LARGE SCALE PV IN ITALY: TECHNICAL, FINANCIAL AND CONTRACTUAL CHALLENGES

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Abstract

Under the Italian photovoltaic support scheme (Conto Energia), from 2007 up to 2010, several initiatives, projects and actual plants have entered into the national power generation scene. A lot of new entrants, historical utilities, and investors put a lot of attention to the Italian renewable market, possibly as never before. Reportedly, the average size of the PV plants actually entered in commercial operation since then is however not very significant, in the range of 5 to 35kWp. Larger plants (over 2MWp) are only a few dozens. However, these are the most important projects to be tracked, playing the most relevant role in the sector and significantly impacting (in case) the system stability and operation. MWH has been retained by several developers, investors, and lenders to provide technical advice and engineering services for developing large size PV plants (typically from 2 to 15MWp, ground and roof-mounted), from the design and authorization phase up to construction, commissioning and start-up. In the development of PV plants, many aspects should carefully be taken into account, as technical feasibility, production estimates, authorization issues, profitability, EPC and O&M contracts. This paper presents a critical review of the assets and project portfolios MWH was involved in. It reports and compares the main figures and issues related to these plants, having different technologies and installation types. Technical figures such as efficiencies and losses as well as economic values such as specific investments, IRR and PBT are compared. Critical aspects in the EPC and O&M contracts are introduced (i.e. guarantees, penalties for delays and underproduction, risks related to the material suppliers), together with a presentation of possible different approaches. Peculiarities emerging from the authorization phase, as well as critical aspects in the construction phase, according to MWH experience, will also be discussed.

1. Introduction

From 2007 to 2010, photovoltaic (PV) plants built in Italy have been incentivized according to the modalities of the Italian second photovoltaic support scheme: the so called "*Secondo Conto Energia".* Entered into validity right after the first incentive scheme, which contributed to the interest arousal for the PV technology, the second incentive scheme gave a big contribution to the technology development.

This incentive scheme applies to all PV plants with an installed power higher than 1kWp and it consists in an extra remuneration for every gross kWh produced over 20 years. The incentive is inversely proportional to the plant's size and its amount depends on the integration modalities of the plant into the building/landscape (i.e. roofs, greenhouses, sheds, etc), as summarized in Figure 1.

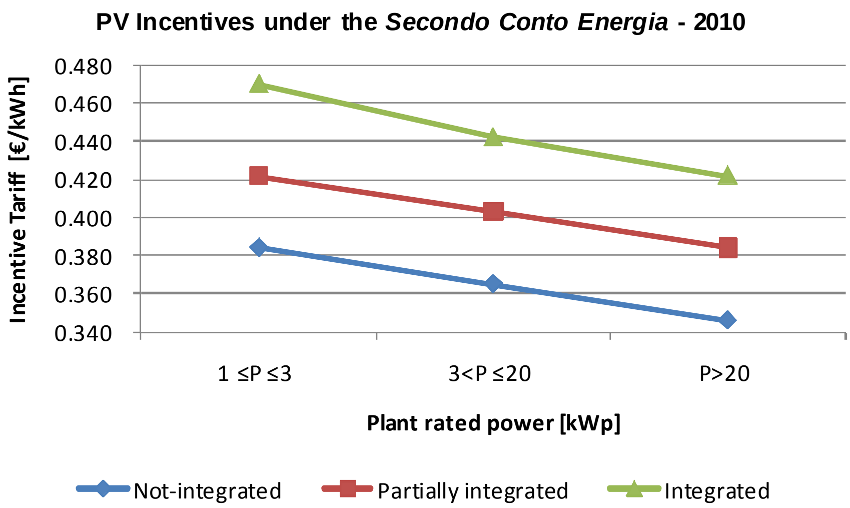

Figure 1: Incentives for PV plants, according to plants' size and construction typology, as in the 2010 Italian incentive scheme (1)

The attractiveness of the PV incentives together with the high solar radiation in Italy (see Figure 2), have originated several initiatives and many plants entered the national power generation scene. A lot of new entrants, historical utilities, and investors put a lot of attention to the Italian renewable market, possibly as never before.

