Addressing the key drivers of PV manufacturing success

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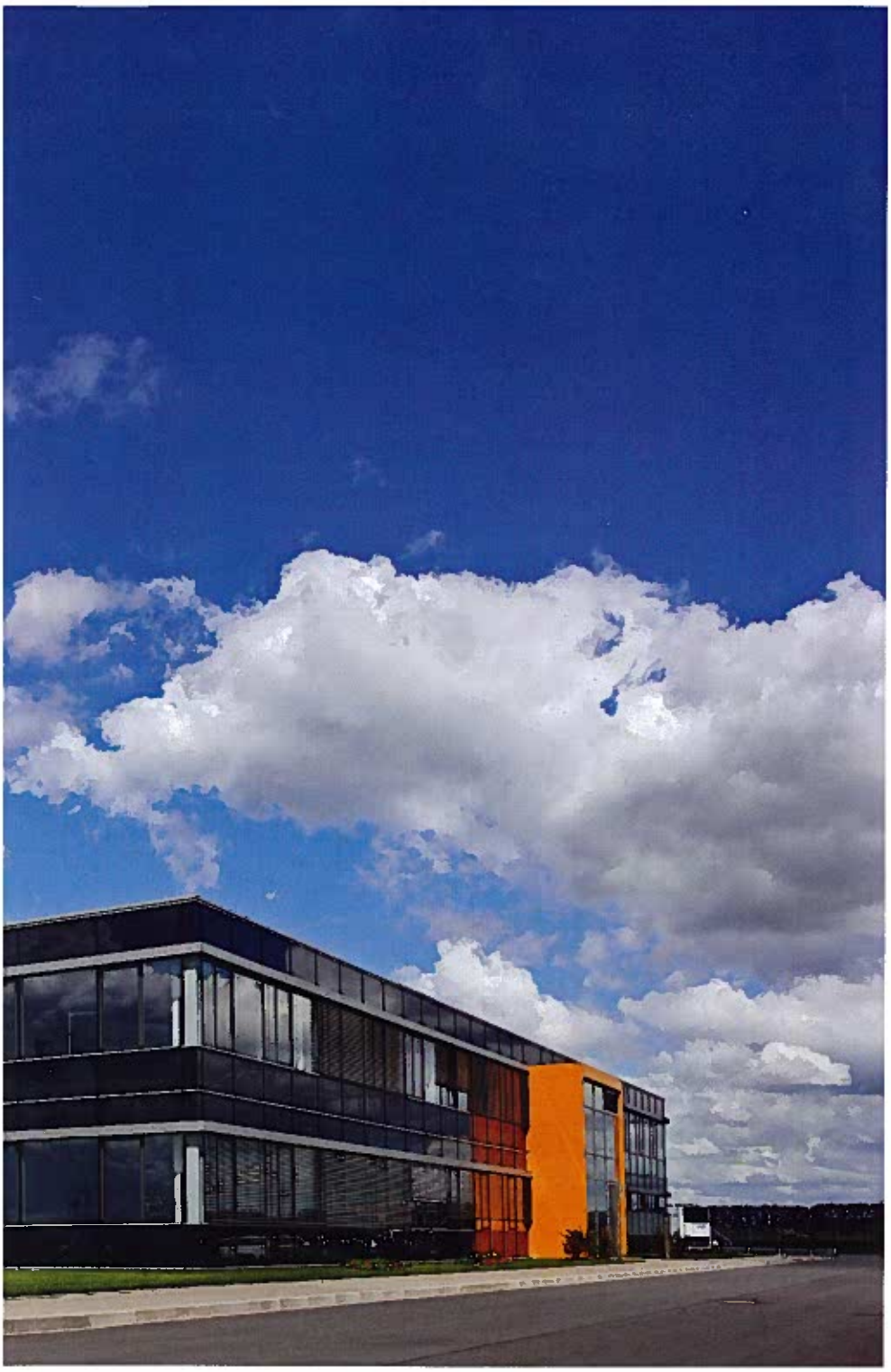
PES: EUROPE



While still overshadowed by wind power in terms of installed capacity, photovoltaics (PV) is the world's fastest growing renewable power generation technology, with the installation of systems growing at between 30 to 40 per cent annually. According to the European Photovoltaics Industry Association (EPIA), on a cumulative basis more than 20GW has been installed worldwide with a further 10GW forecast to be added in 2010. While the EU remains a significant consumer of PV capacity, end use markets are becoming more diverse and the manufacturing base is spreading rapidly – for instance China produces around half of the world's crystalline silicon cells and modules.

