Local PV manufacturing

Matthias Grossmann, Viridis.iQ GmbH, Konstanz, Germany

ABSTRACT

The investment case for the establishment of PV manufacturing hubs in emerging regions became bleak as c-Si PV manufacturing capacities in China ballooned from 2004 to 2011/12. The resulting supply overhang, with dramatic price decreases throughout the PV value chain, led to severe margin compressions and ultimately to closures, insolvencies and postponement of expansion plans by incumbents across the board. A common misperception by private and public decision makers alike – reflected in the recent escalation in global trade disputes – is that products made outside China are, per se, not competitive. In contrast to this mind-set, and on the basis of experience in numerous development projects, the author argues that new entrants have multiple instruments available that can make local PV manufacturing plants commercially viable in many regions of the world.

China, a global powerhouse in PV

After having witnessed – possibly not without envy – the staggering development of the semiconductor and electronic component industries in neighbouring countries such as Korea and Taiwan, the government of China seized the chance and did not miss out on the PV market opportunity.

It took China only eight years to increase its share of global manufacturing capacity from a meagre 7% by the end of 2004 to over 50% in 2012. This tremendous expansion of the relative share held by China-based production capacities took place in a PV environment with extraordinary global growth rates on both the supply and demand sides. Only recently, with the start of the PV market shake-out at the beginning of 2011, did capacity additions level out (Fig. 1).

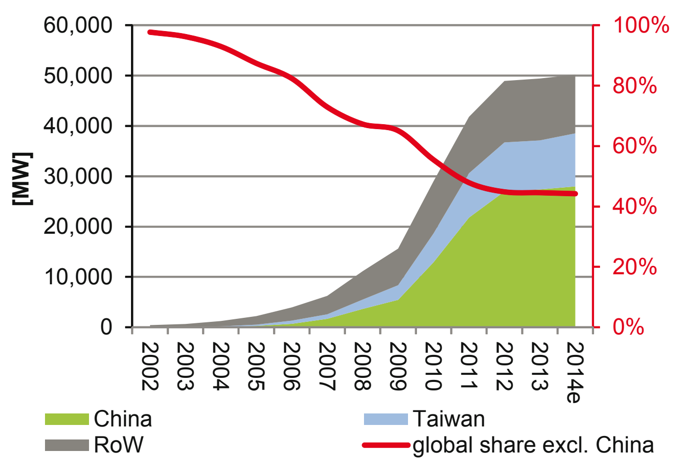
The major driving force on the supply side of the equation has clearly been mainland China, as a simple comparison of compounded annual growth rates (CAGRs) on capacity additions for selected regions reveals (Fig. 2).

The consequential build-up of excess capacity led to an unprecedented and prolonged price decrease on virtually all levels of the PV supply chain. This brought prices close to or even below leading manufacturers' short-term marginal costs, a price point that can only be defended over a short duration in a market-based economy.

> "PV subsidies are seen as tools that could be deployed in an instrument mix that is designed to foster the development of a local production cluster."

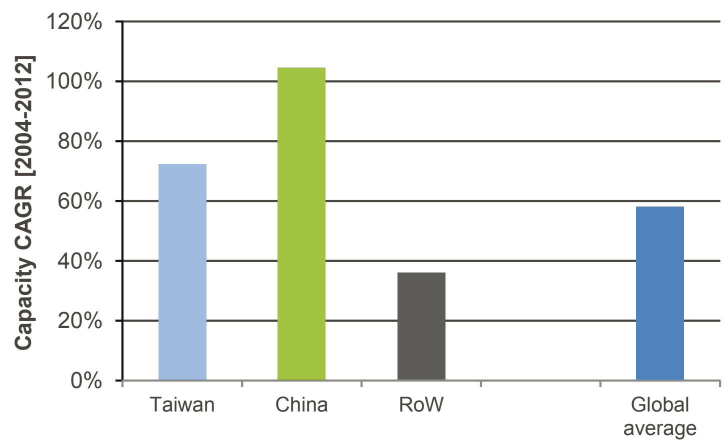
The resulting market clearance, with the failure of some renowned higher cost producers in the Western hemisphere, led to allegations that China-based manufacturers engaged in price dumping. The trade-related aspects of PV subsidies are discussed in the final section of this paper, as these are seen as tools that could be deployed in an instrument mix that is designed to foster the development of a local production cluster. However, the dispute is also seen as a source of distraction, as it deters decision makers from following a compact but comprehensive regional strategy that takes a holistic approach to promoting local installation as well as production.

PV power producers benefitted to a great extent from the unforeseen



Source: Viridis.iQ GmbH estimates

Figure 1. Global c-Si production capacity.



Source: Viridis.iQ GmbH estimates

Figure 2. Capacity CAGR 2004–2012 by region.

module price erosion of the order of 70% over the period 2010 to 2013 (Fig. 3). The improvement in the economics of PV systems resulted in a dynamic end-market environment with flourishing and broad-based demand from numerous countries around the world. The price elasticity of demand contributed to a long-anticipated transition process from subsidized markets to unsubsidized ones. The demand from new PV markets basically overcompensated the negative volume impacts caused by the curtailment of support schemes in many European countries.

