorb one part of the solar spectrum. This technology is not new, and has been used for special applications, such as spatial exploration and satellites, but was considered to be too expensive for terrestrial applications. It is not really true anymore, and this technology could increase efficiencies a lot in the next future. (Lincot et al. 2010) (Fairley 2007)

The efficiency world record for all types of technologies is 42% and has been reached by Spire Semiconductors, using multijunction cells with three layers. (L'Echo du Solaire 2010)

It can be seen that even for the most advanced technologies, the efficiencies are pretty low, while costs are still quite high. That is why the main challenge for photovoltaic industry is to improve solar cells efficiencies while lowering the production costs.

Comparing photovoltaic installations

Different characteristics are used to describe a photovoltaic installation. One of them is the efficiency, that has already been presented.
An important unit to characterize the power of photovoltaic panels is the “peak watt’ (written W_p), which gives the power at standard test conditions (light intensity of 1000W/m², temperature of 25°C, spectrum similar to the one at a latitude of 35°N in summer).
The productivity of a photovoltaic installation is measured in $kWh_{produced}/kW_p$/year.
A good parameter to know is also the performance in W/m². The higher it is the smaller surface is needed for the same production.

Different kinds of installations

Different ways of installing photovoltaic modules exist, with different constraints and usages.

- First there are “roof-mounted” modules, which are placed instead of the classical cover of the roof. If they are to be installed on existing buildings, it means that the previous roof cover needs to be removed. Such installations also need to fulfil waterproofness requirements.
*(*L’usine nouvelle n.d*)*

- The photovoltaic panels can also be placed “on top” of the roof. With this technology, the previous roof doesn’t need to be unbuilt, but the structure of the building needs to be more resistant as a higher weight is put on top of it.
*(*Association Hespul 2010a)

- Another way of using photovoltaic panels is to use them on the façades of a building. It means that the modules are vertical, which leads to a lower efficiency. The modules become part of the design and the architecture of the building.
(Solareo 2010)

- Solar panels can also be used as “brise-soleil”. They are placed above the windows, which has another advantage: in summer it reduces the heat from the sun than enters the rooms, which decreases the air conditioning needs, especially in warm countries. This system enables to place the modules at the optimum angle to the sun rays.
*(*Maville.com 2008*)*

- The last way if using photovoltaic in a building is to use half transparent modules as windows. It has the same advantage as the previous system (decreasing the sunlight entering the room), but is less efficient.
*(*La Compagnie du Solaire n.d.)

- Finally, photovoltaic panels can be used directly on the ground. In that case, they can be placed at the very optimum position to the sun, and are often associated with trackers that enable them to follow the sun over the day and over the year.
(Syndicat des Énergies Renouvelables 2010b)

Optimum position of solar panels

The actual electricity production of the installation depends on the orientation of the array compared to the south and the angle to the horizontal. The optimum position in France is a photovoltaic panel oriented in the direction of the South, with an angle of roughly 30° (this depends on the latitude).
Figure 10 gives the correction factors that need to be applied to the electricity production when the panel is in another position than the optimum one. Orientation to the North does not apply because the efficiency drops a lot, but it can still be worth installing panels to the North with small angles in very sunny places.

FACTEURS DE CORRECTION POUR UNE INCLINAISON ET UNE ORIENTATION DONNEES

INCLINAISON / ORIENTATION	0°	30°	60°	90°
Est	**0,93**	**0,90**	**0,78**	**0,55**
Sud-Est	**0,93**	**0,96**	**0,88**	**0,66**
Sud	**0,93**	**1,00**	**0,91**	**0,68**
Sud-Ouest	**0,93**	**0,96**	**0,88**	**0,66**
Ouest	**0,93**	**0,90**	**0,78**	**0,55**

: position à éviter si elle n'est pas imposée par une intégration architecturale

source Hespul

NB : ces chiffres n'incluent pas les possibles masques qui pourraient réduire la production annuelle.

Figure 10: Correction factors for different roofs positions (Association Hespul n.d)

Economics

The economics of photovoltaic industry is a bit tricky to approach, and depends on a lot of different parameters.

Estimating the costs of photovoltaic

First, the different technologies do not have the same prices. Graph in Figure 11 shows the prices and the performance of the four big categories of photovoltaic technologies. In the two widest used technologies, thin film technologies are cheaper per square meter than crystalline silicon technologies. However, the second ones have better performances, and produce more per square metre and per W_p. This means that for a given power, a smaller surface will be needed, which reduces the cost, or for a given surface more electricity will be produced, which brings more money back.

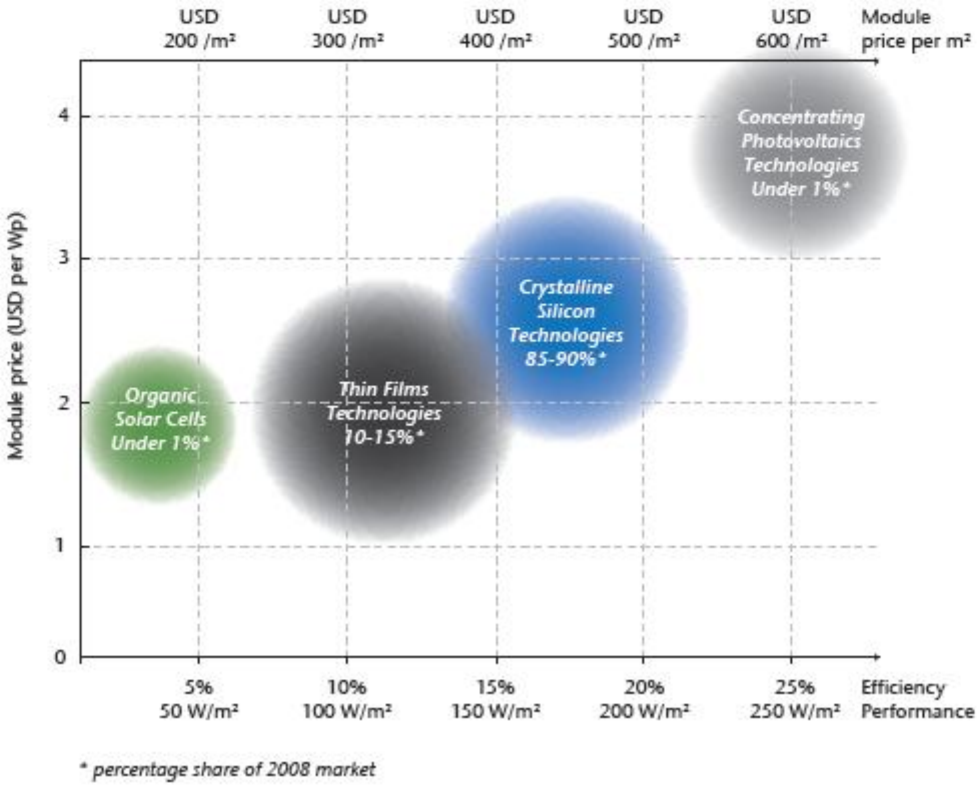


Figure 11: Price and performance of different photovoltaic technologies (International Energy Agency 2010b)

This shows that a global approach is needed, which includes the total cost of the photovoltaic system. To respond this problem, “PVresources” made an estimation of the cost of a whole system. The conclusion was that the cost of installing a 1kW system ranges from 3500€/kW_p to 5000€/kW_p. In this number; only 40 to 60% are for the photovoltaic modules. The rest of the price is for the inverter, the support structures, the electrical cabling, the installation… (PVResources 2010a)

However, this kind of estimations is again not very precise. Indeed, some of costs vary widely from one installation to another. For example, the installation cost will increase a lot if the roof needs to be entirely redone, if the structure of the building needs to be reinforced to support the photovoltaic modules or if asbestos needs to be removed before the works.
Moreover, the previous numbers do not take into account costs such as installation labour or maintenance costs.

A rapid evolution of the prices

Furthermore, the cost of photovoltaic equipments is decreasing quickly as the technology is becoming more mature. This very fast price drop is shown in Figure 12. As production increases, modules prices decrease a lot, and photovoltaic modules have became more than five times cheaper in 25 years.

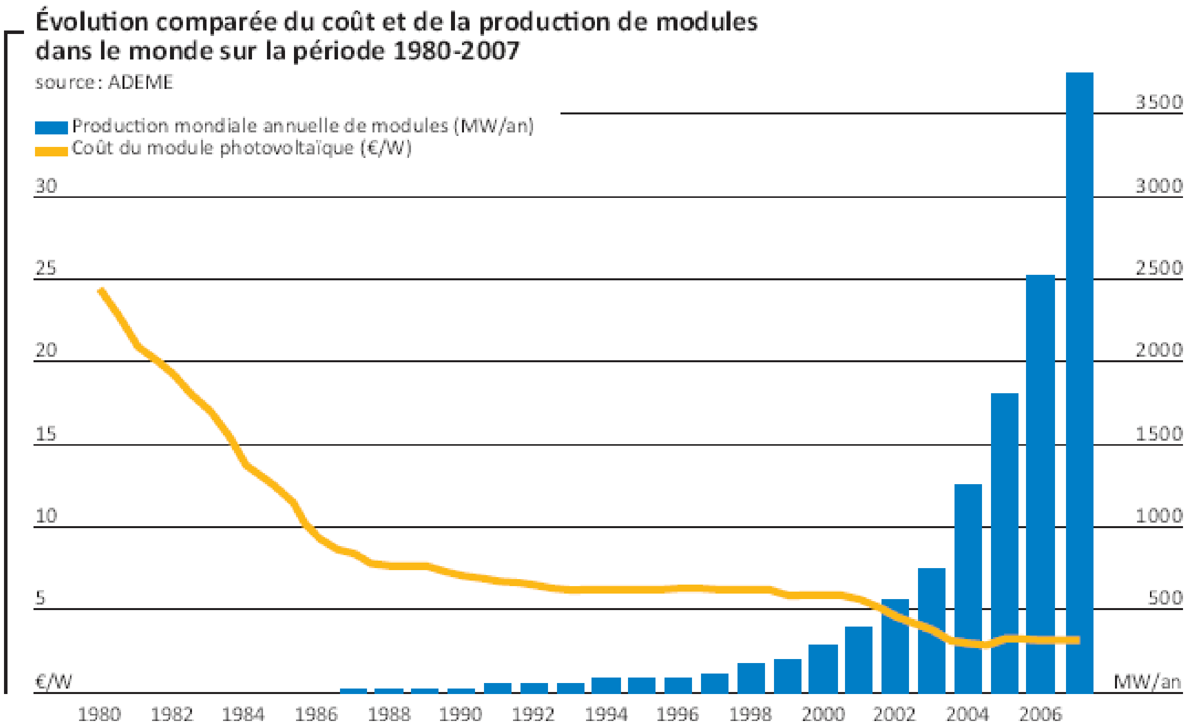


Figure 12: Evolution of PV modules cost (orange, €/MW) and production (blue, MW/year) in the world between 1980 and 2007 (Syndicat des Énergies Renouvelables 2010b)

As the modules costs decrease, the system costs decrease too. In Germany (see Figure 13), where the market is more mature than in France, the total costs of photovoltaic systems dropped from 15000 €/kW$_p$ in 1988 to 3000 €/kW$_p$ in 2009.

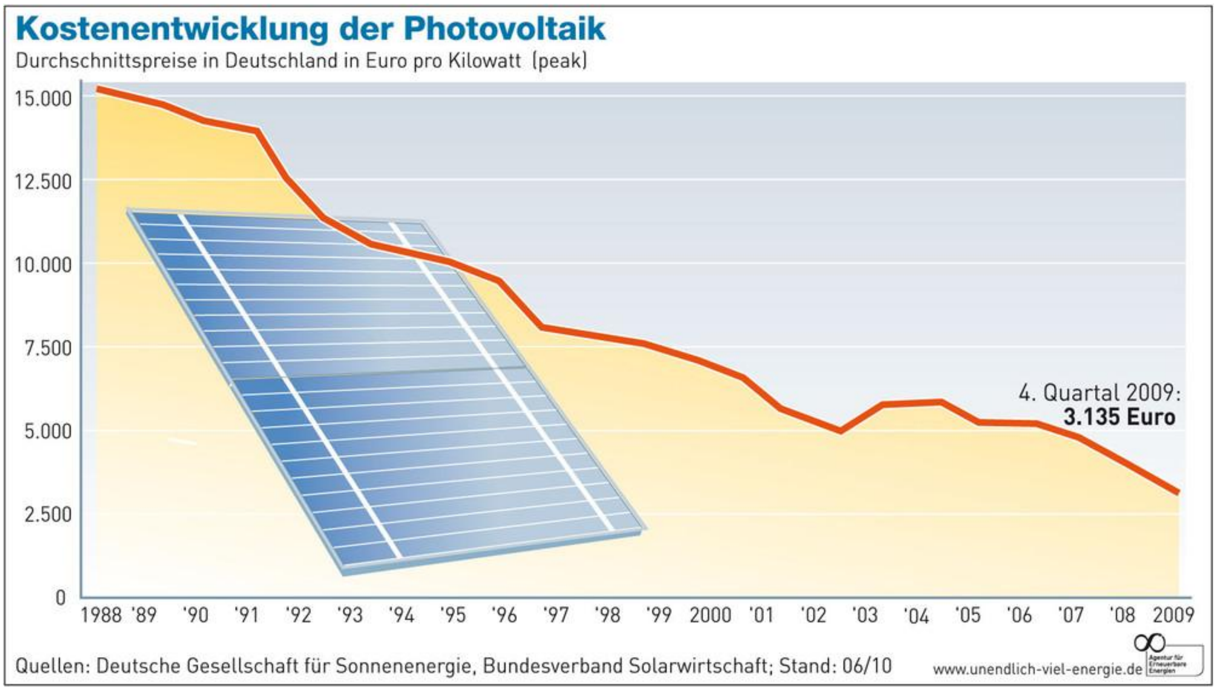


Figure 13: Photovoltaic cost evolution. Average price in Germany in €/kW$_p$ (Agentur für Erneuerbare Energien n.d.)

Comparison with other energy sources

It has been shown that the price of photovoltaic energy has been decreasing a lot in the last twenty years. However, studies show that it is still much more expensive than conventional energies. In France for example, one kWh of solar electricity costs 20 to 25 c€ for ground plants and roughly 40 c€ for a private roof-mounted installation, whereas current electricity production costs 0.1 €/kWh… In other countries, electricity is usually more expensive (25 c€ in Japan for example) and makes photovoltaic a little bit more profitable without any support scheme. (Wikipedia 2010)

Table in Figure 14, from the IEA assumptions, shows the overnight costs of different electricity technologies (Energy Information Administration 2010). It can be seen that photovoltaic is more expensive than most of other technologies, and also more expensive than the other kinds of renewable energies.

Table 8.2. Cost and Performance Characteristics of New Central Station Electricity Generating Technologies

Technology	Online Year[1]	Size (mW)	Leadtime (Years)	Base Overnight Cost in 2009 ($2008/kW)	Contingency Factors: Project Contingency Factor[2]	Contingency Factors: Technological Optimism Factor[3]	Total Overnight Cost in 2009[4] (2008 $/kW)	Variable O&M[5] ($2008 mills/kWh)	Fixed O&M[5] ($2008/kW)	Heatrate[6] in 2009 (Btu/kWhr)	Heatrate nth-of-a-kind (Btu/kWr)
Scrubbed Coal New[7]	2013	600	4	2,078	1.07	1.00	2,223	4.69	28.15	9,200	8,740
Integrated Coal-Gasification Combined Cycle (IGCC)[7]	2013	550	4	2,401	1.07	1.00	2,569	2.99	39.53	8,765	7,450
IGCC withCarbon Sequestration	2016	380	4	3,427	1.07	1.03	3,776	4.54	47.15	10,781	8,307
Conv Gas/Oil Comb Cycle	2012	250	3	937	1.05	1.00	984	2.11	12.76	7,196	6,800
Adv Gas/Oil Comb Cycle (CC)	2012	400	3	897	1.08	1.00	968	2.04	11.96	6,752	6,333
ADVCC with Carbon Sequestion	2016	400	3	1,720	1.08	1.04	1,932	3.01	20.35	8,613	7,493
Conv Combustion Turbine[8]	2011	160	2	653	1.05	1.00	685	3.65	12.38	10,788	10,450
Adv Combustion Turbine	2011	230	2	617	1.05	1.00	648	3.24	10.77	9,289	8,550
Fuel Cells	2012	10	3	4,744	1.05	1.10	5,478	49.00	5.78	7,930	6,960
Advanced Nuclear	2016	1350	6	3,308	1.10	1.05	3,820	0.51	92.04	10,488	10,488
Distibuted Generation -Base	2012	2	3	1,334	1.05	1.00	1,400	7.28	16.39	9,050	8,900
Distibuted Generation -Peak	2011	1	2	1,601	1.05	1.00	1,681	7.28	16.39	10,069	9,880
Biomass	2013	80	4	3,414	1.07	1.05	3,849	6.86	65.89	9,451	7,765
Geothermal[7,9]	2010	50	4	1,666	1.05	1.00	1,749	0.00	168.33	32,969	30,326
MSW - Landfill Gas	2010	30	3	2,430	1.07	1.00	2,599	0.01	116.80	13,648	13,648
Conventional Hydropower[9]	2013	500	4	2,084	1.10	1.00	2,291	2.49	13.93	9,884	9,884
Wind	2009	50	3	1,837	1.07	1.00	1,966	0.00	30.98	9,884	9,884
Wind Offshore	2013	100	4	3,492	1.10	1.02	3,937	0.00	86.92	9,884	9,884
Solar Thermal[7]	2012	100	3	4,798	1.07	1.00	5,132	0.00	58.05	9,884	9,884
Photovoltaic[7]	2011	5	2	5,879	1.05	1.00	6,171	0.00	11.94	9,884	9,884

Figure 14: Cost and performance of different electricity generation technologies (Energy Information Administration 2010)

However, in all these costs estimations the environmental costs and benefits are not included. For example, no one knows what will happen with all the nuclear wastes, and the cost of the damages due to CO_2 emissions in thermal plants is unknown. So, if these costs were included the results would probably be very different, and renewable energies would probably look more attractive from a purely economical point of view.

A recent report from NC Warn (Blackburn & Cunningham 2010) even showed (see Figure 15) that nuclear costs are constantly increasing, while photovoltaic costs are decreasing, and that the crossover happened in 2010 in the USA!

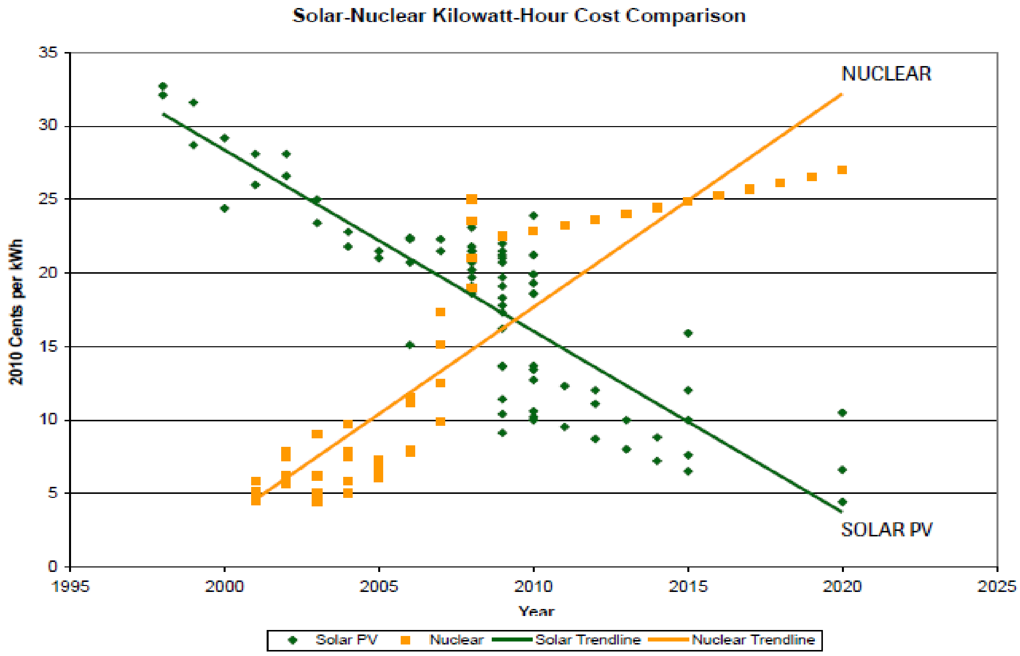


Figure 15: Comparisons of costs per kWh of nuclear and photovoltaic electricity (Blackburn & Cunningham 2010)

The help of the governments

However, one should not forget that the energy technologies used today also benefited from high subsidies from the governments in the past, which helped them reaching such low costs. Even nuclear power plants, pretended to be so cheap, could not be built today if the government, for example in France or Finland, did not finance them.

As the technology and the market are not really ready yet, photovoltaic in a lot of places cannot be competitive with traditional, used for a long time, energies. That is the reason why some countries have set up policy instruments to promote the development of photovoltaic energy. The aim is to support the development of the technologies and to help decreasing the production and installation costs.

The most common support scheme for photovoltaic electricity is feed-in tariffs. 21 out of the 28 countries from EU + Switzerland have set up feed-in tariffs. (Joint Research Centre 2010b) But other incentives are also used, such as tax reduction/exemption and tax credit, mostly for private individuals, reduction of VAT, (tradable) green certificates, investment subsidies… Several of these policy instruments are used jointly in some countries.

Towards grid parity

Grid parity is an important concept when it comes to renewable energies. It will appear when photovoltaic production costs will reach the same level as electricity market price. It means that photovoltaic energy will become profitable in itself. It depends on the price of electricity in the concerned country and so can vary a lot depending on energy mixes.

A study carried out by Enerplan (French professional association for solar energy) concluded that it would be reached for the countries in Southern Europe within two to three years, and between 2015 and 2020 for Northern and continental Europe. It estimated that grid parity would be reached in France between 2014 and 2019 depending on the type of consumer and thanks to the development of bigger photovoltaic plants (see Figure 16). (Enerplan 2008) The study was based on photovoltaic electricity production potential, evolutions of the price of conventional electricity and of photovoltaic electricity, which means that quite big uncertainties remain, and it could change a lot, especially with the big increase in the prices of new generation nuclear power plants…

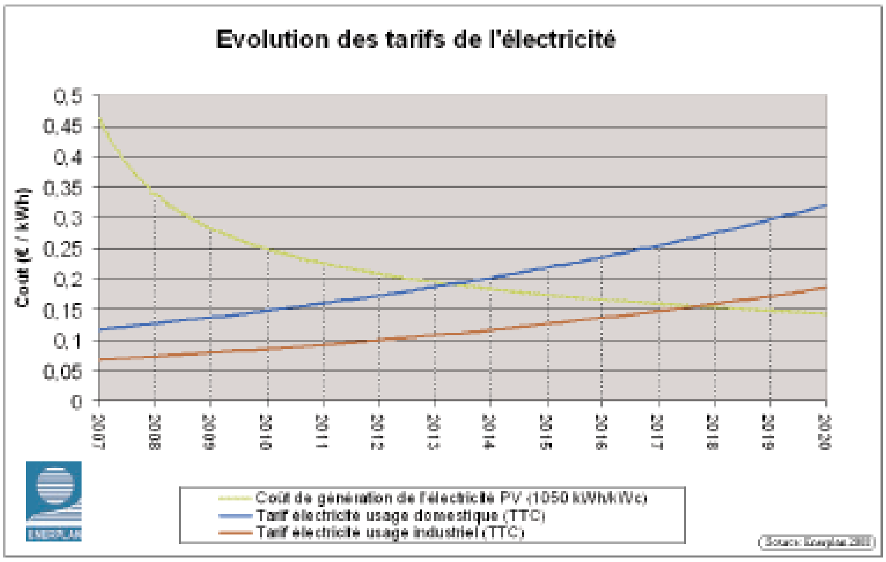


Figure 16: Electricity prices evolution
In yellow: cost of PV electricity generation; in blue: price of electricity for domestic use; in red: price of electricity for industrial use (Enerplan 2008)

As it has been said, grid parity depends on the price of electricity; yet the price of electricity quite strongly depends on the price of fossil fuels, which is likely to increase a lot in the next few years. This could lead to reach grid parity quicker, and make photovoltaic energy more profitable sooner…

Finally, photovoltaic also brings other economical benefits. A lot of jobs have been created in the sector in the last few years, and in 2007 sales of photovoltaic industry worldwide were already more than 13 billions euros. (Enerplan 2008)

Environmental impact

One of the main criticisms heard against photovoltaic energy is its supposedly bad environmental impact. For example, the myth still persists that photovoltaic panels use more energy over their life cycle than what they provide, and that it is not possible to recycle solar cells. However, different studies show that photovoltaic line's environmental impact is on the contrary very positive.

Energy Pay Back time

A study held by the International Energy Agency (Photovoltaic Power Systems Programme), the European Photovoltaic Technology Platform and the European Photovoltaic Industry Association compares photovoltaic electricity in several OECD cities. Several indicators are investigated.
An important one is the Energy Pay-Back Time (EPBT), defined as the time needed before the system has produced the energy that was needed to produce it. The main conclusion of the study is that this time ranges from 19 to 56 months, depending on the solar irradiation of the location and the system used. Another study held by the US department of energy considers the current energy payback time to be between 3 (thin-film technology) and 3.7 years (multicrystalline technology), but expects it to lower down to between 1.1 and 2.1 years for future systems (see Figure 17).

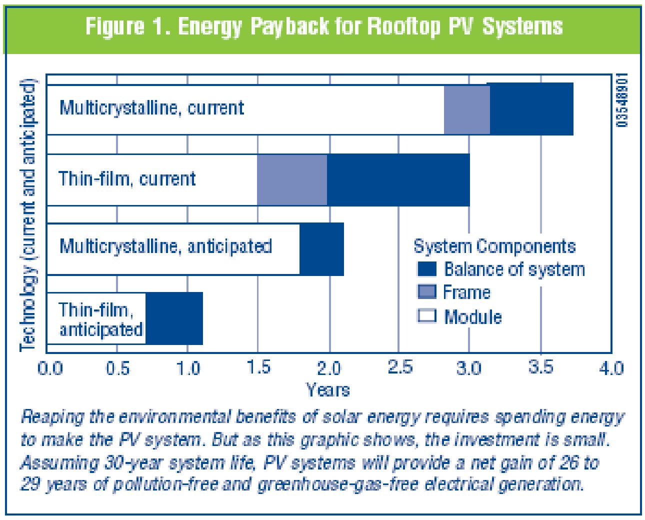


Figure 17: Energy Payback Time for rooftop PV systems (National Renewable Energy Laboratory 2004)

This means that photovoltaic panels do not consume more energy than what they produce. The Energy Return Factor (number of times the system produces the amount of energy needed to build it, over its commercial lifespan of 30 years) is even between 5.4 and 18 depending on the solar irradiation and the energy mix of the country it is built and installed in!
Another important indicator is the amount of CO_2 avoided during the life cycle. Depending on the energy mix of the country, it has been shown that 1kW of roof-mounted photovoltaic panels (approximately 10m²) can avoid up to 40 tons of CO_2!

In France for example, the Energy Payback Time ranges between 1.9 (roof-top in Marseille, South of France) and 4.2 years (façade system in Paris), which is shown in Figure 18.

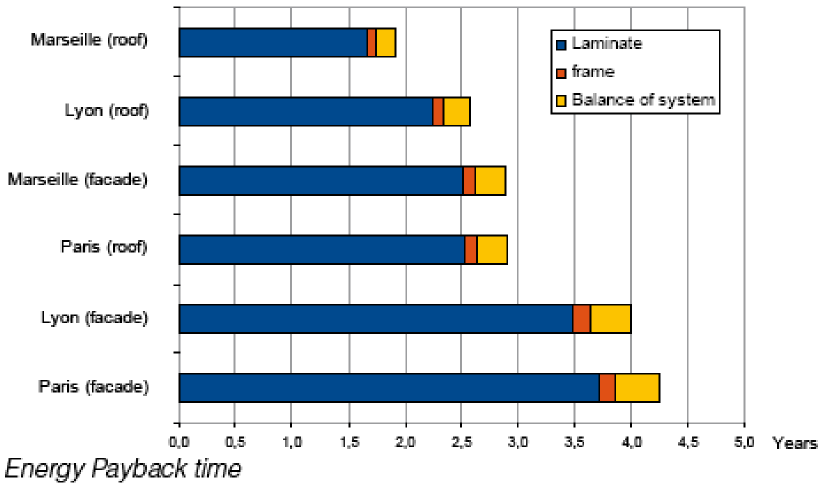


Figure 18: Energy Payback Times for three French cities (EPIA 2006)

In Marseille more specifically (see Figure 19), where the solar irradiation is quite high, a roof-top photovoltaic system produces 14.6 times the energy that had been used to manufacture it, a façade system 9.4 times. It can be noticed that the potential for CO_2 mitigation is not very high, which is due to the French energy mix, mainly made of nuclear energy.

Marseille	Global horizontal irradiation 1540 kWh/m²	
	Roof-top	Façade
Annual output [kWh/kWp]	1 317	878
Energy Pay-Back Time [years]	1,92	2,88
Energy Return Factor [number of times]	14,6	9,4
Potential for CO_2 mitigation [tCO_2/kWp]	3,163	2,108

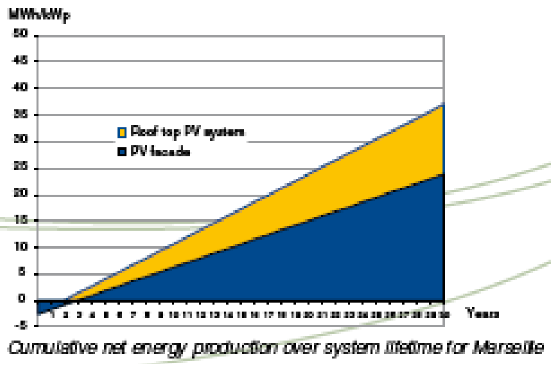


Figure 19: PV environmental indicators for the city of Marseille (EPIA 2006)

The impact of the different parts of the whole photovoltaic installation can also be investigated. A LCA study carried out by the ADEME* (French environment and energy agency) and Transénergie shows the contributions of the different aspects. The primary energy used for each part of the installation is shown in Figure 20. It can be seen that module fabrication is the most energy consuming part, even if posing equipment also uses quite a lot of resources.

