BLACK & VEATCH CORPORATION
11401 LAMAR, OVERLAND PARK, KS 66211 USA
+1 212-973-1339 X12 | MAKO@BV.COM

January 4, 2012

Shanghai BYD Company Limited
No. 999 Xiangjing Road
Songjiang, Shanghai
P.R. China 201611

B&V Project 174681

Via e-mail

Attention: Liam Li

Subject: Final Solar Module Due Diligence Report

Black & Veatch is pleased to submit this Final Solar Module Due Diligence Report to BYD. This Report reflects our best understanding of the information provided as of the date of this Report.

We would be pleased to provide additional updates to this report if new or additional information on the modules becomes available. Any work done to provide these updates will be performed on a time and materials basis at our standard rates as described in our service agreement.

Should you have any comments, please feel free to contact me at (212) 973-1339 x12 or Dr. Ralph Romero at (757) 903-7528.

Very truly yours,

BLACK & VEATCH CORPORATION
Oscar Mak
Manager - Infrastructure Consulting and Engineering

Solar Module Due Diligence

FINAL
B&V Project Number 174681

January 4, 2012

Black & Veatch Corporation
11401 Lamar
Overland Park, Kansas 66211
Tel: (913) 458-2000 www.bv.com

Principal Investigator:
Dr. Ralph Romero

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1.0 Executive Summary

Black & Veatch was retained by Shanghai BYD Company Limited ("BYD") to perform technical due diligence on its P6-30 and P6-36 solar photovoltaic ("PV") modules ("Modules") and its manufacturing process for the Modules.

BYD is a publicly traded company (HKSE: 1211), specializing in the automotive, information technology and energy sectors. BYD was established in 1995 and entered the solar PV market in 2008 with the construction of a silicon wafer and cell production plant in Shangluo, China. In July, 2010, BYD converted its Shanghai plant into a PV module assembly facility with total capacity of approximately 750 MW of module production per year. BYD currently has approximately 160,000 employees with plants and offices situated throughout China, Asia, Europe and North America.

The purpose of this report is to provide a technical due diligence review of the Modules and BYD's manufacturing operations for the Modules as observed during its October 26-27, 2011 visit to the operations. During the due diligence process, Black & Veatch evaluated information provided by BYD and visited the BYD manufacturing facility in Shanghai, China. Information provided by BYD and statements made by its staff were assumed to be current and correct.

Black & Veatch notes the following major conclusions regarding the Modules.

1.1 Company

- BYD is a vertically integrated manufacturer of solar components. It produces monocrystalline and polycrystalline ingots, wafers, cells and modules.
- Manufacturing of ingots, wafers and cells occurs in Shangluo, China and PV module assembly occurs in Shanghai, China.
- BYD produced 80 MW of PV modules in 2010 and 150 MW in 2011 as of October 2011. BYD claims approximately 1,000 MW of ingot, wafer and cell capacity and 750 MW of module assembly capacity.
- Key members of BYD's solar division senior leadership have been promoted from within and have significant experience in high-volume manufacturing of electronic components, especially in batteries. The leadership team of the solar division does not appear to have substantial experience in other companies or other parts of the solar PV industry.

1.2 Module Design and Components

- Black & Veatch finds the designs for the Modules to be substantially similar to the designs of other crystalline silicon PV modules. Black & Veatch believes that the designs of the Modules can allow the Modules to achieve their specified performance.
- Black & Veatch reviewed the bill of materials and suppliers for the Modules. Components and materials used in manufacturing come from both leading suppliers with long track records and from lesser known Chinese suppliers.

1.3 Durability and Reliability

- The Modules have passed the key certification tests (IEC 61215 or UL 1703) which are considered standard qualifications in the solar energy industry. The required certifications vary by jurisdiction and users of the Modules should verify that they have selected the Modules with the appropriate certifications.
- BYD warrants that the Modules will provide at least 90% of the minimal rated power during the first ten years of operation and at least 80% of the minimal rated power for the following 15 years.
- BYD has not provided any information which would enable an estimate of the expected long term degradation of the Modules. In the absence of such data, Black & Veatch recommends assuming a base case annual degradation of 0.7 percent for polycrystalline modules and 0.8 percent for monocrystalline modules. This guidance is based on the most recent publicly available data on the degradation of solar PV modules and the performance of BYD's Modules could be better or worse than these generalized guidelines.
- BYD has a well-equipped test center at its Shanghai campus. This facility is used to perform quality assurance functions and extended product testing.
- BYD has performed environmental testing of its Modules beyond the requirements of the IEC and UL standards. In particular, BYD has tested the P6-36 Modules under salt corrosion and ammonia corrosion environments. These tests are described in further detail in the body of the Report.

1.4 Module Manufacturing Facilities

- Black & Veatch visited the Shanghai module assembly facility on October 26 and 27, 2011 to view assembly of the modules. Upstream process steps were out of scope for this review. The module assembly facility and capital equipment appeared comparable to those used by other leading crystalline silicon PV module manufacturers and reasonable for the assembly of crystalline silicon PV modules.

1.5 Manufacturing Process and Quality Assurance

- Black & Veatch observed each step of the manufacturing process for the P6-36 Modules. BYD has indicated to Black & Veatch that the P6-30 Modules are manufactured on the same equipment using the same procedures. The module manufacturing process was consistent with accepted industry practice for the production of solar PV modules of this type.
- BYD uses automated soldering for attaching ribbons to cells and connecting cells together into strings. Many Chinese module manufacturers with which Black & Veatch is familiar use manual soldering instead. BYD's automated solder machines perform a machine vision, electroluminescence (EL) test of each cell to screen for microcracks in the cells. Black & Veatch considers this inspection step to be best in class.

- During its October 26 -27, 2011 visit to the BYD module assembly facility, Black & Veatch did not observe any significant excursions from the specified process for manufacture of the Modules.
- BYD use of quality checkpoints and inspection steps is consistent with accepted industry practice.
- Black & Veatch identified potential improvements to the assembly process which are described in detail in the body of the report.
- BYD conducts gel content tests of each laminator once per month to determine the degree of cross linking of the EVA. If these tests reveal an excursion in the manufacturing process, BYD will quarantine Modules which may have been affected and will not ship them until further investigation. Black & Veatch considers this quarantine practice to be best in class but also notes that testing each laminator only once per month might result in a very large quantity of scrap or rejected Modules. BYD can reduce this risk through more frequent testing of the laminators.
- BYD shared with Black & Veatch its process for qualifying suppliers and for periodic assessment of its suppliers. Black & Veatch believes that these processes are consistent with accepted industry practices.

1.6 Quality Organization and Processes

- Black & Veatch found BYD's quality management organization to be well-staffed and reasonably experienced in managing manufacturing quality in volume manufacturing environments.
- BYD has processes in place for training manufacturing personnel, maintaining equipment, controlling documentation and tracking key performance indicators that are consistent with accepted industry practice.
- Black & Veatch was informed that BYD's turnover rate for direct labor is much lower than what other solar PV module assembly organizations in China have reported to Black & Veatch.
- BYD's product tracking and serialization practices use a combination of computer based systems and paper records. Black & Veatch finds that this system will store all the pertinent data only if the paper records are preserved, but could require greater effort to extract the necessary information when compared to best-in-class computer based systems. BYD plans to transition to an all-digital record system in the near future.

1.7 Module Performance

- BYD has demonstrated a record of improving cell and module conversion efficiencies.
- BYD shared with Black & Veatch five months of operating data for a 1MWdc system in Italy based on its Modules. Black & Veatch was unable to audit the actual or expected generation but notes that the system appeared to perform well relative to the expected energy generation over the period. Black & Veatch recommends further study of the short and long term performance of the Modules.

2.0 Introduction

2.1 Scope of Work

To conduct this due diligence review, Black & Veatch provided the following services:

- Reviewed BYD's corporate background to provide context for this technology due diligence.
- Reviewed the Module designs and components.
- Assessed available durability and reliability information on the Modules.
- Visited BYD's manufacturing facility to assess the manufacturing of and quality assurance for the Modules.
- Reviewed available information on the Modules' performance.

The primary objective of this report (Report) is to opine on factors that would affect the Modules' performance and longevity in the field and BYD's ability to deliver and service the Modules. Such factors would include the Module designs, quality of materials, performance in the field, environmental tests and the manufacturing and quality control processes. Black & Veatch is uniquely qualified to conduct this study due to its extensive background and experience in solar independent engineering and technology due diligence work.

2.2 Approach and Methodology

The Black & Veatch team, comprised of professionals with experience in solar module manufacturing, solar power plant performance, and supporting engineers, reviewed data provided by BYD to assess the status and performance of the technology and conducted a visit to the BYD module manufacturing facilities in Shanghai, China. Data requests for additional or updated documentation were submitted as necessary.

2.3 Assumptions

During the assessment of this technology, Black & Veatch used and relied upon certain information provided by BYD.