These macrodynamics with flourishing installation volumes, failing business models and escalating trade disputes led to a subdued interest in local manufacturing in regions that are at the same time embracing the value proposition of PV power plants. In that respect the following aspects will be scrutinized in more detail:

- Local business models for integrated c-Si PV production, including depth of vertical integration, location-specific factors, collaborations, etc.

- Empirical evidence on the effectiveness of infant-industry protection in the PV industry (lasting until such measures are subject to formal challenge).

Local PV business models

The essential and most important aspects that need to be analysed at the outset of any business development initiative are addressable market size, competitive environment, supply chain options, and finance and investment needs, as well as country-specific conditions that might influence any of the aforementioned areas. Of course, an early-stage feasibility assessment covers many more vitally critical facets, such as the optimal technology choice, scale, material and mass flows, specification of infrastructure requirements, site selection, environmental assessment and initial project realization planning. However, an early-phase review of the first-mentioned key commercial-, financial- and market-related aspects is of advantage in that it might save precious time in the case of it leading to a clear indication that the project is not viable.

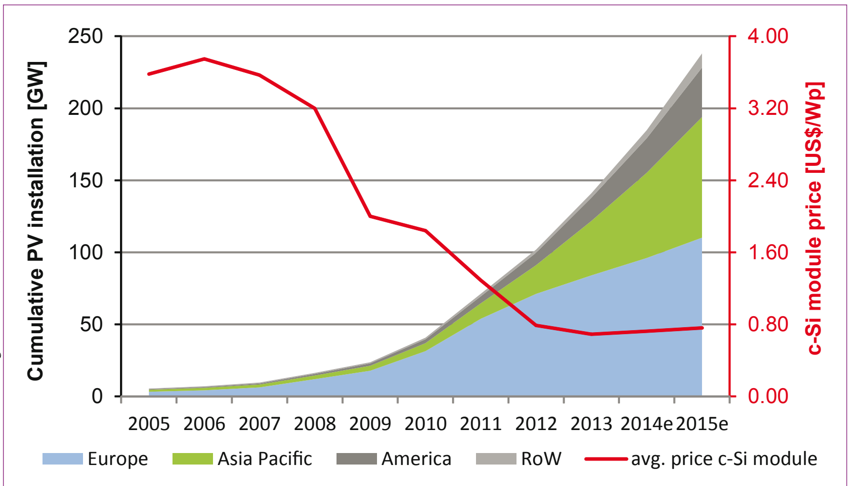
The listing of elements from diverse areas such as commerce, technology and engineering underpins the complexity of an industrial due-diligence process (Fig. 4). Further, the elements not only within the individual field but also from different areas influence each other, which leads to a multiloop and iterative planning process that relies on interdisciplinary expertise.

The decision process increases in complexity when the level of vertical integration is taken into consideration. For example, the crystalline silicon value chain virtually relies on three different industries and consists of five major process steps.

The sheer number of elements that needs to be considered in a holistic planning process to reach a sensible continuation or discontinuation decision exemplifies the magnitude of levers that can be utilized in order to improve the global competitive position of a new plant. Here, the most important areas that should be focused on during early pre-realization planning phases are:

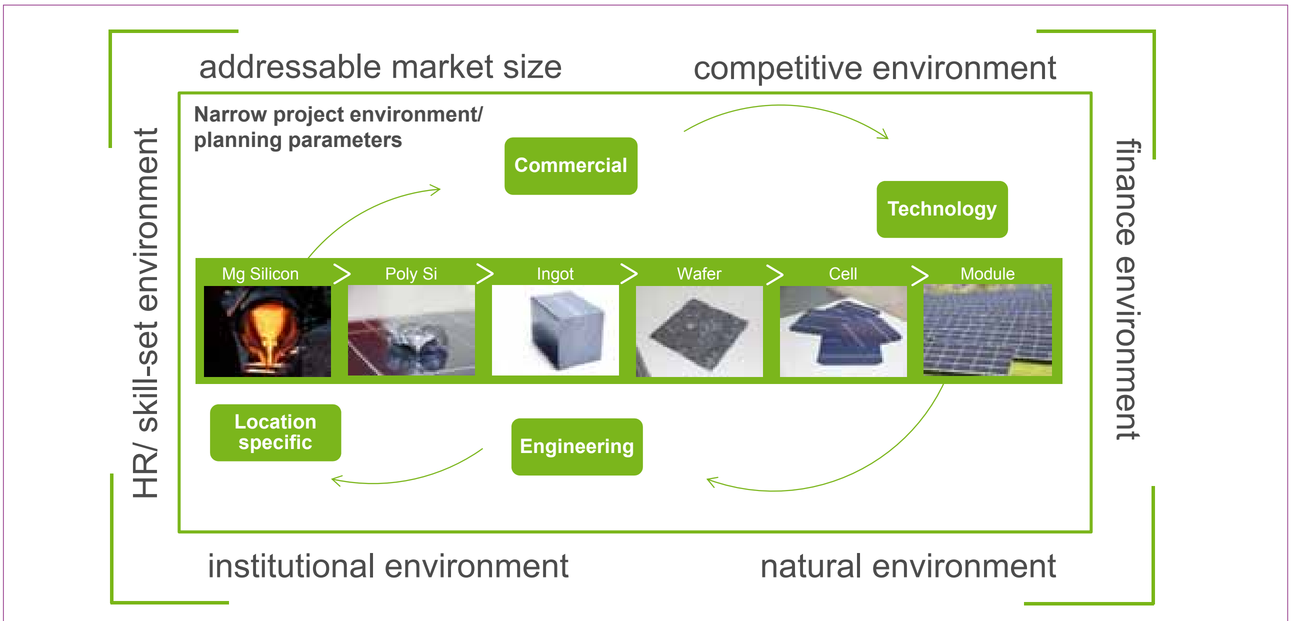
- Determination of the local and regional market size and supply structure in the near to mid term (subsidized and unsubsidized).