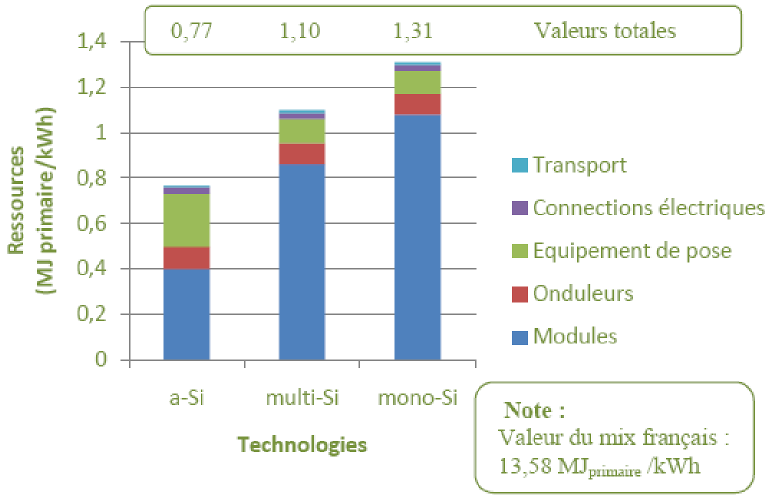


Figure 20: Energy use for the production of different technologies of PV panels. From top to bottom: transportation, electrical connexions, posing equipment, inverters, modules. Note: French energy mix is 13.58 MJprimary/kWh. (Payet & Pedrazzini 2009)

Finally, the same study also shows that the installation system has an important role to play in the environmental impact of the installation. This is shown in Figure 21, in which the first three kinds of installations are related to slanted roofs, while the last three are related to flat roofs. Depending on the system used, the primary energy use varies widely. It is negative for superimposed systems, quite low for integrated systems (132MJ), and much higher for tank PU (667MJ) and bracket alu (645MJ).

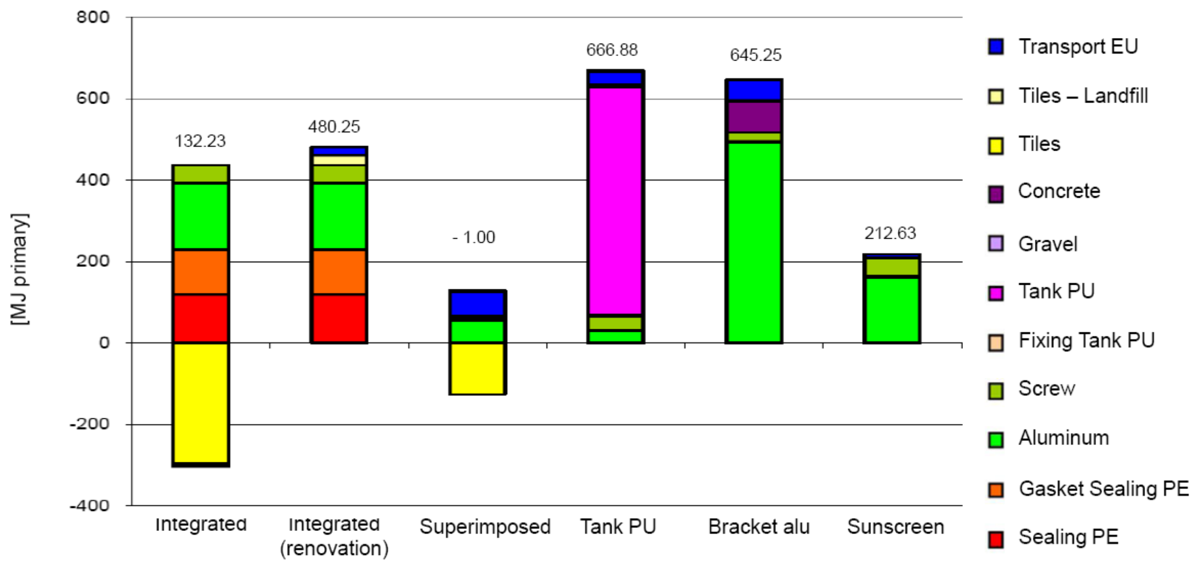


Figure 21: Energy use for the production of different kinds of PV installations (Payet & Pedrazzini 2009)

Recycling

Another common belief is that photovoltaic modules cannot be recycled. However, most of the parts of a solar panel can be recycled today. The main component, silicon, can be recycled, to be reused in new solar cells or in other products. If it is used in new solar panels, price and environmental impact of PV panels drop. Other materials part of the arrays, such as glass or aluminium can also easily be recycled.

European photovoltaic industry voluntarily created the association “PV Cycle”, in order to organise and stimulate the collection and recycling of photovoltaic modules, with the aim of making photovoltaic electricity “double green”.
The first significant photovoltaic installations were built in the 1990s and have a lifespan of more than 25 years, that is why not so many modules have been recycled yet. But the method and the channel exist, and there are today 34 certified collection points in Europe.
(Association PV Cycle n.d.)

Photovoltaic risks

Three main categories of risks have to be considered with photovoltaic installations.

First, there are building-related risks. The first one is linked to structural robustness of the building: photovoltaic panels add an additional weight on the building, and the structure has to be able to carry it. This risk is not very important, as it is compulsory to carry out studies on the structures of the buildings before starting the project.
Another risk related to building is the waterproofness degradation. This is especially true in France, as due to the law the photovoltaic cover has to be part of the watertightness.
Finally, there is a risk of fire. Most of the fires that have happened due to photovoltaic installations were caused by electrical connections defaults under the panels, or by underdesigned electrical cables. Another important point is to look at materials used: most of the photovoltaic components do not burn, but in some panels (made of cadmium for example) toxic gases can be produced.

The second category of risks is weather-related risks. For example, thunder of hail can damage photovoltaic panels, causing electrical risks. To prevent that, installations need to be designed specifically for the place where it will be put, depending on climate conditions in this place.

Finally, the third category of risks is the ones due to fires. In some cases in Germany and also in France, firemen refused to turn off the fire because of photovoltaic panels and electrical risks for them. This is a new field, and rules are being set both by firemen and photovoltaic industry. In new rules, there is for example the need of being able to cut from the outside the direct current under the roof, so that there is electricity only in the panels, and not anywhere else.

(Roussel 2010) (Syndicat des Énergies Renouvelables, Conference, 2010)

Photovoltaic worldwide

The photovoltaic sector saw a big expansion in the last years. In 2006, 6 GW_p were installed in the world, (ADEME 2007a) whereas in 2009 this number was already 21 GW_p! (Enerplan 2010) This important development in the last ten years is shown in Figure 22, that represents the cumulative photovoltaic installations worldwide. It can also be seen that photovoltaic installations are mostly concentrated in a few countries: mostly Germany and Japan, a little bit less USA, and more recently Spain and rest of Europe.

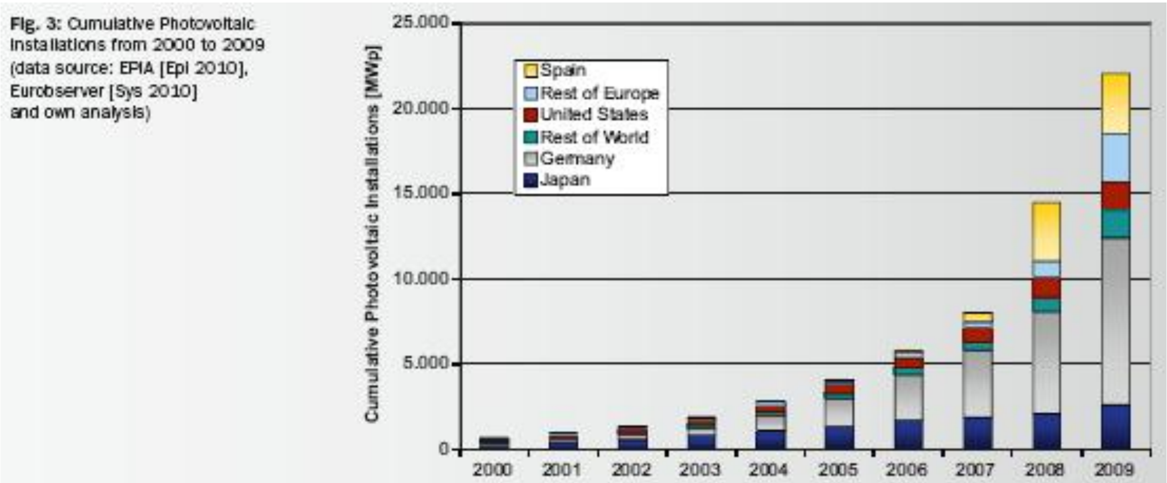


Figure 22: Cumulative PV installations worldwide from 2000 to 2009 (Joint Research Centre 2010b)

According to some studies, this development is very likely to continue in the near future. For example, a study of the ADEME, which results are presented in Figure 23, expects a total of 295 GW_p in 2020.

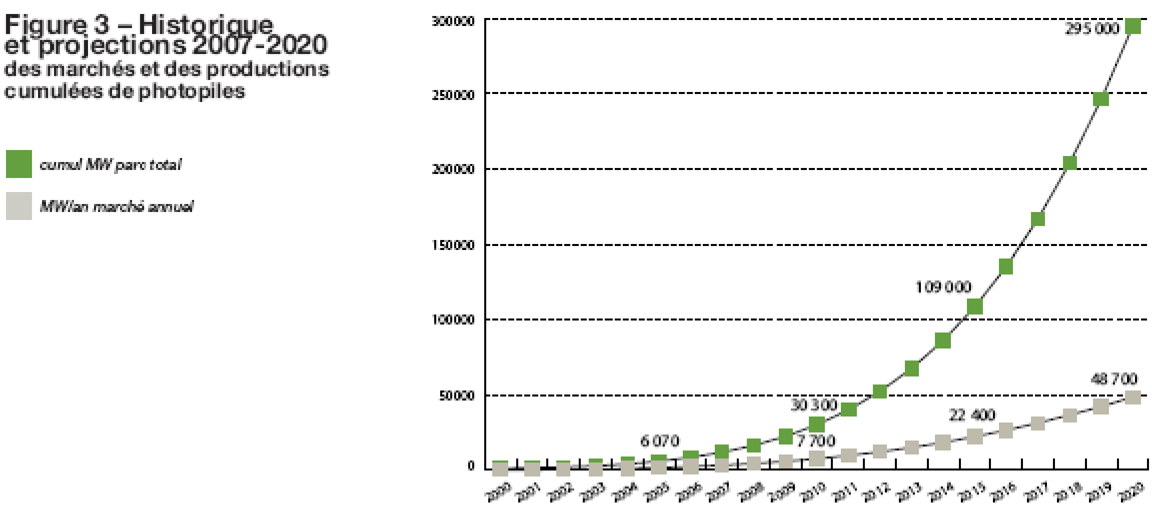


Figure 23: Photovoltaic market: historical and projections (ADEME 2007a)

In Europe, a few countries are really leading the sector. As can be seen in Figure 24, Germany has from far the highest capacity, followed by Spain, and then Italy. Some countries have started expanding their capacities but are still far, like France, Belgium, Czech Republic or Portugal.

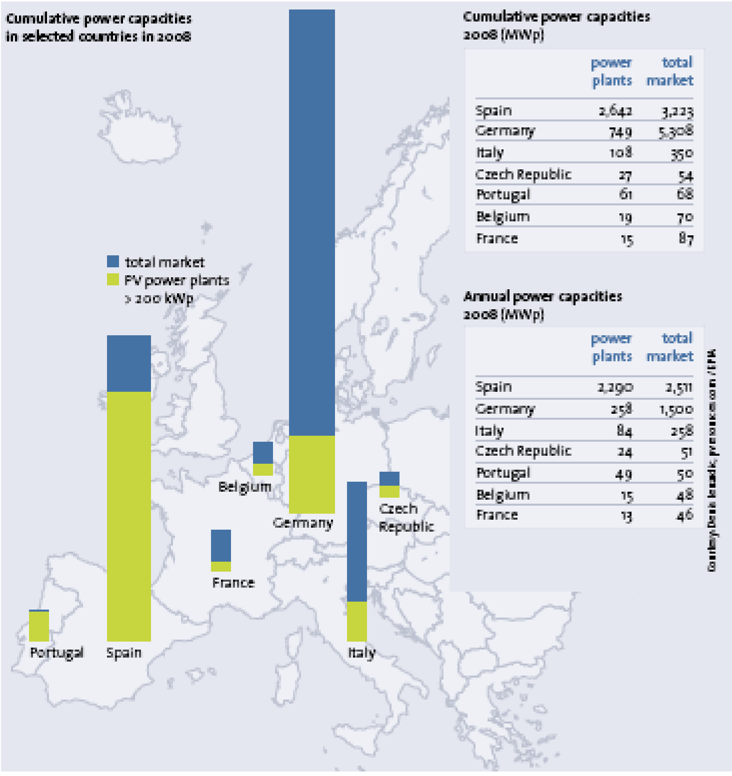


Figure 24: Cumulative power capacities in some European countries in 2008 (Solarpraxis 2010)

Regarding photovoltaic cells production, the most widely produced technology is the crystalline silicon, and this is expected to continue in the future, as it is shown in Figure 25.

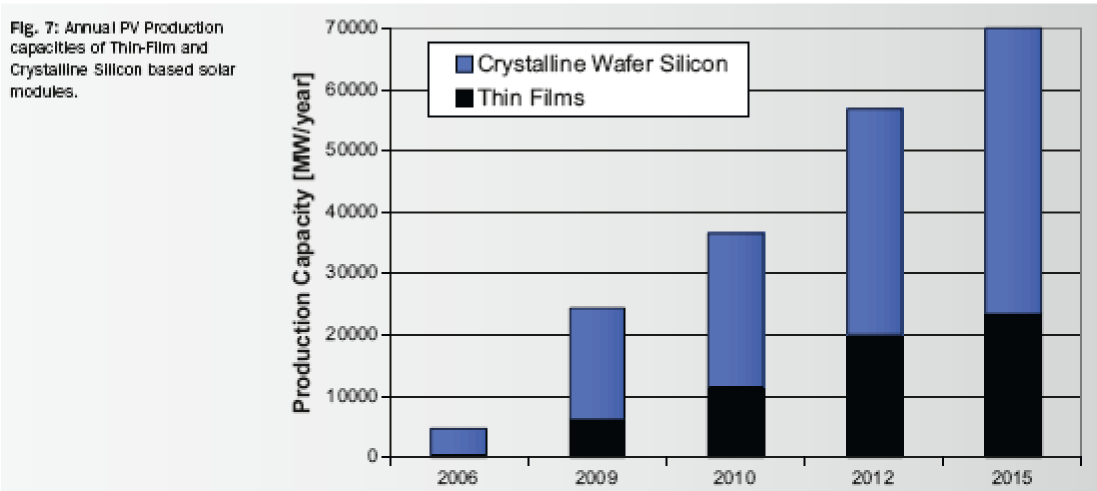


Figure 25: Annual PV production capacities for thin-film and crystalline silicon technologies (Joint Research Centre 2010b)

This production is not based in the same places as it used. China became the leader in production of solar cells in 2008, with around 2.4 GW/year (WorldOfPhotovoltaics.com 2009) and already produced 4.4 GW in 2009. (Joint Research Centre 2010b) It is then followed by Europe (1.9 GW/year in 2008), Japan (1.2 GW/year) and Taiwan (0.8 GW/year). The share of PV production of the different countries in 2009, and planned production in 2015 is shown in Figure 26.

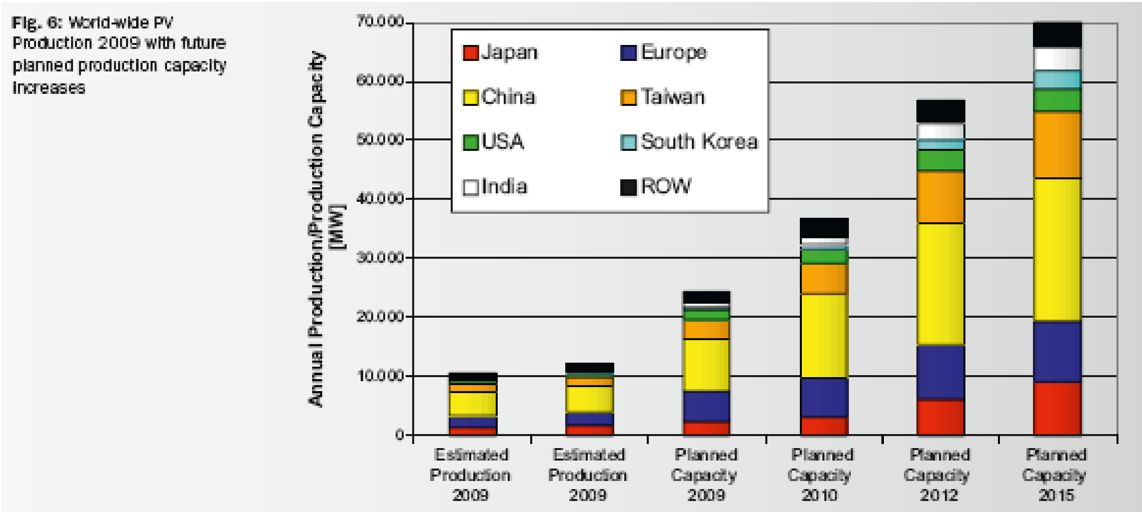


Figure 26: Worldwide PV production in 2009 and planned in 2015 (Joint Research Centre 2010b)

The photovoltaic industry

The photovoltaic actors in Europe have joined together in the “European Photovoltaic Industry Association” (EPIA*). With more than 230 members, it is the world’s largest photovoltaic association. (European Photovoltaic Industry Association n.d.b)

EPIA was one of the founding members of “PV Cycle”. This association was founded by PV manufacturers in 2007 with the aim of organising the collection and recycling of photovoltaic modules, when this will be necessary. Today it covers more than 85% of the European photovoltaic market. (Association PV Cycle n.d.)

This is a typical example of this industry, which has not really been organised by states and governments, but instead has used self regulation to a relatively large extent.

Sun radiation

In Figure 27, a map of the global irradiation (in kWh/m²) for optimally oriented modules in whole Europe is shown. It can be noticed that Germany, which has the most photovoltaic installations, is far from being the sunniest country. Even in North of France, where the lack of sun is often used as an excuse to avoid using solar energy, the amount of sun is bigger than in most of Germany.

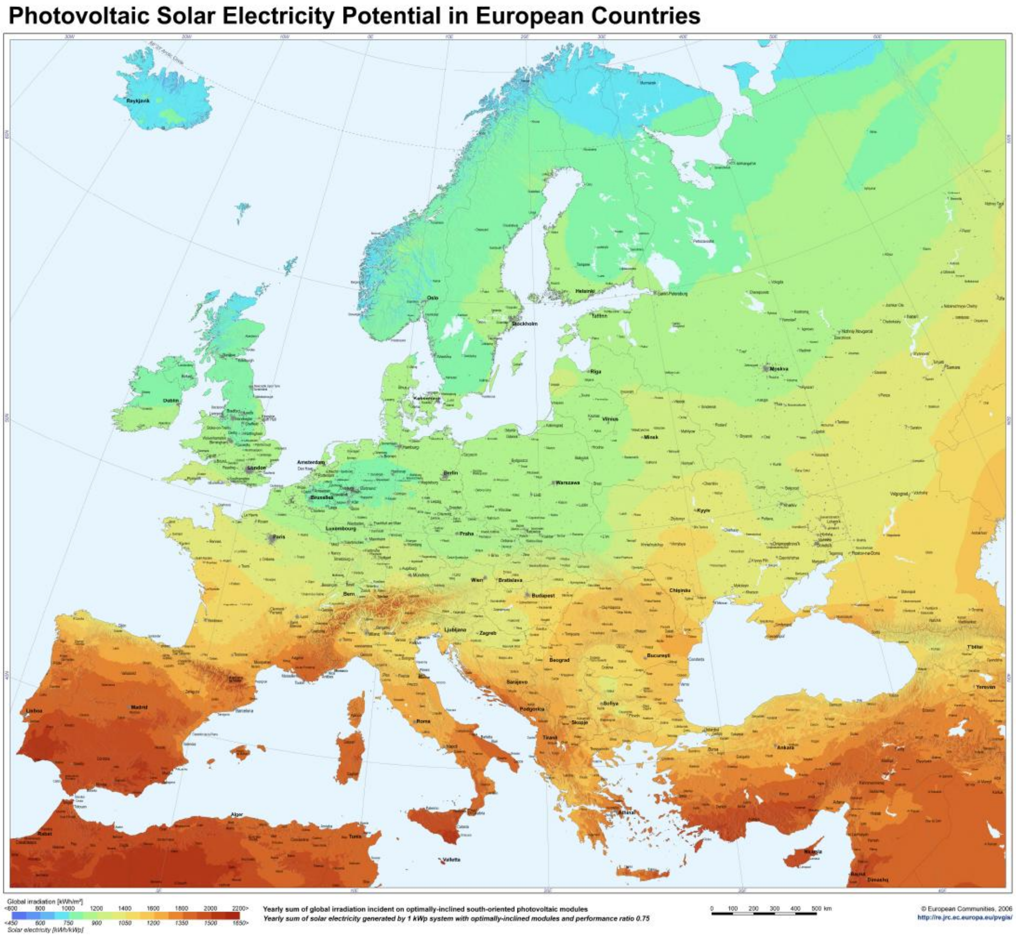


Figure 27: Photovoltaic potential in Europe
(Šùri et al. 2006)

If one looks at the irradiation map of France in more details (see Figure 28), it can be seen that DCNS locations globally have good solar energy potentials. The best sun irradiation appears in south east of France around the Mediterranean Sea, with irradiations up to 1900 kWh/m²/year. The least irradiated region is the north east of France, at the border with Belgium, with irradiations of around 1000 kWh/m²/year. Regions like Normandy and Brittany, famous for their rainy weather, still have irradiations ranging between 1300 and 1400 kWh/m²/year, which should be compared with the 1000 to 1300 kWh/m²/year in almost whole Germany.

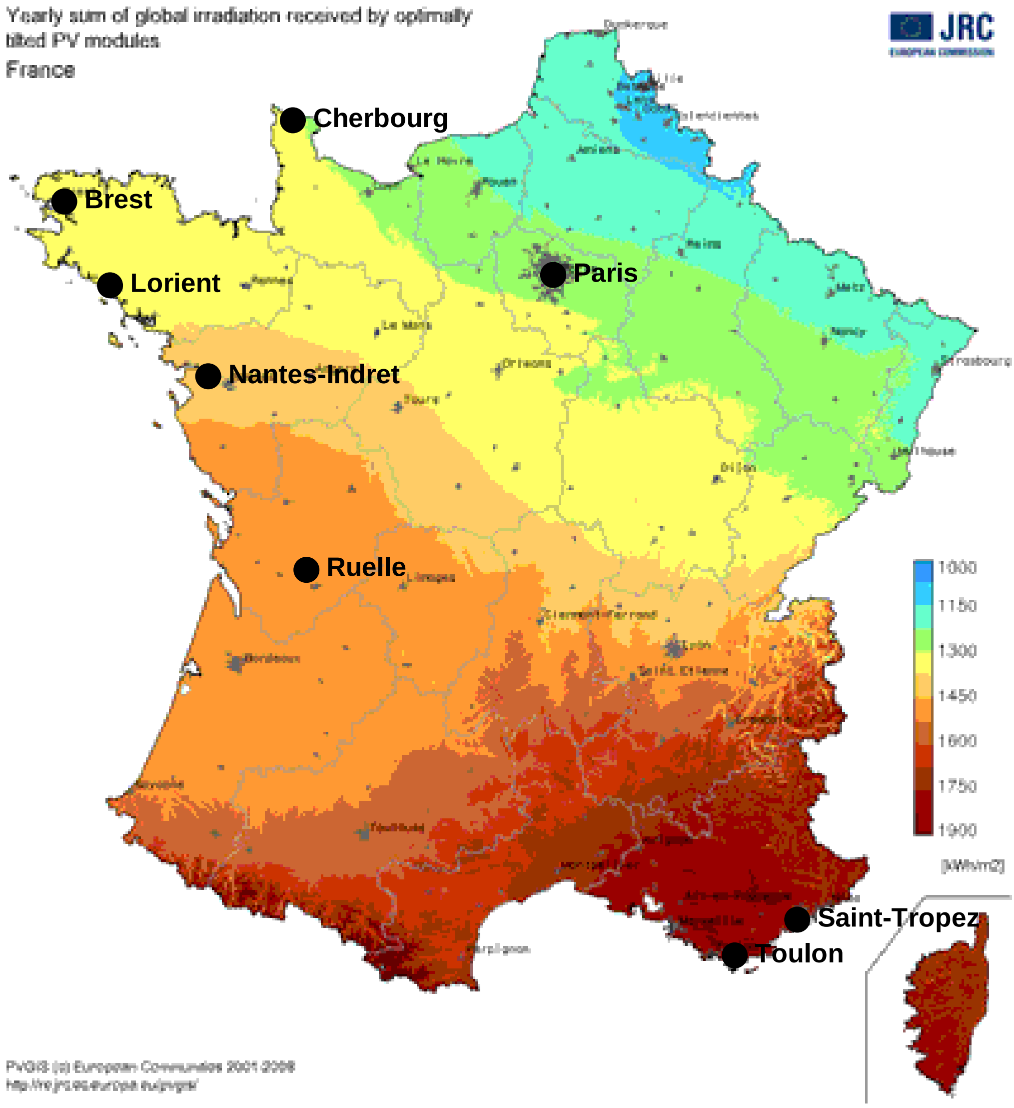


Figure 28: Photovoltaic potential in France (Joint Research Centre 2008)

Moreover, it can be noticed that places where DCNS is set are quite sunny. The "worst" site is Cherbourg, in Normandy, with roughly 1300 kWh/m²/year, and the best ones are the two locations in the "French Riviera", Toulon and Saint-Tropez, with irradiations of more than 1900 kWh/m²/year. If one looks at the number of hours of sun it is even more impressive: 1665 hours of sun per year in Cherbourg (average between 1961 and 1991), 1757 h in Brest, 2020 h in Lorient, 1901 h in Nantes, 1989 h in Ruelle, 2893 h in Saint-Tropez and 2917 h in Toulon. (Meteo Passion n.d.)

Context of photovoltaic in France

An impulse for photovoltaic industry in 2006…

As it was shown before, France has an important solar energy potential, especially at very sunny places in the south. However, the development of photovoltaic industry began later than in its neighbouring countries, Germany and Spain for example, mainly due to late attractive incentives. Feed-in tariffs for solar electricity were first launched in 2000. However, they were at that time quite low, and became really interesting when they were changed in 2006. In 2008, Jean-Louis Borloo, at that time minister of the environment and sustainable development, set targets for photovoltaic development and said France intended to increase the use of solar electricity by 400 times by 2020, up to a total capacity of 5.4 GW. (Joint Research Centre 2010b). In 2012 the planned installed capacity should already be 1100 MW. (International Energy Agency 2010a)

In addition to these feed-in tariffs, other incentives were set from 2006. Additional subsidies were created for private persons, such as 50% tax credits, and accelerated depreciation of photovoltaic systems was enabled for companies. Other local helps were also created by regions, such as grants and financial helps for installing new systems, and fundings for R&D.

With these attractive feed-in tariffs launched in 2006, photovoltaic industry saw a quick and important growth. In 2009, 250 MW_p were newly installed, which was 140% more than in 2008. At the end of 2009, the cumulative power was 430 MW_p. However, due to the delays to obtain grid connexion, the total connected capacity was 268 MW_p, for a yearly production of 290 GWh. (Enerplan 2010). As it can be seen in Figure 29, the installed capacity is not the highest in the regions with highest insulation. This is mainly due to the local incentives and policies.
At the same time, the sector has been organising, and the complete value chain expanded. At the end of 2009, the yearly production capacity in crystalline modules was 210 MW, and the price of equipment dropped by 30% during the only year 2009. (International Energy Agency 2010a)
This expansion continued in 2010. The 30th of September 2010, 720 MW of photovoltaic electricity were connected to the grid, corresponding 109 203 installations, and more than 3000 installations were waiting for grid connexion. (Commissariat général au développement durable 2010)

In three years, jobs in the photovoltaic sector have been multiplied by four: from 800 in 2006 to 3200 at the end of 2009. (Syndicat des Énergies Renouvelables 2010b)

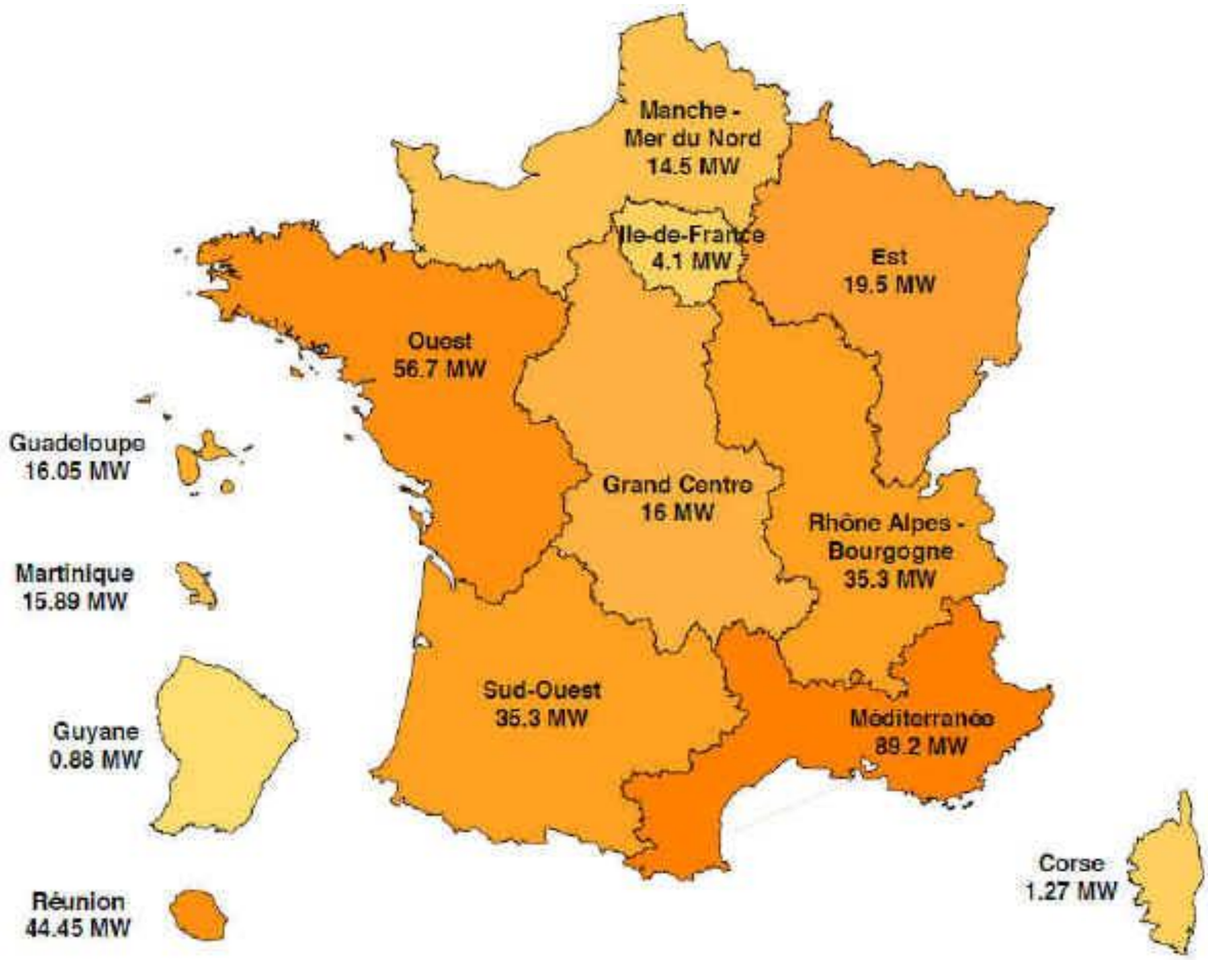


Figure 29: Photovoltaic installations connected to the French electricity grid, 31. March 2010 (Syndicat des Énergies Renouvelables 2010c)

The specificity of feed-in tariffs in France compared to other countries is that Building Integrated Photovoltaic (BIPV) is favoured a lot. It is considered that photovoltaic modules should be integrated into buildings, both on buildings under construction and on existing buildings. There are three main goals for that. The first one is to favour insulation of buildings, for example through the roof; installing photovoltaic modules is indeed an opportunity for people to renovate their roof and improve its insulation, which would not have been done with roof-top modules. The second reason is esthetical considerations: photovoltaic panels integrated into the roof are indeed more discrete and often look better than panels put on top of an existing roof. The third reason is that this specificity is supposed to create specific competences in France, create more jobs, and favour knowledges' exportation.