Black & Veatch believes the information provided by BYD is true and correct and reasonable for the purposes of this Report. Black & Veatch has not been requested to make an independent analysis, to verify the information provided to us, or to render an independent judgment of the validity of the information provided by others. As such, Black & Veatch cannot, and does not, guarantee the accuracy thereof to the extent that such information, data, or opinions were based on information provided by others. In preparing this Report and the opinions presented herein, Black & Veatch has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. Black & Veatch believes that the use of this information and assumptions is reasonable for purposes of this Report. However, some events may occur or circumstances change in ways that cannot be foreseen or controlled by Black & Veatch and that may render these assumptions incorrect. To the extent that the actual future conditions differ from those assumed herein, or provided to Black & Veatch by others, the actual results will differ from those that have been forecast in this Report. This Report summarizes Black & Veatch's assessment of the technology. Throughout this Report, Black & Veatch has stated assumptions and reported information provided by others, all of which were relied upon in the development of the conclusions of this Report.

3.0 Company Background

Black & Veatch performed a brief review of the company history and management team for BYD. This review provides the commercial context for the technical sections to follow.

3.1 BYD Company Background

BYD Company Limited (BYD) is a publicly traded company, specializing in the automotive, information technology and energy sectors. BYD was established in 1995 and entered the solar PV market in 2008 with the construction of a silicon wafer and cell production plant in Shangluo, China. In July, 2010, BYD converted its Shanghai plant into a PV module assembly facility with total capacity of approximately 750 MW of module production per year. BYD currently has approximately 160,000 employees with plants and offices situated throughout China, Asia, Europe and North America.

BYD was first listed on the Hong Kong Stock Exchange (HKSE: 1211) in 2002. Global headquarters are located in Shenzhen, China. The BYD Energy division makes up approximately 10% of BYD's revenues and includes production of PV modules, energy storage systems, home energy systems and inverter technologies. In 2010, solar PV sales totaled RMB¥758 million (approximately US$119 million), accounting for approximately 1.6% of BYD's total revenues. BYD expects this figure to increase as it continues to scale its solar business.

BYD operates under a vertically integrated manufacturing system, with silicon wafers, solar cells and solar modules being produced at separate facilities in China. Since 2008, BYD has steadily increased is solar PV production capacity, with a current 2011 annual production capacity of 1 GW for silicon wafers and cells, as well as 750 MW/year of PV module production capacity. A new module assembly plant in India is expected to begin production in 2011, which will boost BYD's module production capacity to 800 MW/year.

BYD has demonstrated continual improvement in the conversion efficiency of its solar cells since entering the market, with a current average polycrystalline cell efficiency of 17.2%. BYD claims to have sold its PV modules throughout China, Europe and Australia for both rooftop and ground-mount applications.

Financially, BYD has shown strong and steady growth, reflected in increasing revenues since 2005. BYD's revenues in 2010 were RMB¥46.7 billion (approximately US$7.4 billion), with 70% annual growth on average since it was established in 1995. Net profits for 2010 were RMB¥2.9 billion (approximately US$459.9 million), which was a decrease of approximately 28% from 2009. BYD had net assets totaling RMB¥21.2 billion (approximately $US3.3 billion) at the end of 2010.

3.2 BYD Management Team

BYD's senior management team is comprised of professionals with extensive manufacturing, research and development and industrial management experience. Some highlights of the management team's experience include:

- Wang Chuan-fu (Chairman and President) – Mr. Wang Chuan-fu holds Bachelor and Masters Degrees majoring in Physical Chemistry of Metallurgy. In February 1995, Mr. Wang founded BYD with Lu Xiang-yang and took the position of General Manager. Mr. Wang previously held the position of Deputy Director in the Beijing General Research Institute for Non-Ferrous Metals. Mr. Wang is the current Chairman, an Executive Director and the President of BYD group, responsible for overseeing the general operations and business strategy.
- Michael He (General Manager) – Mr. Michael He is the current Vice President and General Manager of BYD. He has held a number of senior management positions at BYD since 1999, including leading the research and development project of the central institute, Quality Manager and the Quality Director of IT product group. Mr. He is responsible for the management, production and research and development of BYD's lithium battery and new energy business, including photovoltaic technologies and electric vehicles.
- Jiang Zhanfeng (Shangluo Plant Manager) – Mr. Jiang Zhanfeng is the current General Manager and PV Business Plant Manager of BYD's Shangluo plant. He is responsible for the management, production, and research and development of the PV business of BYD. Mr. Jiang Zhanfeng has previously held positions with BYD including the head of the research and development project of the central institute, Research Unit Manager of Division 5 and Research Unit Manager of Division 2.
- Tom Zhao (General Manager of PV Global Sales) – Mr. Tom Zhao has 17 years experience as a Supply Chain Manager for Motorola, and is the current General Manager of PV Global Sales. He is responsible for the development of renewable energy sales in North America, South America and India, and for setting up the sales network to promote solar PV modules, inverters, and other BYD renewable and energy efficiency technologies.
- Zhang Caiyu (Shanghai Products Department Manager – Wafer) – Mr. Zhang Caiyu holds a Bachelor of Science in Chemistry and Chemical Engineering. Mr. Zhang has carried out research and development into solar PV cell technology since 2007 and joined BYD in 2009 as the Product Manager responsible for the construction and management of the polycrystalline silicon wafer production line, which currently has a capacity of 850 MW.
- Wang Shenya (Manager of PV Systems Shangluo Plant – Cell) – Mr. Wang Shenya joined BYD in 2007 as a Senior Research and Development Engineer in BYD's lithium ion battery division. Mr. Wang has since held the position of Manager of PV Systems Shangluo Plant, and has been responsible for the construction and operation of 1 GW capacity of solar cell production lines at the Shangluo plant and the construction of a 750 MW capacity solar PV module production line at the Shanghai plant.
- Yu Shaokang (Shanghai Products Department Manager) – Mr. Yu Shaokang graduated from Fudan University and has a Masters of Business Administration (MBA). Mr. Yu joined BYD in 1999 and has held numerous quality and product management positions in BYD's battery and automotive divisions. He is currently the Product Manager of BYD's solar PV Shanghai department.

- Sun Xiang (Quality Guarantee Manager) – Mr. Sun Xiang graduated from the University of Science and Technology of China in 2000, and has since worked with BYD in a number of quality and management roles. Mr. Sun is a quality system engineer and currently holds the position of Quality Guarantee Manager. He achieved the qualification of "Black Belt" in 6 Sigma and has specialized training in 6 Sigma, Statistical Process Control and ISO9001.
- Zhang Chunyu (Purchasing Manager) – Mr. Zhang Chunyu holds a Bachelor degree from Beihang University and held the position of Project Manager for 5 years. From 2007 to the present, Mr. Zhang has held the position of Purchasing Manager for BYD's Division 2. He has achieved the qualification of "Black Belt" in 6 Sigma and has been responsible for the development and application of various purchase strategies and process within BYD.

Black & Veatch finds that key members of BYD's solar division leadership have been promoted from within and have significant experience in high-volume manufacturing of electronic components, especially in batteries. The leadership team of the solar division does not appear to have substantial experience in other companies in or other parts of the solar PV industry.

4.0 Module Design and Components

Black & Veatch conducted a detailed review of the Module designs and bill of materials. Design and components can significantly impact product lifetime and long-term durability and reliability. This section highlights Black & Veatch's findings on the design and components of the Modules.

4.1 Module Design and Specification

Black & Veatch reviewed the designs of the P6-36 series Modules. The Modules have a power output in the 260 to 300 W range. They incorporate 72 polycrystalline cells. Each cell measures 156 x 156 mm. The cells are connected in six strings of 12 cells each and the strings are connected in series. The Modules are rated for maximum system voltages of 600 V or 1000V.

The Module size is 1.94 m^2. The Module specifications and design are similar to that of other major solar module manufacturers. Black & Veatch conducted a detailed visual inspection of a BYD Module and did not observe any fatal flaw that would impede the Module from meeting the technical specifications claimed by BYD.

BYD indicated that the P6-30 were identical to the P6-36 series Modules in materials used and design, with the exception that the P6-30 Modules use only 60 cells and the dimensions of the Module are scaled down accordingly.

Figure 4-1: BYD P6-36 Series Module

Black & Veatch reviewed the operating characteristics of the Modules and compared them to those of the 280W module produced by Suntech. Suntech was chosen as a benchmark because it is the world's largest producer of crystalline silicon solar PV modules. Table 4-1 shows a comparison of the major operating characteristics of these modules. The modules are in similar ranges for maximum power point voltage and current. The power tolerance of the BYD Module is 0/+3% and that of the Suntech module is 0/+5%.