- Estimation of production costs in order to determine adequate capital-return-



Source: EPIA, PVinsights.com, Viridis.iQ GmbH estimates

Figure 3. Cumulative installations vs. price.



Source: Viridis.iQ GmbH

Figure 4. Complexity of project environment.

based average selling price (ASP) estimates, e.g. sustainable pricing.

- Supportiveness of the institutional environment for PV system adoption, e.g. renewable purchase obligations (RPOs), net-metering, feed-in tariffs (FiTs), licensing, etc.
- Country-specific advantages along the value chain, e.g. procurement- or product-related.
- Availability and extent of subsidy packages for fixed infrastructure investments.
- Political willingness to implement infant-industry protection mechanisms.

The transformation taking place in the PV installation market is largely driven by an increased interest from regions or countries that are situated in the 'sunbelt', with stable and high irradiation levels and low variation in seasonal daylight time. There are some commonalities in the motivation for moving forward into PV:

- Independent power producers (IPP) striving to reduce electricity bills as the commercial tipping point is reached for residential-, commercial- and in some instances even utility-scale applications in many regions.
- Generation close to the point of consumption in order to reduce investment in grid infrastructure, with decentralization and rural electrification playing a part in this.
- Diversification of the electricity generation profile in order to increase energy security and decrease dependence on fossil fuels.
- Meeting of mandated renewable targets that were formulated to lessen the negative impact of CO_2 emissions.

These factors have contributed to an unforeseen impetus in project development activities in various countries around the world. These emerging PV markets sometimes reach project pipelines in the multi-GW range, which translates into infrastructure investments of a couple of billion US$. Understandably, this has led or contributed to (cautious) uptake in interest in local production opportunities in some countries, as political decision makers are determined to capitalize on local installations and increase domestic value creation.

An assessment of the addressable market size that could eventually be served by a local PV production cluster is of significant importance for two reasons. First, target capacities and depth of vertical integration as well as phasing options must be defined. Second, a sufficient market size is a necessary pre-condition in considering the implementation of local content requirements (LCRs), which – by all standards of definition – conflict with World Trade Organization (WTO) agreements.

The imposition of LCRs in markets of inferior size is considered to be economically unfeasible, as the trade-barrier-related harm will most likely not be counteracted by social welfare gains. These benefits can potentially be harvested through protective measures that are intended to safeguard the uptake of an infant industry in an otherwise intense global competitive environment.

Apart from potential institutional provisions that might shield against competitive pressure in prospective off-take markets, other location-specific factors that influence the absolute level and slope of the supply curve play a crucial role in industrial PV development projects as well [1]. For example, Viridis.iQ GmbH receives many enquiries from regions that are blessed with vast reserves of hydrocarbons.

The motivation to investigate the 'PV option' builds on the expectation that a sustainable advantage from cheap energy could be reaped in the energy-intensive upstream segment of the c-Si value chain, namely the production of metallurgical silicon (mg-Si) and the subsequent purification to polysilicon (poly-Si). In addition, it is finally being acknowledged that rapidly depleting resources are precious and should not be wasted in subsidized local energy markets. In this regard it constitutes an attempt to internalize negative externalities in an inhomogeneous and discriminatory manner, e.g. a general increase in electricity rates, with preferential treatment of selected industries.