However, this differentiation in tariffs is also source of some problems, and sometimes even if roof-top systems would be better in a specific case, they will not be chosen because of economical reasons.

A sudden brake, market instability and uncertainties after 2009…

This huge growth of photovoltaic market in France seems to have scared politicians and EDF* (the French electricity company, committed to purchasing photovoltaic electricity at the price of these feed-in tariffs), and 2010 saw a big change in incentives to photovoltaic energy. It must be said that due to very attractive tariffs, a few companies sold very bad Chinese panels to private persons, and some people had big problems with their installations, for example companies disappearing with the money before the end of the installation. However, there were also a lot of serious companies expanding and developing serious photovoltaic modules and installations.

For this reason, and because of fear of speculation, a first change in feed-in tariffs applied in January 2010, and more categories of tariffs were invented. The tariffs for building integrated photovoltaic (BIPV) on private dwellings and health care increased a bit, while the one for BIPV on other buildings decreased. A new tariff was also added: for "simplified building integrated photovoltaic", with lower constraints on waterproofness or structure of the modules. A differentiation in tariffs for ground-mounted photovoltaic was also introduced depending on the power of the system; for installations with a power higher than 250 kW a correction factor is applied depending on the location (in order to have a higher tariff in the north than in the south). (Joint Research Centre 2010b)

The same year, a lot of regional grants and financial helps also disappeared, or were reduced a lot.

In September 2010, new feed-in tariffs were set again, which was a second change in less than 9 months, with changes applying one week after the law was decided. This new law created many new different kind of tariffs. But the common point is that suddenly, all tariffs decreased a lot, ranging between 27 c€/kWh for ground-mounted PV and 51 c€/kWh for BIPV on private houses, schools or healthcare centres.

A summary of the evolution of feed-in tariffs in time can be seen in Table 1.

In October, new changes were announced again, with the reduction from 50% to 25% of the tax credits for private people, and the suppression of the accelerated depreciation system for companies.

French photovoltaic industry organised and expressed a common answer to all these unforeseen and sudden changes, arguing that they needed some visibility in order to continue their activities. However, in November 2010 the government changed and the energy was removed from the environmental ministry, coming back to industry ministry, famous for its close links with nuclear and fossil energy industries…

	Between July 2006 and January 2010
BIPV	55
Basic price	30

(Ministère de l'économie, des finances et de l'industrie, 2006)

	January to September 2010
BIPV, houses, healthcare or education buildings	58
BIPV, other buildings	50
Simplified BIPV	42
Other installations	31,4*R, with R=1 if < 250 kW_p, 1<R<1,2 depending on region if > 250 kW_p

(Ministère de l'écologie, de l'énergie, du développement durable et de la mer, 2010a)

	From September 2010
BIPV <3kWc, houses	58
BIPV >3kWc, houses	51
BIPV, healthcare or education building	51
BIPV, other buildings	44
Simplified BIPV	37
Other installations	27,6*R, with R=1 if < 250 kW_p, 1<R<1,2 depending on region if > 250 kW_p

(Ministère de l'écologie, de l'énergie, du développement durable et de la mer, 2010b)

Table 1: Feed-in tariffs in Metropolitan France between July 2006 and December 2010

Finally, this decrease was not to be finished, as it was decided that feed-in tariffs would decrease with 10% each year from 2012, which is shown in Figure 30. The reason for that is that the market is getting more mature, and production and installation costs are decreasing.

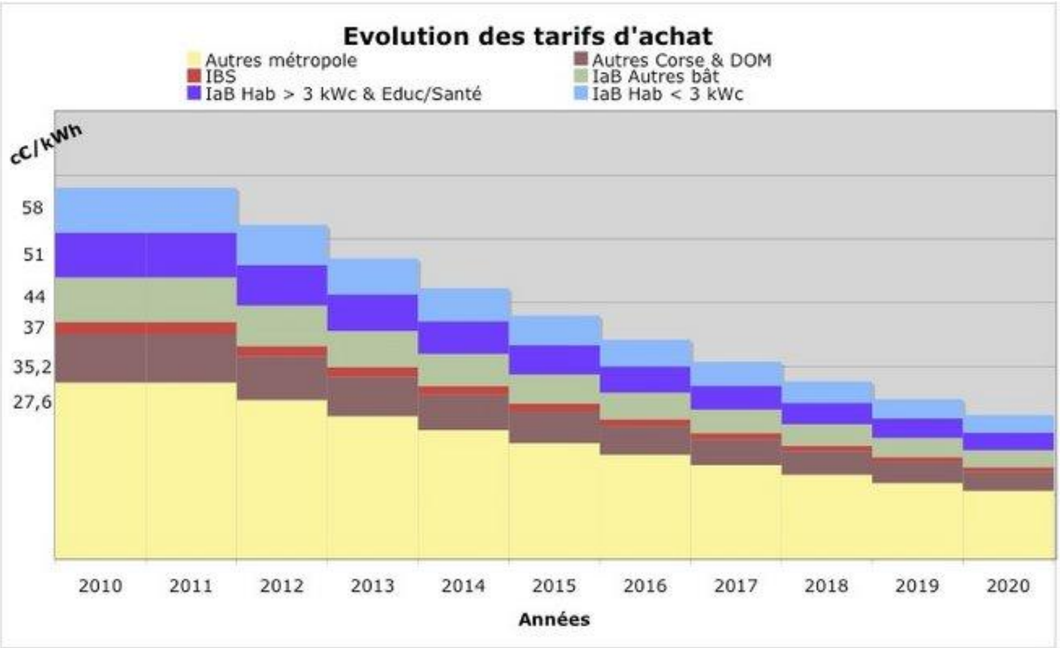


Figure 30: Evolution of PV feed-in tariffs in the next ten years (from top to bottom : BIPV <3kWc, houses ; BIPV >3kWc in houses, BIPV, healthcare or education building ; BIPV, other buildings ; Simplified BIPV ; Other installations in Corsica and overseas departments ; Other installations in Metropolitan France) (Association Hespul 2010c)

The government created an even bigger surprise in the beginning of December 2010 (i.e. in the middle of this thesis) with the announcement of the suspension of all feed-in tariffs and all grid-connexions for three months, for all systems above 3 kW, and a “moratorium” about photovoltaic electricity. (Ministère de l’écologie, du développement durable, des transports et du logement 2010) The aim was to start discussions with companies of the sector in order to decide new policies for photovoltaic industry. There are several reasons behind that, according to the government:

- too many installations are built, and the objective for 2020 will be reached too early;
- all these installations with high feed-in tariffs are expensive and will have to be paid by citizens, through big increases in electricity prices;
- everybody will have to pay, for materials that mostly come from China and thus do not create any job in France. (Verney-Caillat 2010)

All implied actors do not seem to think all of these reasons are true, and the powerful nuclear lobby is suspected to be a lot behind that. The fact that installations under 3 kW – for private persons – still kept the feed-in tariff is also strange, as they are the kinds of installations with the most problems and the most Chinese materials, and the highest feed-in tariffs.

This moratorium was troubled, and the government seemed to have already prepared the answers before each negotiation, and some companies even slammed the door of the meetings. Several had economical problems due to this moratorium, for example Photowatt, the only French company working on the entire photovoltaic chain, announced it would have to relocate part of its production in Poland. (Lecoeuvre 2011) A lot of projects were also frozen, and some factories that were supposed to be opened in France, especially one from the big American company First Solar, stopped their projects because of too high uncertainties. (Chandès 2010)
The moratorium was also disturbed by accusations against EDF EN, EDF's renewable energies subsidiary, accused to have cheated to avoid the moratorium, and to be responsible to a big extent for the very long queue for grid-connexion agreement. It was also discovered that there was a second queue, at RTE* instead of ERDF*, that very few companies knew, and that was mostly used by EDF EN. On the other hand EDF does not want feed-in tariffs to be kept as they have to buy the electricity, so they have a very ambiguous position.

Complete overhaul of the system March 2011

The new decree was published 5^{th} of Mach and set up several changes.

First, a very important point in this new decree is the setting up of a cap, which limits the power that can be installed every year. The cap has for now been set to 500 MW_p/year, which has to be added for 2011 to the queue of projects stopped by the moratorium (around 3000 MW_p). These 500 MW_p/year are made of three caps: 150 MW_p for houses, 150 MW_p for industrial roofs (both under 100 kW_p and above), and 200 MW_p for ground-mounted installations. No more electricity than that will be bought from photovoltaic installations every year.

Furthermore, new frontiers of powers were set. The main one is at 100 kW_p, and under this limit the procedure is the same as before. There are however several categories under this power.
The power limitation for private houses and healthcare and education buildings roofs was raised from 3kW_p to 36 kW_p, which means they can benefit from a special "building integrated" tariff up to 36 kW. There is another limit at 9 kW, with different tariffs below and over it. For other buildings, the limitation power between integration tariff and simplified integration tariff is set at 9 kW.

The feed-in tariffs for these categories of installations have decreased by approximately 20% for the second trimester of 2011, and can be seen precisely in Table 2. They range now between 28,85 c€/kWh (normal building, simplified BIPV, between 36 and 100 kW) and 46,4 c€/kWh (house, BIPV, below 9 kW), but are now going to change every trimester, depending on the fulfilment of the cap. Feed-in tariffs will be automatically revised every quarter in order to respect the yearly cap: if there are too many installations, feed-in tariffs will decrease (up to 9,5% a quarter), if there are not enough, they will decrease, but a bit less (at least 2,6% a quarter).

Kind of installation			New feed-in tariff
Houses	Building-integration	[0-9 kW]	46,4 c€/kWh
		[9-36kW]	40,6 c€/kWh
	Simplified building integration	[0-36 kW]	30,35 c€/kWh
		[36-100 kW]	28,85 c€/kWh
Healthcare or education buildings	Building-integration	[0-9 kW]	40,6 c€/kWh
		[9-36kW]	40,6 c€/kWh
	Simplified building integration	[0-36 kW]	30,35 c€/kWh
		[36-100 kW]	28,85 c€/kWh
Other buildings	Building integration	[0-9 kW]	35,2 c€/kWh
	Simplified building integration	[0-36 kW]	30,35 c€/kWh
		[36-100 kW]	28,85 c€/kWh
All kinds of installations		[0-12 MW]	12,00 c€/kWh

Table 2: New feed-in tariffs, valid between 10th March and 1st July 2011 (Comité de Liaison des Énergies Renouvelables 2011)

Finally, for installations above 100 kW_p and for ground-mounted systems, there will not be feed-in tariffs anymore, but companies will have to answer to invitations to tenders published by the state. In these tenders there will be criterions such as respect for the environment, nice urban integration, or innovation. The companies propose their own tariff, and that can also be a criterion to choose between projects. There should also be a simplified procedure for projects between 100 kW and 250 kW, but at the time this report was written it was not known what that means.

(Ministère de l’écologie, du développement durable, des transports et du logement 2011)

Organisation of the industry

Today, there are four main markets for photovoltaic in France:

- private houses, < 3 kW_p
- collective dwellings roofs, 10 to 100 kW_p
- industrial or tertiary roofs, > 250 kW_p
- ground mounted PV plants, > 1 MW_p

(Enerplan 2010)

One big problem in France is the slowness of administrative work. Obtaining an agreement for connexion (needed before starting to install) takes several months, a lot of permissions and agreements are needed (for example the agreement of the "architect of French buildings" if the installation is to be put "close to" classified monuments), and a lot of papers and documents are asked. For comparison, in a residential photovoltaic project, the share of administrative part in the development cost of a project is 19%, whereas it is only 7% in Germany. (Roussel 2010)

Photovoltaic industry has started to gather, and several associations have been created. The SER* (renewable energies union) has created a specific section for photovoltaic energy: the SER-Soler, which aims at gathering the different players of the sector, and accelerating the development of the sector. It has now more than 270 members. (Syndicat des Énergies Renouvelables 2010b)
Enerplan is another professional association, created in 1983, that promotes the development of solar energy, both photovoltaic and thermal. (Enerplan 2011)
The SYNAIP is a labour gathering photovoltaic installers, which was created in January 2010 to react to the decrease of feed-in tariffs. (SYNAIP 2011)
In 2009 the "Apesi" ("association of independent solar electricity producers") was created to make small and middle size photovoltaic companies' voices heard. (APESI 2011)
Even an association gathering private people producing photovoltaic electricity was created (the GPPEP, "group of private producing photovoltaic electricity"). (GPPEP 2011)
When the moratorium was announced in December 2010, an action group gathering photovoltaic players was created, called "don't touch to my solar panel", and was very active during the moratorium, addressing propositions to the government, organising demonstrations and complaining against and suing EDF. (TPAMPS 2011)

Instruments to certify the quality of products and installations have also been created. The most famous certification is "Quali PV", with two separated sections: one for electricity and one for civil engineering. More than 6000 installers are now certified. (Syndicat des Énergies Renouvelables 2010b)

To gain confidence from firemen and insurance companies, photovoltaic industry is also writing specifications that should be followed to prevent risks. A guide called "UTE-C15-712" was written in 2008, revised in 2010, and a new version will be published in 2011. It describes the equipment that should be installed (electrical protections, thunder protections…), the quality standards that should be chosen, the signs that should be put so that private persons do not get electrified, etc.

METHOD

Presentation of the project

Several aims are leading the renewable energies projects within DCNS:
- modernise the vision of energy in the company
- decrease energetic dependency, diversify purchases
- reduce costs / earn money
- improve its carbon footprint
- develop a green image
- be proactive and change before laws make it compulsory
- develop new competences, and use it as an added value (for example when selling naval bases to navies)

The idea of a photovoltaic project started in the beginning of 2010. Specifications started to be written in the middle of the year, but the project could not really start because of a lack of people and time. The project was mainly led by three persons: Charles Crozon, who is in charge of industrial performance at DCNS, and driver of the “renewable energies workshop” of the Championship program; Élodie Poursuibes, group purchaser, who was then replaced by Dominique Le Ruyet, group energy purchaser (electricity, gas, water…) from January, and Diane Dhomé, project manager, and intern belonging to the environmental direction of DCNS, supervised by Hervé Mazéas, DCNS environmental manager.

From the beginning, photovoltaic energy was chosen as an exemplary project in renewable energies for the group, for several reasons. First, it seems to be able to bring money back quite easily, which makes it easier to convince the executive committee. Moreover, it is something very visible and could develop a greener image in a defence company. Finally, as photovoltaic electricity is carbon free, it can offset some CO_2 emissions.

The idea in this project is not necessarily that DCNS invests in photovoltaic electricity, but rather that a design office associated with a financial company rents the roofs, with an emphyteutic lease, and give DCNS a rent every year. By doing that, DCNS does not need to invest, reduces the risks it takes and does not need to change its status to become electricity producer.

Several companies were consulted in order to have different visions and estimates. The idea was to then choose a short-list of two or three companies and to go further in the project with them, before choosing the definitive company DCNS will work with.

Estimations of the potential for DCNS

In parallel to the consultation of design offices, an estimation of the potential was carried out, in order to be able to understand, follow and check the results from the design offices. This can for example be useful if a design office considers a building is not interesting only because the company does not produce the technology of photovoltaic panels relevant for this building. It enables to have a critical view on what is being proposed.

The method for calculating this potential is as follows. First, for each centre, buildings were chosen. This was done using either maps of the site, aerial photos, or even Google Maps, depending on the documents available. The criteria for selecting a building were: orientation of the roof (it has to be oriented mostly to the south; south-east or south-west are still acceptable), how it is exposed to the sun (angle of the roof, and there should not be any big tree or building south of it, shading the roof), how much space is available on it (if there are too many chimneys for example it is useless), etc.

Then, for each chosen building, the area available for installing photovoltaic panels had to be defined. Once again, documents used for doing that depend on what was available: the best case is if there is a map of the building with the lengths, but sometimes estimations had to be done using the global map of the site, pictures, or Google Maps.

When the area was estimated for each building, the electricity production could be calculated. It was assumed that the photovoltaic panels used had a peak power of 150 W_p/m^2, which is a good value for a good-quality panel available today. This number, multiplied by the area, gives the peak power for each building.

To calculate the electricity production of each building, the productivity for each location is used. The numbers used are shown in Table 3.

Location	Productivity (kWh/kW_p)
Cherbourg	975
Brest	1000
Lorient	1020
Indret	1050
Ruelle	1100
Toulon	1400
Saint-Tropez	1400

Table 3: Photovoltaic productivity in the different locations of DCNS (Joint Research Centre 2006)

Moreover, this gives a theoretical value for a perfectly well exposed roof, so a correction factor has to be applied. Factors used are the ones from Figure 10, which depend on the orientation and slope of the roof.

Finally, the yearly electricity production was obtained, by multiplying the peak power by the productivity and the correction factor.

Specificities of DCNS

Installing photovoltaic panels in a company working for the navy and with a history such as DCNS' is not the easiest thing. Several parameters are very specific to the company and have to be taken into account from the beginning.

First of all, as it is a defence industry, a lot of documents are confidential. This means that photovoltaic companies cannot have all documents needed to work correctly, and need to do a lot of assumptions. These documents can only be given when the supplier has been chosen and a real confidentiality agreement has been signed. Accesses into DCNS' buildings are also complicated: one needs to fill in forms and send identity cards in advance. Some buildings inside of the company have even more restricted accesses. The different sites of the company do not have the same security rules, which make it even more complicated.

Moreover, some buildings are very old, and some required documents do not even exist. Sometimes there can also be several documents saying the opposite: this is for example the case in several buildings regarding asbestos or the charge the structure can support. When the documents exist, they sometimes exist only on a paper version as the buildings are too old; this is for example true in Toulon, where no map exists as AutoCAD file.

Furthermore, there are very big differences between the sites. Ruelle is a very old centre with nice stone buildings and cute red roofs, while buildings in Brest and Toulon have been quickly constructed, mostly using concrete, during and after world war two. There are also big differences inside the sites, with buildings from very different periods with very different characteristics.

The organisation of the company is different between the different centres. After privatisation in 2003, a kind of harmonisation between centres was sought, but it is still not totally there. This makes projects such as renewable energy projects able to work only if there are people believing in them and decided to work on them. For example, in Indret, the documents needed to the companies were gathered very quickly, and it was easy to organise visits and find people to work on the project, whereas in Brest getting one map of a building can take more than one month, and there is never anybody having time to work on the project; they also refuse to work if they do not get money for it. Another difficulty in Brest is that apparently documents are very badly sorted out, and it is very difficult to find one precise map.

Finally, the last difficulty is that some buildings do not belong to DCNS, but to the navy, in Brest and Toulon. This means that if anything is to be done there, negotiations have first to be started.

Consultation method

The forecasted planning of the project can be seen in appendix A.

The principle of the consultation is as follows. First, several companies are chosen and asked if they want to participate. If so, they have to send some information, such as their sales, number of employees, progressions since it was created, organisation, field(s) of activity, references and examples of realisations in photovoltaic energy. Then, a choice of a few companies is done, based on the previous criteria. These companies then have the opportunity to visit all centres of DCNS and to get the documents needed, in order to propose a global offer for the group. At the same time, it is asked to the company to propose one or several visits of photovoltaic installations it has carried out. Based on these offers and their presentations, a short list of two or three companies is chosen, and these companies can discuss with DCNS in order to propose something more detailed. For example, if measures have to be performed, it will be done in this second step. Juridical and financial measures are also discussed there. After that, one company is finally chosen and a contract is signed with it, in order to do the final needed calculations, negotiate the final details, and start the installation.

Unfortunately, the market does not seem to be very mature in France, there are a lot of uncertainties regarding the feed-in tariffs and other financial helps, and companies hesitate before starting such a study in such a big company for free. That is the reason why things did not exactly happen as explained before.
In the first five selected companies – in theory the most serious ones, one said no from the beginning when it realised the size of the project. A second one met the project team of DCNS and discussed with it, but finally refused to work on the project. A third design office accepted to visit only the two centres of the “South” (Saint-Tropez and Toulon), considering the others were not interesting; it finally said that even these two centres were not of interest. In the last two companies, one was a subsidiary company of EDF (French energy company) associated with an external company for the financial part, but EDF refused in the last minute this agreement and imposed another subsidiary instead; this delayed their answer, and is not a very good proof of stability and efficiency. Their second company (still 50% owned by EDF) gave an offer on time, but only included the two most South facilities, St Tropez and Toulon. Only the fifth company (50% Total and 50% EDF) answered correctly to the consultation.
However, due to the lack of experience of DCNS in the field, it was considered that one complete offer was not enough. So a second consultation was launched, with four new companies that were not in the initial list of companies. One of them (a subsidiary of Veolia) accepted only the centres in the “South” (but including Ruelle this time). Another company made all the studies for all centres, but finally decided it was impossible to finance so gave up. The two others made complete offers.
To sum up, it was managed to get five offers, from which only three include Northern facilities.

Specifications

The specs sheet can be seen – in French - in appendix B. The mains ideas are translated here.

"In the frame of its new Energy Workshop, DCNS wants to study the possibility of installing photovoltaic panels on the roofs of its buildings. The French and European laws and rules have to be applied, as well as DCNS' specific constraints. Documents provided by DCNS will be: maps of the centres and buildings, brief description of roofs, photos and juridical specificities (especially for "COT" and "AOT" buildings). The objective is that the company, together with the design office and DCNS, can define the possibilities and conditions of installing photovoltaic on DCNS' roofs. Different aspects will have to be taken into account: technical, financial, juridical and environmental parameters.

The study is to be realised on 7 centres of DCNS: Cherbourg, Brest, Lorient, Nantes-Indret, Ruelle, Toulon and Saint-Tropez. A visit of these centres will be organised, where design offices will get the necessary documents, and see the roofs, their specificities and orientation. There will be one unique person per site in charge of welcoming photovoltaic companies and communicating with them. At the end of these visits, questions will probably be asked, and DCNS will answer to them; if some data lack, hypothesis will have to be formulated. Based on these data, the company has to investigate the possibility of installing photovoltaic. This study relates mostly to the roofs, but other propositions can be seen positively: for example photovoltaic parking covers, brise-soleil, etc.

Different aspects have to be taken into account. First, the project needs to be feasible from a juridical point of view, especially for "COT" and "AOT" buildings.

Moreover, different technical parameters have to be expressed:

- Kind of solar panels, and the way it is integrated into the buildings. Installing solar panels cannot disturb the production, and all things installed on the roofs (such as chimneys, gas exhaust pipes, skydomes...) have to be kept.
- Needs in term of other equipments: space for the inverters room…
- Needs in term of grid connexion: voltage…
- List of works to be done, planning, associated costs, and which ones DCNS will be in charge of…
- Needs in term of maintenance (frequency, access…)

The hypothesis done have to be clearly expressed, and the following results have to be presented: area covered with photovoltaic panels per building, total power forestalled (W_p), total electricity production expected (kWh/year).

The financial assessment has to be formulated. Are to be financed by the photovoltaic company, at least: DCNS visits, technical studies, grid connexion, administrative work, solar panels installation, watertightness works, maintenance. Financial engagements have to be provided, with rent paid to DCNS, possible subsidies, things that have to be paid by DCNS…
Different scenarios can be proposed: DCNS as investor, as lessor, mix of both.

Furthermore, one objective in this study is to be part of a sustainable development approach. For this reason, a life cycle assessment of the installation has to be provided. Moreover, precisions regarding recycling have to be communicated. Finally, the esthetical impact of the installations has to be assessed, for example with pictures of installed systems.

Finally, the security is an important aspect. So the company has to explain how the security of installations and persons will be ensured, during installation, production and maintenance."

Chosen design offices

The five companies that were first chosen are the following ones.

Enertime, for the financial part, associated with **Tenesol**, design office specialised in photovoltaic energy. Tenesol was created in 1983 and used to belong entirely to Total (oil company); it belongs now 50% to Total and 50% to EDF (French electricity company). Originally, its activity was mostly off-grid photovoltaic installations, especially in Africa and Middle-East. It has two solar panels factories: one in South Africa and one in Toulouse, South-West of France, making both monocrystalline and polycrystalline silicone panels. Panels are only assembled and tested in these factories, the cells being bought from two main suppliers (Q cells, world leader, and Photovoltech, a Total's subsidiary). Both factories are certified ISO 14001, and Tenesol belongs to EPIA, PV Cycle, Quali PV and has an integration system certified by the CSTB* (building scientific and technical centre). It is now set up worldwide, employs more than 1000 persons and its sales in 2009 were 249 M€.
Enertime was created in 2008 and is specialised in photovoltaic electricity, biomass plants and industrial heat recuperation. Its sales in 2010 is foreseen to be 800 k€ and it employs 11 persons near Paris.

Sol Finances, for the financial part, associated with **EDF ENR Solaire**, for the technical part. Sol Finances is a very recent company with few employees that aims at financing solar energy projects. EDF ENR Solaire is a company belonging to EDF, specialised in photovoltaic energy for three main customers: private people, farmers and companies. It was created in 2006 and has now more than 300 employees. It does not build itself solar panels but buys them to other companies, including sometimes Tenesol. It uses different technologies, such as amorphous silicone, multicrystalline and monocrystalline silicon modules.
Unfortunately, EDF EN (EN meaning "New Energies"), another subsidiary company of EDF, forbid EDF ENR Solaire to work with Sol Finances. So finally an offer was proposed by **EDF EN** alone.

Coruscant associated with **GDF Suez**. Coruscant is a design office created in 2007. It is specialised in photovoltaic energy, with most of its realisations so far being parking covering. It belongs with 20% to SNCF (the French railway company) and has a capital of 2.7 M€. It is associated with GDF*-Suez, a company originally

specialised in natural gas that used to belong to the state, which is the equivalent of EDF for electricity. Coruscant and GDF-Suez have signed a development partnership.
Coruscant only accepted to work with centres in the South and then did not give any offer, because it considered it was not financially interesting.

Solaire Direct is an independent company existing since 2006. It is specialised in photovoltaic installations, with three main fields: ground-mounted photovoltaic installations, roof-mounted photovoltaic for private people, and roof-mounted photovoltaic for professionals, with two categories, farmers and industrial clients. Solaire Direct did not have any agreement with a financial company as they do the studies, the installations and the financing. It belongs to EPIA, PV Cycle, Quali PV, and SER*.
Solaire Direct decided from the beginning, after meeting the project team, not to continue the project because it seemed too heavy.

Transénergie was created in 1992 and is specialised in renewable energies and energy savings. It belongs to SER. It refused to work on the project after it was selected, because it seemed too complicated to them.

Other companies that were on the first list but were finally not chosen because of a lack of robustness and consistence are: Nass&Wind and Immosun. Ikaros was also chosen, but the person in the company was impossible to call or meet (he had in fact left the company without saying anything).

The additional companies chosen for the second round of consultation were the following ones.

Veolia was chosen, through its subsidiary company Eolfi. Eolfi was created in 2004 and was originally financing wind farms projects. It then diversified and also worked on photovoltaic projects. Veolia Environment's sales in 2009 were 35 billions € and could finance the project. However, they first said that only the three sites the most South were interesting (Ruelle, St Tropez, Toulon) and only visited these ones. Understanding that DCNS wanted as many centres equipped as possible, they also included Nantes using Google Maps, but not more North than that.

Ikaros Solar was finally managed to be contacted and was very interested in the project. This Belgian company was created in 2006 and has been specialised in photovoltaic energy from the beginning. Its activities were first mainly in Belgium, Netherlands and Germany, but it now wants to expand in other European countries such as France, UK, Italy… It is supported by Credit Agricole Private Equity, and as a company "from the North" considers that all DCNS installations are interesting.

Sol Finances (the one abandoned by EDF) also had the opportunity to continue the project, by associating with **Spie**. Spie comes from several old companies, and was originally specialised in civil engineering (1846) and railway systems (1900). Its activities diversified, and the civil engineering part was separated in 2004, and Spie is now specialised in electrical, mechanical, HVAC, energy and telecommunication systems. It is already working with DCNS on a lot of projects and for maintenance of

DCNS facilities. Its sales in 2009 were 4 billions €, it has more than 28000 employees and a quite green image. In this case, the project would be financed by Sol Finances, and installations would be carried out by Spie. They considered all DCNS centres.

Finally, the last company consulted was **SolAvenir Énergies**. Created in 2008, this small company has the specificity of ordering the construction of photovoltaic modules totally produced in France, for environmental and social reasons. From the wafer production to the production of final module, everything is produced, by different companies, in South-West of France. Its sales in 2009 were already 287000 €. Unfortunately, it is a too small and too young company, and it also has higher costs due to production in France, so it considered the project was not feasible from an economical point of view. However, even if it gave up the consultation, it gave a very detailed report of the technical project that would have been carried out.