Table 4-1: Comparison of BYD and Suntech 280W Modules

	BYD	Suntech
Part number	P6-36	STP- 280-24/Vd
Peak Power (Pmax, Watts)	280	280
Power Tolerance (percent)	0/+3	0/+5
Max Power Voltage (Vmp)	35.23	35.2
Max Power Current (Imp)	7.95	7.95
Open Circuit Voltage (Voc)	43.93	44.8
Short Circuit Current (Isc)	8.57	8.33
Pmax Temperature Coeff (%/°C)	-0.47	-0.44
Source: Product datasheets		

The product datasheets list the remaining major operating characteristics and specifications of the Module. Black & Veatch believes that the nominal power temperature coefficient of -0.47 percent is in line with expectations for a polycrystalline silicon solar module. The operating temperature range from -40 °C to 85 °C is appropriate for most locations and installation configurations in North America. The maximum operating voltage of 1000V is consistent with other manufacturers and appropriate for utility-scale systems.

The ribbon used for tabbing and stringing is consists of a copper core and has a maximum tensile strength at breakage of 225 MPa. Black & Veatch notes that copper ribbons are widely used in the solar PV industry but several module manufacturers favor ultrasoft copper ribbons with tensile strengths at breakage below 200 N/mm^2 and elongation at fracture on the order of 25%. Black & Veatch notes that softer copper (<200 N/mm^2) can reduce cell breakage during manufacturing and reduces stress on cells and solder joints due to temperature variations during field operations.

The ribbon has a tin-lead coating that is a few microns thick. The coating is meant for good metallurgical contact between the ribbon and the cell busbar. All of the soldering is done by machine. Black & Veatch believes that this is an important distinction between BYD and other Chinese solar manufacturers that tend to favor manual soldering. The ribbons are attached to the entire length of the front cell busbar. The busbars on the back of the cell are joined to the cells by discrete solder points. In order to reduce stress on the cells due to temperature variations (which can contribute to Module power degradation) Black & Veatch suggests considering the use of discrete solder points along the front cell busbars.

The Module front glass is 3.2 mm thick. The glass is low iron, tempered glass. The front glass is textured on the side that faces the cells. The glass is purchased from a Chinese supplier.

Black & Veatch was informed that the Module backsheet incorporates a polyvinylfluoride (Tedlar®) film that is bonded to a polyethylene terephtalate (PET) film, which in turn is bonded to an ethylvinylacetate (EVA) film. The backsheet is made by a Korean supplier.

The Module assembly is held in place by cross-linked, fast-cure EVA. The EVA is purchased from Japanese and Chinese manufacturers. Lamination of the Module assembly takes place in laminating equipment made in China.

A junction box is adhered to the Module back sheet. Two different junction boxes are used depending on the required certifications, which are largely driven by the destination of the Modules. One of the junction boxes is certified to IEC 61215 and UL 1703, while the other is certified to the IEC standard only (not UL). The junction boxes are made by Chinese and US manufacturers. The junction boxes have an ingress protection (IP) rating of 65. An IP65 rating indicates that water sprayed from a 6.3mm diameter nozzle from any direction for at least three minutes will not have any harmful effect on the electronics inside the junction box. While IP65 junction boxes are commonly used in the solar PV industry, Black & Veatch believes an IP67 junction box could enhance the reliability of the Modules. IP67 junction boxes offer protection against water ingress when immersed in up to one meter of water for thirty minutes. Several other module manufacturers employ junction boxes with IP67 rating.

The junction box contains the provisions for electrical connections from the Module to external wires and the bypass diodes. The diodes and leads coming from the cell strings are held in place in the junction box terminals by pressure contacts and are neither crimped nor soldered. Black & Veatch does not have experience with this type of pressure contact in a PV module. The junction box is not potted which is common among Chinese PV module manufacturers. Black & Veatch suggests that BYD consider the advantages of using a pottant with good thermal conductivity and dielectric properties to enhance heat dissipation in the event of diode overheating and to protect against moisture ingress into the junction box. Extending from the junction box are two TUV-approved solar cables (4.0mm^2 cross section) with TUV-approved, MC-4 compatible connectors. BYD has indicated that it has qualified a potted junction box which can be installed upon special request by its customers and that this configuration is expected to receive IEC and UL certifications in April 2012.

The Module is surrounded by an anodized aluminum extruded frame that is held in place by RTV silicone. Black & Veatch is aware of the use of quick set adhesives by other module manufacturers and suggests that BYD consider replacing the current RTV silicone in this function. BYD has indicated that quick set adhesives can be used upon customer request and that this configuration is expected to receive IEC and UL certifications in April 2012.

4.2 Supply Chain and Major Components

Black & Veatch reviewed a list of vendors supplied by BYD which is summarized in Table 4-2. The suppliers for key components such as EVA, glass, junction box, and back sheet include some leading suppliers with long track records as well as some lesser-known or less-established suppliers.

Table 4-2: BYD-Approved Vendors for Selected Module Materials		
Module Component	**Number of Suppliers**	**Country of Origin**
EVA	2	China, Japan
Glass (tempered)	1	China
Junction box	2	China, USA
Back sheet	2	Korea, Taiwan
Notes: Black & Veatch reviewed the specific suppliers used by BYD but the supplier list is not provided as it is considered sensitive information.		

Black & Veatch believes that the lack of a second glass supplier is a potential risk for BYD and suggests the prompt selection of an alternative glass supplier. BYD has indicated that it is in the process of qualifying two additional glass suppliers to mitigate glass supply risk and that these additional suppliers are on track to begin deliveries in Q2'12.

Black & Veatch was briefed on the supplier selection process performed by BYD. The supplier selection process is based on an internal procedure utilized throughout BYD. The process is well defined and documented. Black & Veatch believes that the supplier selection and monitoring process conforms to accepted industry practices.

5.0 Durability and Reliability

5.1 Certifications and Standards

BYD has tested the Modules to the IEC 61215, IEC 61730 and UL 1703 industry standards. In particular, Black & Veatch notes that the Modules have passed the IEC 61215 qualification testing. This standard is accepted by the PV industry as a suitable qualification test to give a baseline indication of a crystalline silicon PV module's capability to survive in the field. Additional detail on each of these industry standards is provided below.

In addition to the tests required by the IEC and UL standards, the Modules were tested by independent testing facilities for exposure to salt and ammonia corrosion environments. The testing certificates provided by the independent test facilities indicate that the Modules passed these tests. These tests are described in further detail below.

5.1.1 IEC 61215

IEC standard 61215 establishes the IEC requirements for the design qualification and approval of crystalline silicon PV modules. The objective of this test sequence is to determine the electrical and thermal characteristics of the module and to show, as far as is possible within reasonable constraints of cost and time, that the module is capable of withstanding prolonged exposure in climates described in the scope. The actual lifetime expectancy of modules will depend on their design, their environment and the conditions under which they are operated.

IEC 61215 includes tests that are designed to reveal reliability concerns in crystalline silicon modules. Three of the most stringent tests are thermal cycling, which exposes the modules to 200 cycles in which the temperature varies from -40° C to +85° C; humidity freeze in which the modules experience 10 temperature cycles from +85° C (with 85 percent relative humidity) to -40° C; and damp heat, where the modules are held for 1000 hours at +85° C (with 85 percent relative humidity).

Moisture penetration into the module is one of the reliability issues that are exposed by these tests, particularly the damp heat test. Moisture can eventually lead to module failure due to events such as the delamination of the backsheet, electrochemical corrosion of the solder joints and increase in the contact resistance at solder points and electrodes.

Similarly, IEC 61215 includes tests to verify the resistance of the module to breakage of the glass under load or hail impact, junction box failure, robustness of the wires and connectors, among other potential failure modes.

Experience has shown that a module design that receives IEC 61215 certification is very likely to perform adequately in the field.

5.1.2 IEC 61730

IEC 61730 is the internationally accepted safety standard for PV modules. This standard will supersede UL 1703 within the United States. There are two parts to IEC 61730 and a brief description of each is found below.

IEC 61730-1: Requirements for Construction

IEC 61730 Part 1 addresses the fundamental construction requirements for PV modules. It is designed to provide safe mechanical and electrical operation during the expected lifetime of the PV module. It also aims to prevent electrical shock, fire hazards, and personal injury resulting from mechanical and environmental stresses. Part 1 pertains to construction requirements and is to be used in conjunction of IEC 61646.

IEC 61730-2: Requirements for Testing

IEC 61730-2 describes the testing requirements for PV modules in order to provide safe electrical and mechanical operation during their expected lifetime. PV modules are assessed for the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses.

5.1.3 UL 1703

UL 1703 is the standard for safety for flat-plate PV modules most often cited in the US. This standard assesses the safety performance of construction, materials and the manufacturing process of flat-plate PV modules.

Black & Veatch notes that the Modules have been tested to the UL 1703 standard by Underwriters Laboratories, Inc. (UL). UL is a Nationally Recognized Testing Lab as designated by the United States Department of Labor.

The following are requirements of UL 1703, third edition:

- Temperature Test.
- Voltage, Current and Power Measurement Test.
- Leakage Current Test.
- Strain Relief Test.
- Push Test.
- Bonding Path Resistance Test.
- Dielectric Voltage Withstand Test.
- Wet Insulation-Resistance Test.
- Reverse Current Overload Test.
- Impact Test (Wiring Compartment).
- Fire Test (Class C).
- Water Spray Test.
- Temperature Cycling Test.
- Humidity Test.
- Hot Spot Endurance Test.
- Mechanical Loading Test.