Other regions that show interest in the establishment of a local PV production cluster might not have anything else to offer other than a thriving installation market. These regions typically strive to decrease the

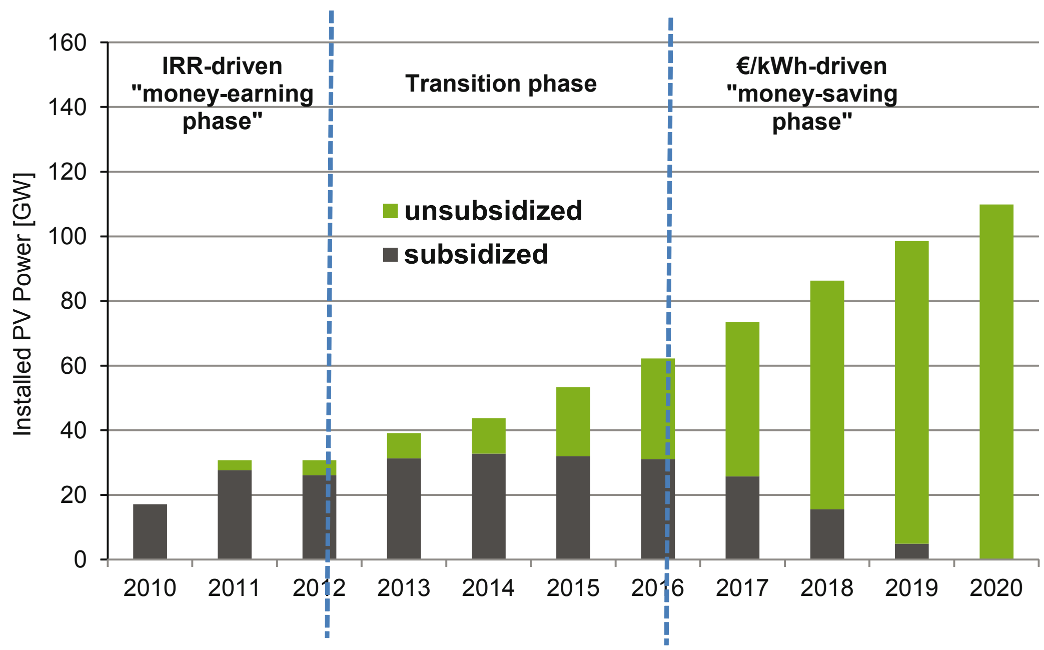


Figure 5. Global PV market in transition.

dependency on fossil fuel imports and provide cheap PV peak-power shaving capacity during the daytime.

> "Production scale and good accessibility to the global PV supply network can partially compensate for higher new-entrant production costs."

In these cases Viridis.iQ GmbH discovered that production scale and good accessibility to the global PV supply network can partially compensate for higher new-entrant production costs. This is especially true when intermediate products, e.g. wafers and/or cells, in the c-Si PV value chain are offered at or below marginal costs.

It is at this juncture that the optimal depth of integration is defined and a reasonable project realization, as well as a phasing strategy, is compiled. As stated, in the optimal case the execution plan should be flanked by various political measures that increase the visibility to potential investors and mitigate scaling disadvantages which exist in comparison with major Asian production hubs that churn out products on a vastly depreciated asset basis.

This raises the question of how a new entrant can compensate for the disadvantage of carrying a higher amount of fixed assets relative to production volume. As already mentioned, a major advantage of almost all established players is that many are operating on a widely depreciated capital stock, with a corresponding positive effect on total production costs. This statement holds for the complete value chain in the c-Si segment, beginning at poly-Si purification. For this reason a diligent investigation of project-specific advantages – such as location factors, scale and supply chain as well as technology differentiation potential – needs to be considered in a holistic cost-estimation and benchmarking process.

Even though each project is unique with regard to operator model, scale, deployed technology, procurement conditions, and labour and energy costs, it is still worthwhile to investigate typical ranges for main cost categories. This exercise reveals the key areas of concern for the different industries involved in the production of c-Si PV modules.

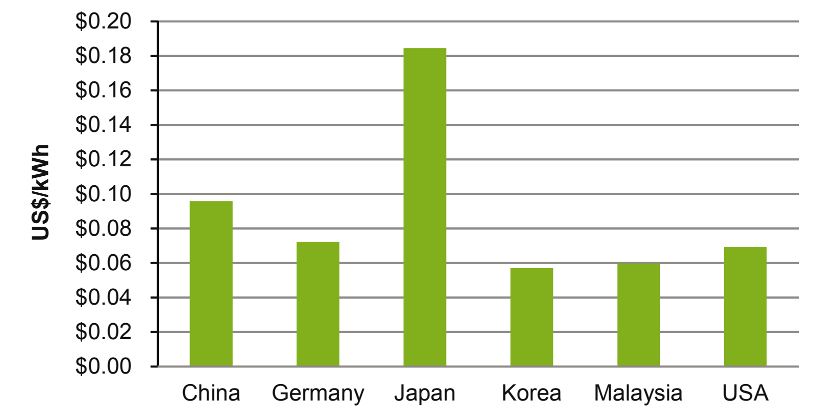
The following high-level cost breakdowns are based on ranges derived from different real-world assessments. The relative ranges are modified in this respect, as they have been based on a standardized electricity procurement rate of US$0.06/kWh, a value that can legitimately be regarded as undercutting a global average of a peer group from major upstream and downstream production hubs (Fig. 6).