Figure 2: Italian global irradiation and solar electricity potential on horizontally mounted PV modules (2)

According to GSE statistics on the "*Secondo Conto Energia*" (2007-2010), the biggest number of installed plants (over 130,000) sized 1-3 kWp and 3-20 kWp. However, these small plants all together represented only about 25% of the total installed PV capacity. On the other hand, the number of large scale PV plants (statistics provide data for plants bigger than 1MWp) is extremely small (less than 200), but they account for more than 20% of the total power installed. Medium size plants, with capacities from 20kW to 1MW, are around 10,000 and they represent around 50% of the total installed capacity. The following figure provides a graphical representation of the installed plants numbers and capacities. (1) - last updated on January, 31st 2011.

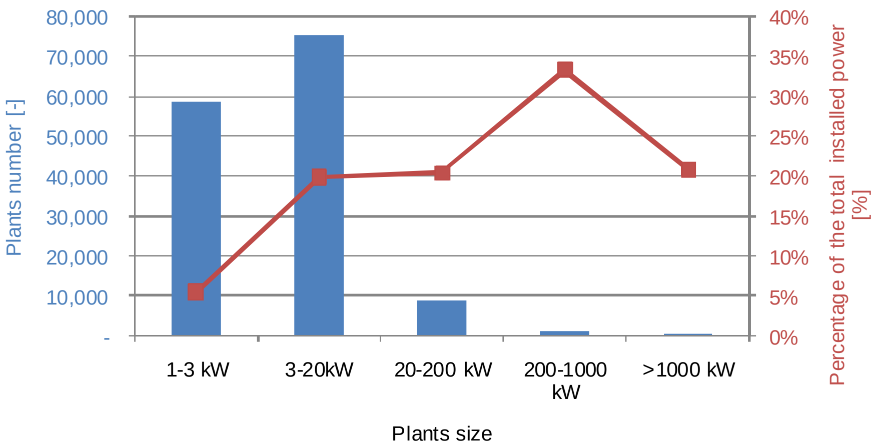

Figure 3: Number and total capacity of PV plants installed in Italy from 2007 to 2010, according to plants size (1)

2. Background

Large scale PV plants are often developed under a project financing scheme. MWH has been retained by several developers, investors, and lenders to provide technical advice and engineering services for developing large size PV plants.

Several Clients have requested MWH services for carrying out a primary evaluation of the proposed plants' equipments, performances, contracts and economic data in order to get indications on the attractiveness of the considered projects. In addition to this, MWH also acted as Lender's Engineer, supporting Banks from the EPC and O&M contract negotiations, to the supervision of the construction works progress and to the plants commissioning.

The involvement in several large scale PV projects allowed MWH to obtain a relatively wide picture of their main issues.
This paper will try to deepen few technical, contractual and economic aspects which are of main importance in the development of large scale PV plants and which have generated discussions and arisen the attentions of the concerned Parties.

The data and information contained in this paper stems from several activities MWH conducted for different clients in the photovoltaic sector, and it is based on a critical review of the assets and project portfolios MWH was involved in. (3)

3. Technical aspects

The main component of a PV plants is the **PV module**. Modules in fact not only are the core technology of the power plant but also have a big impact on the plant investment cost. Figure 3 shows the recent price and performance ranges of the most common PV technologies. The direct proportionality between efficiency and price can be observed. According to MWH's experience, Si-polycrystalline panels are widely used in large scale plants: this is likely to be related to their good compromise between cost and efficiency with respect to other technologies. However MWH has analyzed and followed plants with monocrystalline and amorphous silicon panels, too.