5.1.4 Additional Environmental Tests

In addition to the IEC and UL tests described above, the Modules were tested for exposure to salt and ammonia corrosion environments.

5.1.4.1 Salt Corrosion

BYD provided to Black & Veatch a test report summarizing the salt mist test performed by TechnoLab, an independent test lab which bears the TÜV SÜD certification. This report indcated that two sample Modules were exposed to a 28-day salt fog test in accordance with DIN EN 60068-2-52 (1996-10).

This test involves four one-week cycles. Each weekly cycle consists of four consecutive spray days followed by three consecutive drying days. During each spraying day, the modules are sprayed with a salt solution for two hours then held at 40°C and high humidity (90-95%) for 22 hours.

After the 28-day exposure to the salt mist environment, the Modules were cleaned with deionized water and checked for corrosion or salt ingress. The test report showed no corrosion was visible on the two sample Modules and no salt had entered the connectors. The test did not open the junction box to inspect whether salt had entered the junction box assembly.

5.1.4.2 Ammonia Corrosion

BYD provided to Black & Veatch a test report summarizing the ammonia corrosion test performed by TÜV SÜD Shenzhen. The test was performed to the 82/600/NP: 2010 standard for ammonia corrosion testing of PV modules. BYD submitted three sample Modules for this test. Two of the Modules were exposed to the ammonia environment while the third Module was reserved as a control sample. TÜV SÜD Shenzhen indicated that the test was passed.

The two Modules under test were subject to 20 ammonia exposure cycles. Each cycle consisted of eight hours at 40°C, 100 percent relative humidity and 6667 ppm of ammonia, followed by 16 hours of 18-28°C, 75 percent maximum relative humidity and no ammonia.

After 20 such cycles, the two Modules were cleaned using tap water and visually and electrically tested. Both Modules exhibited some corrosion on the frame and frame sealant delamination, but both were determined by TÜV SÜD Shenzhen to be within the acceptable limits. The electrical characteristics, including output power, were also determined by TÜV SÜD Shenzhen to be within the acceptable limits.

5.2 Warranty and Warranty Claims

BYD offers a 25-year power warranty. Under this power warranty, BYD warrants that its Modules will deliver a minimum of 90% of their nominal power for the first ten years and no less than 80% for the first 25 years. Such warranty terms are similar to those of other module manufacturers.

BYD also offers a 10 year warranty against defects in design, material, workmanship or manufacture. Black & Veatch is aware of module manufacturers that offer this warranty for only five years.

BYD informed Black & Veatch that it has not received any claims under the power warranty for its Modules.

5.3 Changes in Module Performance Over Time

Power degradation of crystalline silicon solar PV modules commonly happens in two phases. There is first a rapid power degradation, commonly called Light Induced Degradation (LID) that takes place in the first few days of a module's exposure to sunlight. The rate of degradation then levels off and the module continues to degrade at a less severe rate for the remainder of its life (the long term degradation rate).

5.3.1 Light Induced Degradation (LID)

BYD presented Black & Veatch with the results of short term degradation measurements performed on one P6-30 polycrystalline Module to assess LID. The module was placed outdoors at the BYD facility in Shanghai.

The irradiation at the site was monitored and the module was removed after 5kWh/m^2 of irradiation. It was then taken indoors and the power of the Module was measured on a flash tester. The LID result was 0.5%. The module was again placed outdoors and removed and flash tested after 20 and 60 kWh/m^2 of cumulative irradiation. The LID results were 0.9, and 1.5%, respectively.

Black & Veatch believes that such LID values are consistent with industry values for polycrystalline silicon solar cells. Nevertheless, the fact that only one Module was measured, limits the strength of conclusions which may be drawn from this test. BYD has indicated that further LID testing is currently underway and that these test results are expected to be available in March of 2012.

5.3.2 Long Term Degradation

BYD provided Black & Veatch with data on Modules which had been exposed to three months of outdoor environments. Black & Veatch does not believe that a long term degradation rate can be determined from only three months of exposure.

In the absence of data which would enable an estimate of the long term degradation rate specific to BYD's Modules, Black & Veatch provides annual long term degradation guidance of 0.4 to 0.7 percent for polycrystalline silicon modules. The degradation rate varies depending on temperature ranges, humidity, and irradiation at the site. These degradation rates are based on publicly available data regarding the degradation of crystalline silicon modules as described in Appendix A. Table 5-1 summarizes the estimated power degradation rates for the BYD Modules based on this assumption.

Table 5-1: Estimated Degradation for BYD P6-36 Polycrystalline Modules					
	Year 1	**Year 2**	**Year 3**	**....**	**Year 25**
Short term degradation (%)	1.5				
Long-term degradation (%)	0.4 - 0.7	0.4 - 0.7	0.4 - 0.7	...	0.4 - 0.7
Total Module Degradation (%)	**1.9 - 2.2**	**0.4 - 0.7**	**0.4 - 0.7**	**...**	**0.4 - 0.7**

Notes: Degradation should be applied year over year. For example, the Year 2 degradation rate should be applied to the end of Year 1 degraded capacity.
* Short term degradation rates are based on test results as reported by BYD.

6.0 Manufacturing Facilities

Black & Veatch visited BYD's module assembly facility in Shanghai, China for a period of two days on October 26 and 27, 2011. BYD personnel described the facilities and expansion plans for the site. Production of wafers and cells takes place at the Shangluo facility which Black & Veatch did not visit since these upstream components were out of scope for this review. The Module manufacturing process witnessed by Black & Veatch at the Shanghai facility will be described in greater detail in the next section of the Report.

6.1 Shangluo Wafer and Cell Facility

BYD constructed the Shangluo facility in 2008 for the production of silicon wafers and solar cells. The plant has a workshop area of approximately 46,000 m^2 with approximately 6,000 employees. The Shangluo facility has total capacity of 1 GW of wafer and cell production. BYD has indicated that the manufacturing equipment used in the production facilities includes equipment from suppliers in the U.S., Europe and Japan.

Black & Veatch did not visit or assess the Shangluo facility as the upstream components manufactured there are out of scope of Black & Veatch's review.

6.2 Shanghai Module Assembly Facility

BYD's Shanghai facility is located in Shanghai close to shipping facilities on the eastern coast of China. BYD indicated that the Shanghai facility has a 750 MW of annual PV module assembly capacity across 27,850 m^2 of workshop area. The facility employs approximately 400 persons. The plant was originally constructed in August 2002 and was converted for solar PV module assembly in July 2010.

BYD indicated that it did not plan to expand module capacity in 2012 but the current plant has space and facilities (power, water, etc.) for 300 MW of additional module assembly capacity in the same building. The campus also contains an entire additional plant with space and facilities for another 1 GW of capacity, if needed, in the future.

Figure 6-1: Artist's Representation of BYD's Shanghai Facility

During its visit to the module assembly facilities, Black & Veatch observed that the major capital equipment in the production line was sourced from Western and Chinese suppliers. The facilities and equipment appeared to be maintained in good condition.

In addition to the manufacturing operations, Black & Veatch personnel were shown the administrative offices, warehouse and quality assurance laboratory. The facilities appeared well-maintained and BYD personnel indicated that it has both space on the site and facilities (e.g., electricity, compressed air) to accommodate the planned expansion. The quality assurance facilities are described in greater detail in a subsequent section of the Report.

7.0 Manufacturing Process and Quality Assurance

7.1 Manufacturing Process Introduction and Summary

Black & Veatch toured one of the seven Module assembly workshops at the Shanghai facility with BYD personnel to witness the Module assembly process and in-process quality checkpoints. Black & Veatch found the assembly process to be reasonable and noted the number and frequency of quality checkpoints were comparable to those observed in other module assembly lines.

Black & Veatch noted the following which could affect Module reliability:

- <u>Box cutter use during Module cleaning</u> - In one of the final steps, excess silicone is removed from the front of the Module where it may have been squeezed out of the frame. Using a box cutter to remove this excess silicone may result in cutting silicone out from between the frame and the glass which can increase the likelihood of moisture ingress in the field. BYD has indicated that it has since switched to a plastic tool which is not likely to be sharp enough to cut silicone out from under the frame. BYD provided photos of this tool to demonstrate its implementation.
- <u>Insulation patch</u> – Black & Veatch observed that a section of backsheet material is used as an electrical insulator between the Module busbar ribbons and the back of the solar cells. This section of backsheet material is laminated between two sheets of EVA. Black & Veatch believes that the backsheet material being used is not designed to be laminated between two sheets of EVA and may cause an adhesion issue in the long term. Black & Veatch recommends that BYD verify that the material is qualified to be laminated between two sheets of EVA or switch to a material that is designed for this use. BYD has indicated that it is evaluating a material made by 3M which is designed for this application.
- <u>Contaminant removal before lamination</u> - If operators find a contaminant in the laminate during visual inspection before lamination, they slide a stick with a sticky tip between the laminate layers to remove the contaminant. Black & Veatch notes that using this sticky tip could leave a residue on the layers which may cause long term adhesion or other issues. Furthermore, Black & Veatch observed that the tip was quite dirty and could introduce other contaminant in the attempt to remove the observed contaminant from the laminate. BYD has indicated that it will attempt to ensure that operators use a clean tip in the future but Black & Veatch has not been able to verify the change in procedure.
- <u>Full gloves not worn during EVA preparation</u> - Black & Veatch observed that the operators cutting EVA from the rolls were wearing gloves without fingertips, leaving their bare fingertips to handle the EVA. This introduces the risk that oils from the operators' fingertips could be transferred to the EVA and compromise the adhesion of the EVA. BYD has indicated that it intends to resolve this through training and tighter observation of the operators but Black & Veatch has not been able to verify the changes in procedures.