The high-level cost types that have been considered in the breakdown for the three industries under investigation are:

- Electricity
- Depreciation
- Materials
- Labour (production)
- Other (e.g. maintenance, SG&A)

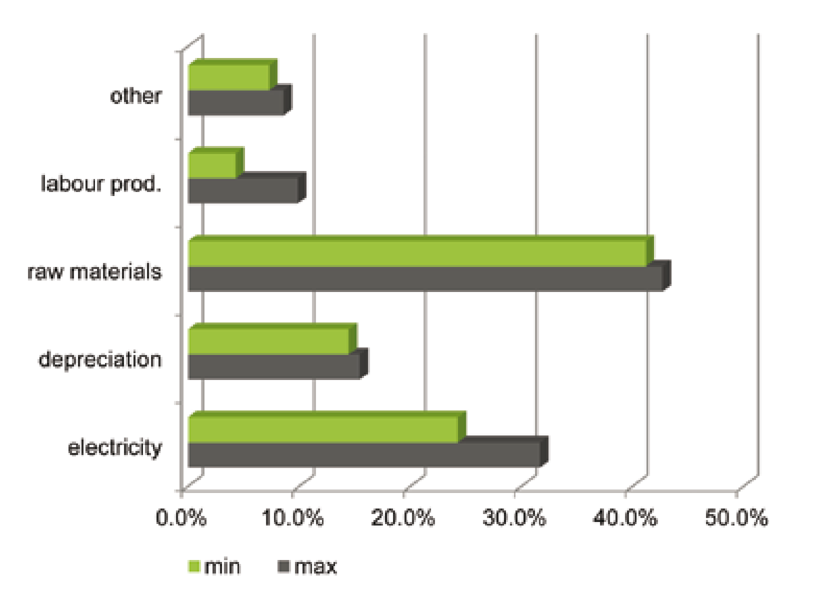
The metallurgical silicon production process, defined as a refinement of minerals, relies primarily on the availability of natural resources, basic chemicals, energy in the form of electricity, and capital-intensive equipment. In a fully utilized plant with a minimum production capacity of 33,000MT per annum, the three main cost types – raw materials, depreciation and electricity – make up ~80–90% of total unit costs (Fig. 7).

The key cost drivers in the category 'raw materials' exhibit a range of approximately 15% around the median value: this is attributable to variations in specification and in cost, insurance and freight (CIF) markups. The electricity rate has been fixed and its variation in relative unit costs is a function of changes in the other parameters. The depreciation charges are dependent on site-specific parameters (e.g. ground levelling, foundation, etc.), equipment selection and operator model; these factors can be influenced positively by subsidy packages. A process of global benchmarking to relative capital investment figures reveals that incumbents are further up the learning curve and save on investments in comparison to new entrants. In addition, the contribution of the labour force to unit costs is minor. These



Source: Compiled by Viridis.iQ GmbH from various sources

Figure 6. Average industrial electricity rates.



Source: Viridis.iQ GmbH

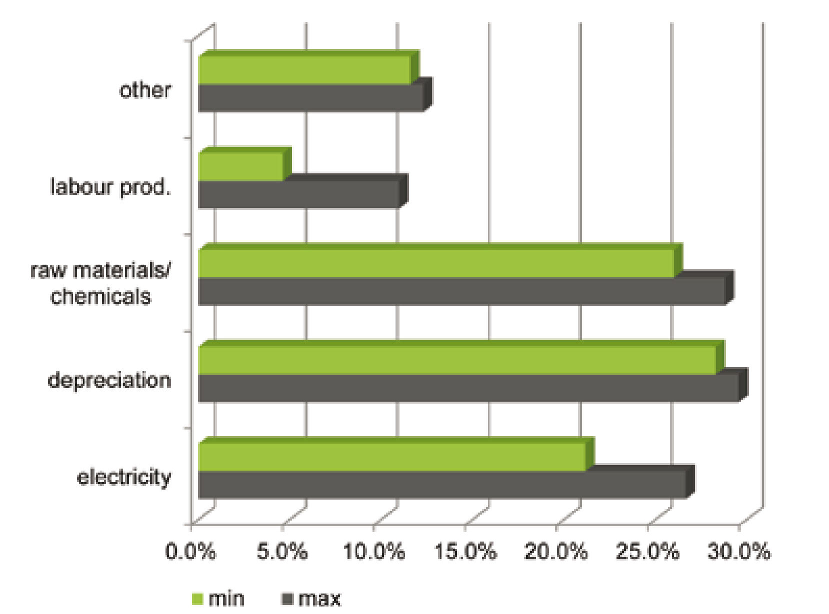
Figure 7. Mg-Si ranges by cost type (relative).

have been varied by a factor of three to reflect labour cost discrepancies between developed and emerging economies. This range of variation is fixed and is also applied to subsequent sections of the value chain, namely poly-Si and c-Si PV downstream.

Depreciation costs lie in the mid-teen percentage range and are therefore the third largest cost driver: this constitutes a potential competitive disadvantage for any new entrant, since established players are operating on a decreased asset basis. This relative disadvantage is a major concern in the subsequent production steps, as many established poly-Si and integrated c-Si PV module manufacturers have registered significant depreciation charges over the course of the past two years.