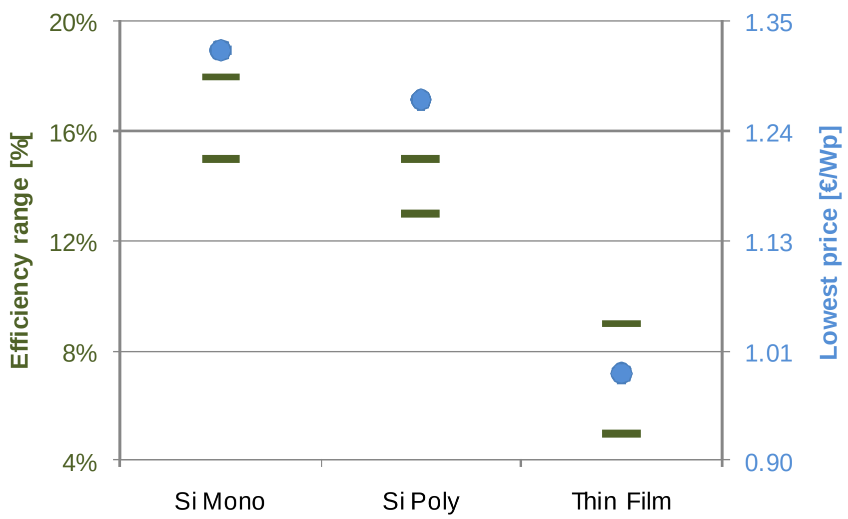

Figure 4: Efficiency and prices of the main panels' technologies (2), (3)

Plants are dimensioned and designed according to the panels' nominal power. However the actual plants performances will be determined by the real panels' output: the **flash test peak power**.

Therefore the nominal power plays the main role in the development phase, whilst the flash test peak power should be the protagonist in the plant's construction phase.

The following table indicates the difference between the nominal and the flash test peak power values recorded in some Italian large scale PV plant. Such data refer to polycrystalline silicon panels only.

Table 1: Comparison of the design nominal power and the flash test peak power for several large scale PV plants

	Nominal Peak Power [kWp]	Flash Test Peak Power [kWp]	Flash vs Nominal [%]
Plant 1	1290.30	1313.98	101.84%
Plant 2	3458.18	3503.22	101.30%
Plant 3	2296.47	2320.76	101.06%
Plant 4	2046.30	2043.31	99.85%
Plant 5	3165.90	3210.20	101.40%
Plant 6	2049.60	2046.68	99.86%
Plant 7	1011.60	1011.45	99.99%
Plant 8	4061.82	4073.11	100.28%
Plant 9	5487.09	5575.03	101.60%
Plant 10	4909.01	4930.67	100.44%

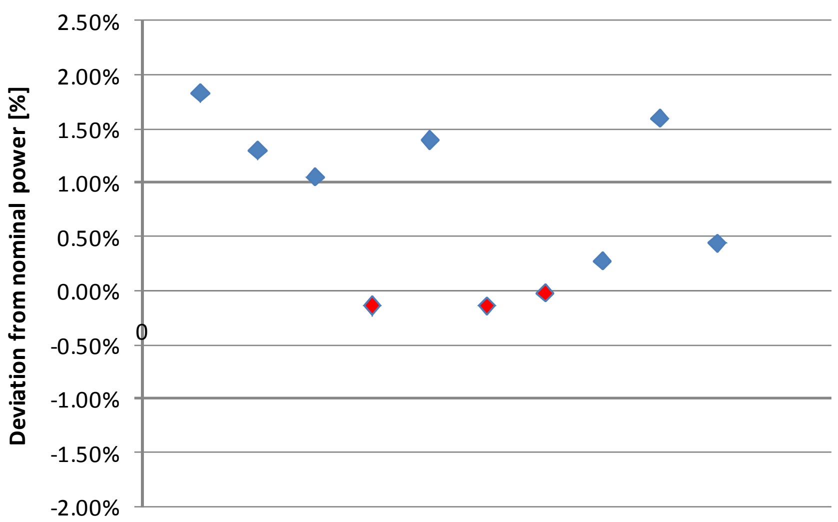

Figure 5: Deviation of the flash test peak power from the nominal one, for a selected number of large scale PV plants