Visits of installations from the design offices

To have an idea of what the chosen design offices already have done, what their installations look like and what were their relationships with the companies they worked with, it was asked them to propose visits of photovoltaic installations they have realised. If possible, it was asked to visit installations in an industrial context, in order to see something similar to what it would be at DCNS, and to meet people who dealt with the project in the company. Only Tenesol proposed interesting visits at an early stage, i.e. before the moratorium, that is why only their visits is described here. If the project can start again after the moratorium, other installations of other companies should be visited.

Enertime/Tenesol

The *« Cité de la voile »* is a museum about sailing boats and sailing history, located in Lorient, South Brittany, that opened in 2008 in a new area with a harbour especially built for racing sailing boats. During the construction photovoltaic panels were installed by Tenesol. They are installed as brise-soleil (see picture in Figure 31), and have a peak power of 19 kW_p, with 252 panels (150 m²) and 6 inverters. They do not produce a lot – around 20% of the total electrical consumption - but also have an educational role, with a didactic sign giving indicators such as the current output, the total energy delivered, and the total CO_2 emissions avoided.

Figure 31: Photovoltaic installation from Tenesol at the "Cité de la Voile", Lorient (ADEME 2007b)

As the previous installation was not really comparable to DCNS, an installation on an industrial company was proposed. This installation is based on the roofs of a factory of the company Pommier, producing inverters and electrical components, in Bagnères-De-Bigorre, in the Pyrénées. The photovoltaic panels are building-integrated, on one of the sheds of the roof (see Figure 32). There are 700m² solar modules, producing 96 kW_p, installed by Tenesol in 2009, for a cost of 550 000 €. The first year, the production was a bit higher than expected even if it was a not so sunny year.

It was very interesting to see the installation, how the integration is actually done, how it looks like in the end and also how the electrical installation and the inverters look like. The person from the juridical direction was also there, which enabled her to understand better what is photovoltaic and what the risks really are.

Figure 32: The photovoltaic modules (left) and the inverters (right) on the buildings of the company “Pommiers”, Bagnères-de-Bigorre (South-West of France)

Finally, Tenesol also gave the opportunity to visit its photovoltaic panels' factory in Toulouse. This was also very interesting, as it was possible to see how they are actually built and how the quality is controlled.

Other companies

Other companies proposed visits of installations, but at the time this report was written none was visited because of a lack of time and delay due to moratorium.

Life Cycle Assessment of the photovoltaic projects

Definition, scope and objective of the study

It was written in the specifications sheet that the companies should provide a life cycle assessment or at least a carbon accounting of their photovoltaic project at DCNS. However, none of them had a real study available about the product they use, and it seemed difficult for them to carry out this study due to a lack of data from their suppliers. As a lot of furniture come from China, it is probably even more difficult to actually get the data.
Moreover, the companies made different assumptions for their environmental impact calculations, so it was impossible to compare them. For example, regarding CO_2 emissions avoided thanks to photovoltaic production, companies took very different values for the emissions from the electricity mix: some chose the French average electricity mix, with mostly nuclear (84 gCO_2eq/kWh), others took the French marginal electricity mix (300 gCO_2eq/kWh), the European average mix (300 gCO_2eq/kWh) or the European marginal mix (600 gCO_2eq/kWh). (ADEME 2010) This lead of course to very different and inconsistent values! Furthermore, some companies chose one mix for the emissions from the production (84 for example) and another one for the emissions avoided thanks to installation (300 for example).
This is the reason why it was decided to investigate this question with a unique methodology for all projects.

The product studied here is the entire photovoltaic installation. It includes solar panels (cells and frames), integration system, inverters and shelters. Other electrical components such as cables were not included due to the too high complexity for finding data, and the small impact they would probably have compared to the whole installation. The shelters were also not included due to the too high number of possibilities and lack of data. The impact of the fact that the roofs would have had to be changed anyway (and the emissions this would have implied) was also not included. Ventilation in the inverters room has also not been taken into account, but should have a limited impact. Finally, the transportation of people doing the installation and the maintenance is not included as it is assumed they live close to the installation and thus have a limited impact.
The goal of this study is to estimate the amounts of CO_2 the different projects from the design offices would avoid (or emit), over the life cycle of the product. The aim is to be able to compare the environmental impact related to CO_2 emissions on a

similar basis, with a common methodology. By doing so, it will be easier to take the environmental aspect into account in the final choice of supplier.
So the final expected output is the amount of CO_2-equivalent avoided or emitted. The functional unit chosen is “kWh”, as this is the typical unit used to compare electricity production projects. This will enable to compare offers that do not have the same level of production, and possibly later to other ways of producing electricity.

The system boundaries of the project are the following ones. From a geographical point of view, the system boundaries are the whole planet, because to have a realistic picture it is important to include emissions appearing in other countries (for example in China), and not only in France. From a timeline perspective, the system is investigated from the beginning of the components production to the dismantling of the panels. The different life cycle steps of the installation are included: manufacturing of components, their transportation to the place they are installed, and electricity production. However, end-of-life of the products and especially recycling is not included: recycling of panels is indeed at its beginning and will probably make a lot of progress until the dismantling of the panels, so it is difficult to estimate the impact it will have. It would probably have a positive impact on the total emissions, but it does not matter as all projects will be studied under the same assumption.

Assumptions

Different assumptions had to be done to carry out this study. A lot of them are based on ADEME’s “Bilan Carbone ™” emission factors manual. “Bilan Carbone ™” is a methodology developed by the ADEME* to help companies accounting their Greenhouse gas emissions caused by all processes related to them.

Manufacturing

The emission factor used for emissions from components’ manufacturing is the electricity provider’s emission factor of the plant where the component has been built. If this data is not available, the emission factor of the country where it has been produced is used, but this is much more imprecise. Emission factors from average electricity mix can be seen in Table 4 for different countries in which components are produced and for Europe.

Country	Emission factor (gCeq / kWh)	Emission factor (gCO_2eq / kWh)
Germany	0,110	0,403
Belgium	0,071	0,26
China	0,215	0,788
Denmark	0,093	0,341
France	0,023	0,084
Italy	0,110	0,403
Japan	0,114	0,418
World	0,138	0,506
Norway	0,002	0,007
Slovakia	0,061	0,224
United Kingdom	0,138	0,506
EU27	0,083	0,304

Table 4: CO_2 emissions of different countries' average electricity mixes (ADEME 2010)

Furthermore, the energy necessary for producing each part of the system has been taken from a study from Alsema and Wild-Scholten, and can be seen in Table 5. It is assumed that the energy used to produce a component is the same wherever the production takes place. The emissions can then be calculated by multiplying this energy needed by the electricity mix of the plant's electricity provider. If cells are produced in one place (usually Chine) and assembled in another one (usually France), it is assumed that 95% of the necessary energy is used for the cells and 5% for the assembly. (Alsema & Wild-Scholten 2005)

Component	Necessary energy	Necessary energy
Polycrystalline module	4000 (MJp/m²)	345 kWhe/m²
Monocrystalline module	5200 (MJp/m²)	448 kWhe/m²
Integration structure and cabling	100 (MJp/m²)	9 kWhe/m²
Inverter	1930 MJp/kW_p	166 kWhe/kWp

Table 5: Energy needed to produce different parts of photovoltaic panels (Alsema & Wild-Scholten 2005)

Transportation

Three means of transportation are considered. The first one is railway transportation. Railway systems do not have the same emission factors depending on the countries, as the share between electrical and diesel trains is not the same everywhere, as well as electricity mixes. It also changes depending on the train line taken inside of a country (electrified/diesel), but this was not regarded as it is too complicated to know. Instead, the average value of the railway system of the country was used (see Table 6). These emission factors are given in grams of CO_2 equivalent per kilometre stride and per tonne of product, so the weight of the products needs to be known. To be rigorous, all routes need to be cut in different parts for each country crossed. The distance of railway can be taken using websites giving itineraries for cars (see below in road transportation), as the railways usually follow more or less the roads. These websites also provide the distances inside of each country. If this level of detail is not known, the European average can be used.

Country	Emission factor (gCeq / t.km)	Emission factor (g CO_2eq / t.km)
Germany	8,7	31,9
Belgium	5,1	18,7
Denmark	10,3	37,8
France	4,8	17,6
Italy	7,9	29,0
United Kingdom	11,2	41,1
Europe (EU17)	6,2	22,7

Table 6: Emission factors of different EU railway systems (ADEME 2010)

Another possible mean of transportation is sea transportation. The problem is that emissions depend on the kind of ship that is used, and this is impossible to know as it can change each time. For this kind of equipment, container ships are usually used. It is assumed that one of these boats contains 1500 “twenty foot equivalent unit” (unit used for this kind of ships, equivalent to one container), which is a bit less than big modern container ships, but as these pollute less it is sure the output value will be a maximum value. It is also assumed that one of these ships emits 52 tonnes Ceq per day on the seas, so 190 tonnes of CO_2eq/day. Then, either the ship speed and the distance are known, which allows to calculate the number of days, or the number of days on the seas is known directly (using websites such as http://www.cma-cgm.com). The emissions over the whole journey can then easily be calculated.
Now the number of equipment in one container needs to be known. This is calculated using the size of the equipment (mostly panels) and the size of one container (the standard size is 6m*2,44m*2,5m). As it is assumed there are 1500 containers in one ship, it is finally possible to calculate the emissions allocated per object transported. (ADEME 2010)

Finally, a last mean of transportation is road transportation. Emissions depend on the kind of lorry used. In order to have some margin and maximise the emissions, worst case has also been chosen. It is assumed that equipments are carried by 3.5 tons trucks. These trucks emit, with an average filling, 1,203 kg CO_2eq per ton of merchandise and per km. The weight of the products and the distance covered need thus to be known. To know the distance, websites such as www.infotrafic.com, www.mappy.fr or www.viamichelin.fr can be used. (ADEME 2010)

Electricity production

Finally, a lot of CO_2 emissions will be avoided thanks to the photovoltaic installation. These are calculated by multiplying the emissions from European electricity mix with the electricity production of the installations. As panels' quality decreases with time, one should calculate how much they will actually produce over the lifespan, and not use the values given by companies, that are in fact the first year production. Producers guarantee a decrease in production of maximum 80% after 25 years. It is assumed that this degradation happens, linearly, which enables to calculate the actual yearly production. It is also assumed that the quality of the panels is the same whatever country they have been produced in. Moreover, calculations were done for two cases: for a lifespan of 20 years (in case DCNS chooses to remove panels after 20 years), and for a lifespan of 30 years (expected lifespan, if DCNS decides to keep the panels after the end of the lease). This also gives the possibility of comparing the environmental impacts of both choices.
It was chosen to consider the European electricity mix (see Table 4) to calculate the avoided emissions. The electricity saved by DCNS' production is indeed not necessarily French, and for example in Saint-Tropez or Toulon it has a big chance of coming from Italy. The electricity saved by renewable energies leads to a decrease in Europe's electricity CO_2 emissions. Moreover, it is considered that this electricity produced will not lead to a dramatic change in the electricity mix, and thus will replace basis electricity and not marginal electricity.

Data collection

As it has been shown previously, different data have to be collected from the companies. First, it is necessary to know where exactly all the components are produced (cells, assembly of cells into panels, inverters, shelters, integration system). Moreover, the electricity providers of the plants where these components are produced are also required; the origin of electricity used can indeed change CO_2 emissions dramatically. Then, the means of transportation need to be known, for all components. For components transported using different means of transportation, they should all be included (for example boat and lorry, or lorry and train…). What is more, all the technical characteristics of the installation need to be detailed: kind of panel, guaranteed maximum decrease of production, peak power, area and weight of panels, power and weight of inverters, relation between inverter power and panel peak power, shelters volume and weight of integration system. Finally, the power and the expected production of installations are crucial parameters.

As it was not possible to get the data on time, mostly due to the slowness of the project after government's decision of a moratorium, it was decided to carry out some calculations with different assumptions in order to compare parameters.
The system used in this comparison is made of monocrystalline panels, with the following characteristics, that are common average characteristics.

Peak power of one panel: 250 W_p
Area of a panel: 1,6 m²
Inverter power: 3,5 kW
Ratio inverter to panel powers: 1
Panel weight: 18 kg
Inverter weight: 22kg

Characteristics of the installation on DCNS' roofs were chosen as an average from offers. The total peak power installed is thus considered to be 7 MW_p. The repartition and the productibility of the 7 centres of DCNS are detailed in Table 7.

	Cherbourg	**Brest**	**Lorient**	**Indret**	**Ruelle**	**Toulon**	**St Trop**
Productibiliy (kWh/kW_p)	980	940	990	1050	1090	1270	1300
Peak power (kW_p)	1000	400	1500	800	1100	1400	800

Table 7: Power assumptions for LCA calculations

Due to a lack of data and estimations, the impact of integration structures and shelters has not been included in these comparisons. However, this impact is not expected to be very important, and as it is not included for all of the calculations it still enables comparisons. Specific electricity providers have also not been included, but instead the national electricity mixes have been taken into account.

The different parameters investigated here are:

- The place where the components (panels and inverters) are produced (especially China vs Europe, Germany vs France…), and what is changed if cells are produced in one country and assembled in another.
- The way these components are transported (especially lorry vs train)

- Changes in electricity mix and decrease in Europe's electricity carbon intensity.
- The differences in results if the panels are used during 20 years (time of lease) or 30 years (expected minimum life span)

Several scenarios have been investigated.
In the first set of scenarios (called "AX"), no change in electricity mix is considered, and avoided emissions are calculated using current electricity mix.
In the first scenario ("A1"), it is assumed that the whole panel is manufactured in China, including cells production and assembling. Inverters are also produced in China. It is considered that these components are freighted by ship to France, where they arrive in Le Havre. Then the components are transported to DCNS centres using lorries.
In the second scenario ("A2"), it is looked at a panel whose cells have been produced in China, and assembled in France. This is for example what is done by the company Tenesol, who pretends it is very good from an environmental point of view because production is in France. To check more carefully what this company says, it is considered that the assembling factory is located in Toulouse. Ships also arrive from China in Le Havre. This scenario is divided into two scenarios: in the first one ("A2a") cells are freighted from Le Havre to Toulouse and then panels from Toulouse to DCNS facilities using lorries, whereas in the second one ("A2b") trains are used. Inverters are assumed to be built in France, in Toulouse too, and transported the same way as the panels.
In the third scenario ("A3"), the panels (including cells production) and the inverters are produced in Germany. Then the same division as before is used: in the first case ("A3a") transportation media is lorries and in the second one ("A3b") it is trains.
Finally, in the last scenario ("A4"), the whole production is assumed to take place in France, with the same two variants as previously: lorries ("A4a") and railway ("A4b") used for transportation.
These scenarios allow comparing the influence of where components are produced, and how they are transported.

In the second bunch of scenarios ("B"), different changes in electricity mix are investigated. The base scenario is the one with the electricity mix used previously: the EU27 2010 mix, assumed to be constant over the photovoltaic production period. In the second case, the French electricity mix is used instead. The three next scenarios are different possibilities of electricity CO_2 intensity decreases: minus 20% between 2010 and 2030, minus 24% between 2010 and 2030 and minus 20% between 1990 and 2020, which is approximately minus 14% between 2010 and 2020 (official EU reduction). The calculations were done for these different possibilities for a production taking place entirely in France, with transportation by train. This enables comparisons depending on political changes in CO_2 emissions from electricity.
These changes only affect the emissions avoided from production, which are the same for all "A" scenarios, so this can easily be included in all previous variants.

Finally, a comparison was done between a life span of panels of 20 years and 30 years (previous simulations). This aims at seeing if there is a really big difference in emissions avoided and if it still has a positive impact. Calculations were done for the "worst case", which is panels built in China and transported by ship and trucks. This scenario has been called "A1-20years".

RESULTS

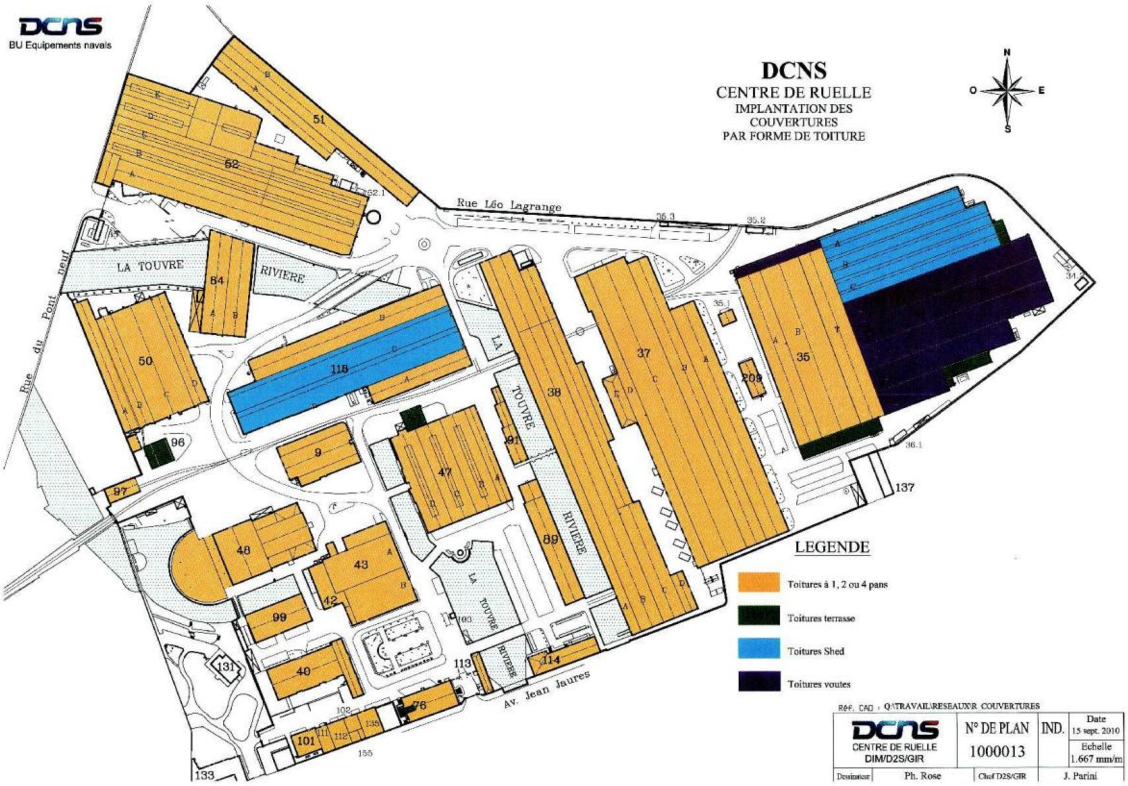
Photovoltaic potential in the different centres of DCNS

Ruelle

The centre of DCNS in Ruelle-Sur-Touvre was created in 1753 and was a foundry for cannons. It became a missile factory after the Second World War. The buildings have kept their original aspects, and most of them are made of old stones and pink tiles. Some roofs have been renovated, and on some of them it was allowed to put steel roof looking like tiles instead of real tiles; on some others however it was not allowed, and real tiles had to be put again. Due to an old classified fountain next to the entrance of the company, the agreement of the “architect of French buildings” is necessary before doing anything on the buildings. The company is located on a river, the “Touvre”, which is used for cooling processes. A project of hydroturbine is also under development.
Ruelle-Sur-Touvre is located quite in the South of France and thus is quite sunny. Moreover, the buildings are spaced out and rather low, so they do not shade each other too much. In Figure 33 the overall aspects of the buildings can be seen.

Figure 33: Aerial views of DCNS Ruelle

As it can be seen on the previous photos, different kinds of roofs coexist in Ruelle: one, two or four slopes roofs, flat roofs, sawtooth roofs and vaulted roofs (see Figure 34).



Legend:

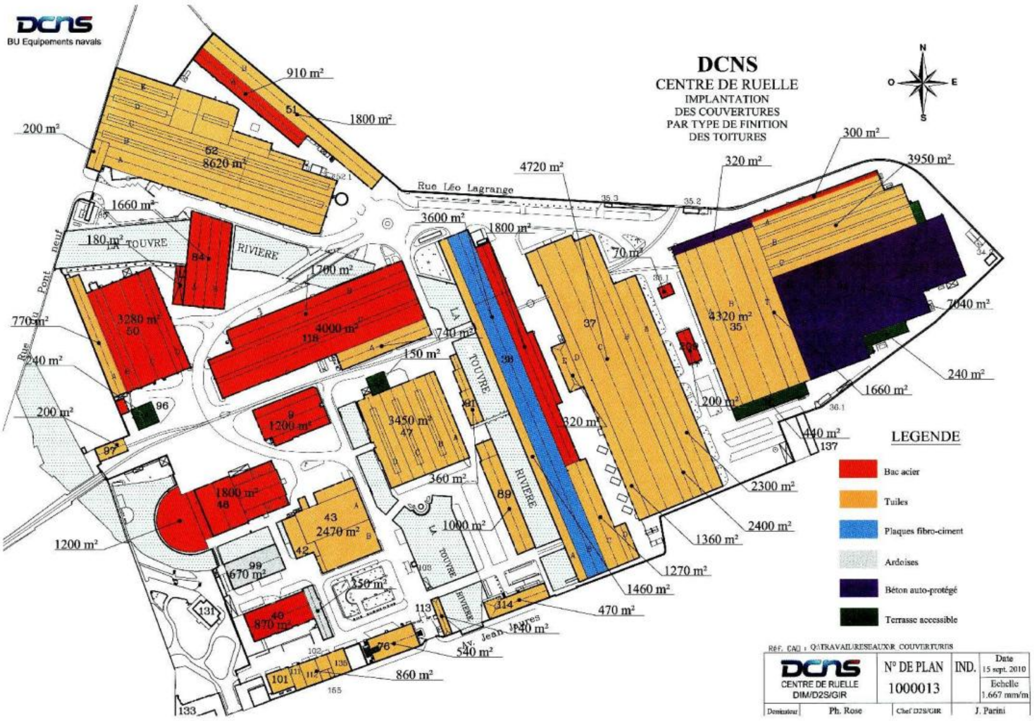
Orange: monopitch roof, gambrel roof, hip-roof

Black: flat roof

Blue: sawtooth roof

Dark blue: vaulted roof

On these different shapes of roofs, different kinds of roofings are used: corrugated steel roofs, tiles, asbestos cement, slates, autoprotected concrete, terrace (see Figure 35).



Legend:

Red: corrugated steel roof
Orange: tiles
Blue : abestos cement
Grey: slates
Dark blue: autoprotected concrete
Black: accessible terrace

Regarding only the orientation of the roofs, a first choice of possible buildings has been established, that is shown in Figure 36.

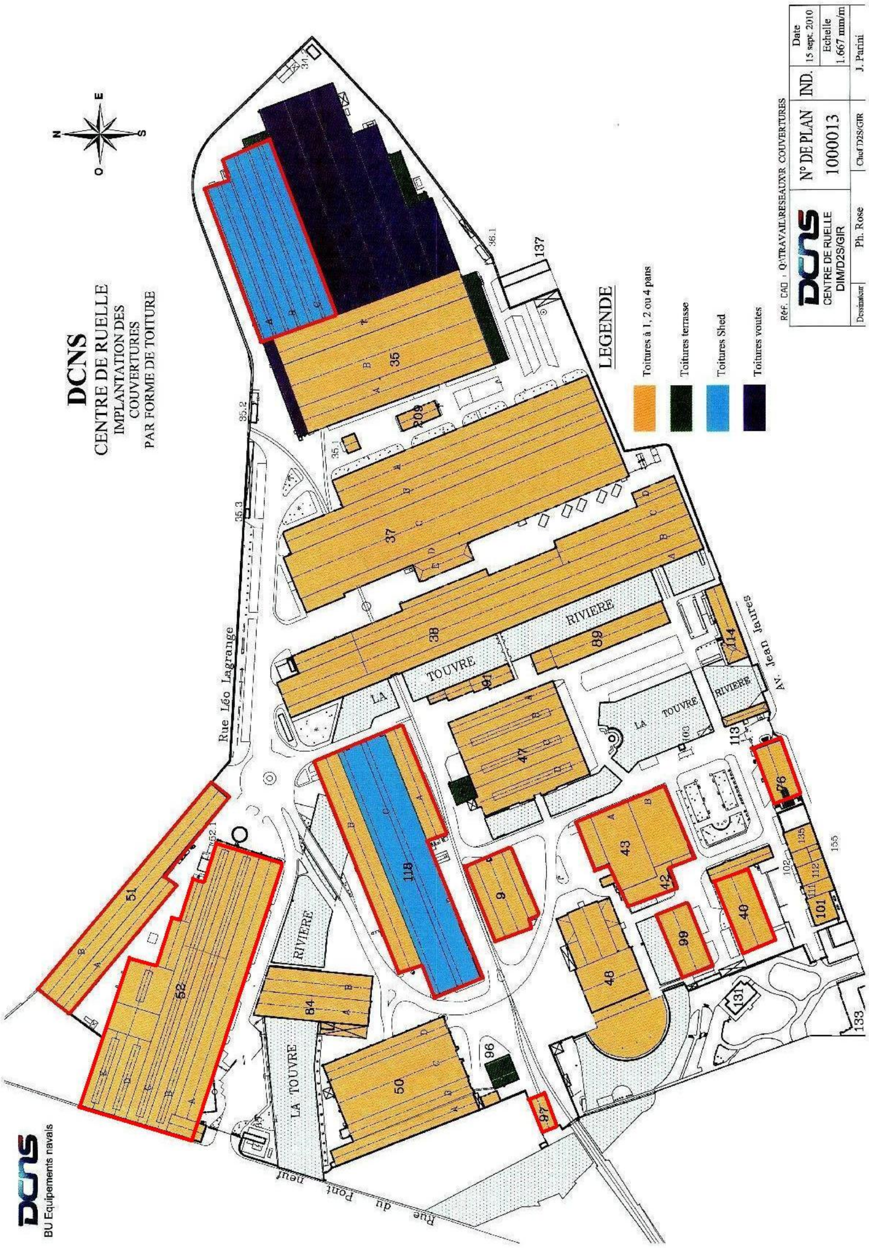


Figure 36: Well-orientated buildings in DCNS, Ruelle-Sur-Touvre

Photovoltaic production characteristics for each chosen building are shown in Table 8. Two different ways of calculating the yearly electricity production have been used. The first one assumes photovoltaic modules of 150 W_p/m^2 and a productivity in Ruelle of 1100 kWh/kWc (Joint Research Centre 2006), to which a correction factor has been applied, depending on the exposure and slopes of the roofs, as it has been explained in the method part. The second method uses the photovoltaic estimation software of the Joint Research Centre of the European Commission (Joint Research Centre 2010a): technology (crystalline silicone), roof slope and orientation have been given as inputs, as well as system losses, assumed to be 12%. The numbers from the two methods (see Table 8) are quite different, that is why the first method will be chosen from now (and also for the other facilities of DCNS), for carefulness reasons as the results are lower.

Building	Area (m²)	Exposure (° to North)	Roof slope (°)	Correction factor	Peak power (kW_p)	Electricity production (MWh/yr)	Electricity production PVGIS (MWh/yr)
34	1500	157,5	30	0,98	225	243	257
51	900	225	30	0,96	135	143	147
42-43	1050	157,5	28	0,98	158	170	176
40	440	157,5	30	0,98	66	71	75
99	345	157,5	35	0,98	52	56	59
76	300	157,5	35	0,98	45	49	51
118 A	400	157,5	35	0,98	60	65	68
118 B	370	157,5	30	0,98	56	60	63
118C	2745	157,5	28	0,98	412	444	461
9	640	157,5	30	0,98	96	103	109
52	2000	202,5	30	0,98	300	323	339
Total	**10690**	**-**	**-**		**1604**	**1726**	**1807**

Table 8: Photovoltaic power and energy for each building of DCNS Ruelle

It can be seen that if all the chosen buildings were covered with photovoltaic panels, the electricity production would be around 1,7 TWh/year, which would cover more than 18% of the electricity consumption of Ruelle (that is 9,2 TWh/year)!

St-Tropez

DCNS centre of Saint-Tropez is also a small one. It is located on the sea, just outside the renowned city of Saint-Tropez. The site is divided into two parts, separated by a castle, which is going to be sold. The western part of the site is not concerned by the photovoltaic project because there are other projects for it. That is why only the eastern part will be included in this study. Its view from the sea can be seen in Figure 37. The buildings are North-West from the sea.

Figure 37: Aerial view of DCNS St-Tropez

There are not a lot of documents available for this centre; that is why a lot of estimations and hypothesis had to be done. Three main buildings could be equipped with photovoltaic modules: the main building, which has both flat roofs and sawtooth roofs, the East building (left on the previous picture), which has a flat roof, and the North building (the closest to the sea), which has a gambrel-roof. The details of where the panels could be installed are shown in Figure 38, based on an aerial view from Google Maps.

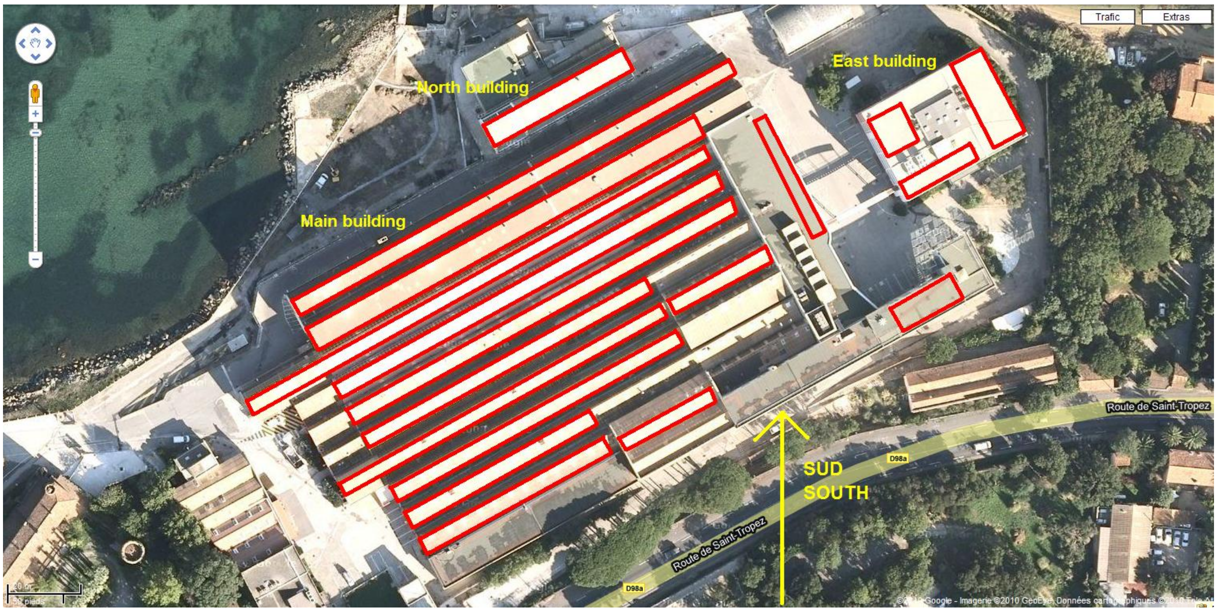


Figure 38: Selected buildings in DCNS St-Tropez
(Google 2010)

There are no detailed maps of the buildings of Saint-Tropez. That is why the areas (see Table 9) were estimated from Google aerial view, and are probably underestimated.