The rapid expansion of manufacturing capacity has brought significant developments in technological capabilities, most notably the development of thin film photovoltaics. Historically PV cells are made using silicon wafers (known as crystalline silicon technology), but in thin film technology, the cells are formed by growing the active layers on lower cost substrates. This has opened up the prospect of significant reductions in both cost base as well as manufacturing scale.

While the mass production of thin film silicon PV modules is still in its infancy, progress has been rapid. In 2008 early manufacturing adopters were achieving around $1.50 cost per watt, and $0.70 is predicted for the end of 2010. Over the same period, manufacturing throughput is predicted to double, while materials costs will fall by around 50 per cent. All these factors are critical in the drive towards grid parity and widespread adoption of thin film PV.

Aside from this necessary focus on costs and efficiency there is also an increasing awareness of the need to drive good sustainable practices throughout the emerging industry. Trade bodies such as EPIA and the SEMI PV Group have active sustainability working groups and studies are beginning to emerge which compare the CO footprint or energy payback time of various solar technologies. In response PV manufacturers are beginning to analyse key elements of their production practices, bills of materials and supply chain for opportunities to improve sustainability.

One element that is providing the industry with opportunities for a quick win is the area of chamber cleaning in the thin film manufacturing process - the current widespread use of nitrogen trifluoride (NF3) is problematic in that it has a Global Warming Potential 17,000 times that of CO. Regardless of how well NF3's use and supply chain is controlled, it is inevitable that there will be leakage to the atmosphere, a fact confirmed in a 2008 study by the Scripps Institute which reported a steep rise in atmospheric concentration of NF3, correlating with increasing manufacturing capacity and applications in electronics industries.

Andreas Weisheit, Head of Global Market Development for solar at Linde Electronics, part of The Linde Group, believes they have just the thing to contribute significantly to both improvements in manufacturing and to solve the problem posed by NF3 - namely the development of technology capable of generating pure fluorine (F2) as an alternative to NF3 for chamber cleaning. Linde's new onsite F2 generation technology has now been successfully installed by thin film photovoltaic module manufacturers Malibu and Masdar at their German facilities. ■

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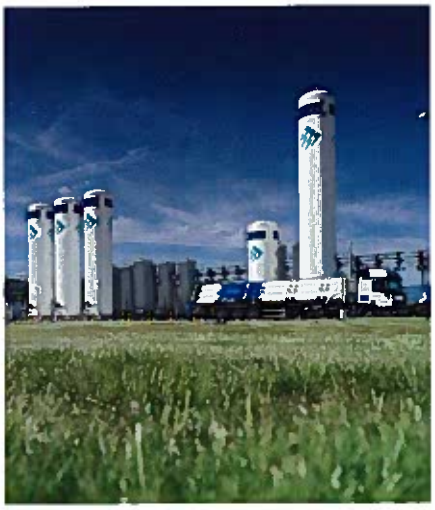
Collaboration reaps rewards



PES speaks to Andreas Weisheit, Head of Global Market Development for Solar at Linde Electronics, part of The Linde Group, and Antje Bönisch, Production Manager at Malibu, a subsidiary of Schüco, about their unique technical partnership.

PES: When did Malibu start working with Linde and why did you choose to partner with Linde?

Antje: Our relationship with Linde began in 2006 when we started R&D in the area of silicon-based thin film technology. We felt Linde was a clear leader in many critical aspects of gas supply for photovoltaics. When our plant in Osterweddingen went into production, we started working closely with Linde as both a supplier and a technology development partner, since we wanted to benefit from Linde's unique F_2 generation technology.

PES: Please describe Linde's F_2 solution in more detail.

Andreas: Electronic device manufacturing processes such as those used in thin film PV are highly complex and multi-stage. One of the key processes used is chemical vapour deposition (CVD), which deposits ultra thin layers of the active materials used to build up the device on to the glass substrate. Between deposition steps, the equipment chambers require cleaning, and this is typically carried out with a reactive gas containing F_2 atoms.

Manufacturing of the default chamber cleaning gas, nitrogen trifluoride (NF_3), is concentrated in Asia and North America. The gas is shipped worldwide in a variety of high-pressure container sizes, from individual gas cylinders to large ISO containers, depending on customers' needs. However, compared to NF_3, pure F_2 is a much more effective cleaning agent – it can be broken down into more reactive compounds more quickly and with less energy than NF_3. This reduces the cleaning time by more than 60 per cent and uses up to 60 per cent less power in the process.

Unique to F_2 is the way it is supplied – the gas is manufactured on the customer's site on demand by a compact, modular plant. Linde is the only gas company with this capability, and over the last 10 years more than 30 of these systems have been installed on customers' sites in the TFT-LCD, semiconductor and PV industries.

PES: What has the partnership with Linde enabled Malibu to do exactly and how does the partnership enable Malibu to meet its business objectives?