The results represented in Figure 5 shows that the flash test deviation is always below and that 7 plants out of 10 have a positive deviation from the nominal power. For plants 1, 2 and 3, the reason is the purchase of positive tolerance panels. In three cases only the deviation is negative, and it is always inferior to 0.2%.
Similar considerations cannot be carried out for amorphous silicon panels, due to their high performance decay in the first 8-10 operational weeks.
Generally, in EPC contracts, a price adjustment is foreseen in case the flash test peak power is lower than the nominal one. This, in fact, will surely lead to a reduced energy output. On the contrary, a flash test peak power higher than the nominal one, does not ensure that the plant will have a higher productivity. In fact, as an example, one low-performing panel in a 20-panels string, will decrease the production of the whole string. However, in MWH's experience, contracts have been signed also with a price adjustment in case of flash test peak powers higher than the nominal ones.

Panels with similar peak powers should therefore be connected in the same strings in order to minimize bottlenecks and performance decrease related to mismatch losses. A 1% losses increase due to mismatch will lead to about 1.3% revenues reduction. For a plant of i.e. 2MWp getting the 2010 partially integrated tariff (0.384 €/kWh), this means annual "losses" of around 15k€. The bigger the plant size, the higher the impact of the losses: it is for this reason that the installation and connection of PV modules in large scale plants deserves a big attention.

Mismatch losses can be limited in two ways: the selection of the positive tolerance panels and the Sorting process. The former allows ensuring that the installed capacity will be equal or higher to the nominal one, thus reducing the underperformance risks (for the EPC Contractor). The latter grants ensuring that the panels are optimally placed and connected to each other.
The **Sorting** in fact, consists in connecting the right panels into the right strings according to their flash test peak power. This generally occurs through the panels' subdivision into performance classes: the manufacturer provides panels packed by performance classes, which are mounted accordingly by the EPC Contractor. Despite its influence on the plant performances, the Sorting is seldom included in the EPC contracts. This might be related to the fact that it is in any case in the EPC's interest to limit its underperformance risks.

After the panels' features, the performances of PV plants are determined by the **system integration**. This includes from the modules disposition and connection schemes, to the DC and AC cabling, the inverters, and the transformers.

The panel layout and the string connection schemes often have to be a compromise between several factors, which affect the plants' performances in different ways. The key elements affecting the technical and economic performances are:

- panels orientation and inclination,
- construction solutions (integration modality, as in the *Secondo Conto Energia)*,
- panels' connection considering the avoidance of turns formation and the shading effects,
- cables path length.

These factors impact both on the DC and the AC losses, as they affect the optimum working conditions of the strings as well as of the inverters.
A 1% loss due to incorrect panels connections and longer cables paths, can lead to more than 1% reduction of the annual energy production, which again is not a negligible value for large scale PV plants.

Inverters are the components of the plant converting DC to AC power. Their dimensioning, selection and position should also be carefully designed as it influences the performances of the plants and its costs. They should be located baricentrally with respect to the strings in order to minimize the cable lengths and ensure an adequate balance.
Two are the possible solutions for large scale plants: the installation of few big inverters or the use of several small and displaced inverters. In MWH's experience, the first solution is the most common, but at least one plant adopting the second solution has been analyzed. The main advantage of having few big inverters (250/300kW or more) is the improved performances of the equipments and a scale effect on the costs. The choice of using small inverters (i.e. 300x10 kW inverters for a 3 MWp plant), instead, allows increasing the reliability of the plant against failures.

In most cases, large scale PV plants are connected to the grid in Medium Voltage (15-20 kV). Transformers can be either included in the inverters, or located separately, however always close to the inverter boxes. Common transformer sizes range from 300 to 500 kW, as this is a good compromise between performance and cost.

A last issue to be addressed for large scale plants refers to the accidental **breaking of the panels** during the plant construction period. The following table lists the number of broken panels in the installation of different types of PV plants, recently monitored by MWH.