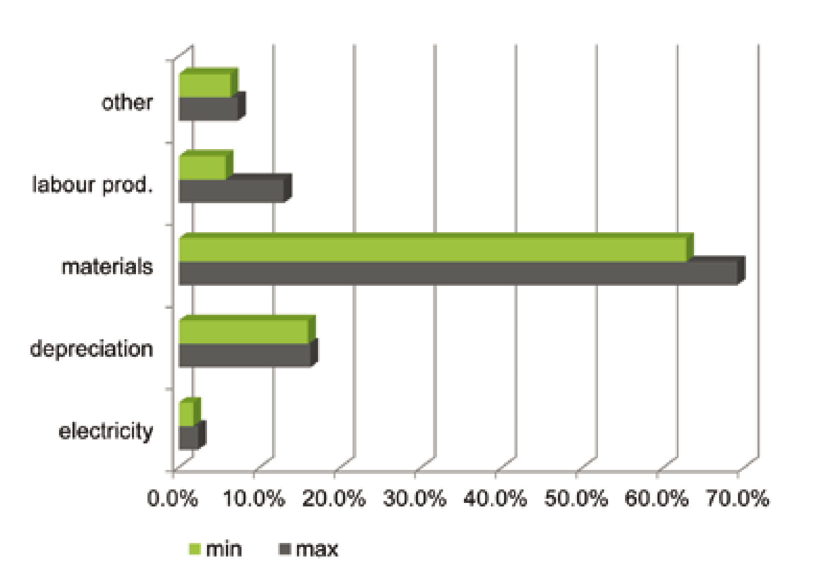
The Siemens-based chemical refinement to poly-Si is the most capital-intensive step in the integrated c-Si PV value chain. Metallurgical silicon is used as feedstock, and various chemicals and thermal treatments are employed in the subsequent decomposition, distillation and deposition steps: all these substances are collectively allocated to the category 'raw materials / chemicals'. The minimum and maximum parameter settings relate to projects with a capacity of more than 5000MT per annum.

The three biggest cost types constitute roughly 75–85% of total unit costs (Fig. 8). The dispersion in the relative contributions of the individual cost types is less pronounced than in the mg-Si case, which means that 'raw materials / chemicals', 'depreciation' and 'electricity' have almost the same impact on poly-Si unit costs. The category 'raw materials / chemicals' is influenced to a great extent by the availability of process chemicals in close proximity to the designated production site. Again – depending on the specific material, chemical or medium – the reference procurement prices exhibit a maximum spread of 40%. The depreciation charges are based on capital investments that are benchmarked, at the low end, to experienced Tier 1 producers and, at the high end, to new entrants. In terms of actual numbers, the investment ratios vary in the range US$87–114/kg, which equates to a relative spread of approximately 13%. The electricity unit procurement cost has been fixed at US$0.06/kWh.



Source: Viridis.iQ GmbH

Figure 8. Poly-Si ranges by cost type (relative).



Source: Viridis.iQ GmbH

Figure 9. Downstream PV ranges by cost type (relative).

This brings the discussion back to the aforementioned longevity aspect, in the sense that actual economic life of the equipment usually exceeds the useful life assumption made at the outset of the investment. The exact amount of poly-Si produced using depreciated equipment has most likely increased over the past two years, as many manufacturers registered considerable depreciation on their capital stock in the light of the weak pricing environment. This in turn has exacerbated the spread in total unit costs for material produced using operational equipment compared with expected costs at a greenfield site operated by an incumbent or new entrant.

These temporary competitive advantages enjoyed by existing manufacturers constitute a market-entry barrier which might discourage public decision makers from industrial development initiatives in regions that otherwise possess location-specific qualities which are superior to the actual site characteristics of existing plants. Regional benefits are usually realized in areas such as procurement, trade and institutional environment, as well as proximity to promising off-take markets.

In recent assessments for different locations, location-specific benefits, in combination with a price reversion assumption to a level at which Tier 1 producers would earn a risk-adjusted return on incremental capacity expansions that is above zero, showed an economically feasible investment case for local poly-Si production.

Moving now to the downstream segment of the integrated c-Si PV value chain – namely the ingot, wafering, cell processing and module assembly stages – the influence of materials on total unit costs becomes even more striking (Fig. 9). Further, the electricity consumption cost contribution can almost be neglected, while labour intensity, depending on the underlying remuneration schedule, can extend into the high teen percentage range. The two largest cost drivers in the material part of the downstream segment are feedstock and module components. The latter category – materials for module assembly – is a convenient starting point for supply chain investigations.

In previous PV projects the strong PV supplier base in Asia has been a useful and valuable source of competitively priced intermediate products. On this point Asia's dominance in the PV industry is not just a curse for smaller-scaled new entrants in emerging PV regions. In various projects the supply base for intermediate products in Asia and China has been tapped in order to increase the competitiveness in the local and regional markets. This advantage can be improved further through trade legislation that exempts intermediate products from import duties.