Black & Veatch notes the following opportunities for process improvements:

- Cold-knife material trimming - Black & Veatch suggests trimming excess EVA and backsheet material with a hot knife to reduce the stress impressed by the cutting action on the edge of the Module. BYD has indicated that it is currently evaluating implementation of a hot knife for this application.
- Junction box pottant - The junction box is not potted. Though not potting the junction box is common among Chinese manufacturers, filling the junction box with an appropriate material could reduce the possibility of moisture ingress, improve thermal conductivity and relieve the mechanical stress on the diodes and busbar loops. BYD has indicated that a potted junction box can be installed upon customer request and that this configuration is expected to receive IEC and UL certification in April 2012.
- Quick-cure adhesive - Black & Veatch recommends an alternative framing encapsulant with a shorter cure time and higher viscosity which does not ooze from the frame. The current silicone adhesive requires time-consuming manual cleaning of the Module after a 20-hour cure period. BYD has indicated that a quick-cure adhesive can be used upon customer request and that this configuration is expected to receive IEC and UL certification in April 2012.
- Electrical safety test calibration - The machine used to conduct the electrical safety test is designed to issue an alarm in the case of failure and is calibrated annually. Black & Veatch notes that the only test of the testing machine to verify that it is working correctly is the annual calibration. A more frequent test of the testing machine should be implemented to reduce the risk of inaccurate testing results.
- Module packaging - Black & Veatch notes that the module packaging used by BYD is common among Chinese manufacturers. The packaging uses a substantial amount of cardboard which could lead to disposal issues for its customers in the field. BYD has since indicated that it is developing alternative packaging options from which is customers will be able to select.
- Personnel safety measures - Black & Veatch identified several measures which could be implemented to improve the safety of personnel in the production area. BYD has indicated that it has adopted all of the safety recommendations. These measures are described in greater detail below.

7.2 Manufacturing Process Overview

Black & Veatch performed a detailed review of one BYD Module assembly workshop at its Shanghai facility. It should be noted that Black & Veatch only observed one of the seven workshops at Shanghai as a detailed inspection of all seven would be time- and cost-prohibitive.

The workshop observed by Black & Veatch was well equipped and organized. The BYD Module manufacturing process, as diagrammed in Figure 7-1, is consistent with accepted industry practices for crystalline silicon modules and incorporates multiple quality control steps. Assembly process steps are shown in blue rectangles and quality inspection steps are shown in green hexagons.

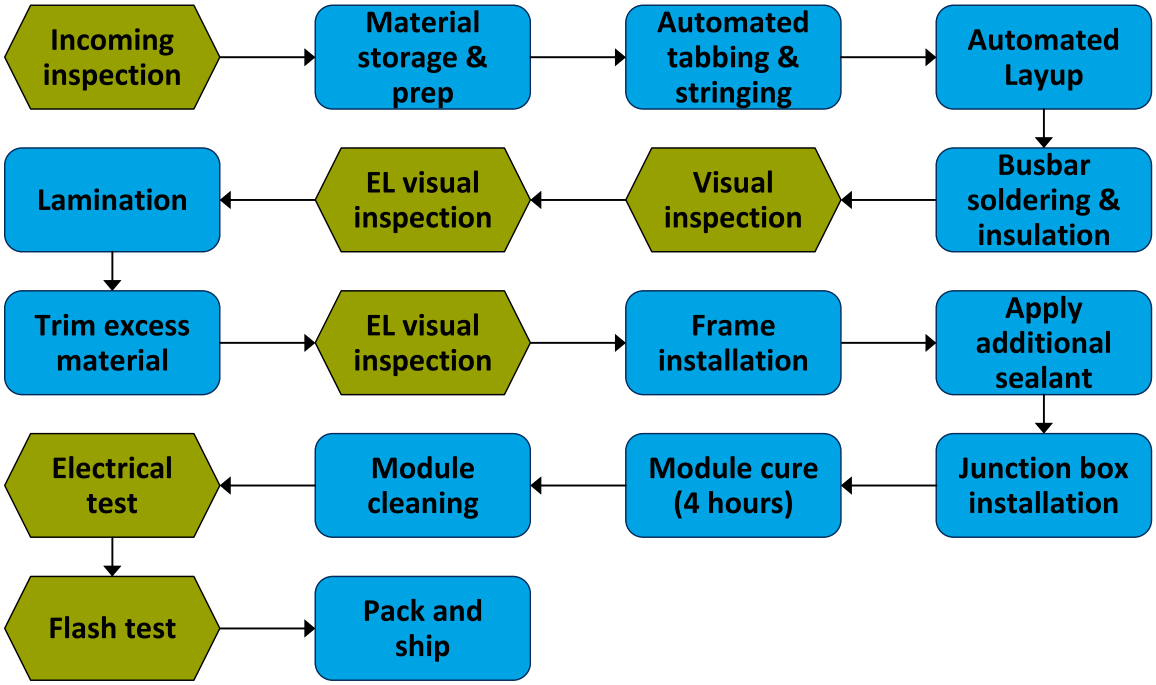

Figure 7-1: BYD Module Assembly Process Overview

The operators seemed well-trained to perform the tasks assigned to them. Black & Veatch was briefed on the operator training program in place at BYD. Representatives of the quality assurance organization were present throughout the manufacturing line. All incoming material is subject to inspection prior to being released to manufacturing.

7.2.1 Incoming Material Inspection

All incoming material is inspected in accordance with an established procedure for each material. For example, EVA is subject to visual inspection, measurement of the physical dimensions and tests of the pull strength and gel content of a laminated sample.

BYD indicated that it followed the AQL 2.5 sampling specifications to determine the frequency of sampling for incoming inspection. Black & Veatch notes that this standard is commonly used by Chinese module manufacturers.

7.2.2 Material Preparation

Black & Veatch observed a material preparation area in which EVA and backsheet materials were cut from rolls into the correct size for the modules. EVA was cut manually using a knife and a template. All cutting of the backsheet material was automated.

Black & Veatch observed that the operators who were trimming the EVA were wearing gloves without fingertips. This introduces the risk that oils from the operators' fingers are transferred to the EVA which could compromise the adhesion of the EVA. BYD has indicated that it intends to address this issue through improved operator training and tighter observation of the operators. Black & Veatch has not been able to verify the changes in the procedures.

7.2.3 Solar Cell Tabbing and Stringing

BYD uses only automated tabbing and stringing of the solar cells. Tabbing is the soldering of electrically conductive ribbon to the solar cells and stringing is electrically connecting the cells together in series. The machines used for the tabbing and stringing operations were supplied by a well-known solar capital equipment supplier and appeared to be maintained in good condition.

BYD indicated that the soldering machines perform machine vision inspections of each cell for cracks and breakage before soldering. The soldering machines also perform machine vision electroluminescence (EL) inspections of each cell after soldering. EL imagery can reveal defects in the cells that can not be observed under normal illumination, such as microcracks and electrically "dead" zones. Black & Veatch considers the level of inspection automatically performed by the soldering machines to be best in class.

BYD indicated that destructive pull tests are performed on two samples from each soldering machine every 12 hours.

7.2.4 Layup and Busbar Soldering

Operators place a sheet of EVA on top of the front glass of the Module and the soldering machines place the cell strings onto the EVA. The strings are taped in place by hand to prevent movement as the Modules are handled. Busbar ribbons are soldered to the strings to provide an electrical path to the junction box (installed later).

BYD indicated that the temperatures of these solder stations are recorded by the quality assurance team every four hours. BYD shared with Black & Veatch records of these measurements for the past few days which showed that the temperature was consistently found to be within the specified range. BYD spot-checked a few solder temperatures during Black & Veatch's visit and each of these spot-checks were within the specified range.

During Black & Veatch's site visit, a section of backsheet material was used as an electrical insulator between the Module busbar ribbons and the backs of the solar cells. This section of backsheet material is laminated between two sheets of EVA. Black & Veatch believes that the backsheet material was not designed to be laminated in this way and could thus present a long-term delamination risk. Black & Veatch recommends that BYD either perform a test to verify that both sides of the backsheet adhere to the EVA with sufficient pull strength or replace the section of backsheet material with a material which is designed to bond well with the EVA in the laminate. BYD has indicated that it is evaluating a material manufactured by 3M which is designed for this application.