Table 2: Broken panels for different plant-types and technologies in recently analyzed large scale PV plants

Total panel number	Plant type	Broken panels [-]	Broken panels [%]	Panel type
15,440	Roofs	3	0.019%	Si poly
5,610	Roofs	2	0.036%	Si poly
15,560	Roofs	0	0.000%	Si poly
56,652	Roofs and sheds	11	0.019%	Si poly and thin film
15,000	Ground	5	0.033%	Si poly
1,600	Sheds	2	0.125%	Si poly

It can be observed that the issue of broken panels is not a main concern, not even for large scale plants. According to MWH's experience, broken panels are generally included in a punch list, drafted at work completion. The completion of the punch list is a pre-requisite for the payment of the last milestone.

Moreover, it can also occur that panels break after the plant's handover to the Owner. In these cases, the EPC contract might foresee a store for spare parts, which preserves the Owner on the long term, assuring the possibility of replacing damaged modules after few years, with panels having the same features of the installed ones. However, the EPC Contractor is generally retained also for the plant Operation: this relieves the Owner from the spare parts issue, as the material guarantees pass by.

4. Contractual aspects

As already mentioned, large scale PV plants are generally developed under a project financing scheme. This implies that payments occur at milestones as set in the EPC contract: each **milestone** refer to a Project progress, from the contract signing to the Test. The way the payment percentages are split among the several Project phases can vary with Projects and Actors.

In general however, the following structure is adopted: an advance payment before works begin, a number of payments proportional to work progress during the construction period (an average value for large scale plant could be around 6 months), a quota paid at work completion and a final payment at the test. The following table provides a typical example of the payments split based on the experience gained through the review of several EPC Contracts.

Table 3: Sample milestone payments

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Contract signing	10%		10%	10%	20%
Performance bond delivery		15%			
Commencement date	15%				
Delivery onsite of 50% panels	20%				
Delivery on site of 50% panels and 20% mounted				10%	
Delivery onsite of 100 kW panels and of 50% structures			20%		
Delivery onsite of 100% panels	20%				
Delivery onsite of 100% panels and 50% mounted				30%	
50% panels mounted			15%		
100% panels mounted			20%	15%	
Work completion			20%	20%	
Mechanical Completion Test	15%				5%
Test	10%				

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Entrance in operation			5%	5%	
Payment proportional to periodic work progress		70%			65%
Provisional Acceptance Certificate (PAC)	10%	15%	10%	10%	10%

The general trend is to pay 10-15% at the signing of the contract, 65-80% proportional to the work progress (either related to material delivery, mounting, or tests) and to leave 10-15% at the Provisional Acceptance Certificate (PAC), which is released after the Provisional Acceptance Test (PAT) execution. It is probably worth remarking that payments proportional to the work progress are unlikely to be precise for large scale plants: this is related to the large amount of materials involved and to the big site dimensions.

