Quality makes all the difference

Nicole Nelles, **Max B. Koentopp** & **Sandra Scholz**, Hanwha Q CELLS GmbH, Thalheim, Germany

ABSTRACT

The aim of this paper is to shed some light on what difference the quality of a PV product makes to the customer and how much effort is required to deliver it. From the customer's point of view, the quality of a PV product is key to a worthwhile investment, since the value of a PV system is defined by its cost compared with its yield over the entire lifetime, or the levelized cost of electricity (LCOE). But while many manufacturers make more or less the same promises, in this paper a closer look is taken at what is really involved in living up to those promises. If quality is understood to be a fundamental attitude that is reflected in every single process along the entire value chain, only then will this eventually lead to high-quality products and services. The paper discusses in detail the principles, methods, tests and processes required to secure a superior quality brand.

Introduction

Quality makes all the difference. This axiom applies in particular to products which are expected to function and deliver constant performance over long periods. With a service life of 25 years or more, photovoltaic modules definitely belong to this category. Yet, in spite of this awareness, superior quality permits only a very slight increase in prices in the solar industry. When it comes to buying, the overriding argument continues to be the price, and brutal competition has driven this down to ruinous levels in recent years – proof of which is the constant consolidation in the sector. But why is this the case? From the customer's point of view, is it really right to base a decision to buy almost entirely on the initial investment?

Admittedly there are, at first sight, few reasons for buying a more expensive product: the visible differences between solar modules are very small. From a distance, or once incorporated into a larger system, modules hardly carry any weight in terms of their looks. And there are also very few differences when it comes to certification by external testing bodies: ISO certification and IEC testing are standard. What is more, many manufacturers make more or less the same promises: guaranteed performance for periods of 20 years or more, as well as apparent guarantees against potential-induced degradation (PID) and hot spots. But not everything that promises quality delivers on that promise, as becomes apparent by taking a second look at product quality, during which the customer should ask the following questions:

- Which manufacturer is able to prove that its PV products will actually do their job without problems for a full 25 years?

Figure 1. Quality is more than a product characteristic – it is a fundamental attitude.

- Are there tests which credibly underpin the promises made in the guarantee?
- What proofs of quality must manufacturers provide, and at what intervals, in order to retain their current certification?
- Are the standards comparable in different countries?
- Are products which have been mass produced selected for random testing, or does the manufacturer provide products of its own choosing for testing?
- What processes are used to effectively rule out hazards such as PID or hot spots?
- Does the manufacturer undertake internal quality testing and how often?
- Are processes also routinely tested for quality or is this limited to products?

"The demonstrable and sustainable quality of a product becomes an increasingly important factor in the purchasing decision."

No matter what the answers are to these questions, one thing is clear: the value of a PV system is measured by the levelized cost of electricity (LCOE). For this, the decisive factor is the yield over its entire lifetime, and, therefore, the constant and reliable performance of the system. Considered against this background, the demonstrable and sustainable quality of a product becomes an increasingly important factor in the purchasing decision. Even if the initial investment costs are higher, a better quality product can save the system operator a great deal of stress and unexpected financial losses. For this, 'product quality' is taken to mean 'meeting the maximum requirements that the customer has of the product'. In the case of PV products these requirements are, in particular, a long service life, a high level of safety, one hundred per cent reproducibility of the product characteristics and an elegant optical appearance (especially for mono products). An outstanding service quality, fast reaction times and a high level of reliability are also important for a good business relationship. From these customer requirements, a set of criteria for product characteristics and criteria for testing have been derived. But at Hanwha Q CELLS it is not just the products of which quality is demanded – and that is how it should be.

Quality as a fundamental attitude

Do you know of a company that is known for the quality of its products, but which does not place any value on the quality of its internal processes or on how colleagues deal with each other or on how it deals with its partners? In the authors' opinion such a contrast is not possible. Quality is rather a fundamental attitude, which either is valued through all levels and processes in a company or will not be found in its products. Furthermore, the theme of quality needs to be implemented at an organizational level throughout all areas and levels of the company. At Hanwha Q CELLS this is the task of the quality management (QM) team. This team drives forward the quality of current and future products through a certified quality management system, and supervises the entire value-added chain of production – from the inspection of all incoming raw, auxiliary and working materials, through the manufacture of solar cells and modules, to the creation of complete PV systems. Hanwha Q CELLS operates a tried and tested, certified, integrated management system that meets ISO 9001, ISO 14001, ISO 50001 and BS OHSAS 18001. The production workshops are ISO 9001, ISO 14001, ISO 50001 and BS OHSAS 18001 certified. For any PV company with an international production footprint it is also worth meeting high standards on an international scale. For this reason, Hanwha Q CELLS not only submits to audits by external certifying bodies, but continuously tests quality through internal cross audits. Likewise, the quality team is involved in product development from an early stage, so that it is possible to improve the standard of quality from generation to generation.