Building	Area (m²)	Exposure (° to North)	Roof slope (°)	Correction factor	Peak power (kW_p)	Electricity production (MWh/yr)
Main building	3200	150	30	0,97	480	652
Main building	220	-	0	0,93	33	43
North building	130	150	30	0,97	20	26
East building	200	-	0	0,93	30	39
Total	**3750**	**-**	**-**	**-**	**563**	**760**

Table 9: Photovoltaic power and energy for each building of DCNS St-Tropez

If all these areas were covered with photovoltaic panels, the electricity production would be around 760 MWh/year, which would cover a bit less than 24% of the electricity consumption (3,2 TWh/year in 2009).

Indret

DCNS centre of Indret is also a quite small one. It is located next to Nantes, and very close to the Loire River. There is also a castle in the middle of the site, but that should not bring any problem as it is not classified and not very high. There is also a lot of unused land around the company. The buildings of Indret are quite well orientated, and several buildings could be equipped. The selected buildings have been shown in Figure 39 (Western part of the site) and Figure 40 (Eastern part).

Figure 39: Aerial view and selected buildings in DCNS Indret, Western part

Figure 40: Aerial view and selected buildings in DCNS Indret, Eastern part

Data are lacking for some of the buildings (especially the ones with flat roofs), that is why a lot of estimations had to be done. The area and characteristics for each selected building or group of selected building is shown in Table 10.

Building	Area (m²)	Exposure (° to North)	Roof slope (°)	Correction factor	Peak power (kW_p)	Electricity production (MWh/yr)
59, 60, 68	700	-	0	0,93	105	103
26 G, J	700	210	30	0,97	105	107
26 K	200	210	15	0,96	30	30
30	950	210	30	0,97	143	145
56A	3000	202,5	30	0,98	450	463
56 B, C, D	6000	-	0	0,93	900	879
54	600	112,5	10	0,91	90	86
Total	**12150**	**-**	**-**		**1823**	**1813**

Table 10: Photovoltaic power and energy for each building of DCNS Indret

So if all these buildings were covered with photovoltaic modules, it would produce 1,8 TWh/year, which represents 14,7% of the electricity consumption of the site (12,3 TWh/year).

Lorient

The centre of Lorient is established on the two banks of the Scorff River, in Lorient. In the left bank (where building names start with "G") it is mainly a production activity, whereas the administrative and scientific works take place in the right bank (where building names start with "D"). For the selected buildings in the left bank (see Figure 41), the maps were available, and the areas could be calculated using them. For the right bank (see Figure 42) on the other hand, a lot of data and maps are lacking, and thus a lot of assumptions had to be done, and some areas were calculated using Google Maps.

Figure 41: Aerial view and selected buildings in DCNS Lorient, left bank

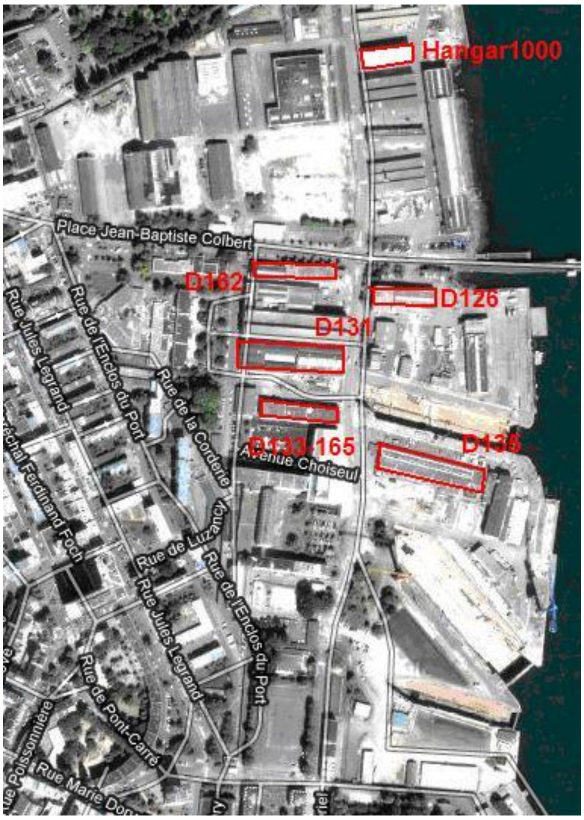


Figure 42: Aerial view and selected buildings in DCNS Lorient, right bank (Google 2010)

Area and characteristics of the chosen roofs are shown in Table 11.

Building	Area (m²)	Exposure (° to North)	Roof slope (°)	Correction factor	Peak power (kW_p)	Electricity production (MWh/yr)
G04	4000	157,5	25	0,98	600	600
G030	4400	-	0	0,93	660	626
G037	4800	-	0	0,93	720	683
D162	550	-	0	0,93	83	78
D135	500	-	0	0,93	75	71
D135	1000	202,5	30	0,98	150	150
D126	400	-	0	0,93	60	57
D131	700	180	30	1	105	107
Hangar 1000	900	-	0	0,93	135	128
Total	**17250**	**-**	**-**		**2588**	**2500**

Table 11: Photovoltaic power and energy for each building of DCNS Lorient

If all these buildings were selected, it would produce every year 2,5 TWh, which would be a bit more than 18% of the yearly electricity consumption (13,7 TWh/year).

Cherbourg

There was a big lack of input data for Cherbourg. In addition to that it is not a very sunny place, some buildings are to be destroyed soon, and there are some high buildings shadowing others buildings around. Using photos, the overall map and information given about buildings, only one building was chosen: the building “CM136”, which is actually made of two buildings (see Figure 43).

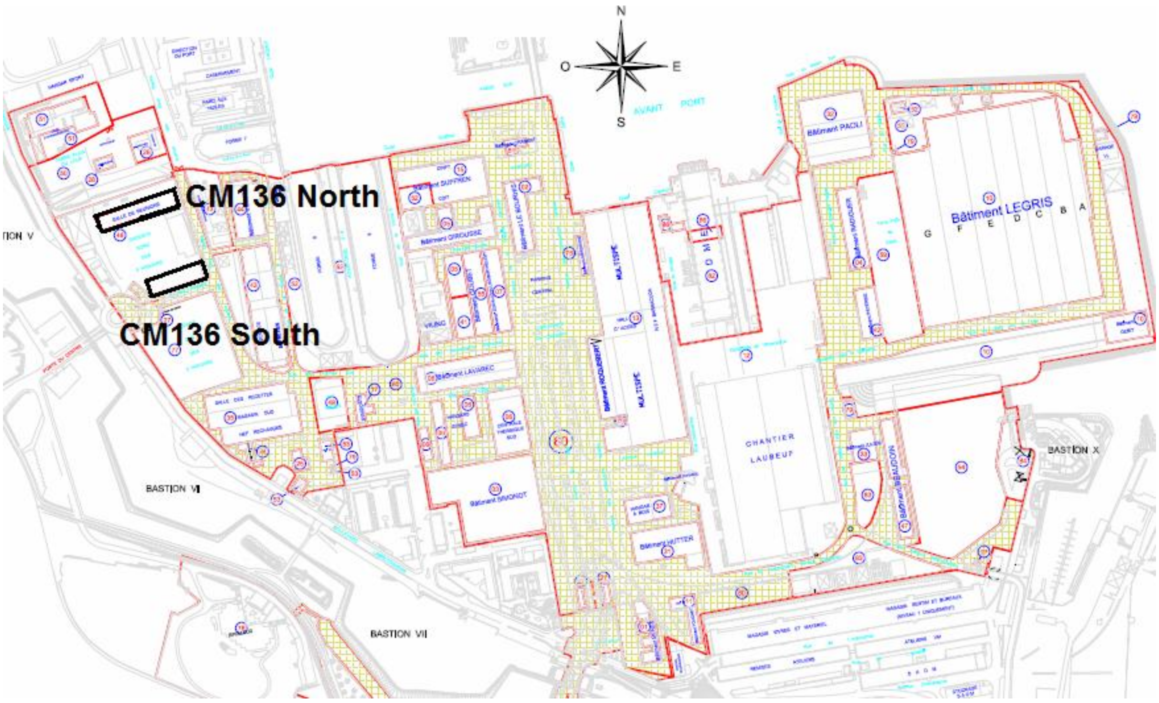


Figure 43: Map and selected buildings at DCNS Cherbourg

Characteristics of these two buildings are shown in Table 12: Photovoltaic power and energy at DCNS Cherbourg

Building	Area (m²)	Exposure (° to North)	Roof slope (°)	Correction factor	Peak power (kW_p)	Electricity production (MWh/yr)
CM136 North	800	135	30	0,96	120	112
CM136 South	500	135	30	0,96	75	70
Total	**1300**	**-**	**-**		**195**	**183**

Table 12: Photovoltaic power and energy at DCNS Cherbourg

So, if these two buildings were equipped with photovoltaic panels, the electricity production would be around 180 MWh/year, which is only 0.7% of yearly electrical consumption.

Brest and Toulon

The centres of Brest and Toulon have not been included in this study, for several reasons. The first one is that both sites are “COT” and thus nothing can be done without the agreement of the French navy; discussions have not started yet, so no photovoltaic project will be started there before some time. Moreover, there is an important lack of data for these two installations: buildings are old, were created mostly during world war two, and sometimes maps do not exist at all. It is also complicated to collect data because of confidentiality reasons; it is also forbidden to give and write data about these two centres. Finally, there are also problems of grid connexion in these two facilities. There are indeed independent networks inside of the centres that belong to the navy, whereas to be allowed to benefit from the feed-in tariff, one needs to be connected to the national grid, outside of the centre. Doing that would bring very high costs, and also complicated problems as it is forbidden by the navy to install aerial cables and a lot of things already occupy the underground.
However, these two sites had to be included by the design offices, knowing that they had to be proposed as “options” and would only be considered in a second step, after discussions with the navy, if the previous problems and costs could be overcome.

Sum of all buildings

To conclude, the brute potentials of the buildings of the five previous DCNS facilities stands around 6700 kW_p, for a production of around 7000 MWh/year (see details in Table 13). This is however only a very theoretical potential: it does not take into accounts neither the costs of photovoltaic installations and the differences between North and South, nor the costs of connection to the national grid, that can become high if a building is located far from the grid, nor the technical and juridical constraints that can appear.

Site	**Power (kW_p)**	**Production (MWh/year)**
Ruelle	1604	1726
St-Tropez	563	760
Indret	1823	1813
Lorient	2588	2500
Cherbourg	195	183
Total	**6771**	**6982**

Table 13: Summary of photovoltaic potential in DCNS sites

If this energy were produced, and if the investment was done by DCNS, it would bring to DCNS approximately 2,6 millions euros per year, with the former feed-in tariff of 37 c€/kWh. It would cover 6% of all DCNS yearly electricity consumption, including sites that are not included in this study (Toulon and Brest, but also headquarters in Paris and Bagneux, and data centre in Le Mourillon), 11% of these five centres’ consumption, and 18% if only Ruelle, St-Tropez, Indret and Lorient are included!

Analysis of the different issues

Several important issues needed to be taken into account in this project.

One first important question is why does DCNS necessarily have to sell the electricity produced to EDF, and why could it not be used for its own consumption? If a typical project (average of offers) is investigated, for example with an investment cost of 18 M€, for a yearly average production of 5,5 GWh/year. The electricity is bought by DCNS at a price of 49 €/MWh, which means yearly savings would be around 270 k€. This would bring a return on investment of around 70 years, which can of course not be accepted! If the CO_2 emissions avoided can be sold on the EU ETS market (today at a price of around 20 €/ton) this ROI is decreased to around 60 years, but it is still well too long.
If it is assumed that a ROI of 20 years can be accepted (which is far from being true, but could be defended), this would require for example a price of electricity of 98 €/MWh (twice as today), a CO_2 price of 150 €/ton, an average production of more than 7GWh/year for an investment of 20 M€. This is too hypothetical to decide such a big investment, so it is better to sell the electricity produced.

So the electricity produced will be sold, but there are different juridical and financial ways of carrying this out. Three main possibilities exist. The first one is very classical: DCNS wants to install photovoltaic panels on its roofs, so it invests in the photovoltaic installations and get revenues every year from EDF. In this case, DCNS needs to take care of the maintenance and good-functioning of the panels, or to buy a maintenance contract to a company. The second possibility is that a company rents DCNS roofs and install photovoltaic panels on them. In this case, DCNS receives an annual payment from this company, that is of course smaller than EDF's revenues, but DCNS is not responsible for the maintenance, this being the other company's affair. Finally, a third juridical possibility is a mixture of the first two. DCNS and the photovoltaic company create together a "project company", which financing is shared, and that is responsible for the installation and maintenance, and receive EDF's rent every year. In this case, DCNS is not directly responsible for maintenance and risks, and receives both an annual payment for the rent of the roofs (from the project company) and part of EDF's revenues, depending on the share DCNS has in the project company.
These three juridico-financial methods have advantages and drawbacks. The main questions are: does DCNS want to invest and be really involved in the photovoltaic installation? Does DCNS want to be responsible for the risk created by this installation, or does it want someone else to be? Finally, does DCNS want to get a smaller rent but without any financial risk, or does is want to get a higher rent, but with some risk (as it depends on the actual electricity production)?
These are the questions that need to be answered by DCNS direction and juridical, insurance and financial units, and that were not answered when this thesis was written.

The first of these possibilities – and the most simple – is that DCNS is investor and owns the installations. If it did so, a typical installation – based on offers from design offices – would have an investment cost of 18 M€, a production the first year of

6 GWh, which means an average production over the 20 years of 5,5 GWh/year (with constructors guarantee of 80% of initial production after 25 years, a linear decrease being assumed). With the former feed-in tariff of 37 c€/kWh, around 2 M€ would have been sold to EDF every year, which gives a return on investment of 8,8 years. Thus it is a long-term investment, but that could be accepted by DCNS.
In the second scenario – roof renting – DCNS would not have to invest anything, and would get a yearly rent between 80 k€ and 200 k€, depending on companies offers. To these revenues one should add savings on roofs renovation, but these costs have not been estimated so cannot be included.
The third scenario is more difficult to assess as it covers in fact a lot of scenarios. DCNS could indeed invest in the project company between 0 and 100%, and investments, rents and revenues would all be somewhere in-between the two previous scenarios. It could be really interesting for DCNS, as it would not have to care about maintenance, would be really involved in the project, and would get both part of EDF's revenues and a payment for the roofs renting.

Another important questions rose is how to deal with the risks occurred by the possible installations, during workings and during electricity production. These are serious problems, taken into account by the infrastructures, juridical and insurances services. There are indeed buildings inside of which very important production takes place, and it is totally out of the question to disturb it in any way. So installing the panels can be done only without endangering the buildings tightness, without any safety risk, and without having to stop producing. Then during photovoltaic electricity production, the risk of a problem (for example fires or lack of water tightness) must be totally avoided. This is one of the biggest concerns, especially in Lorient where the building G04 has a big roof that would be perfect for photovoltaic installations, but is very old, thus would probably need to be reinforced, and the production inside of it is of crucial importance.

Offers of the design offices

The first wave of offers (Enertime/Tenesol and EDF EN) was received in the middle of November, the second one (Ikaros, Eolfi, SolFinances/Spie) in the middle of December. Offers defences were then organised, in order for the companies to present their projects, and so that DCNS employees involved in the project could meet project teams of the companies, and ask them questions about their offers.

Comparing offers

The different companies gave very various offers. Only two companies selected all DCNS centres (Ikaros Solar and SolFinances/Spie). One design office (Enertime/Tenesol) chose all centres except Brest, because of the lack of sun, the lack of well-orientated buildings and a lot of shadows. Then two companies chose facilities under a North limit: Eolfi chose all centres below Nantes, whereas EDF EN only selected Toulon and Saint-Tropez.

In order to compare offers, a comparison table was created, where all parameters and information from the different offers were gathered. This table is shown in appendix C. The different categories and parameters were the following ones:

- General data:
    - Proposed number of centres
    - Foreseen timing of works
    - Impact of the project on DCNS activities
    - Quality plan
    - Management plan
    - Technical proposal strength
    - Financial proposal strength
    - Output data
    - Transparency

- Industrial organisation
    - Industrial organisation consistency
    - Installation: internal or subcontracted?
    - Specificities of each centre and each building taken into account? (example presence of bridge cranes...)
    - Handling of coactivity during works
    - Conditions and requirements during works, specificities per site/building
    - Maintenance organisation
    - Constraints bound to maintenance

- Technical parameters
    - Kind of panels, provider, characteristics (peak power, material, technology…), origin, quality…
    - Quality warranties
    - Implantation of panels on the roofs
    - Reinforcement of structures and frames
    - Kind of inverters, provider, position, expected replacement
    - Principles of grid-connexion (low-voltage / high-voltage; one point / several points…)
    - Integration of risks in the proposition
    - Other equipment requirements (room for inverters…)
    - Tightness kept
    - Possibility to improve buildings insulation
    - Followed norms, certifications, labels…
    - Security against fire
    - Electrical security
    - Supervision and integration in the building technical control software of DCNS
    - Total power expected (kW_p)
    - Total production expected (MWh/year)
    - Total area expected (m^2)"

- Environmental parameters
    - Presence of a life-cycle assessment of the project, consistency
    - End-of-life recycling
    - Origin of materials
    - Sustainable development approach within the company
    - Sustainable development approach during installation
    - CO_2 emissions saved

- Health and safety parameters
    - Recognition of DCNS health and safety requirements
    - Proposed health and safety organisation

- Financial parameters
    - Proposed financial package
    - Feed-in tariff / total sold per year
    - Total investment
    - Yearly rent to DCNS, actualisation
    - Grants possibilities
    - Other benefits
    - Financial soundness of the company
    - Durability of photovoltaic activity in the company
    - Group belonging
    - Experience

- Juridical parameters
    - Example of a lease provided ; pertinence
    - Legal framework
    - Tasks and responsibilities distribution between companies
    - Possibility for DCNS to choose that the company removes the panels and redoes the roofs at the end of the lease ; end-of-lease scenarios
    - AOT - COT

- Insurances
    - Examples of insurances contracts provided, relevance
    - Responsibilities and insurances
    - Relevance of insurances

- Other parameters
    - Presence, reactivity, proactivity during consultation
    - Respect for timelines
    - Presentation of the report
    - Respect for the specifications
    - Organisation of a visit of a photovoltaic installation
    - Additional propositions (parking coverings, facades, brise-soleil…)
    - Offer defence

Table was filled for all companies, using their offers, offer defences, and following questions and discussions. Questionnaires were sent to them, with questions about important information missing.

A system of grades was then applied to these parameters. For each line in the table, a coefficient between 1 and 3 was attributed, and a grade between 0 and 3 could be given. The questionnaire was given to all persons involved in the project so that all points of view could be expressed. At the time this report was written, the final offers had not been received because of government's moratorium and no knowledge of the future of the project, so no grade had been given to companies' offers.

Economical comparison

Some economical calculations were carried out in order to compare offers with different boundaries (number of buildings/sites, inclusion of external costs…), based on former feed-in tariffs, and can be seen in Table 14.

	Enertime	EDF EN	Ikaros	Eolfi	Sol Finances
Investment (M€)	24	8,5	19	19	20
Sold electricity (M€/year)	3	1,1	2,9	2,5	1,8
Rent (k€/year)	107	49	201	-95	81
Area (m²)	47363	16138	?	?	34600
Power (MW_p)	7,5	2,5	6,8	5,8	4,8
Produced electricity (GWh/year)	8,2	3,1	7,9	6,7	4,8
Average productibility (kWh/kW_p)	1083	1235	1168	1151	989
Gross ROI	8,12	7,54	6,35	7,58	11,27
ROI including rents payments	8,42	7,88	6,82	7,30	11,81
Rent compared to electricity sold (%)	3,55	4,34	6,86	-3,84	4,57
Investment per unit of power ($€/W_p$)	3,25	3,44	2,74	3,23	4,12
Investment per unit of electricity produced (c€/kWh)	15,01	13,93	11,74	14,02	20,84
Investment per m² (€/m²)	516,67	526,71			577,62
Rent paid per unit of power installed ($€/kW_p/year$)	14,22	19,85	29,65	-16,38	16,73
Rent paid per unit of electricity produced (€/MWh)	13,13	16,07	25,38	-14,22	16,91
Rent paid per m² (€/m²/year)	2,26	3,04			2,34

Table 14: Economical calculations for the five offers

It can be noticed that offers are quite different from each other. The return on investment is spread between 6 and 12 years. The investment per unit of electricity produced, traditional indicator for cost of electricity, is also very spread: between 11,7 c€/kWh for Ikaros and 20,8 c€/kWh for Sol Finances. The rent paid per unit of electricity produced differs also a lot depending on companies, which seems logical as the investment costs differ. Enertime "only" gives 13 €/MWh produced, whereas Ikaros pays 25 €/MWh.

Several things can be learnt from this table. First, Ikaros Solar has much lower investment costs than the other companies. There can be two reasons for that: the company may not include all costs related to photovoltaic panels' installations, such as removal of asbestos or structures reinforcements. If this is the case, one needs to be careful and include these costs in the final economical assessment. Another reason could be that the company uses a simpler system, that is cheaper to install or that is lighter and does not need to reinforce structures. In this case, Ikaros does not include all costs, but it also seems to have a bit simpler system.

Moreover, it can be seen that Sol Finances is very pessimistic regarding the average productibility. One can wonder if they are just careful, or if they give numbers lower than actual ones in order to increase their margins. Sol Finances also has a high investment costs compared to production. One can think that they are more realistic, that they do not want to take any risk and want to be sure all unknown costs will be included, or that they just want to increase their margin. These questions are important, and need to be investigated carefully before choosing the supplier, by requiring all economical details.

Comparison between design offices' offers and own calculations

A comparison has been done between the design offices' offers and the previous estimations carried out. A table with the results for the different buildings can be seen in appendix D. A number of buildings chosen in the previous estimation are the same as the one selected by design offices, but some differ, mostly due to a lack of data about the buildings or economical parameters such as cost of grid connexion or structure reinforcement.

The total power obtained is a quite good average of the design offices' studies. It is less than complete offers (from companies wanting to install photovoltaic on a lot of buildings in all centres), but more than poor offers (from companies only choosing "easy" buildings in the South).

Life Cycle Assessment

At the time this report was written, data from the design offices had not all been collected, so the life cycle assessment could not be carried out. However, the Excel file is ready, with all formulas included and explanations about what need to be filled, so it should be easy to calculate the carbon footprint of all projects as soon as data are available.

A first calculation was done with assumptions and available data to check the consistency of the method and to investigate the impact of several parameters, using parameters described in the “method” part. The table with the numbers and several indicators for the different scenarios investigated can be seen in appendix E.

The first thing that one should notice is that the photovoltaic project has a positive environmental impact in all cases. Even in the worst case (panels produced in China, transported by ship and by lorry, panels removed after 20 years), there are still 161 gCO_2eq/kWh avoided, and 22742 tonnes avoided over the whole life span.

Influence of manufacturing place

As it could have been expected, the place of manufacturing has a big influence on the carbon emissions of the installations. As can be seen in Table 15, emissions avoided over the 30 years life span are 27% lower if the panels have been produced in China than if they are in France (both with lorry transportation when in Europe), decreasing from 281 to 204 gCO_2eq/kWh.
The results are a bit better if the panels are produced in Germany, but are still much lower than if they are in France, due to French low carbon electricity.
Some companies claim that the carbon impact of panels produced in China and Germany are almost the same as both have a lot of coal in their electricity mix and as ships do not emit so much per unit, but the results would tend to contradict this saying.

		A1	**A2a**	**A3a**	**A4a**
		Complete manufacturing in China, transportation ship and lorry	Cells produced in China, assembly in France, transportation by lorry	Complete manufacturing in Germany, transportation by lorry	Complete manufacturing in France transportation by lorry
Emissions due to manufacturing	tonnes CO_2eq	16731	15207	8557	1784
Emissions due to transportation	tonnes CO_2eq	3587	3835	6849	2953
Emissions due to PV electricity production	tonnes CO_2eq	-61633	-61633	-61633	-61633
TOTAL CO_2 avoided over the life cycle	tonnes CO_2eq	41316	42592	46228	56896
Avoided emissions per kWh	**gCO_2eq / kWh**	**204**	**210**	**228**	**281**

Table 15: Comparisons of CO_2 emissions by place of production

Moreover, this comparison allows to contradict companies such as Tenesol who pretend to be “very clean” just because they assembly panels in France. The final output is indeed almost the same (204 gCO_2eq/kWh for panels entirely made in China, 210 if only the cells are constructed there). This is due to the fact that mining and producing wafers is much more energy intensive than just assembling cells together, so the influence of the latter part is not so important.

Influence of mean of transportation

As shown in Table 16, the panels freight also has an important influence on the overall carbon accountings of the installations. The emissions due to transportation are indeed 70 times lower if railway is used instead of trucks! The final value of avoided emissions is 5% lower with trains than with lorries for panels built in France, and 13% for panels built in Germany (this difference is only due to the bigger distance if panels come from Germany)!

		A3a	A3b	A4a	A4b
		Complete manufacturing in Germany, transportation by lorry	Complete manufacturing in Germany, transportation by train	Complete manufacturing in France transportation by lorry	Complete manufacturing in France, transportation by train
Emissions due to manufacturing	tonnes CO_2eq	8557	8557	1784	1784
Emissions due to transportation	tonnes CO_2eq	6849	97	2953	43
Specific emissions due to transportation	kg CO_2eq / kW_p	978	14	422	6
Emissions due to PV electricity production	tonnes CO_2eq	-61633	-61633	-61633	-61633
TOTAL CO_2 avoided over the life cycle	tonnes CO_2eq	46228	52980	56896	59807
Avoided emissions per kWh	**g CO_2eq / kWh**	**228**	**261**	**281**	**295**

Table 16: Comparisons of CO_2 emissions by mean of conveyance

Influence of choice of electricity mix and its evolutions

Finally, it can be noticed, as shown in Table 17, that even if Europe decreases its emissions from electricity production, photovoltaic electricity would still be profitable from an environmental point of view. With scenario 4b (production in France and transportation with train), even if European Union follows its goal of reducing CO_2 emissions by 20% between 1990 and 2020 (i.e. -14% between 2010 and 2020), the photovoltaic installation would still avoid 228 gCO_2/kWh on average, compared to 295 g in the base scenario.

	B4b (Base case - mix UE27 constant)	B4b-Fr (Mix Fr constant)	B4b-20 (Mix UE -20% 2010-2030)	B4b-24 (Mix UE -24% 2010-2030)	B4b-14 (Mix UE -14% 2010-2020)
CO_2 avoided over the life cycle (tonnes CO_2eq)	59807	15204	51313	49614	46189
Avoided emissions per kWh (gCO_2eq/kWh)	295	75	253	245	228

Table 17: Influence of electricity mix on CO_2 emissions

This table also shows the influence of the choice of electricity mix used: if the French mix is used instead of the European mix, the avoided emissions drop a lot, from 295g/kWh to 75! With worse scenarios, such as panels produced in China and transported by lorry, the total even becomes negative (-16 gCO_2eq/kWh): producing the panels emit more than what is avoided… This is due to the low CO_2 content of electricity in France, mostly produced with nuclear energy. However, if one thinks the French electricity mix should be used for calculations, one could also calculate the avoided nuclear waste…

ANALYSIS

An interesting project for DCNS

As can be seen in Table 18, the photovoltaic project for DCNS installations seems to be very interesting, at least with the former feed-in tariffs. The power installed on buildings would indeed range between 2,5 and 7,5 MW_p, and would produce between 3,1 and 8,2 GWh per year. This would cover between 3% and 8% of DCNS electrical consumption, and the revenues from this electricity sold would be between 1,1 and 3 million euros per year.

	Own estimations	**Enertime**	**EDF EN**	**Ikaros**	**Eolfi**	**Sol Finances**
Number of sites	5	6	2	7	4	7
Installed power (MW_p)	6,8	7,5	2,5	6,8	5,8	4,8
Production (GWh/year)	7,0	8,2	3,1	7,9	6,7	4,8
Electricity sold (M€/year)	2,6	3	1,1	2,9	2,5	1,8

Table 18: Summary of several parameters for the estimation and design offices offers

One thing that can be regretted is that all companies have chosen the same technologies. All of them only use crystalline silicon panels, either monocrystalline or polycrystalline. It would have instead be appreciated if some design offices had proposed something original, or to install, in addition to classical panels, some new technologies demonstrators. This could have been used by DCNS to show its willingness of supporting innovation, and would have enabled these companies to test something new.

The project (again, with the former feed-in tariffs) is moreover interesting for DCNS both as an investor and as a lessor. Investing directly in the project would indeed give a much higher profit, but is also much more risky. DCNS would indeed be owner of the installations, and thus responsible for the maintenance and for any problem occurring. If the panels were not working as good as expected, the loss of money would also be for DCNS. On the other hand, if DCNS is only lessor, all the risk panels create is covered by producers, and DCNS does not need to care about the electricity production and the maintenance. It would get a much lower rent every year, but this rent would be fixe and decided in advance.
At the time of the redaction of this report it was not really decided which model would be chosen, but more likely DCNS would be lessor, or a combination of both (a lessor with some participation in the project company, which gives advantages from both possibilities).

Calculations differences

There are quite big differences between own estimations of the potential and offers from the design offices. Several reasons can explain these differences.
First, buildings included in the estimation are basically all buildings with roofs having good properties for photovoltaic installations (no shadow, oriented mainly to South, not too many chimneys and other objects on top…). This means that several criterions and problems were not taken into account, which could lead to removing buildings from the list. First, some buildings would need an important renovation to reinforce their structures and roofs, which could be too expensive. Moreover, some buildings still have asbestos in the roof, and if the area is too small this will lead to too important costs. Finally, some buildings are located too far from other buildings, and costs for electrical connexion would be too high.
Furthermore, for some sites (like Cherbourg for example), a lot of data were lacking, and thus the estimations are very approximate. When "AutoCAD" maps were available, areas measurements were done using this software, but when they were not, areas were only estimated using pictures or Google Maps, which is quite imprecise. Some buildings have also been removed only because of a lack of data, whereas they could have been chosen.

