A fully-integrated solar factory – requirements for achieving grid parity

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ABSTRACT

Each year, the photovoltaic market has been achieving a two-digit growth rate. The resulting economy-of-scale effects are not enough to achieve grid parity on their own. In order to reduce the production costs to grid parity level, new concepts and ideas must be realised as the basis for a photovoltaic factory. There are four main requirements that must be fulfilled in order to adhere to this cost reduction strategy: a highly integrated factory; automated and stable processes; a production control system (PCS) that provides the statistic data in order to continually optimise the processes; and an optimally-sized aligned production capacity.

Fully-integrated solar module factory

Conergy AG realised an innovative inline concept to produce photovoltaic modules in Frankfurt (Oder), paving the way for new photovoltaic factory concepts. By integrating the three value-creation stages of wafer, cell and module production under one roof, a modern and future-oriented concept as a requirement for grid parity was realised for the first time.

Inline processes enable high productivity. The required handling steps are reduced to a minimum, thus guaranteeing consistent quality and reducing the breakages of the brittle and very thin silicon waters. This is an advantageous feature of the process, given that the trend is towards ever-thinner wafers. While initially the wafers had a thickness of 800µm, now the values are below 200µm. Over the course of time, the format and size of the cells has also changed. The formerly typical 80mm round discs have been replaced by square forms of sizes such as 100x100mm^2, 125x125mm^2 up to 156x156mm^2. Solar cells of dimensions such as 210x210mm^2 are already available on the market.

The installed product lines in Frankfurt (Oder) are state-of-the-art and have a production capacity of between 50 and 65MWp. The individual production lines run parallel enabling a total factory capacity of up to 250MWp per year.

The silicon discs that are sawed in the wafer production are automatically transported to the directly adjacent cell production lines. An integrated transport system supplies the optimal wafer quality to the four cell lines. The finished solar cells then reach the floor below (see Figure 2) where the module production is located, and are allocated to one of the five production lines, according to demand. Inline testing, measuring and sorting units characterise each wafer, each solar cell and each solar module. Adequately dimensioned buffers ensure the constant supply of consistent quality to the production areas. A separate department for quality assurance and