Quality right from the start

As well as enhancing performance and reducing production costs, improving the quality of products and manufacturing processes is a central aim in developing every new Hanwha Q CELLS product. That is precisely why the quality management team is involved in product development right from the start. This enables the introduction of quality targets early in the development, as well as the identification and remediation of discrepancies while still in the project stage.

Thus the actual development process itself is subject to Hanwha Q CELLS' philosophy of quality: in order to launch a new product, the product management must go through various levels, so-called 'gates', which include demonstrating that various quality tests have been passed and specific quality features met. A comprehensive analysis of possible failures and influences – failure modes and effects analysis (FMEA) – provides some guarantee that possible quality risks can be predicted at an early stage and avoided through optimizations of process, technology and/or product designs. In this way, risks can be thoroughly evaluated and minimized, especially in projects which are directly relevant to customers or to safety.

Standardized quality processes are also necessary with regard to internal quality assurance and customer service. So, for example, every new product-related document and every change to existing documents are subjected to a chain of approval by technical and expert auditors, before being automatically made available to all Hanwha Q CELLS' employees worldwide.

Every bit as important as the forecasts are subsequent evidence-based project evaluations and appraisals. At Hanwha Q CELLS, every project close-out meeting includes critical scrutiny of the project process in order to derive the maximum potential for improving process and product quality in every project.

An additional fixed quality checkpoint is the approval of every technical alteration by the change management team at Hanwha Q CELLS. The process of change is managed by the process change review board (PCRB) to guarantee a consistent method of proceeding and to ensure that changes to processes or products can be tracked. The PCRB is made up of colleagues from different sectors, and the quality management team is responsible for it. In addition to ruling on changes to products or processes, the committee makes decisions on quantitative, economic, safety and environmentally relevant aspects. The next level up from the PCRB is the quality board. In this committee, decisions are made on current requirements which involve higher goods values or are of broader scope. Thus it is ensured that the quality of processes and products is accorded the highest priority through all levels of processes and the hierarchy.

Supplier evaluation

Since 2005 Hanwha Q CELLS has established specific benchmarks

against which suppliers are evaluated, and which are continually being developed through dialogue with its partners. If, during the evaluation of suppliers, the quality requirements are not met, urgent measures for improvement can be drawn up. Since 2008 the Hanwha Q CELLS Code of Conduct has obliged suppliers to meet internationally recognized standards, especially in the fields of quality, environmental protection and health and safety. To ensure that suppliers operate a quality management system that meets the standard set by ISO 9001 as well as other quality parameters, regular audits of suppliers are conducted. Requirements are also reflected in the internal purchasing guidelines at Hanwha Q CELLS. Changes made by suppliers to existing processes or intermediate products must be approved by the PCRB.

Incoming goods inspection

All raw, auxiliary or working materials that could affect the quality of the end product are subjected to a thorough inspection by Hanwha Q CELLS upon receipt. The content and structure of each inspection process are determined by how critical the material is to the quality of the end product. The scope of testing is generally defined by an acceptable quality limit (AQL) in accordance with DIN ISO 2859-1. Hanwha Q CELLS also works closely with its suppliers to continually improve their output inspections. In addition to this, specifications for quality assurance are agreed with suppliers; this enables faulty raw, auxiliary or working materials to effectively be controlled, claimed against and, particularly, to be minimized.

Production: quality on the line

In Hanwha Q CELLS' production plants for solar cells and modules at the company sites in Germany and Malaysia (cell production only), as well as at the company's certified contractors in Europe and Asia, all important factors that influence quality are monitored through 100% testing. The basis for this testing is a set of key parameters. In the event of deviation from Hanwha Q CELLS' target values, reaction plans are activated. This allows Hanwha Q CELLS to narrow down the root cause of the failure systematically and solve problems quickly.