Additionally, location-specific sourcing advantages might exist for other module components that are available in close proximity to the planned manufacturing site. The commercial benefits from local sourcing stem from shorter delivery times and reduced transportation costs. The increase in local value creation through spillover to regional supplier markets, e.g. multifilm laminate or aluminium profile producers, can result in broad-based public and political support for the industrial development initiative.

Local expertise in the production of key components can also contribute to the creation of regional market-entry barriers through product differentiation. The design of modules that are tailored to the climatic conditions of specific regions and applications is a trend that is expected to continue in the foreseeable future.

As already discussed, the investment case for the integrated downstream segment of the c-Si PV value chain depends largely on the terms and conditions upon which the PV supply chain is or will be accessed. The variation in the relative contribution to total costs in the low to upper sixties percentage range is a consequence of applying benchmark prices for major material cost drivers that lie within a range of ±15% around the median. The individual price points are heavily influenced by the scale and location of the individual reference project. Further markups for freight and insurance can skew the picture either way.

Depreciation costs are at an early stage, meaning that equipment depreciation has been fully taken into account. Capital expenditures have been benchmarked, at the low end, to Tier 1 operator investments and, at the high end, to turnkey production-line offerings. As can be seen in Fig. 9, charges related to the depletion of capital are the second-largest component, while labour is strongly dependent on the circumstances of the specific location. Labour intensity can be relatively high, especially compared with the upstream parts of the c-Si PV value chain.

The main contributors to total cost by type for the individual parts of the c-Si PV value chain have been presented in order to provide a better understanding of the various factors that drive production costs along the integrated value chain. Actual figures have not been published, as they are confidential and typically exhibit a wide range because of project-specific scaling, technology, product and procurement differences.

Empirical evidence suggests that a local production initiative only makes sense when flanked by a reasonably sized off-take market. This pull factor can lower market-entry barriers for new entrants and thereby contribute to high utilization rates in the early phases of the plant's life cycle.

Such an approach to realizing a project is especially suited to downstream plants, as these reach competitive economies of scale at lower nameplate capacities. These initial capacities can be adjusted to regional market needs and scaled up in accordance with market growth. Materials produced further upstream are likely to exceed local or regional market needs as a result of higher minimum capacity threshold levels: for these plants, additional distribution channels have to be established in export markets.

In a nutshell, the interest in local production is always tied to a strong PV installation market from which domestic stakeholders envision an increase in domestic value creation. The technology choice is usually part of the investigation, but in almost all instances it is biased towards c-Si technologies. This is a direct consequence of regional considerations, such as competitive advantages and product specification, as well as technology-specific reflections, such as maturity, industrial scale and project implementation risks. The operational risks are usually lower in the c-Si domain, especially if a new-entrant approach is followed.

Regional advantages in the upstream segment typically exist in countries where industrial electricity rates are low. As indicated in previous paragraphs, low rates can help to mitigate or even offset the disadvantages associated with established marginal producers that operate on a vastly depreciated asset basis.

On the surface, this line of argument might sound schizophrenic, as it promotes the usage of 'cheap' energy to manufacture a product that eventually will deliver energy at a higher cost. However, the general perception taken from conversations with decision makers boils down to the simple explanation that such a strategy fits into a transformative process in which these regions gradually step back from heavily subsidized electricity markets. It is therefore a precursor for a regime change where negative externalities from available hydrocarbon reserves are slowly internalized.

The local advantages for establishing a downstream cluster are usually found in high-volume regional end markets and, if viewed from an integrated perspective, in a secure and reasonably priced supply of silicon feedstock material. Regardless of the depth of vertical integration, a rigorous supply chain analysis can reveal significant levers in an investment case that is heavily influenced by sourcing conditions.

The extent to which an industrial development project should be flanked by accommodating legislation should be decided on a case-by-case basis. Instruments such as LCRs, import quotas and duties can protect an infant industry throughout its development phase. Nevertheless, such types of measure are most likely not in compliance with WTO agreements and, as such, have a high chance of being lambasted by trade partners with their own vested interest in the PV industry. On the other hand, it seems to be common practice to state that direct or indirect support should be granted to an industry which is sometimes regarded as a strategic asset. The next section gives a brief overview of the current trade dispute, and a review of trade strategies that are less prone to litigations.

Once the preconception that solar is expensive and at most a niche application in the global energy generation profile had been dispelled, many regions began to embrace the PV value proposition. A prospering regional end market is a necessary condition for the establishment of a local production cluster. The strength of the sufficient conditions is case specific and relates to the local supply chain, envisioned scale, capital expenditures and financing terms, as well as to the available labour pool. These areas must be investigated in a thorough due-diligence process in order to come up with a succinct decision as to whether and to what extent the state should resort to direct and indirect subsidies.

PV trade disputers

It is no coincidence that the protagonists of the global PV trade dispute are the three major economic zones, namely Europe, China and the USA. These regions have been at the forefront of the silicon electricity age and therefore have a vested interest in the production and deployment of solar power.