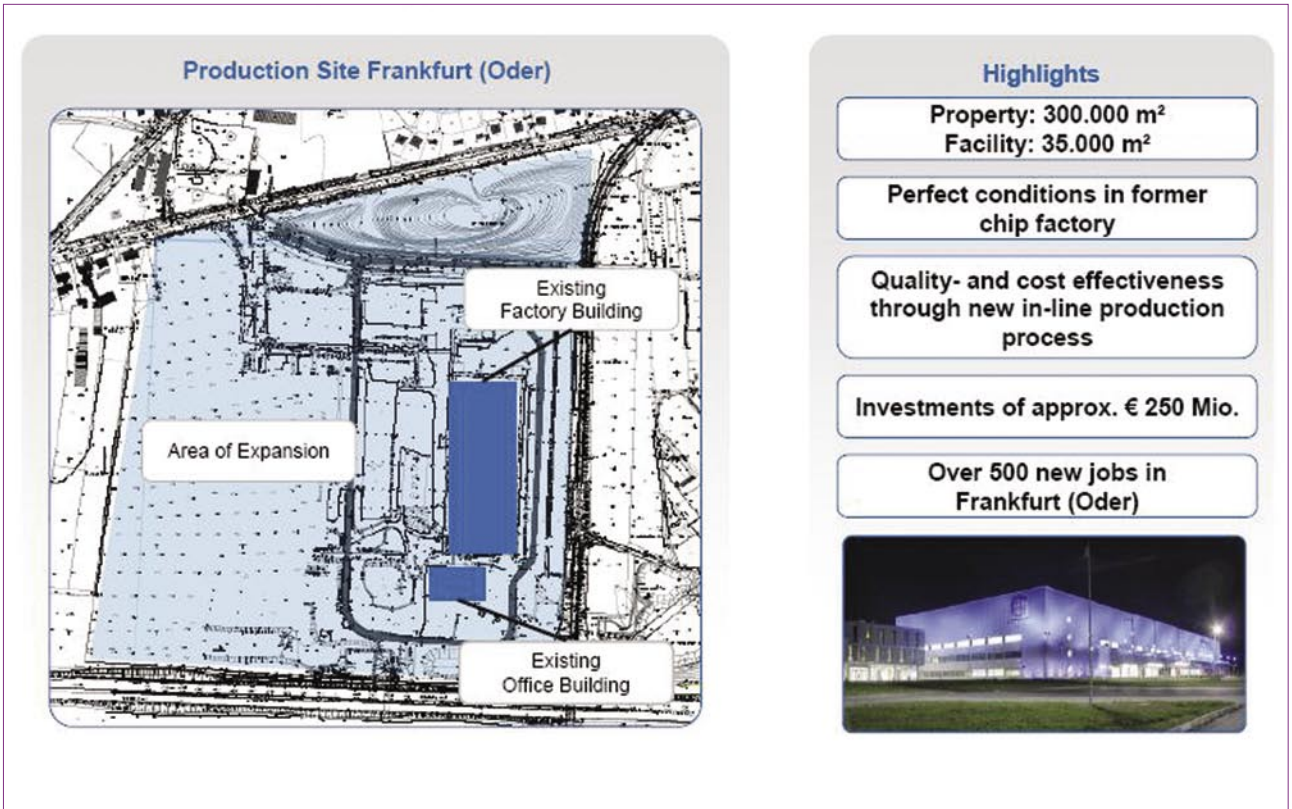

Figure 1. Conergy's Frankfurt (Oder) production site features.

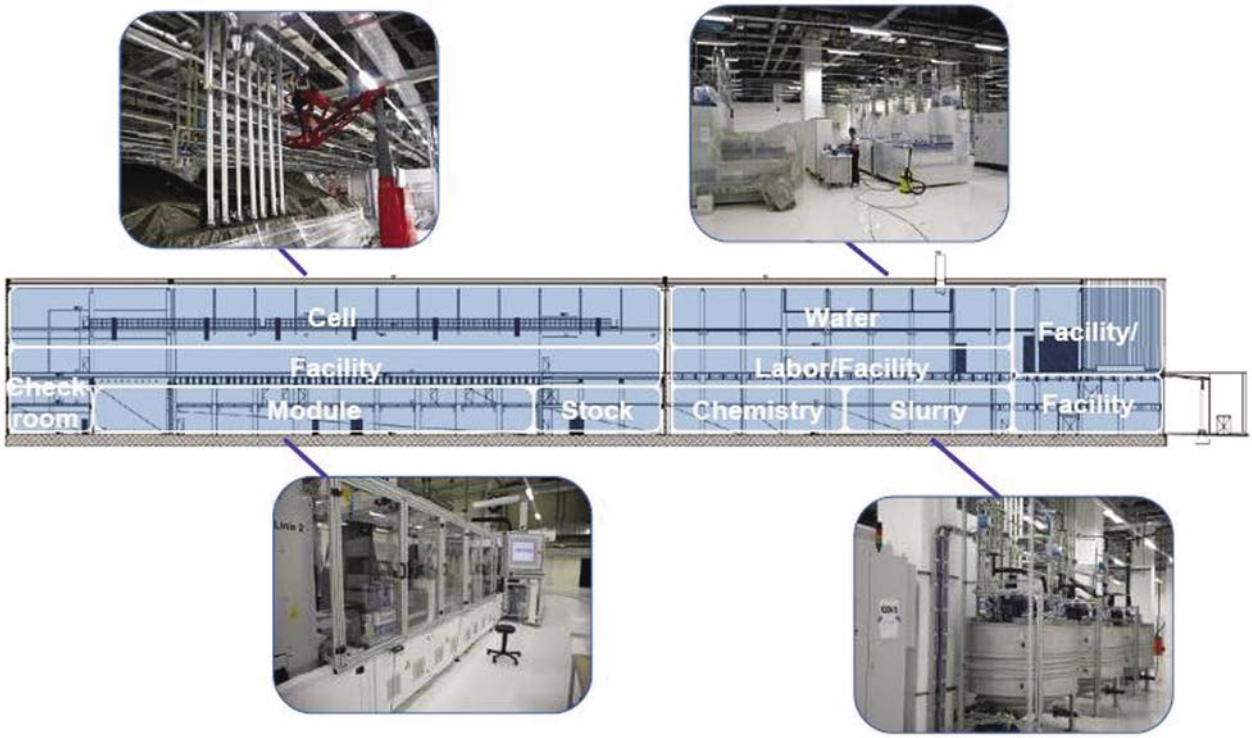

Figure 2. Dual-floor production layout.

analysis, equipped with climate chambers, flasher, cleanroom, electron microscope and further highly technological devices to produce solar cells and solar modules, makes it possible to recognise differences in quality and to advance the research and development directly at the production location.

Location and staff recommendations

On looking into the production areas of the solar module factory, it soon becomes clear that dark production halls with noisy machines are a thing of the past. Large window fronts let adequate light into the production areas, while high rooms give an airy feel to the employees working in the area. The material transport is almost completely automated and well organised. The facilities of central media delivery and removal with unavoidably loud generators, such as vacuum pumps, are located in separate areas or on an intermediate level.