> "All important factors that influence quality are monitored through 100% testing."

For the fault analysis, the patented process TRA.Q is used, whereby every wafer is assigned a laser-engraved ID, which enables faults to be tracked individually, the sources to be identified and the underlying problem to be corrected. In addition to this, experts at Hanwha Q CELLS inspect and classify every cell according to optical and electrical parameters. For the inspection and classification, for both solar cells and modules, consistent calibration standards, verified by independent institutes, are used. Additionally, proprietary internally devised testing methods, such as the 100% hot-spot test, are in use throughout the company. A constant product quality is ensured through visual follow-up inspections.

And that is not enough – even the quality of the packaging is tested and optimized through regular random sampling. In this regard, close collaboration between all sectors involved, and particularly with customers, is very important, so that continual improvements can be made. In the development of the packaging it is important to strike the right balance between providing the best protection for the products and using packaging materials in a way that saves resources. To guarantee the protection of the cells and modules, the packaging materials are tested to international standards in independent testing laboratories. Transport and handling tests are also

Figure 2. Load testing at the Hanwha Q CELLS test centre.

carried out under real conditions, whereby product features before and after transportation or handling are compared.

Test centre for cells and modules

Covering an area of approximately 2300m^2 at the Thalheim site, Hanwha Q CELLS' test centre for solar modules is one of the biggest and most modern in the sector. This is evidenced by: sixteen climate chambers (damp-heat, thermal-cycling and humidity-freeze tests), with a capacity of 240 crystalline modules; seven light chambers, which can be used flexibly as UV or light soaking systems; two flasher lines, with an integrated electroluminescence imaging; and insulation measuring stations for dry insulation testing, hipot and wet leakage tests. During 2012 more than 4500 solar modules were tested in these flasher lines.

In addition to this, with two mechanical stress test machines (static/dynamic), a hail impact tester, a load testing capability, a hot-spot measuring station and three PID measuring stations, Hanwha Q CELLS regularly conducts a wide range of standard and special tests. Equipping the test centre with a range of other tests allows the execution of all the tests necessary for meeting IEC 61215 Ed. 2.0 and IEC 61730-2 Ed. 1.0 in house. It is therefore possible to achieve maximum security and flexibility in evaluating new combinations of materials, certifying new products and ensuring the high quality of Q CELLS products.

Hanwha Q CELLS' test centre is accredited by the Test Data Acceptance Program (TDAP) of the German VDE (Association for Electrical, Electronic and Information Technologies). This ensures that all results are verified by an independent third party, as well as speeding up certification and module development.

Test criteria for best products

To ensure the highest quality of Hanwha Q CELLS products, three basic principles for testing are adhered to: test hard, test continuously and test realistically.

Test hard

The IEC certification ensures a basic quality for PV modules, thereby setting a minimum standard (Fig. 4). Hanwha Q CELLS products, by contrast, must survive considerably tougher tests and are all certified 'VDE Quality Tested' – from cells to modules and all the way through to the standard block for large solar power plants, Q.MEGA. The VDE certification process sets much more demanding test criteria, which ensures the long-term performance of the products. For example, 'VDE Quality Tested' means that the test duration for standard damp-heat tests is increased from 1000 hours to 1500 hours, and the number of cycles for thermal cycling from 200 to 400. In addition to this, the number of test modules for the damp heat, thermal cycling and UV/thermal cycling/ humidity freeze sequence is doubled from two to four in each case.

> "The VDE certification process sets much more demanding test criteria, which ensures the long-term performance of the products."

The dynamic stress test was introduced specifically for the VDE certificate. At the start of the UV/ thermal cycling/ humidity freeze sequence, testers check the fracture behaviour of the solar cells within the module compound and thus increase the stress on the module. The subsequent ageing tests enable the long-term behaviour of the previously stressed modules to be predicted. The requirements are once more increased, since a module is only allowed to show a maximum performance loss of 5%

Figure 3. Testing must be hard, continuous and realistic in order to guarantee 25 years of quality performance.