A second sheet of EVA and the backsheet are placed over the cell assembly before visual inspection.

7.2.5 Pre-Laminate Visual Inspection

After layup, the Module is placed on glass-down on fixture a mirror underneath for visual inspection. The operators inspect the front side of the cells for contaminants and uniformity of the cell spacing.

Black & Veatch observed that the operators use a tool comprised of a stick with double-sided tape (or other adhesive material) at the tip to remove any contaminants found during this step. The adhesive tip appeared to be quite dirty. Black & Veatch notes that use of this tool might introduce additional contaminants in the process of attempting to remove a contaminant. The adhesive material may leave a residue on the cells or the glass. BYD has indicated that it will work to ensure that a clean tool is used for this operation. Black & Veatch has not been able to verify the change in procedure.

7.2.6 Electroluminescence Inspection

An operator then inspects the Module using electroluminescence (EL) imagery. EL imagery can reveal defects in the cells that can not be observed under normal illumination. Such an inspection can help identify actual defects, or potential sources of latent defects, in the cells. Black & Veatch notes that this EL inspection before lamination is consistent with accepted industry practice.

7.2.7 Lamination

The glass, cell, EVA and backsheet layers are fused together through the lamination process. Lamination takes place in a single chamber at high temperature and under pressure. The laminate is then allowed to cool in open air before continuing to the next process step. Black & Veatch finds BYD's process for lamination to be consistent with those observed for other leading manufacturers of crystalline silicon solar PV modules.

7.2.8 Trimming

Trimming of excess EVA and backsheet after lamination is done manually with a cold blade. This results in a jagged cut that can compromise the adhesion of the glass, EVA and backsheet layers at the edge of the Module. Black & Veatch notes that this practice is fairly common in the industry. Black & Veatch recommends using a hot knife to perform this trimming as doing so would reduce the stress impressed by the cutting action on the edge of the Module. BYD has indicated that it is currently evaluating implementing a hot knife in this application.

7.2.9 Electroluminescence Inspection

Neither of Black & Veatch's representatives observed an EL inspection step after lamination. Upon Black & Veatch indicating this to BYD, BYD provided photos and a process flow chart indicating that an EL inspection step occurs after lamination but before framing. Black & Veatch notes that this inspection step is in line with common industry practice to screen the laminate or framed module for cell defects that can not be observed under normal illumination.

7.2.10 Framing

A robot is used to automatically dispense a silicone adhesive into the frame members. The frame members are then applied to the edges of the Module laminate with a "corner key" with a sawtooth pattern inserted at each corner. A machine presses the frame members together and crimps the frames at the corners. This crimping step is intended to press the frame members into the sawtooth "teeth" of the corner key, making it harder to pull the frame apart.

Black & Veatch considers this crimping of the frame onto the corner key to be a best practice among solar PV module manufacturers. Black & Veatch is aware of module manufacturers that use the corner key without a crimping step and instead rely on surface friction between the corner key and the inside of the frame member.

7.2.11 Junction Box Installation

An operator manually applies silicone adhesive to the busbars as they exit the laminate. Black & Veatch finds this process to be consistent with accepted industry practices but notes that the operator must take care in ensuring complete encapsulation of the busbar exit area.

The junction box is attached to the back of the Module using an automatically-dispensed silicone adhesive. The junction box is not potted (filled with material). Not potting the junction box is common among PV module manufacturers. Black & Veatch notes that filling the junction box with a pottant provides additional protection of the junction box electronics. In the case of the BYD's Modules, the presence of such a pottant could impede moisture from entering the junction box and potentially corroding the electrical contact between the Module busbar and the junction box terminal. This contact is a pressure contact that is neither crimped nor soldered. Black & Veatch does not have experience with this type of connector in a PV module. The pottant also has the potential to relieve mechanical stress at that joint and offers the possibility of reducing the operating temperature of the diodes. High diode operating temperatures are known sources of diode failure. BYD has indicated that a potted junction box may be used upon customer request and that this configuration is expected to receive IEC and UL certifications in April 2012.\

Black & Veatch notes that the junction box cables are left to dangle freely when the junction box is installed. This introduces the risk that the connectors at the end of the cables could come in contact with excess adhesive that has been squeezed out of the frame. Black & Veatch observed at least one instance where the connector end had come in contact with the adhesive such that the adhesive had been removed from the frame (where it should be) and was deposited onto the connector (where it should not be). This could be addressed quite easily by taping the cables to the backsheet or by making a small loop with the cables.

7.2.12 Silicone Curing

The Modules sit for four hours after the installation of the frame and junction box to allow the silicone to cure. Temperature and humidity are both controlled in the room in which the silicone is cured. Black & Veatch observed that both of these parameters were within the specified range during its visit. BYD indicated that these values were checked and recorded by the quality assurance department on an hourly basis. BYD has indicated that a quick-cure adhesive can be used upon customer request and that this configuration is expected to receive IEC and UL certifications in April 2012.

7.2.13 Electrical Safety Test

Each Module undergoes a dry hipot test (electrical safety test) prior to flash testing. The dry hipot test station is performed in an open environment which could pose a safety hazard to the operator and others in the area.

The machine used to conduct the electrical safety test is designed to issue an alarm in the case of failure and is calibrated annually. Black & Veatch notes that there is no more frequent test of the testing machine to verify that it is working correctly other than this annual calibration. More frequent test of the testing machine could be implemented to reduce the risk of inaccurate testing results.

7.2.14 Module Cleaning

The Module front glass is then cleaned using isopropyl alcohol and steel wool. Excess silicone is removed from the front glass and frame using a box cutter or similar sharp blade.

Black & Veatch notes that the removal of excess silicone from the frame using a sharp blade could cause silicone to be cut out of the frame which could increase the likelihood of moisture ingress. BYD has indicated that it has switched to a plastic knife which is too dull to cut the silicone from under the frame. BYD has provided photographs of the new tool to demonstrate its implementation.

7.2.15 Flash Test

The flash test of the Modules occurs on a horizontal tester supplied by a respected Japanese company. The testing apparatus includes a thermometer and the software is configured to correct the measurement for the temperature of the Module.

The flash test room is temperature controlled to 25±2°C so that the Modules are tested reasonably close to 25°C as defined by Standard Test Conditions. Black & Veatch observed that the temperature in the flash test room was within the specified range during its visit.

The flash test results are used to sort the Modules into separate bins by power.

7.2.16 Module Packaging

Modules are placed vertically on their long edges in a corrugated cardboard box. Black & Veatch notes that this packaging is common among Chinese PV module manufacturers. Black & Veatch further notes that the high volume of cardboard could cause disposal issues for customers in the field. Black & Veatch encourages BYD to consider alternative packaging schemes which use less material. BYD has indicated that it is developing alternative packaging options for its customers.

7.3 Safety Issues

Black & Veatch recommended to BYD the following personnel safety improvements for their consideration. BYD has since indicated that all of these recommendations have been adopted.

- <u>Safety glasses</u> - Black & Veatch noted that not all employees wear safety glasses. The PV module assembly process presents many eye hazards. Black & Veatch recommends that all employees wear safety glasses.
- <u>Protective footwear</u> - Black & Veatch observed employees handling heavy objects, such as glass or modules, without safety shoes with toe and

metatarsal protection. This can lead to severe injuries. Black & Veatch recommends that all employees that handle heavy objects wear safety shoes with toe and metatarsal protection.

- Electrical safety test workstation – The hipot tester operates at high voltage (3000V) and can cause severe injury or death. Black & Veatch observed that the operators at this workstation were not isolated from the high voltage. Black & Veatch recommends that the workstation be redesigned to protect anyone on the work floor from a possible shock.
- Module flash test - Black & Veatch noticed that employees could observe the bright flash from the module flash tester. This can potentially damage employee eyesight. The flash tester must be enclosed so the bright flash is not visible.

8.0 Quality Organization and Processes

Black & Veatch discussed BYD's quality management organization during its visit to the Shanghai facility. Black & Veatch was also briefed on practices in place regarding personnel training, documentation control, and product serialization.

8.1 Quality Assurance (QA) Organization

BYD shared with Black & Veatch the organization chart of its QA team. The team consists of 60 quality control personnel on the manufacturing floor and 10 managers and engineers which are focused on the following activities:

- Quality assurance of incoming materials
- In-process quality control
- Quality control of outgoing products
- Customer service and project improvement
- System quality and custom auditing

The BYD quality assurance program has been certified to ISO 9001:2000 which is an international standard for quality management systems.

8.2 Quality Assurance Facilities

BYD's Quality Assurance lab is co-located with the manufacturing operations at the Shanghai facility. The lab is used to perform testing of PV modules, materials and systems.