Being the last milestone payment of the EPC contract and an indicator of the plants' performances, the **Provisional Acceptance Test** plays a main role. It also provides the Owner with an indication about the goodness of its plant. At a successful completion of the PAT, a Provisional Acceptance Certificate (PAC) is released by the Owner. Generally, upon issuance of the PAC, all the liabilities connected with the safekeeping and maintenance of the plant shall be transferred from the Contractor to the Owner. The modalities for the execution of the Test are clearly reported in the EPC contract.
Several are the approaches which can be adopted for the Test execution: it can consider the plant operation over a time period, or it can be a spot measurement of the power produced under a certain radiation. The former allows determining the energy production and the plant availability over a time period, whilst the latter foresees spot measurements of radiation and power, which are the inputs for the calculation of the Performance Ratio (PR), the indicator of the plant performances. According to MWH's experience, in Italy most plants use the second approach: its concerns are therefore briefly presented in the followings.
The PAT might require measuring both the DC and the AC performances or solely the latter one. Such a test has to be carried out with high accuracy instruments and an adequate number of repeated measurements shall be undertaken in order to ensure the accuracy and the reliability of results. The test provides instantaneous measurements, which indicate how the plant was built and how it will be performing. Therefore, in order for the PAT to be significant, it is important that the circumstances under which it is carried out are representative of the average annual working conditions and that they stress the equipments enough. A generally accepted boundary condition to be fulfilled for the execution of the PAT is the existence of a minimum radiation of 600 W/m^2: this value origins from the *Secondo Conto Energia*. The GSE (the Italian entity which has, among others, the responsibility of delivery the incentive tariffs) in fact, required the plant's DC and AC performance ratios to be tested at a minimum radiation level of 600 W/m^2. This is the reason why, most of MWH's analyzed contracts, require a minimum radiation of 600 W/m^2 in their test procedures.
The deadline of December 2010 of the *Secondo Conto Energia* acted as a booster for the completion of diverse PV plants. As most contracts foresee the execution of the PAT a few days after the work completion date, several PV plants had to carry out the PAT in the winter period. However, radiation levels in winter are often lower than 600 W/m^2, and this is mainly true for plants located in North Italy. Therefore, the fulfillment of the minimum irradiation level has been an issue for several PV plants. As far as MWH's 2010 experience with large scale PV plants concerns, the risk of PAT delay due to insufficient radiation, has seldom been taken into account by the Parties at the moment of the contracts drawing, and this has caused the following drawbacks for the Parties:

- a delayed cash flow, in disadvantage of the EPC Contractor,
- a review of the status of the insurances (i.e. erection risk insurance) and, in case, their extension,
- a delay of the loan for the Bank.

Beyond the time schedule, the way the PAT is undertaken plays also a very important role. In particular in fact, large scale PV plants can have complex layouts, which do not ease the test

execution. Of primary importance is the synchronization of all measures: the instrumentation, the logging of the data, the cable dimensions and the possibility of isolating inverter parts are the main items to be considered in the test planning. For instance, the commonly used HTsolar300N has a limited number of entrances for the pyranometer input. In MWH's experience, it can occur that panels connected to the same inverter have more inclinations than the instruments entrances. Moreover, it can also happen that inverter cablings are not measurable with common 1000A-current clamps. As these aspects might be an obstacle to a proper test execution, they should be adequately planned by the Parties.
In order for the PAT to be successful, EPC contracts require a PR equal or higher than the Guaranteed Performance Ratio (GPR), and however higher than the Minimum Performance Ratio (MPR). In some contract, as additional clause for a successful PAT, a certain availability (on a limited time period, such as few days) might be required.
In case of non successful PAT, the EPC Contractor generally has a make-good time period in order to improve the plant's performances. Is this not the case, the Owner has the right to reject the plant (in case the PR is lower than the MPR), or to obtain a Price Adjustment, or to ask the EPC Contractor to pay penalties proportionally to the estimated energy loss.
The Owner's interests are generally preserved by a Performance Bond, issued at the contract signature and whose amount is generally equal to the PAC milestone percentage payment.

The PAT penalties generally refer to one year only, as other Acceptance Tests are undertaken in the first two operational years. These are: the Intermediate Acceptance Test (IAT) and the Final Acceptance Test (FAT), respectively carried out after one and two years from the PAT. The general scheme for the evaluation of the performances at the IAT and the FAT is the same as for the PAT.
In case the Test results show the plant performs less than the guaranteed levels, penalties are due to the Owner. Penalties are proportional to the underperformance levels and according to the formulas stated in the EPC contract. The risk of underperformance is covered by the Warranty Bond, which is issued at the PAC and lasts until the FAC. This Bond represents a percentage of the contracts' price, generally around 10-15%.