HANWHA Q CELLS QUALITY REQUIREMENTS

REQUIRED TESTS	IEC CERTIFICATION	VDE Q.TESTED	INTERNAL TESTS
TEST FREQUENCY	once, only for initial certification	continuous sampling, quarterly monitoring	continuous sampling and monitoring
THERMAL CYCLING TEST (TC)	200 cycles	400 cycles	additional tests
DAMP HEAT TEST (DH)	1000 h	1500 h	additional tests
HUMIDITY FREEZE TEST (HF)	10 cycles	10 cycles	30 cycles
LOAD TEST	✓	dynamic load test before TC & HF	additional tests
HOT-SPOT TEST	✓	✓	100 % of cell production
EL TEST	certification module only	100 % of module production	100 % high resolution EL inspection
PID TEST	–	–	weekly production monitoring
USED SEAL	IEC	VDE Quality Tested ✓ high reliability ✓ low degradation ✓ frequent product surveillance ID 40032587	Q CELLS YIELD SECURITY ✓ ANTI PID TECHNOLOGY (APT) ✓ HOT-SPOT PROTECT (HSP) ✓ TRACEABLE QUALITY (TRA.Q™)

Q CELLS a Hanwha company

Figure 4. The quality test matrix for Hanwha Q CELLS products.

per test sequence. In comparison, the maximum performance degradation permitted for standard certification is 8%.

Test continuously

According to the criteria set down for IEC certification, for the certification process a product only has to pass the qualification test once with a specific number of test products. The products tested are often prototypes. In contrast to this, for the internal VDE Quality Tested certification, Hanwha Q CELLS products regularly undergo testing of randomly selected samples from mass production. As a result, deviations caused by production processes or by materials used can be promptly identified.

To closely monitor quality during production, Hanwha Q CELLS conducts not only in-line safety tests, but also supplementary in-line tests, as well as regular testing during production in order to test the cells and modules for hot spots, PID and so forth. Furthermore, at the end of production, the modules are checked for possible abnormalities with the aid of a 100% electroluminescence test. In addition to this, a specified percentage of the finished products are subjected to further insulation, ground continuity and reverse-current overload testing every day, with the aim of ruling out any safety problems. Only modules which are in perfect optical and electrical condition leave the production plants.

But it is not only Hanwha Q CELLS' internal tests that are continually being conducted. As a fixed element of the VDE Quality Tested seal, production is tested every quarter using randomly selected samples. This process includes – among other things – safety-related test measurements, such as hipot, wet leakage, reverse-current overload, hot-spot and ground continuity tests. Dynamic stress tests with subsequent thermal cycling and damp-heat tests are also a compulsory part of the testing. With the aid of these test sequences, production can be checked for consistent quality, possible deviations and faults. The results are reported to the VDE every quarter in order to retain the VDE Quality Tested seal.

Test realistically

Twenty-five years is a long time, and no PV product has so far been on the market long enough to test product quality through real-time testing. That is why testing methods which simulate as realistically as possible the stresses on products throughout their service life are being developed and employed. The comprehensive equipment in the Hanwha Q CELLS test centres allows more rigorous testing than is usual in the sector, and enables those results to be transferred, taking into account varying local conditions. For example, models developed using climate data are employed in order to translate the significance of the tests and testing procedures to realistic, location-dependent climatic conditions. This yields information about the degradation process or the appearance of various effects of ageing under a range of climatic conditions – whether in a temperate climate or in the desert, for example.

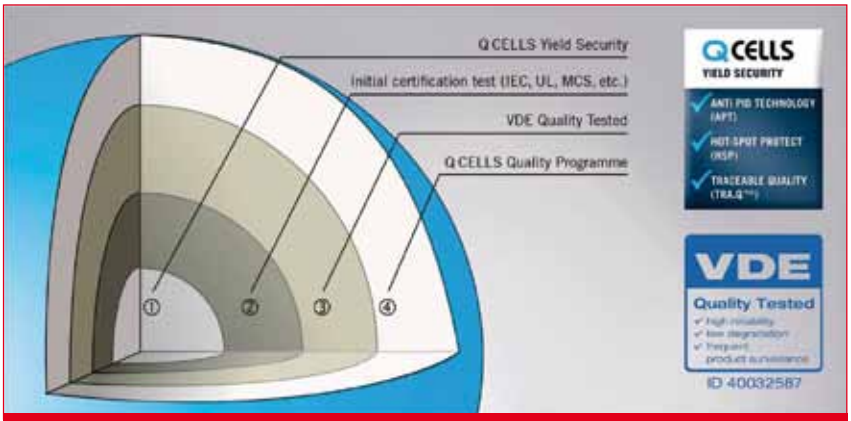

Figure 5. The four quality programmes operated by Hanwha Q CELLS.