However, it should be noticed that offers also differ a lot one from each other, and the estimations that had been carried out previously were not so bad, and quite a good average of companies' proposals. These differences between offers can be explained by several factors.
First, companies do not all use the same level of risk, and do not have the same kind of risk management.
Moreover, companies do not have the same profitability requirements. Some of them want a short return on investment (less than 7 years for instance) whereas some others can accept a much longer one (such as 12 years). It was noticed that big groups require higher levels of returns on investments, which is why they only chose Southern facilities.
Furthermore, companies do not make the same technology choices. For example, some of them (for example Spie) excluded all flat roofs, whereas others (for example EDF EN and Ikaros) chose a lot of them. That is really a pity because it means that – maybe - no company includes all possible buildings. It would be more interesting if companies would propose a partnership with other companies using other technologies so that they can equip as many buildings as possible.
What is more, there seemed to be a choice to do between choosing a lot of buildings per site, which should induce scale savings, and choosing fewer buildings close from each other, with lower electrical connexion costs.
There are also big differences between offers regarding financial aspects, for example rents between minus 95 k€ and plus 200 k€ per year, and wide investment costs differences. These can also be explained by the level of return on investment and the risk management the companies use. It also reflects differences in costs taken into account: for example Ikaros does not include asbestos removal or structures reinforcement in its costs, whereas other companies do. As a consequence, it is very important to check what is actually taken into account in costs for each offer before choosing the cheapest one.

A sector under development

This project shows the immaturity of the photovoltaic sector in France.

On the one hand the government prevents companies from having a long term view. It changes indeed rules all the time, with for example three changes in feed-in tariffs in less than one year! Feed-in tariffs can suddenly drop a lot, without anybody being told about it. As a consequence, companies have to do smaller projects and block the feed-in tariff quickly, because they know that otherwise the rules might change in the meanwhile.
There also seems to be a lack of trust between companies and the government. The government indeed not only changes rules constantly, but also makes retroactive laws, which is difficult to handle for small or medium-size companies.

A scandal was also broken during moratorium, with heavy accusations against EDF EN, subsidiary of EDF, previous France unique electricity company and still mainly controlled by the state. They were accused by other companies of:

- being aware of new decrees about feed-in tariffs in advance, so that they were able to submit a lot of projects just before;
- having started a second queuing list at another of their subsidiaries (RTE*), that they were the only ones to know;
- being responsible for the main part of the queue and for speculation, due to a high numbers of fake projects or easy projects, bringing a lot of money;
- installing very big projects (300 MW_p ground-mounted project in South of France for example) whereas only less than 12 MW_p projects can officially benefit from feed-in tariffs, and for that separate their projects in a lot of small projects with several companies created;
- cheating at the beginning of the moratorium in antedating documents so that they were accepted, with the help of ERDF* and RTE.

All of this did not help creating a climate of trust, especially as the government did not do anything to prevent this kind of behaviour.

On the other hand, companies do not really seem to be able to carry out such big industrial projects, but rather to be more used to cover small houses or agricultural buildings. It seems to be even worse with big groups, such as EDF EN, Tenesol and Veolia. These do not seem to be flexible at all, and to be only looking for maximal profits and high return on investment rates. For example, EDF EN and Veolia only accepted to study facilities located South. They also do not seem to be very honest. For example, Tenesol pretended that it was sure the project would still be feasible, interesting and profitable after the moratorium, and thus wanted DCNS to sign a contract of exclusivity, so that Tenesol could carry out the studies and DCNS could not choose another company. Of course DCNS did not accept, and Tenesol gave up the consultation a long time before the end of the moratorium, when no decision of the government was known and hope was still possible, forgetting all its promises.

Smaller companies seem to be more interested in the project in itself and better listening to DCNS wills. Companies such as Spie or Ikaros understood both DCNS industrial and confidentiality complexity, and its will of installing photovoltaic panels on all centres, with an objective closer to developing a green image and acting as an example than earning a lot of money from it. They proposed an offer that was covering all centres, with real answers to questions such as coactivity, insurances, buildings capacities…
The Belgian company that was consulted (Ikaros Solar) seemed to be more pragmatic than French companies. However, they probably do not realise the French juridical and administrative specificities and heaviness: for example, it was discovered that a project that would take two months in Belgium would take at least one year in France!

Follow up of the project

At the time this report was written, no decision had been taken about the future of the project, if it would be continued or not and how.

Discussions need now to be started with the companies in order to decide of the future of the project. Questions that need answers are: is the project still feasible from an economical point of view? What feed-in tariff should be proposed? Are the same buildings kept, or should some of them (the ones with highest costs) be removed? Should the project be kept as ambitious as before? As it is now, DCNS project would cover between one third and one quarter of the cap for industrial roofs: is it reasonable to think it can be accepted? Can DCNS take advantage of the fact it is partly state owned, or of its good relations with the states? Should that be done from a moral point of view?

DCNS and the photovoltaic companies now have several choices. They can decide to continue the project to the same extent as before. This means they will have to answer to invitations to tender, and probably to one per site. This will necessitate a heavy work, but can be really interesting if it works. The problem is that it is difficult to decide that now as the invitations to tender are not written yet. Another choice is to continue the project, but to a much smaller extent. Photovoltaic installations can be lowered down to 100 kW_p per site, keeping only the best oriented and easiest buildings, so that they can benefit from normal feed-in tariffs, and do not need to answer to invitations to tender. Also, a third possibility is of course to give up the whole thing, but this is not the favourite option.

Life Cycle Assessment

The results of the CO_2 life cycle assessment show the importance of several parameters in the final environmental benefit.

The example of panels produced in China has been taken because it is common, but the conclusion can be expanded to all carbon-intensive electricity mixes. Producing panels in a country that uses a lot of fossil fuels to produce electricity is much less beneficial than manufacturing them in a country with low-carbon electricity.

Moreover, mean of transportation also has a quite big impact. Thus it is important to try to produce as close to the place where it will be used as possible. Furthermore, railway transportation should be preferred as much as possible. For that, policy instruments are needed, because it is today not always possible to use railway transportation, and it is usually more expensive.

Finally, this carbon accounting shows the importance of such calculations. Environmental parameters are more and more a criteria in companies' decisions. It has been seen that today none of the photovoltaic companies is able to provide a real life cycle assessment or carbon accounting of its products and installations, whereas it is something wanted by customers. So design offices and big photovoltaic companies should really work on that topic, in order to be able to provide all data to their customers. This would also enable to select the best projects from an environmental point of view, which was one of the criticisms of the government during the moratorium. Having an exemplary industry is important when critics are so numerous against it...

When the project can start over, the methodology should be used with the data from the different constructors, in order to be able to compare environmental benefits from the different offers and include them in the final choice.

DISCUSSION

Influence of external elements

This thesis has enabled to highlight how big the influence of governments can be on companies' projects. This shows the importance of consistent and lasting policy instruments.

Another parameter that was noticed is that one should not always trust big companies from big groups. In this project, one of them pretended indeed, at the beginning of the moratorium, that the project would for sure be possible and profitable after the moratorium, even if feed-in tariffs dropped a lot, but then gave up before end of moratorium, because DCNS did not want to definitely sign with it. This shows that if these companies do not sign a kind of contract of exclusivity at the very beginning of the project, they do not want to invest money and do not want to take any risk, even if they are more able to invest than smaller companies. So one lesson from this thesis is that one should be careful with this kind of companies, in this sector, and really deeply investigate the offers and proposals, and not accept first good-looking proposals from companies very good at communicating…

Results

The results of the estimations of photovoltaic potential in this study are very approximate. One reason is the lack of experience and practical knowledge in this field. One needs indeed to have very specific economical and technical data in mind in order to carry out a more precise study. For example, one needs to know the cost of reinforcing structures, or connecting a far building to the grid. Another reason is that a lot of data are needed, and a lot of them were simply not available. Some of them do not exist at all, whereas others are complicated and long to find. But these data will be needed if the project goes on, so DCNS will have either to find these data, or to finance studies to calculate the missing ones (for example roofs maps and roofs capacities).
The calculations carried out are also not very precise. The area of the roofs is especially sometimes very imprecise, when numerical maps and photos were not available. However, it can give an idea of the area available on the chosen buildings. Moreover, calculations seem to be consistent as they are in the middle of the offers received by professional design offices.

It has also been seen that offers received from different design offices are very different from each other, and cover wide ranges of installed powers. This can also be another consequence of the previous observation: at the hand of a lack of data

and information, some companies are more careful, whereas others are more optimistic.
It is therefore difficult to get a real idea of what is actually possible to be done on the roofs of DCNS, and further investigation is needed.

One thing that could be done in the future to prevent such problems, for this project or for other projects, is to specify more clearly what is asked from the beginning. In this case, a collection of all available data and documents could have been done at the beginning of the consultation, so that all companies have the same input data. Moreover, because of the moratorium and the expected decrease in feed-in tariff, it should have been decided at the beginning what hypothesis companies should use in their offers, for example if they should use the previous feed-in tariff, this tariff minus 10% or this tariff minus 20%, if they should include environmental parameters because of a possible inclusion of them after the moratorium, how they should deal with the possible new definition of building integration, or if they should do their own – as realistic as possible - hypotheses, etc.

Influence of internal elements

It is not easy to carry out such a project in such a big company.

First, this kind of project is never the priority for people, as it is not the core business of DCNS, but only something that is done in addition, “for fun” or to develop a so-called environmental friendly image. So a lot of people consider it as a waste of time, as something that prevents them from doing their real jobs. This is even truer for this project as some people do not believe in photovoltaic energy and consider it as polluting and expensive.

This is a crucial parameter, as a lot of different actors are involved in such a project. The infrastructure teams are key players. They were indeed in charge of making visits for the design offices, finding and providing them the necessary documents, and give opinions about the chosen buildings and how they could be affected. In the next stage of the project, their role will be even more important as they will have to discuss the technical parameters (resistance of buildings, organisation with regard to activity inside of the buildings, access to the site, space for stocking materials…) with the design offices, installers and DCNS head office. They should thus feel really concerned by the project.
Other persons involved include juridical and insurances services. They were already integrated in the project in the first stage, and have raised a number of issues. This project represent indeed a risk for DCNS, and everything should be studied in details and locked so that nothing bad can happen, or that insurances can cover everything. That is why insurance and juridical services are already demanding with design offices.

It has been noticed that all actors are not enough involved or do not feel enough concerned. This is one very important point that the project team needs to work on in the near future. For such a project, everybody should really feel involved in the project and believe in it. Currently, a lot of persons, especially in the facilities infrastructure teams, think they are only been given additional workload, without being involved in the decision process. So it is crucial to explain everybody the project once again, and propose them to be part of the decisions.

Local environmental services were also not very involved. So it is important to include them in these projects too, because otherwise they can have the feeling that the head office is doing their job instead of them. So energy questions should really be part of local environment advisers, and these should be involved in the project.

All of this shows the importance of communication. Every concerned employee from every service from every centre should be involved in the project, and be aware of its evolutions. In the future, the project management team should give them information, reassure them if they are afraid of something, convince them of the good of the project and what it will bring to DCNS. Another possibility is to delegate the project directly to the sites, so that the project is conducted locally by the impacted persons.

Environmental analysis

The CO_2 LCA carried out in this thesis is, as explained previously, approximate. But it still gives an order of magnitude of the photovoltaic installations impact, and it allows comparisons between different scenarios. In the simulations done, data are imaginary, as the data from the design offices were not available yet. But they are taken from different sources, and especially from photovoltaic panels constructors' technical data.
The results seem to be consistent. It can be compared to ADEME's value of 55 gCO_2eq/kWh emitted by manufacturing and transportation, to which one needs to remove the emissions avoided, 304 gCO_2eq/kWh if the European mix is chosen. This makes a total of 250 gCO_2eq/kWh avoided, whereas calculations give values between 161 and 295 depending on the parameters.
When the actual data from the design offices will be known, the excel file should enable good comparisons between offers.

These –even approximate – results show the importance of such environmental impact studies. The outcome can indeed vary a lot depending on the means of conveyance used and the place of production. It probably also depends on which company produces the panels (it can indeed make efforts to be more or less energy-intensive, or change electricity producer), but that could of course not be taken into account yet. So it seems important that companies start to do their own carbon accounting or life cycle assessments of their products. This would enable the final customer to make good choices, knowing the real environmental benefits of its actions.
This is something that can for that matter be found in the moratorium output: for projects having a power over 100 kW_p, a system of invitations of tenders will be set, and such environmental parameters are planned to be included. Companies will thus be obliged to carry out such studies.

CONCLUSION

The subject of this thesis was to study the techno-economical feasibility of developing photovoltaic installations within the company DCNS. The answer to this question should be separated into two parts, and unfortunately half of it cannot really be answered yet.

It has been shown that from a technical point of view, this project is totally viable. A lot of buildings are indeed suitable for photovoltaic installations, and due to its position along the French coast DCNS benefits from a quite good sunshine. The estimated electricity production would cover between 5 and 8% of DCNS' total electricity consumption, which is really good.

On the other hand, from an economical point of view it is far from sure that the project will be suitable. With the previous feed-in tariffs, it was interesting. DCNS could have been investor or lessor, and it would have been profitable in both cases. Today, after the moratorium, the situation is different. DCNS and the photovoltaic company will have to respond to invitations to tenders, it is not sure the projects will be accepted, and it is not known at what tariff the electricity will be bought. Depending on this tariff, the project can either keep being profitable, or become economically unsuitable. Another possibility is to decrease the size of photovoltaic installations a lot, so that DCNS does not need these invitations to tenders, and instead simply sells its electricity. But in that case the project would lose a lot of its soul…

What is sure today is that almost everything needs to be done again, and a lot of concessions will have to be accepted.
Several points should be really investigated in order to increase the chances that the project succeeds. To begin with, DCNS should show how important the image of such a project would be, and not only for it. DCNS indeed belongs to a big extent to the state, and DCNS and the state are still linked together in a lot of people's minds. So benefits, especially communicational benefits, would also indirectly profit to the state. Several of DCNS installations are furthermore located inside arsenals, where the visibility is very important, and this would be a good example for militaries.
Furthermore, DCNS should work on the different criteria that will be in these invitations to tender. The environmental aspects should for example really be taken into account, and DCNS should try to use French, or at least European materials, if possible conveyed by train, and be sure they can be recycled. From a social perspective, DCNS should try to work with local companies and with local workers. Finally, building integration and urban aspects are very important, and should be perfectly treated.

This kind of project is very interesting to develop in big industrial companies such as DCNS. Several things can be learnt from this project, that should be kept in mind for its future, and for other projects of this kind. First, communication is really important, and especially as it is such a big company, with facilities all over France. It is important to explain the projects to everybody, and that all concerned persons feel really involved in them. Otherwise, people feel like they are just asked additional work, that will benefit somebody else or that is useless. This point is really something to improve in the future.
Moreover, it is important to organise things well in advance, and set up feasible deadlines, both for DCNS employees and for external companies. This also enables people to better organise their work, which makes them more available for the project. In the same idea, project specifications should be well written and detailed from the beginning, to avoid misunderstandings.
By doing so, DCNS will be able to continue developing energy efficiency and renewable energies projects more serenely, and probably even more successfully.

For that, one good thing would also be to have a stable political context, without incentives changes every six months. This is true for photovoltaic energy, but also for other environmental policies. Without discussing politics, a government should be consistent and coherent, so that companies are able to have a long-term view. In the case of photovoltaic industry, DCNS was not in the worst position as it had just started its photovoltaic project; for some companies on the other hand it has been much worse, as they had to totally give up much more advanced projects on which they had been working for a long time.

This thesis has also been extremely interesting from a personal point of view. I first got a lot of knowledge in the field of photovoltaic energy. Specialised in energy systems, I did not know so much about this specific energy, and I learnt a lot about the technologies, the environmental impacts, organisation of the industry worldwide, politics and the importance of feed-in tariffs before reaching grid-parity.
I also learnt a lot in project management. I was indeed practically energy project manager at DCNS, and supervised this project and others to a smaller extent. It was thus very interesting to discover project management with such a big project in a big company. DCNS was in addition previously public and thus still has a quite heavy administration, which enables to discover problems such as administrative rules, confidentiality or communication.

GLOSSARY

ADEME (“Agence De l’Environnement et de la Maîtrise de l’Énergie”): French Environment and Energy Management Energy agency, public organism in charge of encouraging, supervising, coordinating, facilitating and undertaking operations with the aim of protecting the environment and managing energy.

CSTB (“Centre Scientifique et Technique du Bâtiment”): Scientific and technical building centre, French undertaking created in 1947 to deal with reconstructing the country. Today working within 4 areas (research, expertise, valuation, knowledge broadcasting) to answer to sustainable development objectives in the field of construction materials, buildings and their integration in cities. Responsible for photovoltaic panels integration certification.

EDF (“Électricité de France”): French Electricity Company, state owned and monopoly until 2004, today 85% of the capital still belongs to the state.

EPIA: European Photovoltaic Industry Association, world’s largest solar photovoltaic industry association, representing companies from the whole photovoltaic value-chain.

ERDF (“Électricité Réseau Distribution France”): 100% subsidiary of EDF, born from the division of activities at EDF when it was privatised, responsible for the French electricity distribution grid.

GDF (“Gaz de France”): French Gas Company, state owned and monopoly until 2004, today 80% of the capital still belongs to the state.

RTE (“Réseau de Transport d’Électricité”): 100% subsidiary of EDF, born from the division of activities at EDF when it was privatised, responsible for the French high voltage electricity grid.

SER (“Syndicat des Énergies Renouvelables”): Renewable Energies Union

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APPENDIXES

A. Project plan – 06. October 2010

		13-Sep	20-Sep	27-Sep	4-Oct	11-Oct	18-Oct	25-Oct	1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec	20-Dec	3-Jan	10-Jan	17-Jan	24-Jan	31-Jan	7-Feb	14-Feb	21-Feb	28-Feb	7-Mar
	Week	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Action																										
Discovery of the company, its different projects and locations																										
Literature research about solar energy																										
First estimations of photovoltaic potential on the different buildings																										
Writing of specifications for PV consultation																										
Beginning of design offices' consultation for pv projects																										
Study of the buildings architecture and roofs, advices for pv installations																										
Visits of companies clients installations																										
Economical calculations, investigation of contracts possibilities																										
Design offices' data collection and analysis, check of consistency																										
Choice of companies for first stage																										
More detailed studies from the chosen design offices																										
Final follow-up and negociations with a short list of companies																										
Recommandations for PV installations																										
Choice of supplier																										
Juridical and administrative aspects, contracts writing																										
Works beginning and follow-up																										
Writing of documents for future projects in the company																										
Report and presentation of Master's thesis																										

B. Specifications sheet (in French)

Division Services Brest

CHAMPIONSHIP - PLAN ENERGIE

Etude d'opportunité de l'installation de panneaux solaires photovoltaïques sur l'ensemble des sites DCNS

EXPRESSION DE BESOIN

Rédaction	Vérification	Approbation
Benjamin CAER NSE / BECC / MMS Chargé d'études Nom, Entité, Fonction	Cédric AUVRAY NSE / BECC / MMS Chargé d'études Nom, Entité, Fonction	Charles CROZON NSE Responsable performance industrielle Nom, Entité, Fonction
30/06/10 Date, Visa	08/07/2010 Date, Visa	15/07/2010

DOCUMENT SOUMIS À ACCEPTATION Client OUI ☐ NON ☒ DOCUMENT ACCEPTE ☐

Référence du document : Réf. ? Indice **A**

DCNS	Installation de panneaux photovoltaïques	Page 2 / 10
	EXPRESSION DE BESOIN	

Suivi des modifications

Indice	Date	Pages modifiées	Paragraphes modifiés	Description de la modification	Auteur
A	30/06/2010			Rédaction initiale du document	B.CAER

DCNS	Installation de panneaux photovoltaïques **EXPRESSION DE BESOIN**	Page 3 / 10

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Référence du document : **R é f ?** Indice **A**

Avant utilisation d'une version papier s'assurer de son état de validité.

Sommaire

1 OBJET DU DOCUMENT

Dans le cadre du plan Energie DCNS et notamment de son chantier « nouvelles énergies », DCNS souhaite étudier la possibilité d'installation de panneaux solaires photovoltaïques sur les toits des bâtiments de l'ensemble de ses sites et de profiter de la revente d'électricité via un opérateur responsable de cette installation.

Ce document a donc pour but d'exprimer les besoins et les contraintes de DNCS dans ce domaine.

2 DOCUMENTS APPLICABLES

D'une manière générale, les prestations proposées par le titulaire devront être conformes aux directives, réglementations, normes, recommandations françaises et européennes en vigueur. Les règlements spécifiques aux sites DCNS seront également appliqués, en fonction de la localisation des travaux (processus internes, contraintes d'accès, etc.).

3 DOCUMENTS DE RÉFÉRENCE

Les documents généraux relatifs aux bâtiments concernés seront fournis par DCNS :

- Plan général des sites DCNS concernés, avec échelle et orientation des bâtiments
- Descriptif succinct des toitures et photographies d'ensemble (type de toiture, état général…)
- Contraintes juridiques, notamment pour les sites et bâtiments en AOT / COT

4 GLOSSAIRE ET DÉFINITIONS

AOT	Autorisation d'Occupation Temporaire
COT	Convention d'Occupation Temporaire
PV	Photovoltaïque
ROI	Retour sur investissement (Return On Invest)

5 DÉFINITION DU BESOIN

5.1 OBJECTIFS

L'objectif est de définir conjointement entre l'opérateur, son bureau d'études techniques et DCNS, les modalités d'implantation de panneaux photovoltaïques sur les différents sites de DCNS et les conditions de revente.

Pour ce faire, différents aspects seront pris en compte et justifiés par l'opérateur : aspects techniques, financiers, juridiques, environnementaux. Ces points sont détaillés ci-après.

5.2 SITES D'ÉTUDE

L'étude sera à réaliser sur l'ensemble des sites DCNS c'est-à-dire :

- Brest (29) ;
- Cherbourg (50) ;
- Lorient (56) ;
- Nantes-Indret (44) ;
- Ruelle (16) ;
- Toulon (83) ;
- Saint-Tropez (83).

5.3 DÉROULEMENT DES OPÉRATIONS

5.3.1 ETAPE 1 : VISITE DES SITES

Le bureau d'études mandaté par l'opérateur effectuera une visite détaillée de chaque site DCNS et pourra avoir accès aux documents internes nécessaires à la réalisation de son étude (plans des bâtiments…). Une visite complémentaire s'avèrera certainement nécessaire :

- Visite n°1 : sélection de bâtiments en fonction des dimensions et des orientations des toitures (vérification des renseignements visibles sur plans au préalable)
- Visite n°2 : accès toitures si nécessaires et précisions pour établir les données d'entrée de l'étude de faisabilité

Chaque site désignera un unique interlocuteur qui sera le point d'entrée de l'opérateur, et qui aura pour mission de faciliter le déroulement de la prestation. Les documents de référence généraux concernant les bâtiments seront réunis au préalable par DCNS et fournis au prestataire.
A l'issue des visites, l'opérateur précisera les points sensibles et les questions en suspens, auxquelles DCNS cherchera à répondre (exemple : types de toitures, etc.). En cas de manque de données d'entrée, des hypothèses seront formulées et validées conjointement.

5.3.2 ETAPE 2 : ETUDE DE FAISABILITÉ

En se basant sur les données recueillies lors de la visite des sites ainsi que celles qu'il jugera nécessaire (données climatiques…), l'opérateur réalisera une étude de faisabilité d'implantation de panneaux photovoltaïques sur chaque site DCNS qui prendra en compte les aspects cités ci-après.

Remarque : l'étude porte principalement sur l'implantation de panneaux photovoltaïques en toiture des bâtiments de DCNS, mais toute proposition élargissant l'offre (par exemple, utilisation des parkings et zones de circulation piétonne, façades, brise-soleil…) est bienvenue et encouragée.

5.3.2.1 Aspects juridiques

L'opérateur se rapprochera de la direction juridique de DCNS afin de s'assurer de la faisabilité réglementaire du projet, particulièrement en ce qui concerne les sites de Brest et Toulon dont DCNS n'est pas propriétaire (bâtiments en COT / AOT).

Il faut noter que la réalisation éventuelle de la présente opération sur les sites en COT/AOT sera liée à la faisabilité juridique et à l'accord du propriétaire, après présentation du dossier technique « projet photovoltaïque » contenant les offres des opérateurs répondant à la présente consultation.

5.3.2.2 Aspects techniques

L'opérateur précisera :

- le type et le fournisseur des panneaux ainsi que leur mode d'implantation sur les toitures. Il s'assurera entre autres de la compatibilité d'installation de panneaux solaires en fonction de l'activité du bâtiment concerné et de l'encombrement de sa toiture (par exemple, cheminées de sorties de gaz).
- son besoin en termes d'équipements annexes : surface et caractéristiques nécessaires du local onduleur, etc.
- son besoin en termes de raccordement : tension, exigences spécifiques… (NB / le raccordement se fera a priori en limite de propriété)
- la liste des travaux à effectuer et le planning associé, et notamment ceux qu'il ne prévoit pas d'être à sa charge, ainsi qu'une estimation de leur coût (désamiantage par exemple).
- dans quelle mesure les travaux d'implantation des panneaux nécessiteront une gestion de la coactivité dans les ateliers en fonction des différentes phases (besoin d'intervenir avec un local vide ou non, etc.).
- le besoin en maintenance (fréquence et durée) des panneaux photovoltaïques.

L'opérateur présentera succinctement sa méthode et ses résultats de calcul en justifiant les hypothèses retenues notamment concernant les données météorologiques. L'opérateur fera apparaître dans son rapport les éléments suivant :

- La surface de capteur prévue sur chaque bâtiment du site (m²) ;
- La puissance totale prévue (Wc) ;
- La production solaire prévue (kWh/an).

5.3.2.3 Aspects calendaires

L'opérateur fournira un planning prévisionnel comprenant la phase de demande de raccordement et la phase de travaux. Il précisera quelles sont les conditions météorologiques pénalisantes pour le chantier d'installation.

5.3.2.4 Aspect financiers

Le bilan financier sera fait sur une durée de 20 ans d'exploitation (durée des contrats EDF).

Seront à charge de l'opérateur a minima :

- la(les) visite(s) de site
- les études techniques
- les demandes de raccordement au réseau
- les travaux de préparation des toitures et d'installation des panneaux
- les travaux d'étanchéité
- les opérations de maintenance

L'opérateur précisera :

- ses engagements financiers sur la revente : prix de rachat du kWh auprès de DCNS, garanties, règles d'actualisation des prix si existantes ;
- les possibilités de subventions, si elles incombent à DCNS ;
- les exclusions techniques (opérations qu'il ne prévoit pas à sa charge, hypothèses prises en compte mais pouvant s'avérer inexactes, etc.) et les coûts associés pour DCNS ;
- une estimation du retour sur investissement pour DCNS.

La proposition fera la synthèse des différentes schémas possibles (DCNS investisseur, DCNS bailleur, …).

5.3.2.5 Aspects environnementaux

Un des objectifs est de s'inscrire dans une démarche de développement durable.

L'opérateur précisera donc dans son étude de faisabilité :

- le bilan carbone et l'ACV (analyse du cycle de vie) des solutions proposées, en fonction des données disponibles ;
- un plan assurant le recyclage de l'ensemble de l'installation en fin de vie (prise en compte des déchets, notamment le silicium) ;
- l'impact visuel de ses solutions (photographies d'exemples installés, etc.)

5.3.2.6 Aspects sécurité

Au sens de la sécurité des personnes et des installations, l'opérateur précisera :

- Les moyens et l'organisation proposés pour garantir la sécurité des installations pendant les travaux et en fonctionnement
- Les moyens et l'organisation proposés pour garantir la sécurité des personnes pendant les travaux et en fonctionnement/maintenance

5.3.3 ETAPE 3 : DEMANDE DE RACCORDEMENT AU RÉSEAU EDF

L'opérateur effectuera les demandes de raccordement et prendra à sa charge leur coût.

6 FOURNITURES ATTENDUES

A l'issue de l'étape n°2, l'opérateur fournira un rapport synthétisant la ou les solutions proposées pour chaque site DCNS qui contiendra les informations demandées ci-avant.