Black & Veatch visited the lab and confirmed visually that it is equipped with several environmental test chambers and other test equipment required for the characterization of materials and the performance of PV modules and systems. The lab is equipped to perform the full complement of IEC 61215 and UL 1703 tests, such as damp heat, thermal cycling, humidity freeze, hail test, and robustness of terminations. It also has equipment for tests beyond the IEC 61215 and UL protocols, such as electroluminescence, salt mist and extended UV exposure. The lab appeared well-organized and well-managed.

The lab is also used to perform certain tests of in-process quality. As an example, a test of crosslinking (how well the EVA has cured) is performed on each laminator once per month. If these tests reveal an excursion in the manufacturing process, BYD will quarantine Modules which may have been affected and will not ship them until further investigation. Black & Veatch considers this quarantine practice to be best in class but also notes that testing each laminator only once per month might result in a very large quantity of scrap or rejected Modules. BYD can reduce this risk through more frequent testing of the laminators.

8.3 Equipment and Maintenance

Most major equipment on the production line observed by Black & Veatch was produced by reputable Western and Chinese equipment providers. The line was operational and seemed well maintained.

BYD described to Black & Veatch the preventive maintenance program that is in place. Black & Veatch reviewed the maintenance logs for several pieces of equipment. The maintenance logs were accessible on the manufacturing floor and were up to date. Black & Veatch was informed that BYD's maintenance team consists of three engineers and 17 technicians that provide around the clock coverage for manufacturing operations.

8.4 Document Control

BYD personnel described the documentation and control systems in place. The documentation is controlled by a document control department at the BYD corporate level. Documentation is stored and maintained on a centralized database. Black & Veatch reviewed several controlled documents and they seemed accurate and up to date. Black & Veatch was informed of the engineering change control process in place. The process is consistent with accepted industry practices.

8.5 Product Serialization

BYD has an enterprise management system in place that allows for the traceability of Module inputs and operations. The system currently uses a mix of paper and computerized records to track Module-specific information. The computerized records for BYD Modules include the flash test data and electro-luminescence images for each Module.

Each Module is accompanied by a run card during the manufacturing process on which certain information is recorded. The information on these run cards include which operators worked on the Modules and the identification for input materials such as backsheet and EVA. These run cards are currently stored and the run card for a specific Module can be retrieved if the Module serial number is known.

BYD informed Black & Veatch that the system will be fully digitized eliminating the need for a manual run card. BYD also stated that the existing run card information will be digitized. Black & Veatch notes that best-in-class data tracking systems are fully computerized.

9.0 Module Performance

9.1 Field Performance Data

BYD provided performance data for a 1 MWdc system in Italy based on its Modules. The data consisted of actual daily power generated and expected daily power generated for August, September October, November, and part of December in 2011.

Neither the energy production model nor the weather conditions at the site were made available to Black & Veatch. For this reason, Black & Veatch was not able to audit the expected daily power generated and could not verify that the expectations were reasonable for the system or that they were properly adjusted for the irradiance, temperature and wind conditions at the site.

Although the expected generation could not be verified, Black & Veatch does note that the system appeared to perform well, with the actual energy production exceeding the expected energy production in four of the five months.

9.2 Record for Increasing Module Efficiency

BYD provided Black & Veatch the chart in Figure 9-1 which illustrates the increase in BYD's module efficiency from 2008 through 2011.

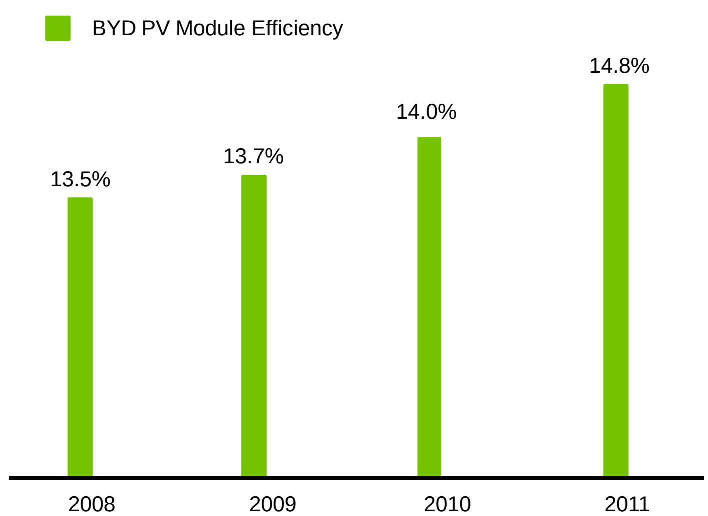

Figure 9-1: Performance Increase in BYD PV Modules

BYD explained that the sources of module efficiency improvements in 2011 include:

- Narrower busbars on the solar cell to increase the active area of the cell.
- Combination of screen printing and electroplating on the cell front contact pattern to reduce the series resistance of the cell.
- Selective emitter design to increase the short wavelength response of the cell.

Black & Veatch was informed that all BYD cells currently incorporate narrow fingers and selective emitter, while the combination of screen printing and electroplating is provided as an option to clients.

9.3 Definitions of Performance

Performance of a PV module is defined by how well that module converts sunlight into electricity in various irradiance and temperature conditions. Due to the many operating conditions PV modules operate in, a comprehensive single metric of module performance has yet to be agreed upon, and therefore multiple relevant metrics exist.

9.3.1 STC Rating

The performance of a module is quantified by the module rating which is provided by manufacturer and measured at standard test conditions (STC) in accordance with IEC 61215 and IEC 61646. Standard conditions are laboratory conditions which are rarely seen in the field: 1000 W/m^2 and 25 degree Celsius cell temperature. The STC rating of a module represents how efficiently the module will convert sunlight into electricity under high irradiance low temperature conditions. These test conditions are the “standard” because they are easy to emulate in laboratory settings.

9.3.2 Temperature Coefficient of Power

PV modules are less efficient at converting sunlight into energy at high temperatures and more efficient at low temperatures. This is often a linear or near linear relationship which can be defined by a single parameter referred to as temperature coefficient of power. This value is typically provided in units of (%/°C) to show the reductions of conversion efficiency as temperature increases.

9.3.3 Low Light Performance

The conversion efficiency of a PV module is also varies with light level. This is largely a function of the shunt and series resistances within the cell; however other factors play a role. Quantifying low light performance is often difficult and few standards exist.

9.3.4 Performance Ratio

Performance ratio is a metric of performance which often captures the performance of the entire system, including modules, inverter, wiring, shading and soiling. Performance ratio also captures the effects of temperature and low light on the module. The performance ratio of a plant is defined as:

$$pr_{plant} = \frac{\left(\sum_i kWh_i\right)}{\sum_i \left(kWp * \frac{POA_i}{GSTC}\right)}$$

Where:

pr_{plant}	=	performance ratio of the plant in (%).
kWh_i	=	ac plant production in kWh for the ith hour.
kW_p	=	STC dc capacity of the plant.
POA_i	=	measured plane of array irradiance for the ith hour in W/m^2.
GSTC	=	irradiance at STC conditions or 1,000 W/m^2.

9.4 Rated Module Performance

BYD has quantified the performance of its Modules under STC conditions in accordance with IEC standards to develop the Module ratings as represented in its product datasheets. BYD supports this performance with the performance warranty described in Section 5.2 of the Report.

9.5 Temperature Effects

The listed temperature coefficient of power for BYD's polycrystalline and monocrystalline modules is -0.47 (%/°C) which means that for every degree Celsius increase in cell temperature above 25 °C, the module will output 0.47 percent less power. BYD indicated that this value was determined by an independent testing laboratory.

Appendix A. NREL Benchmark for Degradation

Black & Veatch has reviewed publicly available literature on the topic of performance degradation of crystalline PV modules. During the review, Black & Veatch established a range of representative degradation values for monocrystalline and multicrystalline PV modules. The value derived by Black & Veatch appears in Table B-1.

Table B-1. B&V Crystalline Module Degradation Rate	
Technology	**(%/year)**
mc-Si	0.4 to 0.8
pc-Si	0.4 to 0.7
Notes: Degradation should be applied year over year. For example, the Year 2 degradation rate should be applied to the end of Year 1 degraded capacity.	

The primary sources of information in the review were two papers published in November/December 2010 by Dirk Jordan et. al. of NREL. These papers study the data measured by NREL on multiple modules over many years. The papers also review the module degradation results reported by a variety of authors worldwide. The NREL papers are academic studies, which are specific to a given module technology. The results are not traceable to any particular module manufacturer. The degradation results reported in the literature reviewed vary significantly within a study and from one study to another. It should be noted that Black & Veatch's values are subject to review as more information on module performance becomes available. Black & Veatch encourages manufacturers to provide specific degradation rates data relevant to their product.

The primary limitations of this task were threefold. First, there is not an industry standard for quantifying the degradation loss for a given module. Secondly, module technologies, while sharing similarities, vary considerably by manufacturer and product design. Thirdly, each technology will likely react and respond differently to location climate[1], based on factors like temperature fluctuations, UV radiation, and humidity. Despite these limitations, we believe that the available data can provide helpful guidelines, and a workable estimate of degradation loss per year.