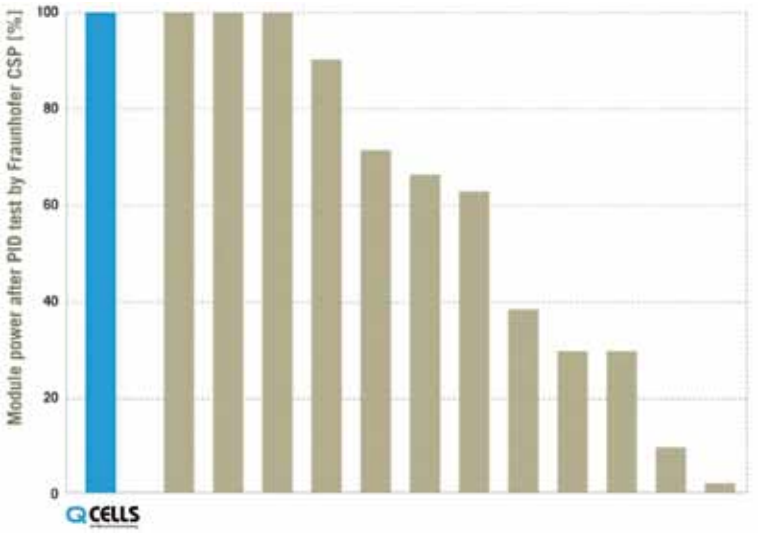

Figure 6. In May 2012 Fraunhofer CSP tested thirteen modules from brand manufacturers – nine of the modules failed.

Figure 7. A sign of above-average quality: the 'VDE Quality Tested' seal.

The four levels of quality at Hanwha Q CELLS

Before a product is worthy of using the name 'Q CELLS', it has to undergo and pass four independent quality programmes (Fig. 5):

1. Since 2011 the Q CELLS Yield Security has been the guarantee for reliable products from Hanwha Q CELLS. It combines guaranteed resistance to PID, security against hot spots and protection against the counterfeiting of the company's products.

2. The second layer comprises the international initial certification tests, for example in accordance with IEC, UL, MCS, JPEG and Kemco. These guarantee the electrical safety of the module and the safety of its construction in accordance with international standards.

3. The VDE Quality Tested programme (Fig. 7) exceeds the initial certification testing. Additionally, the quarterly re-testing guarantees consistent quality and product safety at all times.

4. The Hanwha Q CELLS internal quality programme ensures that all products meet the company's high safety requirements on a daily basis.

Quality as an international standard

To ensure that the Hanwha Q CELLS quality programme is implemented in external production plants, three essential tools have been introduced: on-site presence, Q-sampling and Q-monitoring (Fig. 8). The Hanwha Q CELLS quality control engineers visit the module conversion sites of the company's partners at regular intervals in order to ensure the quality and to improve it. For Q-sampling, the manufacturers must conduct regular random sampling tests and report the results to Hanwha Q CELLS. Finally, with Q-monitoring, random sampling tests on the conversions undertaken by partners are also regularly conducted in Hanwha Q CELLS' laboratories on site and in Thalheim.

Test the test

Hanwha Q CELLS' testing procedures are continually updated to optimize still further the standard of its testing methods. Good connections within the scientific community are maintained, and current developments as well as newly occurring faults in modules are always pursued. Thanks to its well-equipped test centres, Hanwha Q CELLS is then in a position to investigate and determine the causes. New test methods are developed in order to rapidly optimize processes and products and to eliminate occurrences of the fault in question. One example is the anti-PID technology (APT) test,

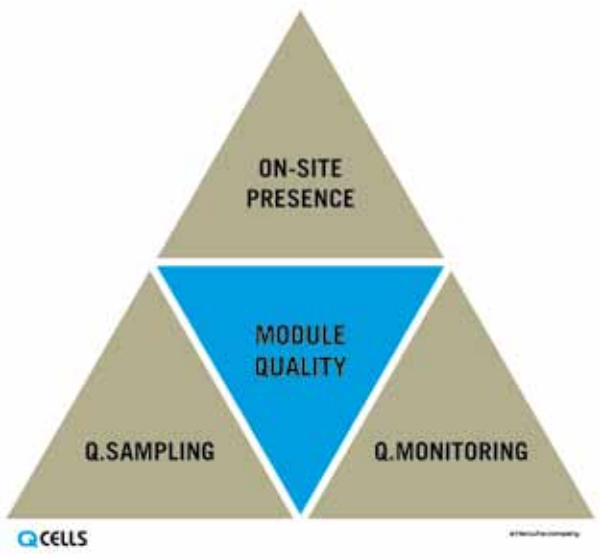

Figure 8. Tools to ensure that the internal quality programme is put into practice internationally.

