Site selection in the photovoltaic industry

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ABSTRACT

Climate change, oil shortage, green energy, energy security – these are some of the global 'mega'-topics currently dominating the agenda in the news, in politics and in private lives. One of the industries that has most profited from the ever-growing consciousness about the need to de-carbonize current energy use is the photovoltaic industry.

With this economic background, the photovoltaic industry has experienced impressive growth rates in the last decade and is expected to grow at 30% per year over at least the next couple of years. Since its upswing, it has become a multi-billion dollar industry and subject to speculation on stock exchanges worldwide. At the beginning of the solar boom there was a shortage of available silicon to produce wafers and cells. One response of the industry was the quest and the use of alternative thin-film materials to produce solar cells. The reaction of the silicon supply industry was (and actually still is) the expansion of silicon production facilities, including specialized solar-grade silicon production facilities. Despite a much more relaxed outlook on the silicon supply-demand ratio, investments in solar silicon production facilities is predicted to amount to more than €4.0 billion by 2010. This is slowly reducing the supply gap, enabling photovoltaic producers to invest heavily in new production capacities.

Introduction

Electricity produced by means of photovoltaic energy devices is still much more expensive than that produced by traditional nuclear or fossil fuels. Hence, it will be vital for producers of photovoltaic devices to decrease the cost per KW of capacity produced. The industry is currently addressing this challenge by leveraging several dimensions of innovation:

1. **Product innovation** – e.g. using thinner wafers, more effective materials, etc.
2. **Process innovation** – e.g. energy consumption, automation, etc.
3. **Enterprise model innovation** – leveraging internal efficiencies, potentials or innovations of the production network and seeking locations with competitive cost advantages.

Site selection in emerging industries lacks any kind of benchmarks or standard procedures and project managers and consultants have been pioneers in this task. This article is meant to highlight the most important factors when doing site selection for PV manufacturing facilities.

As the various elements in the production chain are somewhat different, the article is split into three site selection approaches:

		SILICON PHOTOVOLTAICS VALUE-ADD STEPS		
		SILICON to WAFER	WAFER to CELL	CELL to MODULE
Process feature	General technological level of production process	Medium – High	Medium to High	Low
	Level of process automation	High or Medium to High	Medium to High	Low
	Involvement of specialized workforce	Medium to High	High	Low
	Involvement of manual labour	Low	Medium	High
	Sensitivity towards energy cost	High	Medium	Medium – Low

Table 1. Process features and potential for value addition in silicon PV production.

- Wafer production (SILICON to WAFER)
- Cell manufacturing (WAFER to CELL)
- Module manufacturing (CELL to MODULE)

The site selection for each of the above listed steps is focussed on individual location requirements. In order to determine which of the location criteria are important and which are not, it is useful to have a look at the particular process features.

Table 1 clearly shows the two more technology-based steps are SILICON to WAFER and WAFER to CELL. The regional technological level and the availability of specialized workforce are prime factors when choosing the most suitable location. The CELL to MODULE production is clearly less technology-based. Site selection should focus on different criteria in this value-add step.

In cases where all production processes are being consolidated at one particular location each of the individual location requirements have to be taken into account in order to find an appropriate location for the investment.

In order to gain a general understanding of the different steps in site selection for manufacturing projects, the following section of this article illustrates the general site selection roadmap, while the third section focuses on the important criteria for site selection in the different value-add steps of the photovoltaic industry.

General process of site selection

Before selecting the preferred location for an investment, a clear and project-focused strategy is key for success in site selection. The globalization of recent decades has extensively broadened the freedom of choice when it comes to location for production facilities. Trade barriers have been diminished and IT enables knowledge and know-how to circulate around the globe practically without boundaries. This enables companies to become so-called globally integrated enterprises, ones that allocate resources for each different operational unit at its most convenient location.