Recent results in the area of PV module degradation estimates were reported by Dirk Jordan of NREL in the Survey of PV Field Experience presented at the DOE Utility/Lab Workshop on PV Technology and Systems held on November 8-9, 2010 in Tempe, AZ and the related article "Module Reliability Trends" co-authored by Sarah Kurtz and Dirk Jordan and published in the December 2010/January 2011 issue of *SolarPro*. Based on a literature review of 780 field- tested PV modules comprising crystalline and thin film technologies, the authors report that the most commonly reported degradation rate is 0.5 percent per year, while the average rate is 0.7 percent per year. [2] Thus, the distribution of degradation

[1] King DL et al. Photovoltaic Module Performance and Durability Following Long-Term Field Exposure. Sandia National Laboratories, April 2000.
[2] Jordan D, Kurtz S. Module Reliability Trends. SolarPro, December 2010, pp 24-28.

rates is clearly skewed to the higher values, with a highest statistically significant reported value of 4.0 percent per year. These degradation rates are usually modeled as the slope of the least-squares linear fit of a power vs. time plot.[3]

Because of the difficulties of amalgamating the results of various studies performed on modules in the field—due to factors like differing testing conditions, manufacturers, dates of installation and geographical location—NREL conducts controlled and monitored studies at the Performance and Energy Rating Testbed (PERT). Their goal is to scientifically study module performance degradation over time. A critical feature of the analysis of the PERT results is that degradation rates have only been calculated for modules that have been monitored for over two years. This factor provides considerable legitimacy to their test results.

Table B-2 summarizes the NREL findings from their study of 44 individual modules from over 10 manufacturers on PERT. As shown, the values are reported by module technology and between installation years, pre-2000 and post-2000. The box and whisker plots demonstrate the statistically significant range of the data.

Table B-2. PERT Median Degradation Rates

NREL Median Degradation Rates (%/year)	Pre-2000	Post-2000
a-Si	0.89	1.35
CdTe	0.89	0.28
CIGS	2.41	0.97
mc-Si	0.52	Unavailable
pc-Si	2.54	0.52

Source: Jordan D, Kurtz S. Module Reliability Trends. SolarPro, December 2010, pp 24-28.

[3] Osterwald, C. Comparison of Degradation Rates of Individual Modules Held at Maximum Power, NREL, 2006.

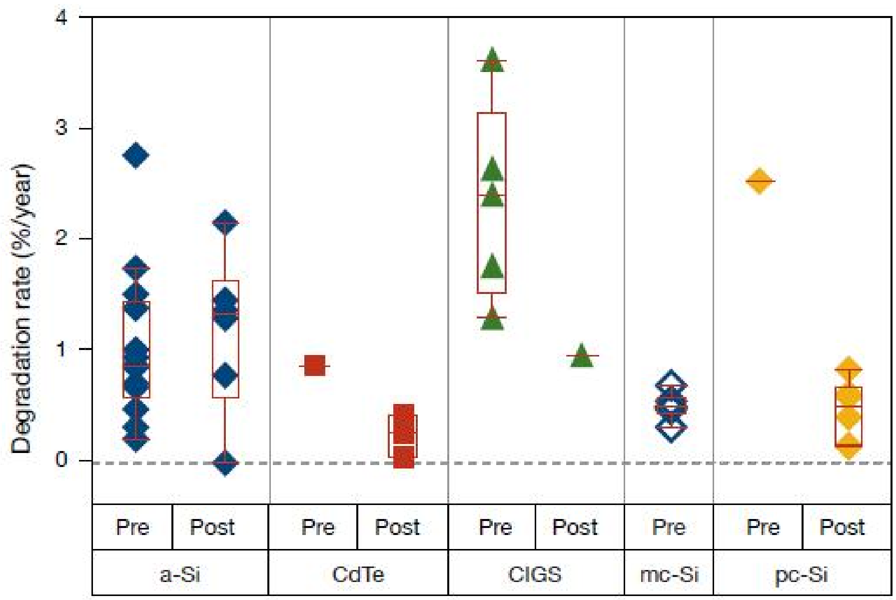

Figure B-1. PERT Data Across Technology and Pre-2000/Post 2000 Year of Manufacture

The lower section of the box encompasses the middle 25 to 50 percent of the data range, while the upper section of the box includes the middle 50 to 75 percent of the range. The data from the box to the whiskers represents the lower 25 percent and upper 25 percent of the range. Any data points beyond the whisker are considered to be outliers.

NREL also compiled degradation data from the PV field test literature. This dataset is larger than the PERT data and the resulting degradation rate ranges are larger. Table B-3 shows the median values for each technology.

Table B-3. Field Literature Test Median Degradation Rates

Field Literature Median Degradation Rates (%/year)	Pre-2000	Post-2000
a-Si	1.4	1.31
CdTe	1.1	0.32
CIGS	2.53	0.77
mc-Si	0.41	0.9
pc-Si	0.43	0.79

Source: Jordan D, Kurtz S. Module Reliability Trends. SolarPro, December 2010, pp 24-28.

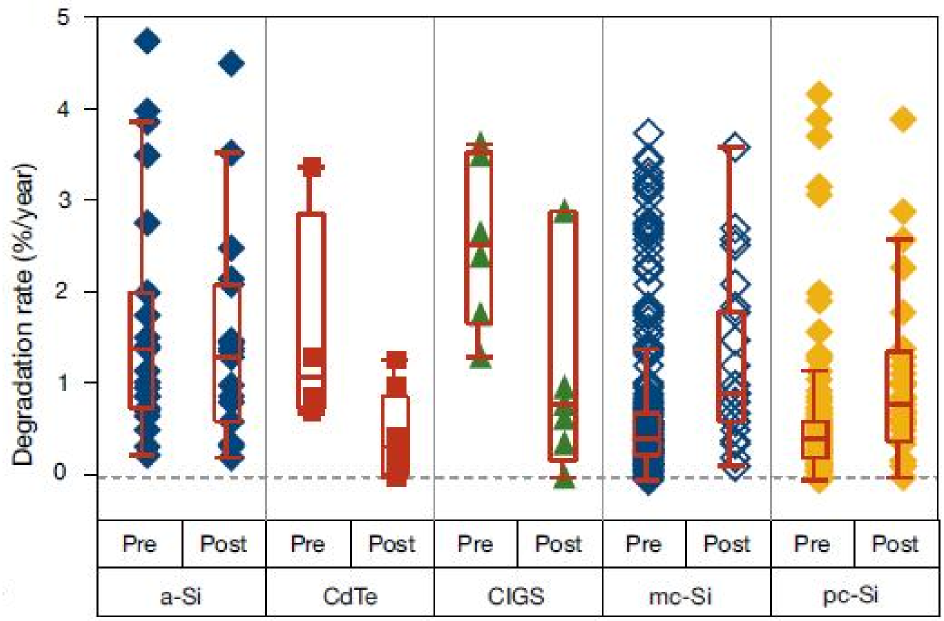

Figure B-2. Field Test Literature Data across Technology and Pre-2000/Post 2000 Year of Manufacture

Based on this data, we do observe an interesting trend among the silicon technologies in field literature degradation rates. The mono-crystalline and poly-crystalline both exhibit an upward trend in their median value from pre-2000 to post-2000.

The findings of the recent NREL study are helpful because they assess degradation across technology types and review multiple data sources. Given the limited amount of published module field performance data available for review, it is difficult to establish a reliable degradation rate for a given module type operating in a given climate. At this point in time the recent study by Dirk Jordan and Sarah Kurtz provides arguably the most trustworthy degradation rate for pc-Si publicly available.

The number of samples in the pre and post 2000 categories for NREL PERT and for data reported in the literature appears in Table B-4.

Table B-4. Number of Samples in PERT and Field Literature Data

Module Type	PERT Pre-2000	PERT Post 2000	Literature Pre-2000	Literature Post-2000
pc-Si	1	>5	>20	>20

Black & Veatch's rationale for degradation values by technology is as follows: the PERT modules were monitored and measured rigorously. The same level of assertion cannot be made for the data taken from the literature. Thus, for pc-Si post 2000 data a 75 percent - 25 percent weighted average was performed in favor of PERT data. For pc-Si pre-2000 data comprised of one PERT data point, the weighted average was reversed in favor of the field literature because of the absence of sufficient PERT data. Manufacturing technologies have changed over time for mc-Si and pc-Si, and many contemporary modules are made by different companies than before 2000 and likely use alternate materials assembled with changing criteria. Thus, a 75 -25 percent weighted average was performed in favor of the post 2000 data to reflect more contemporary degradation rates.

Dirk Jordan has published additional data on the degradation rates by climate type, including continental, desert, hot & humid, polar, steppe and temperate. Although there appears to be some connection between climate and climate type, the current data is inconclusive. Black & Veatch does not give guidance on degradation by climate currently.