7 ANNEXE : LISTE DES CORRESPONDANTS SITES ET SIÈGE

Brest	Diane Dhomé	Ddhome.exterieur@dcnsgroup.com	**Services Brest- NSE** CS 72837 - 29228 Brest cedex 2 Tél. : +33 (0)2 29 05 20 00 Fax : +33 (0)2 33 95 58 97 N° SIRET : 441133808 00036
Lorient	Jean-Jacques Danard	Jean-jacques.danard@dcnsgroup.com	**Chantier Naval de Lorient -** NSE rue Choiseul - 56311 Lorient cedex Tél. : +33 (0)2 97 12 10 00 Fax : +33 (0)2 97 12 14 25 N° SIRET : 441133808 00036
Cherbourg	Hervé Traisnel	Hervé.traisnel@dcnsgroup.com	**Centre de Cherbourg**- NSE BP 440 - 50104 Cherbourg-Octeville cedex Tél. : +33 (0)2 33 92 10 00 Fax : +33 (0)2 33 95 58 97 N° SIRET : 441133808 00028
Toulon	Pierre Cador	Pierre.cador@dcnsgroup.com	**Services Toulon** - NSE BP 517 - 83041 Toulon cedex 9 Tél. : +33 (0)4 94 09 09 75 Fax : +33 (0)4 94 18 26 61 N° SIRET : 441133808 00077
Saint-Tropez	Patrick Sardelli	Patrick.sardelli@dcnsgroup.com	**BU Armes Sous-Marines** BP 240 - 83997 Saint-Tropez cedex Tél. : +33 (0)4 94 79 44 44 Fax : +33 (0)4 94 43 44 80 N° SIRET : 441133808 00069
Indret	Alexandre Boschat	Alexandre.boschat@dcnsgroup.com	**Centre de Nantes-Indret -** NSE 44620 Indret-La Montagne Tél. : +33 (0)2 40 84 85 00 Fax : +33 (0)2 40 84 87 56 N° SIRET : 441133808 00051
Ruelle	Philippe Soulet	Philippe.soulet@dcnsgroup.com	**Centre de Ruelle** - NSE BP 30 - 16600 Ruelle Tél. : +33 (0)5 45 24 30 00 Fax : +33 (0)5 45 24 33 33 N° SIRET : 441133808 00101
Siège	Christiane Tournat	Christiane.tournat@dcnsgroup.com	**Direction juridique** 01 40 59 55 58
Siège	Hervé Mazéas	Herve.mazeas@dcnsgroup.com	**Direction Qualité Sécurité Environnement -** Pilote plan énergie 01 40 59 52 89
Central NSE	Luc Bodennec	Luc.bodennec@dcnsgroup.com	Pilote technique plan énergie - Pilote économies d'énergies 02 97 12 19 57
Central NSE	Charles Crozon	Charles.crozon@dcnsgroup.com	Pilote chantier ENR 02 29 05 39 42

C. Analysis and comparison questionnaire

		Enertime / Tenesol			EDF EN / EDF ENR Solaire		
	Coeff		Grade	Total		Grade	Total
General data							
Proposed number of centres	3	All of them except Brest (6) ; Cherbourg and Lorient can be done only if St Tropez and Toulon are equipped too.		0	Two : St Tropez and Toulon		0
Foreseen timing of works	1	Total time : 15 to 21 months (from beginning of administrative work to grid connexion) ; proposition to start with a demonstration building (ex. Building 30 in Indret).		0	10 months to obtain all authorizations ; 6 to 8 months for installations ; grid connexion delay depends on ERDF.		0
Impact of the project on DCNS activities	2	Nothing said.		0	Nothing said.		0
Quality plan	1			0	Workings : one operations officer EDF EN France + local workings supervisor. Installations controlled by an independent design office after end of works. Respect of "low nuisance charter".		0
Management plan	1			0			0
Technical proposal strength	3	Communication via a didactic notice board per site/building.		0	Didactic notice board with production and CO2 avoided. Learning modules to educate employees to sustainable development / photovoltaic energy.		0
Financial proposal strength	2	Possibility for DCNS to be part of the investment.		0			0
Output data	1			0			0
Transparency	2	Several data are provided (amount if investment per site…)		0	At the beginning no figure provided (investment cost, return on investment, financing, chosen buildings…)		0
Total General data	**16**			**0**			**0**
Industrial organisation							
Industrial organisation consistency	3			0			0
Installation : internal or subcontracted ?	2	Local installers, chosen by Tenesol, with an agreement QualiPV Bat and QualiPV elec ; workings supervised by Tenesol		0	Subcontracted (roofers and tightness specialist partner companies ; electricity done by Photon, EDF subsidiary). Subcontractors certified QualiPV elec or Quali Bat. Operations officer EDF EN, local workings supervisors.		0
Specificities of each centre and each building taken into account ? (example presence of bridge cranes...)	2	Yes, included in costs (example : "construction form" in Lorient ; structures reinforcement…)		0	Included in costs.		0
Handling of coactivity during works	3	Yes, to be decided with DCNS timing of workings determined with DCNS in order to minimize impact on its activities. Possibility to work in the nights or during week-ends if necessary.		0	Yes, to be seen with DCNS. EDF EN will coordinate with DCNS managers in order to plan the workings depending on production inside the buildings.		0
Conditions and requirements during works, specificities per site/building	2	Nothing said.		0	Nothing said.		0
Maintenance organisation	2	Preventive maintenance (cleaning, check up of shadows and components...) + corrective maintenance (always stock of equipment available). Daily remote check-up, possibility to follow production on the Internet.		0	Corrective maintenance with remote monitoring, reparation in less than 48 hours in case of a problem. Preventive maintenance (yearly check-up of tightness, connectors, inverters, electrical components... ; production monitored, cleaning when necessary). EDF EN totally responsible for maintenance and tightness during 20 years.		0
Constraints bound to maintenance	1	Nothing said.		0	Access to the buildings, to be discussed with DCNS depending on the sites.		0
Total Industrial organisation	**15**			**0**			**0**

		Ikaros Solar			Eolfi		
	Coeff		Grade	Total		Grade	Total
General data							
Proposed number of centres	3	All.		0	4 (Toulon St Tropez Ruelle Indret) with DCNS financial participation (no loan) OR 3 (Toulon St Tropez Ruelle) without participation (loan). Could include Lorient maybe.		0
Foreseen timing of works	1	3 steps : preliminary design ; production design ; end of project design. ERDF delays : 12-16 months. Workings : Brest 1 month, Lorient 2 months, Cherbourg 6 weeks, St Tropez 1 month, Toulon 1 month, Ruelle 1 month, Indret 1 month. Proposition to start with a demonstration site (Lorient or St Tropez)		0	Procurement of "non opposition certificate" : 4 to 6 weeks ; procurement of a grid connexion technical and financial proposition : 4 months ; beginning of workings : 6 months after the company has been chosen ; construction of plants : 6 months. per site. From reception of grid connexion proposition : 16 months maximum to commission all generators.		0
Impact of the project on DCNS activities	2	Nothing said.		0	At least 50cm around the modules in order to be able to access to technical installations (smoke vents, air conditioning…)		0
Quality plan	1	Yes, will be done. Used to VCA standard from the petrochemistry industry, that has became the norm in Belgium. Are used to do a lot of quality check-ups. Documented checklists, from the designing to the final realisation.		0			0
Management plan	1	Same.		0			0
Technical proposal strength	3	Panels on top of the roof. Proposition that DCNS already carries out stability and structures studies, and that the chosen company pays them back later, in order to save some time. Communication ; internal or external articles, relations with press. Have a marketing department, with experience for communication on this kind of project. Can also install a didactic notice board at the entrances of all sites.		0	Trainings can be proposed.		0
Financial proposal strength	2	Proposition that DCNS partly invests. Hypothesis taken regarding moratorium : 10% decrease of feed-in tariffs.		0			0
Output data	1			0			0
Transparency	2	A lot of data provided.		0	ok		0
Total General data	**16**			**0**			**0**
Industrial organisation							
Industrial organisation consistency	3	Will associate with a French partner.		0			0
Installation : internal or subcontracted ?	2	Subcontracted. Project management : Ikaros, subcontractors educated and well-qualified (for example famous subcontractors, such as Spie or Cegelec). A rigorous choice will be done, depênding on specialties.		0	Subcontracted (choice of local companies, using call for tenders)		0
Specificities of each centre and each building taken into account ? (example presence of bridge cranes...)	2			0	Not really. Have not visited Indret (Google Maps…)		0
Handling of coactivity during works	3	Existing roof not removed, so neither installation of nets is required, nor activities interruption. Strict rules for work in height (in Belgium stricter than in France) : harnesses, personal protective equipments, aerial lifts, safety barriers…		0	Will "minimize" disturbances during workings.		0
Conditions and requirements during works, specificities per site/building	2	Space for employees / material storage during workings.		0			0
Maintenance organisation	2	Preventive maintenance one a year. In case of a problem, intervention as quickly as possible (yield guarantee anyway, so problem is for them).		0	Maintenance done by Dalkia (subsidy of Veolia) (preventive, repairing of electrical cabinets, cleaning of PV modules); 48 hours maximum to act in case of a problem, 1 week maximum to have a normal functioning back. Centralised supervision. Preventive and corrective maintenance.		0
Constraints bound to maintenance	1	Day and time of interventions decided between DCNS and Ikaros. DCNS has to take into account the possible emergency of the situation.		0	Electricity : 2 maintenance visits per year ; roof / tightness : one visit per year, scheduled in advance. Corrective intervention : need to be able to have access to the pv installations in less than 48 hours in case of a problem. => need of an embryo plan.		0
Total Industrial organisation	**15**			**0**			**0**

	Coeff	SolFinances / Spie	Grade	Total	SolAvenir Énergie	Grade	Total
General data							
Proposed number of centres	3	All		0	5 (Cherbourg, Lorient, Indret, Ruelle, Toulon)		0
Foreseen timing of works	1	Can be provided precisely only after the moratorium. Approximately 18 months between signature with Sol Finances and end of workings. 3 months to receive financial and technical proposition from ERDF, 3 months of studies and workings preparation, 2-3 months to finish and start the installations.		0			0
Impact of the project on DCNS activities	2			0			0
Quality plan	1	Management plan of Quality, Security, Environment.		0			0
Management plan	1			0			0
Technical proposal strength	3	2 kinds of integration (total or simplified). In Cherbourg, 2 grid-connexion points in order to benefit from 2 different feed-in tariffs. Prefabricated shelters for the inverters. Communication : participation to information meetings with employees; didactic board per site/building (at the expense of DCNS!!)		0			0
Financial proposal strength	2	3 propositions (DCNS investor, roof-renting, roof renting with participation in the capital) Financial projection with a production decrease of 8% the first year and 8% over the rest of the 20 years.		0			0
Output data	1			0			0
Transparency	2	Technically very comprehensive about potential and possible installation on buildings, but poor except that (at the beginning nothing regarding juridical, insurances, organisational, environmental, security parameters...). Quite a lot of financial data, but some are missing (column "costs" in the detail of equipments from Spie has been removed for example), which gives some doubts about financial transparency.		0	From a technical point of view : good.		0
Total General data	**16**			**0**			**0**
Industrial organisation							
Industrial organisation consistency	3			0			0
Installation : internal or subcontracted ?	2			0			0
Specificities of each centre and each building taken into account ? (example presence of bridge cranes...)	2	Well seen and explained what the roofs were made of, what is installed on them and what should necessarily be kept. Well integration of problematics of all sites. Different inverter shelters for Ruelle because of the need of "France's buildings architect" agreement.		0			0
Handling of coactivity during works	3	Workings can be done in producing buildings. Roof removal and new roof installation are done simultaneously. Safety nets inside the buildings, with a membrane if there is asbestos.		0			0
Conditions and requirements during works, specificities per site/building	2	Not sure about construction form in Lorient : impossible to uncover the current roof and install the new one without disturbing the production at all. => on-top of the roof ? (but lower feed-in tariff). But structures need to be checked.		0			0
Maintenance organisation	2	Maintenance contract signed with Spie for 20 years, with minimum maintenance guaranteed. Preventives check-up planed, curatives visits 24h/24 on call of DCNS or Sol Finances or on alarms from the remote supervision.		0			0
Constraints bound to maintenance	1	Permanent access to the sites. Free access to water and electricity.		0			0
Total Industrial organisation	**15**			**0**			**0**

	Coeff	Enertime / Tenesol	Grade	Total	EDF EN / EDF ENR Solaire	Grade	Total
Technical parameters							
Kind of panels, provider, characteristics (peak power, material, technology…), origin, quality…	2	Panels Tenesol, manufactured in its factory in Toulouse ; monocrystalline silicon, efficiency > 150 Wp/m² ; size 990*1660*50mm ; peak power per panel : 250 or 260 Wp; cf. technical documentation. Individual control end of factory using electroluminescence. Origin of cells : Germany, Belgium or Asia. By-pass diodes.		0	Monocrystalline silicon modules Suntech, 190-195 Wp; size 1,57*0,808m ; efficiency 153Wp/m² - 15%		0
Quality warranties	1	Maximum efficiency losses 10% after 10 years, 20% after 25 years.		0	80% of initial power after 25 years.		0
Implantation of panels on the roofs	1	Simplified building integrated. Metallic roof integration system Tenesol SIT-M, got a favourable recommendation from CSTB ; 22kg/m² (24 with maximum condensation regulator) ; corrugated steel roof ; ventilation and air flow under it ; possibility to include smoke vents, sky domes...		0	Simplified building integrated. Roof integration "Helios B", designed by EDF EN and Marchegay, structure with corrugated steel roof ; 28 kg/m², agreement "Passeport Innovation". No renovation of roofs if needed by the law (e.g. law has changed since roofs/buildings were built). Only put back things that were there before.		0
Reinforcement of structures and frames	2	Not included in this first study ; only a statistical approach with their experience (needed by 1/3 of buildings, at a cost of 3,30 c€/Wp). Structures calculations necessary.		0	A priori not necessary. Will be checked by a certified design office.		0
Kind of inverters, provider, position, expected replacement	1	- for decentralised inverters : Solivia, by Delta (German group), designed by and built for Tenesol ; from 3 to 6 kW ; efficiency 96% ; 20kg ; IP65 protection ; 5 years guarantee, extendable to 10 or 20 years ; one replacement expected. - for centralised inverters : Concerteam, by Alsthom		0	SNA or Schneider ; next to buildings in concrete shelters ; replacement after approximately 12 years.		0
Principles of grid-connexion (low-voltage / high voltage ; one point / several points…)	1	Nothing said. For most of the sites, know the position of grid-connexion points and transformers. When possible, will use existing technical corridors.		0	End-of-property grid connexion, high voltage.		0
Integration of risks in the proposition	2			0			0
Other equipment requirements (room for inverters,…)	1	Will be discussed later.		0	Concrete shelters for inverters : ground area 50m² ; precasted shelter for grid connexion (property side) ground area 20m². 20m² needed per equipped building for inverters (depending on space available, will be inside of the building or outside)		0
Tightness kept	2	Yes. During workings too : simultaneous roof removal and reinstallation. Directly after roof removal, a tarpaulin is installed on the building's frame. Installation is done in two steps, and corrugated steel roof is put first to guarantee watertightness.		0	Yes. during workings : installation of new cover at the same time as the previous one is removed and asbestos removed. During exploitation : partnerships. At least 2 yearly check ups.		0
Possibility to improve buildings insulation	2	Yes, solutions with sandwich, additional cost 15 to 20 €/m². Can be decided building per building. Not included in costs yet. Additional overweight.		0	Yes, but additional cost for DCNS. (rock wool, polyurethane…).		0
Followed norms, certifications, labels…	1	Member of PV Cycle, SER-SOLER, EPIA, QualiPV, QualiSol ; Factories certified ISO 9001 et ISO 14001 ; Panels certified : IEC 61215 et IEC61730 ; Integration system : follow rules NV65 (snow and wind) ; Inverters : security norms (EN60950-1; EN50178; IEC62103; IEC62109-1; IEC62109-2), anti-islanding protection (DIN VDE 0126-1-1; RD 1663; DK 5940 Ed. 2.2; EN50438), guidelines CEM (EN61000-6-2; EN61000-6-3; EN61000-3-2; EN61000-3-3; EN61000-3-12) ; Energrid data EN50081-2 ; EN50082-2 ; CE ; Circuit breaking boxes UTE 15-712. ; components suppliers certified ISO9001		0	Member of PV Cycle, SER-SOLER, EPIA. EDF EN certified ISO 14001 ; NF EN 60904-3 (C 57-323) ; NF EN 61643-11 (C 61-740) (lightning arresters) ; NF EN 61730-1 (C 57-111-1) et NF EN 61730-2(C 57-111-2) (quality) ; NF EN 62262 (C 20-015) ; NF EN 62305-1 (C 17-100-1, 2, 3) (lightnings) ; NF C 14-100 and NF C 15-100 (installations low voltage) ; UTE C 15-105 (conductors guide) ; UTE C 15-443 (low voltage lightning guide) ; UTE C 15-712 (low voltage guide) ; UTE C 17-108 (lightning risk analysis guide) ; DIN VDE 0126-1-1 (generator/network disconnecting) Partners (tightness specialists and electricians) certified QualiBat and QUaliPV		0
Security against fire	2	Guidelines from UTC712 guide followed (fires) ; local firemen consulted before installation. On the installations : emergency kicks offs, that enable firemen to act.		0	Follow firemen requirements, talk with them before installation.		0
Electrical security	2	Direct current protection box (atmospheric over-voltage) + alternative current protection box with differential circuit breaker (indirect contacts) + lightning arresters ; ground connexion of structures, boxes and inverters ; monitoring system.		0	Office design + workings supervisor check norms are followed. Validation by CONSUEL (mandatory). During installation : connectors insulated. Installation and production : DC side : follow C15-712 guide (no DC polarity connected to the ground, class II components, all grounds connected together, unplugable connectors, outside cables protected against UV bad weather and corrosion, opening only with tools, general circuit breaker before inverter...) AC side : norm NFC15-100, emergency circuit breaker. Distances between subgroups as short as possible (especially DC). Labelling on electrical cables every 5 meters, signs next to circuit-breakers, connectors, inverters...		0
Supervision and integration in the building technical control software of DCNS	1	Remote monitoring (Energrid), data available on the Internet. BTC : to be seen, depends on compatibilities between informatic languages.		0	Remote monitoring. Data provided directly on didactic boards, or via Webboxes.		0
Total power expected (kWp) Total production expected (MWh/an) Total area expected (m²)	1	7524 kWp 8150 MWh/year 47363 m²		0	2469 kWp 3050 MWh/year if all sites were covered : 30000m² ; only Toulon and St Tropez : 16138m²		0
Total technical parameters	**22**			**0**			**0**

		Ikaros Solar			Eolfi		
	Coeff		Grade	Total		Grade	Total
Technical parameters							
Kind of panels, provider, characteristics (peak power, material, technology…), origin, quality…	2	Panels Suntech Power ; model: Suntech MSZ-185B-D Just roof. Monocrystalline silicon. Power 185Wp (-0 +5). Size 841*1621*33mm. 18kg/m²; 143 Wc/m²		0	Modules : silicon polycrystalline, Suntech STP210-18/Ud (or equivalent), 210Wp. Efficiency >140Wp/m², minimum efficiency 14,5%. Size : 1482*992*35mm, 16,8kg. 20kg/m²		0
Quality warranties	1	5 years guarantee against manufacturing defects (glass, frame or contacts breakages) ; production guarantee (95% after 5 years, 90% after 12 years, 85% after 18 years, 80% after 25 years). AC and DC cabling losses maximum 2%.		0	Manufacturing guarantee : 5 years ; production guarantee : 95% after 5 years, 90% after 12 years, 85% after 18 years, 80% after 25 years. Cabling : overall voltage losses <1%		0
Implantation of panels on the roofs	1	Simplified building integrated. Over existing roof. Total weight 18kg/m².		0	Sloppy roofs, slope >4°: integration system with corrugated steel roof. Pass Innovation. Sloppy roofs, slope <4° : integration system with corrugated steel roof. No drill out of the building tightness. Flat roofs, slope <2° : ballasted integration system that takes the roof tightness and heavy protection.		0
Reinforcement of structures and frames	2	Not taken into account yet. Maybe will exclude some buildings. Cost of the study ; 2000 to 4000 €/building. Costs of reinforcement can be between 5000 and 100000€/building ! Also have an integration system where the load is distributed on the structures of the building (so you drill out in the roof and fiw the integration system on the columns), but doesn't work with the simplified integration feed-in tariff. Removal of asbestos not included but mandatory. Stability and structures study compulsory before starting workings.		0	Not included in the offer. Structures study from a design office necessary. Might change the profitability of the offer and the loans.		0
Kind of inverters, provider, position, expected replacement	1	Brand SMA or Emerson Control Technique. Centralisés. 5 years guaranteed. Usually choose big inverters : in case of a problem on one of them, the electrical production is divided on the others.		0	Brand: Power-1, range Aurora (or equivalent) power 6, 10, 12,5, 55 kVA. Choice done with respecting a load ratio (PV power / inverter power) between 0,95 and 1,15. Decentralised. Replacement of the power and control board, usually once in the life time.		0
Principles of grid-connexion (low-voltage / high voltage ; one point / several points…)	1	Grid connexion cost not included. DC cabling : Lapp ölflex or equivalent ; resistant to bad weather, ozone, UV, hydrolyse, -40°c to 105°c; AC cabling : XVB-F2, in troughs on the roofs.		0	Grid connexion costs : 40000€/plant (if higher : DCNS pays !!!)		0
Integration of risks in the proposition	2			0			0
Other equipment requirements (room for inverters,…)	1	30-35m² per inverters building ; trenches.		0	Use as much as possible of the existing mechanical rooms. If not enough space : light shelters Seifel or wood. If high voltage installation, transforming station in a concrete shelter. Shelter for grid connexion at property side, 12 to 25m² depending on installed power. In total 20 to 90m² per site (depending on chosen inverters and power installed), from which 20m² for grid connexion house.		0
Tightness kept	2	During workings : yes, no problem, installed over existing roof so tightness is never damaged. Otherwise; use of a waterproof underlayement. During production : yes, done by the panels. Warning, panels are fixed in the existing roof, so at the end of life of photovoltaic panels, roof below has to be redone.		0	During workings : installation only when no bad weather. Temporary tightness, will work as one goes along, will never remove the whole roof of a building. Roofers that guarantee there will be no water inside of the buildings during workings, for sensitive buildings. During production : one preventive check-up per year. Commit themselves to maintain tightness and act in case of a problem. Roof renovation and decennial responsibility for 25 years on the whole roof, even for parts that are not covered.		0
Possibility to improve buildings insulation	2	Yes, but necessarily from the inside. Some space needs to be let between current roof and panels. Higher cost for DCNS. Warning higher loads on the buildings.		0	Yes, but higher cost for DCNS. Not included in costs yet. Need thermal diagnosis of the buildings.		0
Followed norms, certifications, labels…	1	Certified "PV Qual" et "Bel PV" (Belgian certifications) Panels and integration system: CEI61215 (2nd édition), CEI61730 CSTB (currently), IEC, TÜV, CE		0	Member of SER-Soler. Security : follows UTE C15-712 ; guide ADEME « Spécifications techniques relatives à la protection des personnes et des biens dans les installations photovoltaïques raccordées au réseau » (technical specifications for persons and goods protection in grid connected PV installations). Panels : certificates IEC 61215 and IEC 61730. Integration system : DTU40-35 and NV65. Electricity : C13-100 and C15-100. Suntech : ISO9001, ISO14001(2004), norms CEI61215, CEI61730, UL1703, CE Veolia Environnement : ISO 14001, ISO 9001, OSHAS 18001. Eolfi currently being certified ISO9001 Partners certified ISO 9001 14001 QualiPV and QUaliBat.		0
Security against fire	2	Standards dispositions. Nothing special, all materials are conform to European norms. Infrared thermography, Q19 certificate. For firemen, there is no problem if they use a diffusing jet instead of a direct jet. Discussions with firemen are part of the agreements and procedure during conception. (usually there's no problem).		0	Transmission of a description of the project to the local firemen before installation, and inform them when installation is finished. Emergency DC kick-offs, as close to the PV panels as possible, remote driven with a common control with the building disconnection command. Inverters general cut off next to that too.		0
Electrical security	2	All security rules required by French norm : UTE C15-712-1 (July 2010) Automatic disconnection system in the electrical cabinet. In case of a problem, the string production decreases, so it is detected immediately.		0	Signs outside of the building, where the emergency persons need to go, in the technical rooms, where there are PV related equipments, on cables every 5 meters. Lightning arresters.		0
Supervision and integration in the building technical control software of DCNS	1	Remote monitoring, visible on a computer. Network interface Webbox. Output data :: usually CAN buses; can be transferred in IP or something else, can adapt.		0	Remote monitoring, necessary tools (history, curves, alarms…) Building technical control software integration : no problem, universal language, can adapt easily.		0
Total power expected (kWp) Total production expected (MWh/an) Total area expected (m²)	1	6796 7940 Not given.		0	5801 6679 ?		0
Total technical parameters	**22**			**0**			**0**

	Coeff	SolFinances / Spie	Grade	Total	SolAvenir Énergie	Grade	Total
Technical parameters							
Kind of panels, provider, characteristics (peak power, material, technology…), origin, quality…	2	Sharp, silicon polycrystalline, efficiency up to 14%, 140W/m², by-pass diodes to minimise power losses due to shadows. Size : 1652*994*46mm (1,64m²), weight 20kg, power 230Wp.		0	Silicon smelt and wafers production by Emix and Zws, transformation into cells by Irysolar, assembly of modules by Fonroche. Polycrystalline silicone panels, 220Wp, size 1641*989*46mm ; 23,5kg.		0
Quality warranties	1	Product guaranteed 5 years, production guarantee : 90% after 10 years, 80% after 25 years.		0	Product guaranteed 5 years, production guarantee : 90% after 10 years, 80% after 25 years.		0
Implantation of panels on the roofs	1	Depending on buildings : total or simplified integration system. 22kg/m² (simplified) or 18kg/m² (total). Integration system SpieBac (corrugated steel roofs with rails on which the panels are fixed. Pass Innovation. Corrugated steel roof enables to uncover and recover directly the roof.		0	Structure Solar 300 by Solar Construct. Pass Innovation.		0
Reinforcement of structures and frames	2	Structures study for the construction form in Lorient mandatory. Cost of studies included, but not possible cost of reinforcement (impossible to estimate). Reinforcement at the expense of DCNS!! Removal of asbestos included.		0			0
Kind of inverters, provider, position, expected replacement	1	SMA, Sunny Tripower, from 10kW to 1MW, maximal efficiency 98% "already fulfils 23 April 2008 decree requirements" !!!!		0	Inverter Pvmaster (PVM), guaranteed 5 years extensible to 20 years OR Aurora (PVI)		0
Principles of grid-connexion (low-voltage / high voltage ; one point / several points…)	1			0			0
Integration of risks in the proposition	2			0			0
Other equipment requirements (room for inverters,…)	1	Prefabricated inverters shelters, wired in advance, located outside of the buildings (quicker to install, no need of entering DCNS buildings for maintenance, easier to keep a good environment...). Except in Ruelle (landscape integration). Area of one shelter : 6m*3m.		0			0
Tightness kept	2			0			0
Possibility to improve buildings insulation	2	Possible, but higher cost. Also, useless if the other part of the roof is not insulated... 2 technical possibilities : rock wool or corrugated steel roof. In both case approximate cost of 65€/m²		0			0
Followed norms, certifications, labels…	1	Spie certified ISO9001, ISO14001, OASHS18001, QualiPVélec, member of SER-Soler		0	IEC 61215		0
Security against fire	2	Infrared thermography every 1 to 2 year to detect hot spots. Only risk is at the electrical connexions. Discussions with local firemen before each installation. Installation of fire-extinguishers. Personalised training of fire personnel of each centre. Sending of intervention procedures.		0			0
Electrical security	2	Electrical organisation divided in several parts. Each string can be disconnected. Circuit breakers outside, below each roof slope. When circuit is cut, electrical current only on the roof. Inverter : integrated DC swith-disconnector, strings electronical fuses, detection of strings malfunctioning, string current followed. Emergency kick-off close to inverters shelter. Labelling on cables every 3 meters. Labels fulfilling UTE15-712-1.		0	AC and DC break switch, inverters : protection against overvoltage, grounding supervision, AC and CD overvoltage protection.		0
Supervision and integration in the building technical control software of DCNS	1	Information available after the inverters, data recovery and processing under DCNS responsibility.		0	Inverter has an Ethernet interface to get data on the local network (access to all data from PV equipment). Also visible on the Internet.		0
Total power expected (kWp) Total production expected (MWh/an) Total area expected (m²)	1	4845 4794 34600		0	2397 2543 15740		0
Total technical parameters	**22**			**0**			**0**

	Coeff	Enertime / Tenesol	Grade	Total	EDF EN / EDF ENR Solaire	Grade	Total
Environmental parameters							
Presence of a life-cycle assessment of the project, consistency	2	Yes, carbon accounting provided but no input data nor assumption given. Absurd and inconsistent results (e.g. energy payback time : 4 years in France, 52 in China ! ; moreover assembly of panels is only a small part of energy consumption but it is the only part done in France)		0	Yes, carbon accounting provided, but inconsistent data (transportation evocated but not included, installation not included, life span 30 years, European data for Chinese panels…)		0
End-of-life recycling	1	Yes, member of PV Cycle.		0	Yes , member of PV Cycle, only works with PV Cycle members suppliers.		0
Origin of materials	3	cells : Qcells, produced in Germany or Asia, or Photovoltech, produced in Europe (but European cells have lower efficiency) ; panels assembled in France ; inverters produced in Germany or Slovakia. Possibility to order products built only in Europe, but higher cost		0	Panels Suntech, produced in China (for their higher quality and efficiency) ; inverters SMA produced in Germany		0
Sustainable development approach within the company	1	50% Total (petroleum) ; 50% EDF (nuclear)…		0	50% EDF (nuclear)... Reports brought printed on one-side colour paper the day of the offers defence. EDF EN ISO14001 only for its wind activity !		0
Sustainable development approach during installation	1	Not specified (except security).		0	Follows "low nuisance charter" (especially cleaning and waste separation, employees health, fluids consumption followed, respect of acoustics limitations...)		0
CO_2 emissions saved	2	2380 tonnes CO_2eq/year (based on electricity mix 300gCO_2/kWh)		0	914 tonnes/year (based on electricity mix 300gCO_2/kWh)		0
Total environmental parameters	**10**			**0**			**0**
Health and safety parameters							
Recognition of DCNS health and safety requirements	2			0	Appointment in each site before starting the workings, in order to take specificities into account. Learning modules can be proposed to buildings managers to sensitize them to risks.		0
Proposed health and safety organisation	2	Security during workings (specifically educated workers, respect of rules for working at heights…).		0	For persons safety : a special coordinator will be there. EDF EN will also follow all specific to DCNS rules. Workings markings will be decided with sites managers and checked daily by the workings supervisor. One security report per site will be written and signed by SOCOTEC.		0
Total Health and safety parameters	**4**			**0**			**0**
Financial parameters							
Proposed financial package	2	Financing 20% capital (80% Tenesol, 20% Dynergies (Enertime's subsidiary)) 80% debts. Possibility for DCNS to invest in Tenesol's share (so between 0 and 80%). 20 years commitment.		0	Financing by a project company owned by EDF EN.		0
Feed-in tariff / total sold per year	1	37 c€/kWh => 3015 k€ sold per year.		0	37 c€/kWh => 1128 k€ sold per year.		0
Total investment	1	24471 k€		0	approximately 8,5 M€		0
Yearly loan to DCNS, actualisation	2	107 k€ (revised with formula: L = 0,8 + 0,1 (ICHTrev-TS/ ICHTrev-TS0) + 0,1 (FM0ABE0000/ FM0ABE00000)) => 3,5% of total annual profits		0	49 k€ => 4,3% of annual profits		0
Grants possibilities	1	No possible grant (only feed-in tariffs)		0	No possible grant as EDF EN is a professional photovoltaician and DCNS is not investor.		0
Other benefits	2	Savings on roofs renovation (not estimated)		0	Savings on roofs renovation : 8 k€/year		0
Financial soundness of the company	2			0			0
Durability of the photovoltaic activity in the company	2	Enertime : recent, Tenesol : photovoltaic since 27 years (first Africa, off-grids systems, then Europe)		0	A priori yes, subsidiary EDF ENR Solaire; ambiguous position of EDF to photovoltaic.		0
Group belonging	1	Enertime : no ; Tenesol : yes (50% Total, 50% EDF)		0	Yes (EDF 50%)		0
Experience	3	Enertime : recent, Tenesol : photovoltaic since 27 years.		0	Renewable energies since 1990, PV since ??? (2006??)		0
Total Financial parameters	**17**			**0**			**0**
Juridical parameters							
Example of a lease provided ; pertinence	3	Not provided		0	Provided. Favours EDF EN too much. Length 20 years. - Possibility for EDF EN to extend the lease for 5 more years twice, without DCNS agreement. - resolutory condition not acceptable as such (if EDF stops buying electricity, consequences only for DCNS) - §easement : conditions for entering a "defence confidential" site are not taken into account - §constitution and acquirement of interest in land : EDF EN will be able to establish negative easement on DCNS properties without its agreement - §sublease : choice of subcontractors without DCNS agreement - §right of pre-emption : EDF EN could become owner of buildings ? - §loan: payable in arrears. DCNS can sue EDF EN only after 2 years and 9 months after a rent has not been paid. - §networks easements : do not have to set to rights - § non altus tolendi easement : DCNS accepts not to build any building that could disturb PV production		0
Legal framework	1	Emphyteutic lease of 20 years between DCNS and the project company (made of Enertime and Tenesol)		0	Emphyteutic lease 20 years.		0