The **FAT** is generally the latest test on the plant, which will run without further tests for the following 18 years. It should be highlighted that the IAT and the FAT are included in the EPC contract, although they are undertaken during the O&M period (respectively in the first and second year). Penalties are proportional to the revenue loss due to the energy underproduction, and generally an intolerance margin is foreseen, where no penalty is due.
In some cases, after a non-successful FAT, an 18-years equivalent penalty is required. A sample penalty can be a Final Underperformance Contract Price Adjustment, which takes into account the energy production losses due to the lower Performance Ratio at the FAT. The payment of these penalties is covered by the above-mentioned Warranty Bond. This entails that the Owner has higher warrantees/bonds for the milestone, related to the fact that the FAT belongs to the EPC contract.
In other cases, the penalties at the FAT refer to 1 year only, and the annual production has to be determined for every year of the O&M period. In this cases, the plant annual performances fall under the clauses of the O&M contract and not of the EPC one. Such approach is possible thanks to the fact that, in general, the EPC Contractor is also retained for the plant operation. The main consequence of this approach however is that the (annual) penalty will never be superior to the O&M cost, as the Operator yearly fee acts as a cap. In these cases therefore a Guaranteed Energy Production Levels is envisaged in the O&M contract: this represents the minimum performance level to be reached. The minimum energy level of the O&M contract can either be a fixed number (calculated according to rules and standards), or it can be proportional to the measured total annual irradiation (measured with the field instrumentation). Even if both formula can be applied, it is MWH's opinion that, the use of the irradiation data measured by the field instrumentation is not always accurate as the field instrumentation accuracy is not always high, and the measure instruments are not always in a "good" status all the year long (i.e. dust on the pyranometer). Therefore, MWH considers that the use of a fixed value should be preferred.

Finally, is the energy production higher than the guaranteed one, O&M contracts might foresee the payment of a bonus, generally split 50/50 with the Plant Operator.

O&M contracts might require the Operator to issue an O&M Bond, whose value is however proportional to the O&M costs and not to the Plant Investment cost.

5. Economic aspects

According to MWH's experiences, the profitability of large scale PV power plants can vary significantly. MWH had the opportunity to carry out preliminary evaluations and reviews for several large scale PV plants. The following figures summarize the impact of the main factors on the plants' KPIs (Payback Time, PBT, and Internal Rate of Return, IRR). The numbers stem from around 15 large scale PV plants recently analyzed by MWH. All considered plants are mainly based on polycrystalline silicon technology.
Economic calculations have been undertaken with the following assumptions: 31% corporation tax, 0% loan, 18 yrs refunding period and 7% WACC. Despite their development under a project financing scheme, the numbers represented here are barely economic data. They should be regarded as the starting point for a preliminary evaluation of the project attractiveness, which will only decrease under an external financing.

Figure 6 shows the impact of the scale effect for PV plants: 1MWp plants have lower IRR and higher PBT than plants over 2MWp. Plants with an installed capacity of around 1MWp have IRR ranging from 8.2% to 10.1% and PBT from 8.5 to 9.6 years. Larger plants instead have IRR from 13.5% to 16.8% and PBT from 5.7 to 6.8 years.