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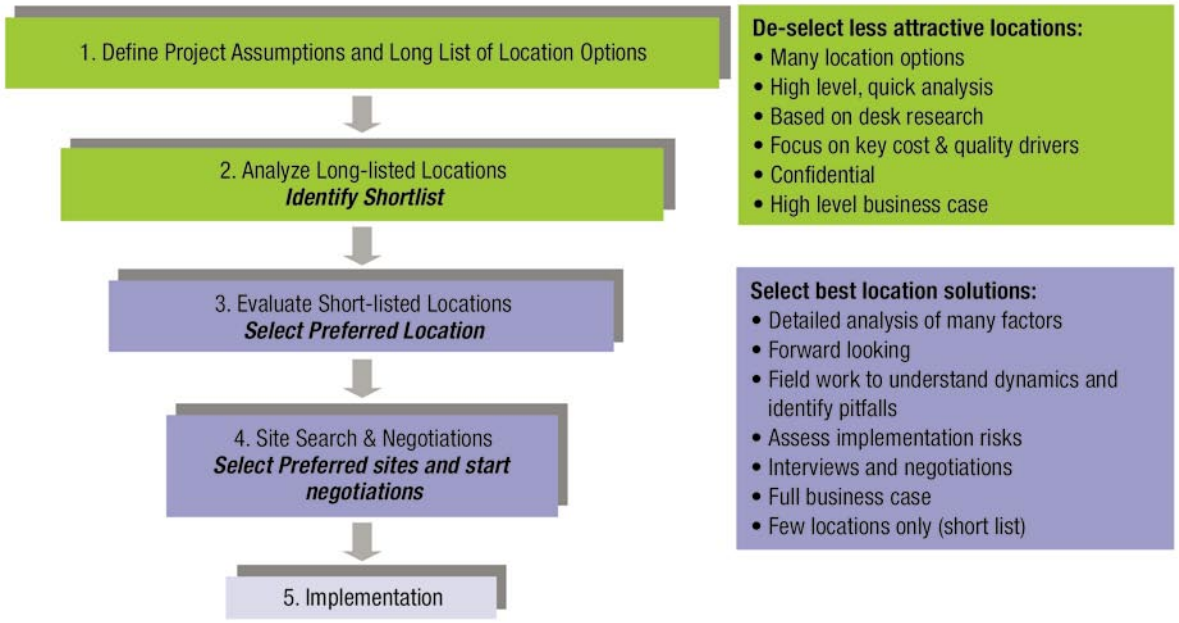
The task of selecting a preferred location can roughly be split into three steps:

1. Long-list identification through de-selection of less attractive locations
2. Selection of preferred location option(s) through assessment of short-listed locations
3. Site search, due diligence and simultaneous start of negotiations with preferred location options.

1. Long-list analysis

This first step is aimed at quickly reducing the initial list of potential location options to a manageable amount. Depending on the nature of the project, site selection processes can even start at a global geographical scope. By identifying and applying the main project drivers, this initial scope quickly narrows. These main project drivers are regularly translated into criteria that define minimum requirements that a location must fulfil in order to make it to the long-list of candidate locations. These criteria may include geography-driven factors like time zones, distances to other locations of the company, or distances to market or customer. Other



Source: IMD World Competitiveness Yearbook 2008 (based on OECD data)

Figure 1. Stages and important factors involved in site selection.

factors often used to reduce the initial range of possible locations are technology-driven factors, general cost levels of a country/region, and factors describing the competitiveness of a location by assessing its general business environment.

For the photovoltaic industry, such long-listing criteria could include:

- Risk mitigation-driven criteria focusing on the general business environment, technological level of a region, ruling out countries or regions with less promotional business environments or less technological development;
- Purely cost-driven criteria focusing on countries with a general lower cost level; or
- Market-driven criteria focusing on current key or future growth markets (e.g. Germany vs. developing Asia).

The selection of broad elimination criteria is determined by the particular project and the growth strategy of the company.

Once a long-list has been identified, the locations are assessed via:

a **qualitative analysis** assessing all key non-financial factors, each weighted on their importance. Locations are being scored on each location factor and an overall weighted analysis identifies best quality candidate locations.

a **high-level financial analysis**, which focuses on key financial performance drivers showing the different cost levels of the locations assessed.

This analysis is carried out by the use of information provided by official sources from the long-listed locations, as well as information included in industry-specific literature and market studies. The most important financial factors also have to be researched and identified based on strategic, geographical, industry, and corporate context. The combination of the qualitative analysis and the high-level cost analysis are combined in so-called cost/quality-maps to identify locations that best meet the project requirements.