The over-capacity-induced price correction with marginal cost pricing led to allegations that certain regions engaged in exploitive trade practices. A cascade of formal complaints to the WTO and investigations by local trade bodies have prompted the imposition of various anti-dumping and countervailing duties (CVDs) in a tit-for-tat-like manner.

In international trade, dumping means that an exporter of a commodity persistently sets the international price below the domestic reference price. In national trade, dumping means that a manufacturer sells a commodity at a price below its production cost.

Because the drastic fall in prices of intermediate and final products in the PV market has been a function of over-capacity, a situation in which producers revert to marginal cost pricing, the argument for selling below total cost has never been too convincing. Moreover, the domestic market prices of poly-Si or PV modules were, in most instances, no higher than prices in the respective markets of the claimants. On the basis of this reasoning, the imposition of anti-dumping tariffs came as a surprise and leads to the conclusion that protective industry policies have the inherent risk of being confronted by an onslaught of unsubstantiated accusations.

The anti-subsidy investigation is another story, as there seems to be ample evidence that China utilized this instrument excessively in order to gain a competitive advantage in the renewable energy markets. Apart from the involvement of numerous state-owned enterprises, *indirect subsidies* are evident in the high gearing levels of top-tier manufacturers that in some instances receive financing on negative equity. In this case the imposition of CVDs is consequential and consistent with WTO rules, as one might legitimately claim that subsidies are one of the factors that have harmed the PV industry.

Typically, subsidies are part of the game of attracting investments and are used in the Western hemisphere too. The question is, up to what point are subsidies acceptable and not attacked by trade partners? Here, a balanced strategy has to be developed on a case-by-case basis, reverting to representative heuristics.

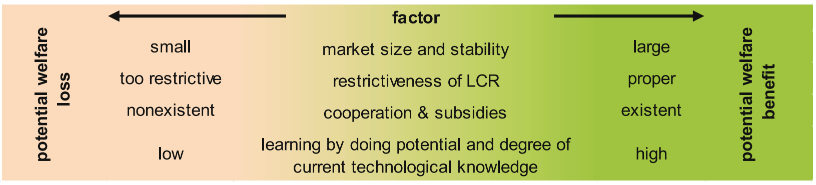


Figure 10. Empirical evidence of LCR effectiveness (Kunze et al. [2]).

Finally, there needs to be a brief discussion of the effectiveness of LCRs, as these are popular instruments utilized by political decision makers to return portions of public funds to domestic manufacturers for the installation of renewable energy plants. LCRs are a directive to investors to source a certain quota of components from domestic suppliers. In the PV context these quotas are typically applicable to the power system, e.g. the scrapped regulation in Ontario that required a local content of 60% in renewable power projects in order to be eligible for attractive FiTs. Another commonly seen implementation of LCRs is in combination with public tenders in which bidders are obliged to adhere to certain local procurement requirements.

These regulations can be characterized as an indirect subsidy and are effectively a form of infant-industry protection. The motivations for implementing such regulations are manifold but generally founded on industrial development, job creation, know-how transfer, increased tax base and spillover to local academic R&D clusters.

Kunze et al. [2] presented empirical evidence that LCRs which are structured as financial subsidies (e.g. an FiT attached to an LCR) are more likely to be disputed than legislations that tie LCRs to bonuses or tendering systems (Fig. 10).

> "New entrants have various levers at their disposal for improving their competitive position in a low-margin but steadily growing industry."

Conclusion

Viridis.iQ GmbH is involved in various early stage assessments concerning the development of industrial PV production clusters. The experiences from these investigations are that new entrants have various levers at their disposal for improving their competitive position in a low-margin but steadily growing industry. These are not necessarily tied to subsidies and restrictive or opportunistic trade practices. Nevertheless, it needs to be acknowledged that industrial development and trade in the PV market is certainly far away from the purist Chicago School, and that certain protective industry measures should be made available in order to improve the chances of success of an industrial development in a sustainable long-term growth market.

References

[1] Goodrich, A.C. et al. 2013, "Assessing the drivers of regional trends in solar photovoltaic manufacturing", *Energy & Env. Sci.*, Issue 10.

[2] Kunze, J.-C. et al. 2012, "Local content requirements and the renewable energy industry", UN Conf. Trade & Develop.

About the Author

Matthias Grossmann studied business administration and economics at Georg-August-Universität Göttingen. He works as a business development manager at Viridis.iQ GmbH, a specialized PV advisory boutique. Prior to this he worked at centrotherm photovoltaics AG and in the investment banking industry, with a focus on high-tech companies.

Enquiries

Dipl.-Kfm. Matthias Grossmann, CFA, FRM
Director Business Development & Strategy
Viridis.iQ GmbH
Moltkestr. 2–4
78467 Konstanz
Germany

Tel: +49 7531 698 4627
Email: matthias.grossmann@viridis-iq.de
Website: www.viridis-iq.de