Antje: The complementary core competencies of Linde and Malibu have brought significant benefits to both companies – Malibu's speciality is with the research and production of solar cells, and we regard Linde as a leading provider of technical gases. Linde has been developing the concept of F_2 for chamber cleaning for some time. We are proud that Malibu was the first company that had the technology and R&D investment to enable the transfer from NF_3 to F_2 in the photovoltaic industry. We are also the first to have fully ramped-up production using F_2.

A key outcome of the partnership has been the smooth transition of PV production from NF_3 to F_2 in the chamber cleaning process, and this has been an important step for us towards greening our operations and being able to offer greener products to our customers. Additionally we are seeing faster processing and less material use, which of course has a positive effect on manufacturing costs. F_2 actually increases PV manufacturing efficiency, which ultimately enables us to increase productivity. Therefore, we can still offer solar cells at a competitive price. So for our customers, being green doesn't come at a price, but can actually add value.

PES: What interest has Linde received from the thin film industry for F_2?

Andreas: We have received strong interest from both end user customers as well as the principle turn-key equipment providers. For most manufacturers, once they have their production lines stabilised, it is important to continue to optimise the process in terms of module efficiency and production output. Both factors are crucial in the drive to grid parity and beyond. If manufacturers can see a way to improve the production line throughput, as well as potentially reduce material costs, they will be more interested in utilising the solution. In

2009, we announced that two of our major thin film customers – Malibu and Masdar – had chosen to adopt Linde's F_2 solution, and we are working closely with many others around the world.

Customers have also been keen to understand more about how Linde's F_2 solution can reduce the environmental impact of the module manufacturing process, specifically in terms of CO_2 footprint. We're certainly seeing an industry-wide shift to more sustainable practices and while this has not been the primary reason for adoption so far, we're certainly seeing an increased focus on the application of our F_2 gas technology to drive sustainability from customers who see an opportunity for green differentiation.

In addition, some of the leading PV industry bodies are beginning to develop sustainability programmes, and we are working with both EPIA and the SEMI PV Group in areas such as the CO_2 footprint and energy payback times for different manufacturing processes. Finally on the equipment side, we are working with one of the major manufacturers on a programme to improve the economic and environmental viability of solar. Implementing F_2 chamber cleaning is a key component of that study. ■

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Increasing performance with F2

High purity fluorine gas is the highest performance cleaning gas available, improving productivity on CVD tools, reducing energy consumption and environmental impact, with zero Global Warming Potential.

- F_2 cuts cleaning time by >60 per cent, reduces tool downtime and improves line throughput by up to 10 per cent
- F_2 reduces the mass of cleaning gas required by 50 per cent
- F_2 reduces the power consumption of the plasma source by 60 per cent

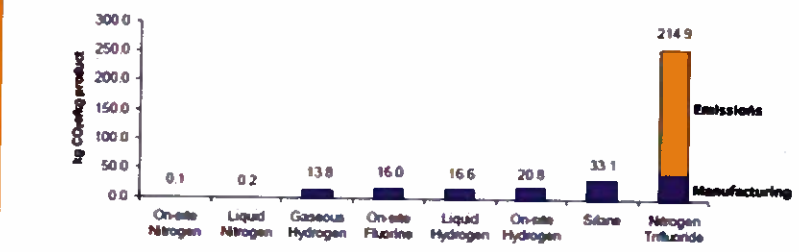
These benefits are realised due to the simple mechanism and low energy required to create F radicals compared to other Fluorinated gases.

	F_2	NF_3
Total Activation Energy	1 mol F from F_2 80KJ	1 mol F from NF_3 281 KJ
Bond Strength	F-F 159 KJ/mol	F_2N-F 248 KJ/mol
		FN-F 278 KJ/mol
		N-F 316 KJ/mol

CO_2 impact of gases used in thin film PV manufacture

Linde has characterised the CO_2 footprint of the various high volume gases used making thin film modules. For instance changing from liquid nitrogen shipped to site by road tankers to onsite generation can halve the CO_2 footprint of supplying that gas.

In the case of chamber cleaning it is quite clear that the largest impact comes in switching from NF_3 to F_2.



Gas	Gas use T/MW	CO2 equiv. T/MWp
N_2	28.0	2.8
SiH_4	0.4	14
H_2	0.35	4.7
NF_3	1.0	215
		237 TMWp

Cleaning gas replacement

Gas	Gas use T/MW	CO2equiv.T/MWp
N_2	28.0	2.8
SiH_4	0.4	14
H_2	0.35	4.7
F_2	1.0	13
		35 TMWp

For a typical 65MW tandem lin
CO_2equivalent saving of 13[illegible]