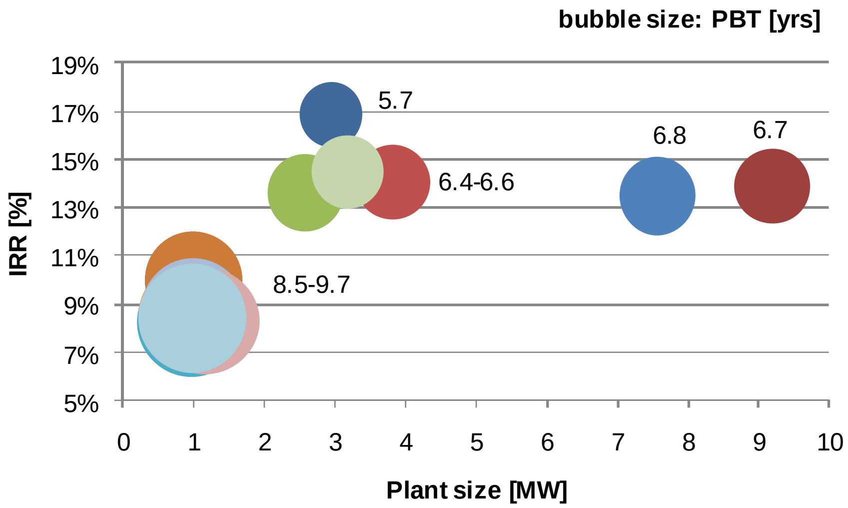

Figure 6: IRR and PBT as a function of the plant size – values before taxes

These differences are mainly related to variations in specific investment costs, as shown in Figure 7. A large scale plant with a specific investment of around 2,500€/kW has the lowest PBT (5.7 yrs) and the highest IRR (around 17%). On the contrary, large scale PV plants with an investment around 3,000€/kW have PBT ranging from 6.4 to 9.8 years and IRRs around 14%; and these values worsen with higher investment costs.

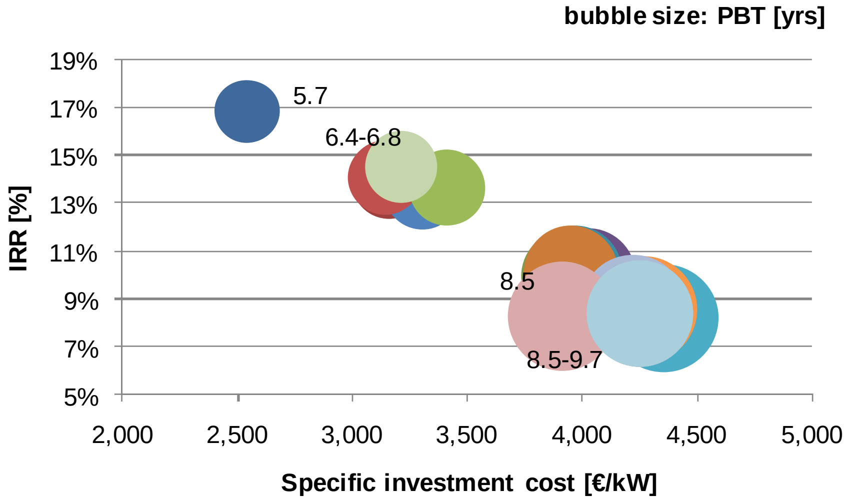

Figure 7: IRR and PBT as a function of the specific investment cost

6. Conclusions

Large scale PV plants require indentifying the best balance between technical and economic aspects in order to be successful. The optimal solution has to be implemented throughout the project: from the design phase and up to the plant construction and commissioning.
Despite its conceptual simplicity, several are the aspects impacting PV plants performances. The design choices, the optimal implementation of the designed solutions and the proper "tuning" of the plants in the first years of operation, are all elements of main importance in order to minimize the plant's losses, and to increase the plant's output and its profitability.
The final aim should be to find out the best harmony for the project, in terms of technical, economical and contractual solutions.

Several are the technical aspects to be considered in the drawing up of EPC and O&M contracts: materials, losses and actual performances, test execution, etc. It is important that all technical aspects are accurately taken into account and that each issue is properly addressed in the EPC and O&M contract and it is properly connected to all other aspects.

Unlikely from other technologies, photovoltaic plants have very disproportioned cash flows: a big sum has to be disbursed in a relatively small time period, and very small payouts are required during the operation period. In fact the main payments are related to the EPC contract period, which generally refers to the few months of the construction period. On the contrary, the disbursements of the operation period last around 20 years and are of much less importance. For this reason, the EPC contract is crucial for PV plants.
Moreover, PV plants operation is characterized by the considerable difference of revenues and OPEX: this is a further reason why owning a well-designed and constructed plant is of big importance. Few are in fact the leverages the Owner has on the Operator during the O&M period.

The main peculiarity of PV plants however, is probably their weather dependency. This affects both the plant's EPC and O&M phases, as the weather factor impacts the test execution, the energy production and the cash flows.

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