The highly-integrated production of the facility reduces the interfaces along the value-creation chain of solar module production. In comparison to the benchmark, considerable productivity improvements are achievable in terms of logistics, construction volume, quality management expenses, and facility systems. The sorting of the wafers regarding TTV (Total Thickness Variation), sawing damages, thickness, etc. and the associated adaptation of the processes in the four cell production lines geared towards increasing efficiency can only be easily and effectively realised in an integrated factory. Process automation ensures guaranteed and

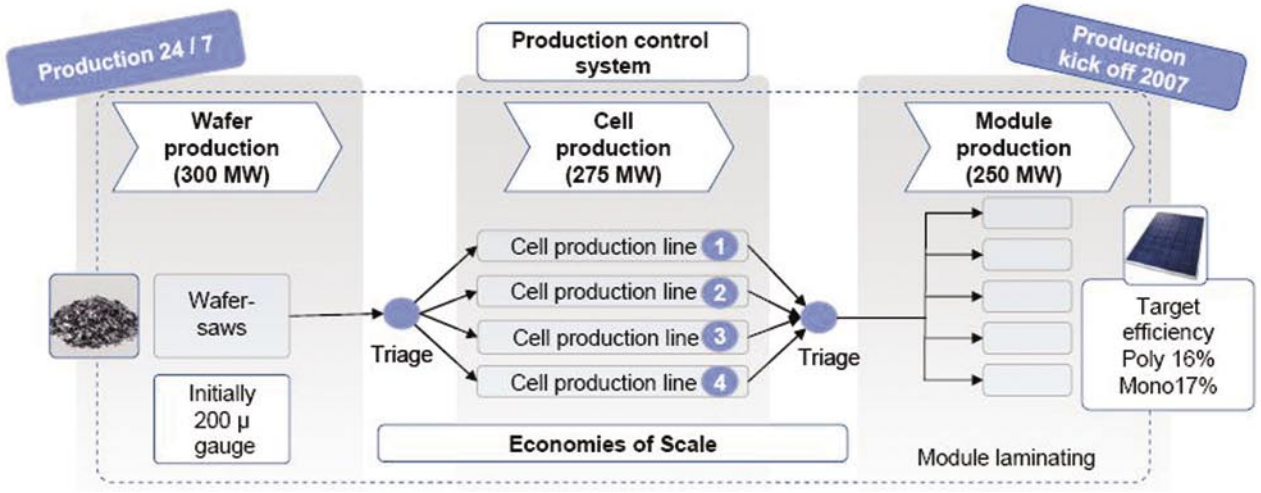

Figure 3. Production and process overview.

sustainable quality.

A workforce of up to 500 is employed in a four-shift system for the continuous production in Frankfurt (Oder), among them many skilled workers who operate and service the machines. The operators work at the machines in teams. Through in-company training, they can further their qualifications and thus become indispensable all-rounders. The operators are supported by trained technologists, and attend to the detail processes and use their expertise for production optimisation and research.

The high level of process automation drastically reduces the direct staffing costs and also the infrastructure costs per person. In Frankfurt (Oder), 200 employees work in module production. In comparison, in a semi-automated production facility, up to 1200 people are necessary. In addition to the obvious reduction of wage costs, lower staff costs also means a reduction of the indirect costs, e.g. for parking spaces, break rooms, work clothes, etc.

The inline concept

With its module production in Frankfurt (Oder), Conergy is combining an inline concept with a clustering principle. The inline concept guarantees a high flow rate; the integrated clustering principle enables a shift from the individual lines during the process and so creates the necessary flexibility to increase the run-up time. Moreover, sufficient capacity is available in the cell production to install further processes to increase the cell efficiency.

The installed production control system in Frankfurt (Oder) is based on wafer tracking (patent pending). Each ingot is marked so that the process history of the individually sawed wafers can also be recorded, enabling the location of each wafer – even in the finished module. This requirement creates the precondition for a permanent feedback process from the production over the analysis to R&D. This communication flow continually enhances expertise, makes it easier for employees to understand complex contexts and provides the motivation to constantly improve the production processes.

The cycle time of the factory in Frankfurt (Oder) is 20 seconds. Every 20 seconds a 220Wp module is produced, and this volume is such that it needs to be managed logistically. Logistical management of such a process also determines the optimal size of a factory. Extensive studies have shown that the optimal unit size of a wafer-based solar factory is approximately 250MWp. This is precisely what Conergy is realising in Frankfurt (Oder).

About the Author

Sylvère Leu was born and educated in Switzerland, and graduated from ETH Polytechnic in 1975 with a degree in Electronic Engineering. After joining BBC (ABB) in engineering nuclear power plants, he studied industrial design and business administration at the University of St.Gallen (HSG). He managed production processes at Hilti AG Principallity of Liechtenstein, and also worked as an associate lecturer at the University of HSG for several years in the field of industrial production. As a Swiss pioneer, Sylvère Leu started working in photovoltaics 18 years ago. He constructed the first industrial relevant laminator and sun simulator in his own company. In 2001 he sold his company to Conergy. As Managing Director, he was substantially involved in increasing profit and turnover of SunTechnics between 2001 and 2005. At the beginning of 2006 he was charged to build up an integrated 250MWp photovoltaic facility for Conergy AG, including wafer, cell and module manufacturing at Frankfurt (Oder).

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