With the help of these kinds of charts, the relative value propositions of locations can quickly be identified and the locations for further in-depth location evaluation can be selected.

2. In-depth assessment of short-listed location options

The subsequent in-depth short-list location assessment is meant to further detail the facts and figures for the remaining options. It aims at the selection of preferred location option(s) and respective back-up options. This process regularly requires on-site meetings with stakeholders of different disciplines. In executing the in-depth field work, critical requirements, many of which are necessary data-points for the input into the business plans, are further evaluated. Usually, these kinds of prospective business plans are made for a fraction or even all of the short-listed cities, allowing comparison of the projected return of investment at the different locations regarded. The result of this phase of the location selection process will be the identification of the preferred location options.

3. Start of negotiations and implementation

Before the final location decision is done, many site selection project managers start negotiations simultaneously with several potential final location candidates. The main topics in these negotiations are subsidies and incentives, as well as other investment costs that can be influenced on the local level (e.g. land cost, waste water discharge cost, etc.).

Site selection for the value-add steps in silicon PV production

Solar wafer manufacturing

Using silicon as the prime input, solar wafer manufacturing is the first step in photovoltaic manufacturing. Solar-grade silicon is thermo-treated and transformed into ingots, and cut and sliced into thin wafers.

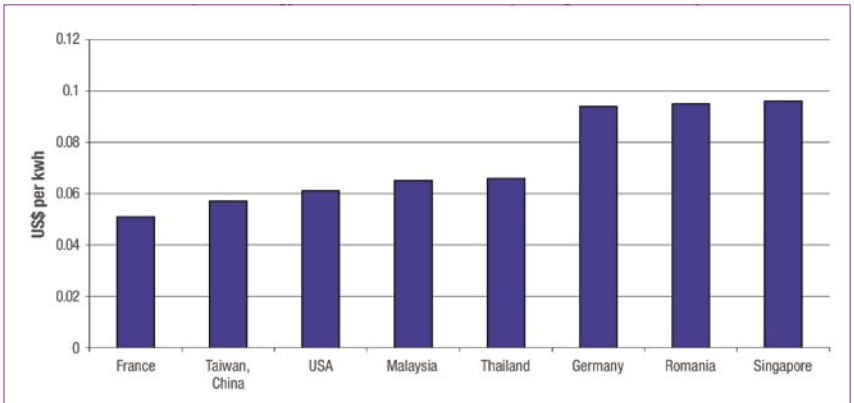


Figure 2. Sample of energy costs for industrial clients (generalised data from 2007).

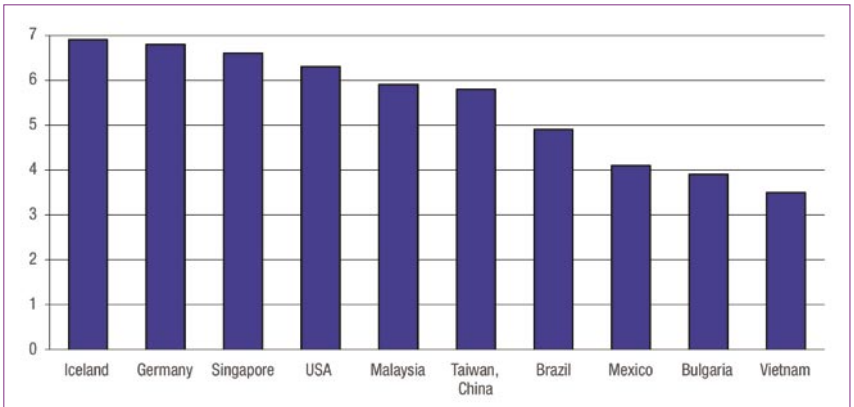


Figure 3. Geographical breakdown of quality of electricity supply indicating lack of interruptions and voltage fluctuations (from 1 to 7, where 7 indicates best quality of electricity supply).