	Coeff	Ikaros Solar	Grade	Total	Eolfi	Grade	Total
Environmental parameters							
Presence of a life-cycle assessment of the project, consistency	2	Systems manufacturing and installation required approximately 2500 kWh/kW. Emission factor (based on a "recent LCA" not provided) 8 to 13g Ceq/kWh, extrapolated to France 15g (in fact emissions factors from ADEME !). For DCNS : 119,06 tonnes Ceq before and during installation. Insisted on the difficulties for choosing the system boundaries and assumptions, can give very different results (Europe/France, marginal/average...). DCNS should provide a methodology and give it to all companies in order to compare them.		0	Yes, detailed Carbon Accounting (Ademe methodology). Needed energy to manufacture panels : 3230 kWh/kWp. Conclusion : during life cycle 9100 tonnes CO2eq emitted.		0
End-of-life recycling	1	Suntech member of PVcycle. Panel will be totally recycled. First panels have been recycled in Germany, no problem.		0	Today not possible to recycle pv panels, but it will probably be possible when we reach the panels end of life. Suppliers are members of PV Cycle. Veolia Propreté is one of the companies asked to bring technical solutions for recycling.		0
Origin of materials	3	Panels : China (15 to 20% cheaper ; Suntech leader and world biggest producer) Inverters : SMA (Germany) for decentralised ones, and Emerson (UK, manufactured in Germany) for centralised ones. (market leaders)		0	Panels Suntech : China (20% cheaper than a European equivalent) Inverters : Denmark (or Italy) Integration systems : France ; Cables, electrical equipment : France Lightning arresters, transformers : Europe		0
Sustainable development approach within the company	1	Only PV. Talk about nuclear waste reduction. But choose Chinese panels (=> environmental and social aspects)		0	Veolia ISO 14001		0
Sustainable development approach during installation	1	Yes : wasted separation, transportation limitation, use of sustainable materials. Specific security plan for each site. Security formations for Ikaros and subcontractors employees. Workers certified VCA/BESSAC. Follows BeSaCC : Belgian Safety Criteria for Contractors.		0	Favour local employment during workings ; subcontractors certified ISO14001, Veolia ISO14001. Are taken into account : cleanness, risk, fire, security, acoustics, dust, waste separation…		0
CO2 emissions saved	2	1986 tonnes per year (based on electricity mix 250gCO2/kWh = Belgium!!) + nuclear waste !		0	2041 tonnes CO2/year (based on electricity mix 0,6kg CO2 /kWh, margin value in Europe ; emissions during life cycle removed) with same data : CO2 payback time 4,7 years		0
Total environmental parameters	**10**			**0**			**0**
Health and safety parameters							
Recognition of DCNS health and safety requirements	2			0			0
Proposed health and safety organisation	2	Installation on existing roofs. Personal and collective protective equipments, equipments and installations will follow the regulation. Security instructions for personal protective equipment, phone number of first aid services and other measures will be specified in the security plan BeSaCC.		0			0
Total Health and safety parameters	**4**			**0**			**0**
Financial parameters							
Proposed financial package	2	Investment fund financed by two partners. 15% private fundings, 85% debts. Possibility for DCNS to invest. In the 15% : Credit Agricole Private Equity (CAPE) 50/%, DCNS (if wanted) 30%, Ikaros Solar 20%.		0	20% capital, 80% debts		0
Feed-in tariff / total sold per year	1	37 c€/kWh => 2937,8 k€ sold per year. ROI 10-15%		0	building integrated (44c€ if <250kWp, 37c€if >250kWp) ; here 0,37 => 2471 k€/year sold		0
Total investment	1	18650		0	18722 (Toulon 5147, ST Trop 1489, Ruelle 6667, Indret 5419)		0
Yearly loan to DCNS, actualisation	2	201,5 k€ (loan in €/kW different depending on sites, to multiply with installed power) => 6,8% of annual profits. No actualisation, fixed loan.		0	2000 € if Toulon, St Trop et Ruelle ; minus 95000€/year if Indret in addition !! (Toulon 35000€/year, St Trop 14000, Ruelle -47000, Indret -97000) actualisation : RD = RD-1 * 0,995 * L		0
Grants possibilities	1			0			0
Other benefits	2			0			0
Financial soundness of the company	2			0	End of 2010 investment capacity Eolfi 1 billion euros Sales VEOLIA Environnement: 34 billions € in 2009 from what 13 billions € in France; Sales EOLFI in 2009: 3,5M€		0
Durability of the photovoltaic activity in the company	2	Only activity of the company is PV. Have less and less households clients, more and more industrial companies.		0	Eolfi exists since 2004, originally wind energy projects financing.		0
Group belonging	1	No		0	Yes Veolia		0
Experience	3	Exists since 2006		0			0
Total Financial parameters	**17**			**0**			**0**
Juridical parameters							
Example of a lease provided ; pertinence	3	Provided. - Reference to commercial laws (which cannot be accepted by DCNS) - Length 22 years, loan during 20 years - Interesting lease with the reference to that fact that the lease would be broken in advance by common consent in case of dispossession or demolition of buildings. - Return of roofs without any damages (but no removal of modules and integration structures) - Study of chosen buildings relevance under Ikaros responsibility and paid by Ikaros. - Mandatory for Ikaros to show its permits and certificates that allow it to install and run a plant. - Ikaros responsible for any damage caused by the installation, and shall assume the reparations and their costs - the notary who will write the lease has to be DCNS notary and not Ikaros notary !		0	Provided, but favours Eolfi way too much. Length 25 years, loan during 20 years. - §occupation and exploitation conditions : "if the need arises" Eolfi will check he does not hinder the use of the building below - § exploitation stop fees : asked by Eolfi, but not reciprocal - §installations maintenance : installation with not include roof standards compliant making, removal of asbestos, structures reinforcement - §cancellation : if EDF stops buying electricity, lease cancelled without any penalty. - §end of lease : imprecisions about what exactly will be removed (tightness ?) - right of first refusal (possibility to buy buildings) - reduction of the possibility for DCNS to build or raise the heights of buildings - Eolfi can be substituted by anybody without DCNS agreement.		0
Legal framework	1	Emphyteutic lease 20 years.		0	Emphyteutic lease 25 years ! (2 years for the workings 3 years of margin after the 20 years)		0

	Coeff	SolFinances / Spie	Grade	Total	SolAvenir Énergie	Grade	Total
Environmental parameters							
Presence of a life-cycle assessment of the project, consistency	2	No : impossible as the constructors do not give access to the LCA or carbon accounting of their panels.		0			0
End-of-life recycling	1	Yes, supplier member of PV Cycle. Panels have to be handed in one of the collection points.		0			0
Origin of materials	3	Panels and cells : Japan or Wales. Inverters : Germany.		0	Entirely French production : silicon smelt and wafers cut in Saint-Maurice la Souterraine (23), transformation into cells in Montpellier (34), modules manufacturing in Roquefort (47).		0
Sustainable development approach within the company	1	Printed report given in duplicate, on one side paper, one of them in colours, several hundreds pages... Answers to the questionnaire given on paper, printed in several copies, A3 simple recto ; the same with the example of planning, of quality plan,... Spie : member since 2003 of the Global Compact, use of VIGEO referential (CSR) ; ISO12001, SERCE energy efficiency label , "Spie green economy" approach, security certified OHSAS18001, security important, 3,5% of total payroll in employees education...		0	Report only sent on paper first.		0
Sustainable development approach during installation	1	Spie takes care of all wastes produced during the workings. + Health and safety.		0			0
CO2 emissions saved	2	469039 kgCO2/year (based on electricity mix 0,09kgCO2/kWh, average value in France)		0			0
Total environmental parameters	**10**			**0**			**0**
Health and safety parameters							
Recognition of DCNS health and safety requirements	2	A PPSPS (Specific Security and Health Protection Plan) will be set between Spie security engineer and DCNS security responsible for each site.		0			0
Proposed health and safety organisation	2	During installation, use of Personal Protective Equipment, harnesses, protection nets, etc. Labelling fulfilling UTE15-712-1.		0			0
Total Health and safety parameters	**4**			**0**			**0**
Financial parameters							
Proposed financial package	2	3 possibilities : 1) DCNS investor => 20% own capital, 80% debts 2) simple renting => investment by Sol Finances 3) Renting with admission fee => rest of the investment made by Sol Finances		0			0
Feed-in tariff / total sold per year	1	part 37c€, part 44c€, 1774k€/year sold		0			0
Total investment	1	19 985 499 €		0			0
Yearly loan to DCNS, actualisation	2	1) nothing (DCNS directly sells electricity to EDF which means 1801793€/year - operating expenses 90090 € => 1711703€/year) 2) total for all sites over 20 years : 1621600 => per year: 81,080 k€ (based on 6% of EDF sales, except for Brest and Indret 4,5%) 3) over the first 18 years : 200 k€/year, the last two years : 1400 k€,=> over the 20 years : 6400k€ Actualisation : same as EDF formula.		0			0
Grants possibilities	1	A priori no.		0			0
Other benefits	2	Electricity sold after the end of the lease.		0			0
Financial soundness of the company	2			0			0
Durability of the photovoltaic activity in the company	2			0			0
Group belonging	1	SolFinances no, Spie		0	No		0
Experience	3			0			0
Total Financial parameters	**17**			**0**			**0**
Juridical parameters							
Example of a lease provided ; pertinence	3	Provided, very late. - constitution of easements between batches. - duration of workings not specified. - loan : payments follow EDF payments => need of a deadline. Revision of loan not acceptable : DCNS should have a fixed loan. - enjoyment : same lease as for a poultry company !!! - reinforcement works at the expense of DCNS : not acceptable, should be included in financial analysis. - easements : nothing about construction permit and other legal obligations. Not acceptable that DCNS gives right to SolFinances to acquire any necessary easement. - possibility to ask removal of panels not guaranteed. Need to add a bank guarantee. - constitution of mortgage - Need to add it is forbidden to sublet - End of lease : DCNS can't accept non payment after two terms but wants possibility to act after only one term		0			0
Legal framework	1	Direct investment by DCNS, or emphyteutic lease or admission fee + lease.		0			0

	Coeff	Enertime / Tenesol	Grade	Total	EDF EN / EDF ENR Solaire	Grade	Total
Tasks and responsibilities distribution between companies	1	Plant engineering : Tenesol ; administrative and juridical work : Enertime helped by Tenesol ; components provider : Tenesol ; Workings supervision : Tenesol helped by Enertime ; lease writing : Dynergies ; creation of the operating company : Dynergies; Financing : Tenesol/Enertime ; Plant operating : Dynergies and Tenesol		0	Engineering : EDF EN and external design offices ; installation : roofers partners, electrical work: Photon ; Maintenance: EDF EN Services, subsidy of EDF EN. EDF EN takes care of workings, maintenance, guarantee of watertightness for all buildings equipped (including parts of the roof that are not equipped). Gutters not included.		0
Possibility for DCNS to choose that the company removes the panels and redo the roofs at the end of the lease ; end-of-lease scenarios	3	After 20 years (end of lease), several choices : - Disassembly of the plant, roof reclamation. Funded over the 20 years. - Plant is still working (25 years 80% of production guaranteed => valuable asset), so continue to sell at market price, either with : o plant given to DCNS, DCNS continues to sell electricity. o project company continues ; loans to renegotiate o for own consumption Financial provision to guarantee the company will be able to finance the disassembly. Existing, foreseen scenario. Cost not taken into account yet (scenario chosen = plants given to DCNS). Possible disassembly include removal of panels, mounting rails, cabling, electrical components. Only staples are left.		0	No, installation given to DCNS at the end of the lease. Impossible to reclaim the roof (too expensive), but possible to remove panels and cabling.		0
AOT - COT	1	Nothing said. DCNS has to talk with the navy.		0	for Toulon : contract signed with the State, through an AOT; has experience in doing that.		0
Total Juridical parameters	**5**			**0**			**0**
Insurances							
Examples of insurances contracts provided, relevance	3			0			0
Responsibilities and insurances	2	Enertime will buy insurances from one or several reknowned insurance companies, one or several insurance policies that (i) cover "fire, explosion, water damages", for furniture, equipment, goods that guarantees rented places, rental risks, recourse of neighbours and external persons.		0	Insurances "property damages" and "legal liability" will be bought. Subcontractors will have their own "legal liability" insurances.		0
Relevance of insurances	3	If workings are not under article 1792 of Civil Code, the attestation seems to be adapted against responsibility risks. Maximum guarantee seems to be 500k€.		0			0
Total Insurances	**8**			**0**			**0**
Other parameters							
Presence, reactivity, proactivity during consultation	3	Good, done all visits, on time, organised customer's installations visits, were present during consultation…		0	Relationships between EDF subsidies not very clear ; intervention of EDF EN in the last moment (EDF ENR Solaire was supposed to be associated with another company, that was rejected one day before offers had to be handed in...), few explanations about the way they work... On the other hand, the person from EDF ENR Solaire West was very present during consultation (unfortunately no western site chosen).		0
Respect for timelines	1	Yes		0	No (offer 3 weeks late compared to initial deadline).		0
Presentation of the report	1	A few typos (copy-pastes from "Gardanane city council" : no proofread (twice!), number for power in Indret wrong, number for CO2 avoided wrong...) , no pages numbers…		0	Half = presentation of EDF and its references ; EDF ENR Solaire not referred to ; letter of intention to "Monsieur" ; a lot of things without any link to the consultation (photos of ground-mounted plants, abroad subsidiaries...) ; a lot of repetition (objective 500MW end of 2012...) ; information not up to date ("commissioning expected first semester 2010") ; "these THREE renovation projects" (p17, to talk about St Tropez and Toulon) ; not any technical detail.		0
Respect for the specifications	2	At first sight yes ; but no LCA at the beginning, Brest centre not considered, "other additional equipments required" not treated.		0	Only St Tropez and Toulon chosen ; no roof reclamation at the end of the lease, no LCA.		0
Organisation of a visit of a photovoltaic installation	2	Yes : "cité de la voile" in Lorient ; visit of the factory in Toulouse and two installations in the Pyrénées.		0	To do		0
Additional propositions (parking coverings, facades, brise-soleil…)	1	None (too expensive, can be done but with another logic, with an investment) ; internal communication proposal with the didactic board		0	Brise-soleil and facade panels do not have high powers and are very expensive. Their use is not profitable.		0
Offer defence	2	6 persons, with different specialties. Subject dominated. Proposal to continue working during government break in order to progress on technical, financial, juridical points... propose to sign a contract for exclusive work in order to be able to incur expenses (structural calculations...). Final decision could then be taken quickly, with a ready to be signed contract.		0	One person (sales representative), no technical information. Brought printed offers on one hand not recycled colour paper. Not possible to decide anything before end of moratorium, but possible to progress on technical points in the meanwhile.		0
Total Other parameters	**12**			**0**			**0**
Total grade	**113**			**0**			**0**

	Coeff	Ikaros Solar	Grade	Total	Eolfi	Grade	Total
Tasks and responsibilities distribution between companies	1	Internal design office. Ikaros is responsible for any damage caused by the installation of the plant ; for the maintenance and well-functioning of modules (can be subcontracted) ; for any damage caused by the use of the plant ; for the material transportation if necessary... Ikaros is responsible for the roofs on which pv panels are installed + 2 meters around.		0	Flat roof : the whole roof and its tightness will be renovated by Eolfi with a decennial responsibility. Gambrel roof: if only one side is equipped, the other one will not be renovated. On one side, depending on the proportion of solar panels on it, Eolfi can take care of the renovation of the whole side (above 70% of surface taken by modules).		0
Possibility for DCNS to choose that the company removes the panels and redo the roofs at the end of the lease ; end-of-lease scenarios	3	2 possibilities : - we continue to run the installations, the pv plant is given to DCNS (life time more than 30 years). Increased profits will largely finance the disassembly a few years later... - disassembly, but handling costs not including, additional cost for DCNS. Moreover, current roof will have been drilled out, so it will have to be rebuilt (cost not included). In any case, the rood under the panels will have been protected during all this time, so its lifespan will have been increased.		0	2 possibilities : - plant given to DCNS - disassembly of equipments (and "maybe" also of modules that could be removed without damaging the structure and tightness!!) If integration parameters change with the moratorium, it is not sure that this will still be working. If panels themselves have to do the tightness, it will not be possible to remove them.		0
AOT - COT	1	Taken into account. Will have to be re-negotiated with the owner.		0			0
Total Juridical parameters	**5**			**0**			**0**
Insurances							
Examples of insurances contracts provided, relevance	3			0			0
Responsibilities and insurances	2	Owner : properties (buildings and their furniture) and photovoltaic plants have to be insured against fire. Does not have to insure damages caused by or to a third party who is inside of the building. Ikaros has to insure the damages related to pv installations and damages they could cause to the owner's properties. Contracting authorities : have to have an insurance "property damages". Project manager: contractor's guarantee insurance FLEXA (Fire, Lightning, Explosion, Aircraft) extended insurance is foreseen in the juridical construction of the investment fund. => DCNS will still get the loan in case of a breakdown.		0	Eolfi will buy insurances covering : damages during materials transportation ; damages due to installation ; revenue losses ; legal liability during workings ; legal liability as project manager... Project company will buy insurances covering : damages to goods, machines breaks, revenue losses ; property damages ; legal liability owner and electricity producer ; legal liability after workings ; professional legal liability ; decennial responsibility.		0
Relevance of insurances	3			0			0
Total Insurances	**8**			**0**			**0**
Other parameters							
Presence, reactivity, proactivity during consultation	3	No problem, all visits have been done (except Ruelle because of snow), discussions…		0	Only visited Toulon, ST Trop, Ruelle. Indret done with Google maps. Didn't ask any information or document except those provided during visits. Nothing asked for Indret (not		0
Respect for timelines	1	Yes		0			0
Presentation of the report	1	Spelling!!! LCA : "copy-paste" of Ademe emissions factors claiming it is for "their system"		0	21 separate PDF files Spelling mistakes Sentences without meaning. A few typos (different numbers per site, different panels brand, Caen) Repetitions		0
Respect for the specifications	2	Globally yes. No roof reclamation proposed at the end of lease; subject "other additional equipments required" not treated.		0	Only 3 or 4 sites		0
Organisation of a visit of a photovoltaic installation	2	Possible to visit installations in a marine industrial environments, but not with building integration. To do.		0	Proposition to visit plant of PSA in Sochaux (1,4MWp)		0
Additional propositions (parking coverings, facades, brise-soleil…)	1	None.		0	Communication (example organisation of a press conference at the end of the project, communication medias, communication events...) Proposition of parking covering in St Tropez, but would require to cut all the trees!!!!!		0
Offer defence	2	3 persons with different specialties, no problem.		0	2 persons, one "financial", one "technical", no problem.		0
Total Other parameters	**12**			**0**			**0**
Total grade	**113**			**0**			**0**

		SolFinances / Spie			SolAvenir Énergie		
	Coeff		**Grade**	**Total**		**Grade**	**Total**
Tasks and responsibilities distribution between companies	1			0			0
Possibility for DCNS to choose that the company removes the panels and redo the roofs at the end of the lease ; end-of-lease scenarios	3	Nothing said. Impossible to include the cost of disassembling as it will be in 20 years and don't know today how much it will cost. (!!!!!)		0			0
AOT - COT	1			0			0
Total Juridical parameters	**5**			**0**			**0**
Insurances							
Examples of insurances contracts provided, relevance	3	only Spie's decennial responsibility provided		0			0
Responsibilities and insurances	2			0			0
Relevance of insurances	3			0			0
Total Insurances	**8**			**0**			**0**
Other parameters							
Presence, reactivity, proactivity during consultation	3	Spie very responsive, gathered a team very quickly. Sol Finances on the other hand needs several weeks to send any document.		0	No problem, came to all visits, get informed.		0
Respect for timelines	1	Report : 1 day late (numerical version a bit more) SolFinances : usually very long to answer to emails or information requests and to send documents.		0	Paper report on time ; numerical version 2 weeks late.		0
Presentation of the report	1	First only paper version. Sentences without sense, grammar and spelling mistakes. Poor presentation, report not organised, no page number, no table of content. A few typos, inconsistence of numbers or lack of explanations. "Copy-paste" from a website ("Energiebio") for PV explanations. No presentation of chosen furniture, only technical documentation without any explanation. Numerical version : 44 independent files, without any logic, with pieces of documents, without titles nor numbering... Questionnaire : spelling mistakes everywhere. Lease : first copy of a lease from the internet ; then a lease talking about the "poultry" activity of DCNS...		0	Only a technical presentation (but quite well detailed). No real offer (financial, organisation etc.). No environmental analysis.		0
Respect for the specifications	2	No LCA ; subject "other additional equipments required" not treated ; no foreseen timing of work ; subject "security" (during installation and exploitation, of equipments, buildings and persons) not treated .		0	Not at all, only technical analysis of potential in DCNS buildings..		0
Organisation of a visit of a photovoltaic installation	2	Proposed by Spie, to do. (industrial building, but not as big and complicated as DCNS)		0			0
Additional propositions (parking coverings, facades, brise-soleil…)	1	No : brise-soleil and facade low profitability. Parking covering : lack of time to study this possibility.		0	No		0
Offer defence	2	6 (?) persons, part Sol Finances part Spie, with different specialties. No problem.		0	No defence (refused consultation)		0
Total Other parameters	**12**			**0**			**0**
Total grade	**113**			**0**			**0**

D. Design offices offers details per site and comparison with own calculations

	Own estimations	Enertime	EDF EN	Ikaros Solar	Eolfi	SolFinances	SolAvenir Energie	Average design offices
Cherbourg								
Productibility (kWh/kW$_p$)	938 (calculated)	940		1068 on average		919 (calculated)	1008 (average)	1013
Selected buildings	CM136	Legris	None	CM 136, Entretien, Legris, Simonot, Hutter	None	CM136, Magasin Sud	Hutter	
Roof surface (m²)		8250				4123		
Solar panels surface (m²)	1300	6188				3084	602	
Investment cost (k€)		2903		5246		1589		
Expected power (kW$_p$)	195	916		1930		432	79	839
Expected production (MWh/year)	183	861		2062		397	79,611	850
Specificities	lack of data					eligible tariff 0,44. Magasin sud : abestos		
Brest								
Productibility (kWh/kW$_p$)		925	904	1074 on average		852 (calculated)		990
Selected buildings		None : small potential, COT and lack of documentatio n	None (A16)	A11, B01, B06	None	A11	None	
Roof surface (m²)		-	1090			3880		
Solar panels surface (m²)		-	990			1783		
Investment cost (k€)		-		1572		1133		
Expected power (kW$_p$)		-	124	543		250		306
Expected production (MWh/year)		-	112	583		213		303
Specificities						abestos		
Lorient								
Productibility (kWh/kW$_p$)	966 (calculated)	960		1109 on average		908 (calculated)	957 (average)	1003

Selected buildings	G04, G030, G037, D126, D131, D135, D162, hangar 1000	G04, G30, G037, D112, D135	None	G04, G09ext, G030, G037, D135, 136, méca,	None	G04 (D135)	G04, G30, G37	
Roof surface (m²)		16495				6765		
Solar panels surface (m²)	17250	11600				4493	8037	
Investment cost (k€)		7445		5550		2451		
Expected power (kW_p)	2588	2152		2000		629	1303	1521
Expected production (MWh/year)	2500	2066		2218		571	1246	1525
Specificities						G04 only if compatible with activity of the building (production) ; old roof structure, structural study mandatory		
Nantes-Indret								
Productibility (kWh/kW_p)	995 (calculated)	1000	1030	1180 on average	1021	937 (calculated)	1107 (average)	1035
Selected buildings	26 (G,J,K), 30, 54, 56 (A,B,C,D), 59, 60, 68,	26 (nefs G, J, K), 30, 56 (nef A),	None (26 nef G, 30)	26, 30, 56A	None	26 G et K, et 30 (56)	22, 26(G,K), 30	
Roof surface (m²)		7018	2627			3870		
Solar panels surface (m²)	12150	6240	1875			3420	3422	
Investment cost (k€)		2960		1455	5	1987		
Expected power (kW_p)	1823	934	250	510	1681	479	451	718
Expected production (MWh/year)	1813	934	256	602	1716	449	499	743
Specificities						Installation of an injection point high voltage 20kV.		
Ruelle								
Productibility (kWh/kW_p)	1076 (calculated)	1049	944 !!	1210	1123	917 (calculated)	1264 (average)	1063
Selected buildings	9, 34, 40, 42-43, 51, 52, 76, 99, 118 (A,B,C),	9, 34 (A,B,C), 42, 43, 51 (A,B), 99, 118	None (9, 35B, 37C, 38B, 40,	???	9, 34, 35, 36, 37, 38, 43, 50, 51,	35B, 37C, 40, 43A, B, 50A,C, 84A,B, 118 A,C	9, 40, 43, 51, 118	

		(A,B,C)	43A,B, 50A,C, 52A, 84A,B, 118A,C)		52, 89, 118			
Roof surface (m²)		20145				9778		
Solar panels surface (m²)	10690	8045				7792	3145	
Investment cost (k€)		3927		1338	7	4003		
Expected power (kW_p)	1604	1239	1369	463	2071	1091	414	1108
Expected production (MWh/year)	1726	1301	1356	560	2326	1001	523	1178
Specificities								
Toulon								
Productibility (kWh/kW_p)		1320	1222	1400 on average	1273	1091 on average	1295 (average)	1251
Selected buildings		CA04, CA13, CA15, CA43, MY04	CA04, CA13, CA15	CA04, CA10, CA15	CA10, CA13, CA15	CA04, CA13, CA15	CA04, CA15	
Roof surface (m²)		20145	18791			18800		
Solar panels surface (m²)		10152	10229			10250	1136	
Investment cost (k€)		4827		2036	5	5661		
Expected power (kW_p)		1523	1485	855	1596	1435	150	1174
Expected production (MWh/year)		2011	1814,6	1197	2032	1566	194	1469
Specificities								
Saint-Tropez								
Productibility (kWh/kW_p)	1350 (calculated)	1286	1259	1450	1336	1128		1285
Selected buildings	Main, North, East	Main building		Main building		Main building	None	
Roof surface (m²)		10700				9000		
Solar panels surface (m²)	3750	5138	5909			3777		
Investment cost (k€)		2409		1452	1	2391		
Expected power (kW_p)	563	760	904	495	453	529		628
Expected production (MWh/year)	760	978	1138	718	605	597		807
Specificities								

E. CO_2 life cycle assessment: main results

1) Influence of place of manufacturing and mean of conveyance

		scenario							
		A1-20years	**A1**	**A2a**	**A2b**	**A3a**	**A3b**	**A4a**	**A4b**
		Complete manufacturing in China, removal after 20 years	Complete manufacturing in China	Cells produced in China, assembly in France, transportation by lorry	Cells produced in China, assembly in France, transportation by train	Complete manufacturing in Germany, transportation by lorry	Complete manufacturing in Germany, transportation by train	Complete manufacturing in France transportation by lorry	Complete manufacturing in France transportation by train
Emissions due to manufacturing	tonnes CO_2eq	16731	16731	15207	15207	8557	8557	1784	1784
Specific emissions due to manufacturing	kg CO_2eq / kW_p	2390	2390	2172	2172	1222	1222	255	255
Emissions due to transportation	tonnes CO_2eq	3587	3587	3835	542	6849	97	2953	43
Specific emissions due to transportation	kg CO_2eq / kW_p	512	512	548	77	978	14	422	6
Emissions due to PV electricity production	tonnes CO_2eq	-43060	-61633	-61633	-61633	-61633	-61633	-61633	-61633
Specific emissions due to PV electricity production	kg CO_2eq / MWh	-304	-304	-304	-304	-304	-304	-304	-304
TOTAL CO_2 avoided over the life cycle	**tonnes CO_2eq**	**22742**	41316	42592	45884	46228	52980	56896	59807
Avoided emissions per kWh	g CO_2eq / kWh	161	204	210	226	228	261	281	295
Average of avoided emissions per year	tonnes CO_2eq / year	1137	1377	1420	1529	1541	1766	1897	1994

2) Influence of electricity mix and its changes

		B4b	B4b-Fr	B1-Fr	B4b-20	B4b-24	B4b-14
		Base scenario - mix UE27 constant	Mix Fr constant, production Fr, train	Mix Fr constant, production China, lorry	Mix UE -20% 2010-2030	Mix UE -24% 2010-2030	Mix UE -14% 2010-2020
Emissions due to manufacturing	tonnes CO_2eq	1784	1784	16731	1784	1784	1784
Specific emissions due to manufacturing	kg CO_2eq / kW_p	255	255	2390	255	255	255
Emissions due to transportation	tonnes CO_2eq	43	43	3587	43	43	43
Specific emissions due to transportation	kg CO_2eq / kW_p	6	6	512	6	6	6
Emissions due to PV electricity production	tonnes CO_2eq	-61633	-17030	-17030	-53139	-51441	-48016
Specific emissions due to PV electricity production	g CO_2eq / kWh	-304	-84	-84	-262	-254	-237
TOTAL CO_2 avoided over the life cycle	**tonnes CO_2eq**	**59807**	**15204**	**-3288**	**51313**	**49614**	**46189**
Avoided emissions per kWh	g CO_2eq / kWh	295	75	-16	253	245	228
Average of avoided emissions per year	tonnes CO_2eq / year	1994	507	-110	1710	1654	1540