which was developed in the Hanwha Q CELLS testing laboratory in 2009, to counteract PID. Since then this test has been further developed, so that it is now possible to test the PID resistance of cells during production and have conclusive results available within 48 hours.

Nobody's perfect

In the international PV market, the brand name Q CELLS stands for quality. And this is not the least of the reasons why the South Korean Hanwha Group decided to take over the company in 2012 and begin a bright future with Hanwha Q CELLS. But nobody is perfect, and complaints are occasionally received; in the ensuing process, the same attitude is taken as with the products – quality counts!

In the event of a complaint, customers contact the engineers in the complaints management department. Together with the customer, it is quickly decided what the best way to help will be: Is a plant visit required? Are test modules needed or does the available data suffice? If on-site measurement is necessary, Hanwha Q CELLS' field service team is available with its highly experienced technicians. They have been trained to test not only the modules, but also the whole plant with all its components. This service is provided for customers free of charge.

At the test centre it is then possible to carry out all the usual, and many additional, tests quickly and flexibly. If this is still not sufficient, there are links to independent institutes, such as the Fraunhofer Center for Silicon Photovoltaics in Halle, Germany. The cause of the problem is then determined using the eight disciplines (8D) problem-solving method, and the customer can be provided with a detailed 8D report if desired. If the analysis shows that the fault is covered by the guarantee, the customer will immediately be provided with a free replacement.

> "Quality makes all the difference."

Conclusion

Quality is not just a sticker on a module or a promise made by a manufacturer. Quality is the result of a fundamental attitude and an immense effort, which runs through all levels and processes within a company and finally shows in the product. No less important is the financial and strategic basis on which a company makes the promises in its warranty at a time of constant consolidation in the solar industry. This makes the financial stability and sustainability of a company an integral part of quality from the customer's point of view. This very broad understanding of quality is the fundamental prerequisite for promoting customer satisfaction, and is an increasingly weighty argument to be considered when deciding which PV products to buy. For, at a time when solar electricity is partially achieving grid parity, and funding is being reduced, the importance of energy consumption, and hence of the yield of a PV system or the LCOE over the entire service life, is growing. A good-quality PV system is therefore one that comes from a financially secure company and on whose stable performance the customer can rely – for many years to come. Quality makes all the difference.

About the Authors

Dr. Nicole Nelles holds a Ph.D. in physics awarded by the Hamburg University of Technology (TUHH). She joined Hanwha Q CELLS in 2004, working as a project and process manager within the technology department, where she was responsible for projects including hot-spot protection and line support. She then advanced to the position of director of line technology in the production department. Since October 2011 she has been globally responsible for quality at Hanwha Q CELLS as vice president of quality management.

Dr. Max B. Koentopp received his Ph.D. in physics from the University of Karlsruhe (Karlsruhe Institute of Technology) in 2005, studying the simulation of electronic transport through molecular nanostructures. In 2009 he joined the R&D team of Hanwha Q CELLS as a project manager and simulation expert. As senior manager of the analysis and modelling group, he is currently responsible for module reliability testing, cell characterization, and device modelling and simulation.

Dr. Sandra Scholz received her Ph.D. in physics from the University of Freiberg in 2007, with a thesis topic of carbon distribution in solar silicon and its impact on electrical properties. She joined the R&D team of Hanwha Q CELLS as a process technologist in 2007. In 2008 she became a project manager for R&D crystallization, later advancing to senior manager in 2009, and then to expert quality engineer in 2012.

Enquiries

Jochen Endle
Hanwha Q CELLS GmbH
Sonnenallee 17–21
06766 Bitterfeld – Wolfen
Germany

Tel: +49 (0) 3494 6699-10121
Email: presse@q-cells.com
Website: www.q-cells.com