Looking at the key human resources needed to operate and maintain this production step, the dependency on qualified technician and engineering skills becomes obvious. As this process includes thermal treatment as well as sawing and slicing using specialized machines, different engineering skills are needed. Process, mechanical, electrical, and chemical engineers as well as qualified maintenance technicians are needed to operate and maintain the highly specialized machinery. The recruitment of such experienced skills is usually much easier in highly developed countries and in countries where the industry is already present. In countries where photovoltaic technology is still not common, the key engineering staff must be brought in until local labour has been educated and trained to meet the industry's specific needs. Depending on the technological level and the focus of education institutions of the destination location, this state of play can last as long as several years. Also depending on the destination location, the levels of expatriate involvement can vary from operations management to the temporary employment of the whole engineering team until local labour is available. The availability of specialized key engineering skills has to be determined beforehand. A wrong assessment of the availability can have huge impacts on payroll, because expatriate involvement has considerable impact on payroll costs.

Handling of the ingots and wafers is a task that can either be manually controlled or can utilise automated handling and packaging processes. In general, manual and low-skilled labour is not crucial for this step in the value-add chain.

The majority of the processes used for silicon wafer production are still fairly energy-intensive, with the majority of plants requiring huge amounts of energy. In fact, energy makes up the bulk of annual operating expenses. Thus, local power costs play a key role for site selection in this value-add step. Publications that list prices in relation to power cost often tend to generalize or are geared towards a specific profile of industrial user. As Figure 2 shows, general levels of energy cost can vary substantially between countries. However, there are some aspects that can prove problematic when selecting a specific plot of land:

- Energy prices often vary considerably by region within a country (e.g. United States)
- Large industrial customers are often charged individual additional taxes, capacity fees, infrastructure and network fees that considerably change the basic rates per kW/h (e.g. Germany and several Asian countries).

Availability of specialized technician and engineering staff
Energy cost
Quality and reliability of technical infrastructure
Incentives
Vicinity of support industry (technical)

Table 2. Important criteria for site selection in solar wafer manufacturing (silicon to wafer).

Although the illustrations on energy prices in Figure 2 are generalized, they can be used to determine if electrical energy is comparably cheap or costly in a particular country and can therefore be used in the phase of long-list location assessment. A more detailed calculation of the energy bill – including all additional fees, taxes etc. – has to be created during the in-depth assessment of the short-listed location options.

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As the CapEx for special machinery in the photovoltaic industry is quite high, subsidies and incentives often play an important role in lowering the investment cost. Many European governments are actually using cash grants to attract these kinds of projects, cash grants that can be as high as 50% of the eligible investment expenditures. In fact, these levels are only reached in the least developed regions of Europe, but levels of between 20 and 40% are still being reached by numerous regions in Eastern Europe and in the eastern part of Germany. In Asian countries subsidies in form of cash grants are rather unknown. Therefore, the practice of giving tax holidays up to a certain percentage of CapEx is widespread to attract such investments. Preferential depreciation terms are another instrument of investment stimulation, which is being applied in many Asian countries.

Due to the high dependency of the production process on specialized furnace, sawing and slicing machinery, having key support companies within easy reach is a further factor to be considered in the location of such investments.

The quality and reliability of electrical power supply is a valuable indicator of the general suitability of the energy infrastructure of a country. In countries where the risk of power interruptions is too high, soundly maintaining the production process can become a hard and costly task. Countries that show increased risk for power outages are therefore often sorted out using this indicator; however, when looking at the example of China with a huge amount of different regional economic compounds, the viability of this kind of indicator can be limited.

The limits of informative value of this indicator can be illustrated by taking the case of booming Shanghai. Albeit a region with power shortages, foreign companies in Shanghai are rarely subject to power shutdowns.

As previously stated, electricity cost is an important location factor for photovoltaic fabs as the energy bill can make up as much as 75% of the operating expenditures. Therefore, some regions are using electricity cost as an incentive. Heavily-reduced electricity rates are exclusively being offered to photovoltaic companies in order to attract investments in the sector.

Solar cell manufacturing

Site selection for a solar cell manufacturing facility has to balance cost effectiveness and a high level of technological capability, even more so than in the site selection for wafer manufacturing. Site selection for solar cell manufacturing has to find the right balance between cost, human resources availability and technical infrastructure reliability.

The engineering team required of this kind of facility consists of a broad bandwidth of disciplines (e.g. specialized process, chemical, electrical or quality engineers), and so the labour market has to be comprised accordingly. In many cases, when these facilities are located in less developed labour markets, engineers and technicians that have the right basic education and experience get hired and then receive extensive training focussed on the particular technology and tooling of the fab. In contrast to the on-the-job training engineers and technicians receive in developed countries, which tends to be relatively brief, this training can take more than a year in less developed countries. The cost of this training combined with traditionally higher turnover rates in the first years of a facility's existence have to be carefully considered in the business plan. Hiring of expatriate resources for key positions is a strategy that is often followed by investors investing in Asian countries. The bulk of Asian countries have tailored their immigration laws accordingly and the workforce is highly mobile. In most cases, the local Investment Promotion Agencies (IPAs) offer special guidance through the visa application processes.

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Depending on the production technology used, water and electricity are key inputs in this step of the photovoltaic value-add chain. Water has to be available in the right quantity and the right quality, as many processes require a certain level of water purity. This is especially relevant to countries and regions with weaknesses in their technical infrastructure. In regions with temporary or ongoing droughts, steady availability of sufficient water has to be assessed carefully. Parts of the production process (e.g. doping) require thermal treatment and are therefore sensitive to energy cost. As the transformation of wafers into solar cells includes treatment with several speciality chemicals, stringent and complex environmental laws often cause complicated, time-consuming and costly permitting procedures. A compatibility assessment of the specific production process with national and local environmental regulations can save the project from unnecessary delay or even cancellation. Local agencies prepared to help and facilitate investors through the procedure for environmental applications can be very helpful. Investment promotion

Technological level of local technician and engineering staff
Energy cost
Incentives
Level of complexity of environmental regulations
Dedicated science and university programmes
Vicinity of support industry (technical)

Table 3. Important criteria for site selection in solar wafer manufacturing (wafer to cell).

Availability of cheap manual labour
Market vicinity
Transport Infrastructure

Table 4. Important criteria for site selection in solar wafer manufacturing (cell to panel).

agencies, regional development agencies and local governments that have specialists dedicated to promoting the PV industry in their territory can therefore be seen as important assets in the implementation of a project.

Solar panel manufacturing

Solar panel manufacturing, as the last step in silicon PV manufacturing, is also the least technologically intensive. Most companies still assemble the cells manually to form panels using tailor-made frames and profiles that they receive through specialized suppliers. The lower technological level of this production step is one of the reasons why the first facilities that are aiming to supply markets in Germany and Spain have started to locate to low-cost locations in Eastern Europe. An example of such a scenario would be a big Japanese PV company investing in a panel production facility in the northwest of the Czech Republic, receiving cells from Japan, and supplying markets in western and southern Europe. The Czech Republic's EU membership (for taxation reasons – import of unfinished goods and finishing within the EU), low wage cost and the direct market vicinity to Germany would make the Czech Republic a location of choice in this instance.

The involvement of manual labour and the low technology level of this production step make the availability of cheap labour an important criterion in location selection for PV panel production. However, cost is not everything. Depending on the size and output of the facility, sound and stable logistics are becoming more important, guaranteeing stable supply and delivery of each of the production steps.

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It is vital for the PV industry to further decrease the cost of the manufactured devices; choosing a location that offers the right trade-off between cost and quality is crucial. Site selection in the PV industry, therefore, has to consider the different value propositions of developed and less developed regions. The big question in site selection for the PV industry is how to decrease cost through choice of location, while still being able to maintain technological standards. Each of the production steps has its own requirements and its own sensitivities. In order to avoid the many pitfalls in site selection, specialized knowledge is needed to evaluate cost, human resources, infrastructure, incentives and local IPA support. Thus, a company must be assured that the project team and its advisors have in-depth experience in locating these kinds of facilities.

About the Author

Steffen Weiser is senior strategy consultant with PLI Global Location Strategies, a global service offering within IBM Global Business Services, exclusively specialised in global location strategies. He has expertise in location selection, business and economic development projects and advises corporate clients in multiple technology sectors as well as economic development authorities worldwide for the development of corporate location and economic development strategies. Steffen Weiser received his diploma in economic geography from the University of Stuttgart, Germany.

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