



Prospectus

Solar Photovoltaics: Opportunities for Manufacture and Use

 **Nexant**

Prospectus

*Solar Photovoltaics:
Opportunities for
Manufacture and Use*

October 2010



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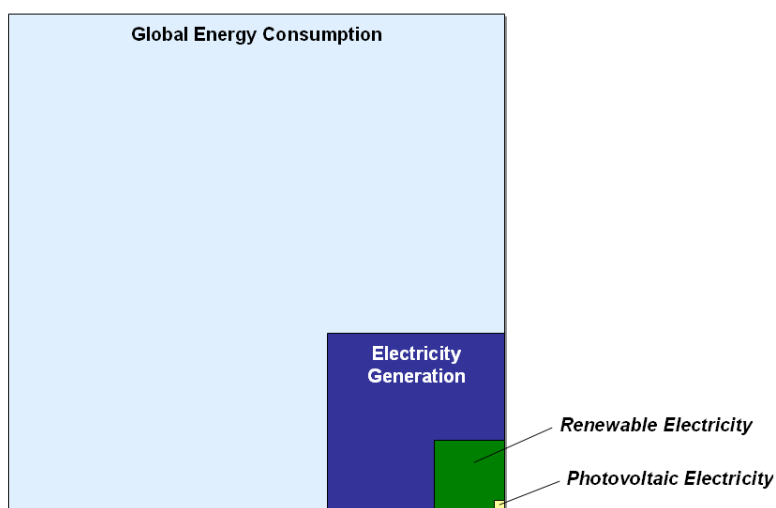
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1.1 INTRODUCTION

Solar photovoltaic (SPV) is an emerging renewable energy technology with high growth potential. Global investments in SPV are now in the billions of dollars annually. Growth rates of capacity installed in various regions are as high as 40 percent annually. Over \$2.5 billion was reported to have been invested by venture capitalists in thin-film solar alone over the last few years. Additionally, Dr. Steven Chu, the United States Secretary of Energy said in a March 2009 interview with National Geographic that, “we’re in a war to save our planet,” and renewable energies that reduce carbon footprint such as SPV are the solution to a sustainable future and to energy independence. To further these goals, the United States Department of Energy has announced a commitment to spend up to \$200 million dollars over the next five years to spur developments in SPV manufacturing and in SPV supply chain projects. These investments will help create new supply chain solutions and will help SPV achieve cost-competitiveness with conventional forms of energy.

Although there has been and will continue to be significant investments, SPV accounts for only a small fraction of the current energy market. However, SPV projects have reached the threshold scale of hundreds of megawatts each, which is indicative that SPV has the potential to expand and grow into a significant fraction of power for large facilities and electric grids around the world.

Figure 1.1 Share of Global Energy Market, 2010



With improving competitive position for SPV technologies, it is increasingly important for industry players to examine and evaluate various SPV technologies, supply-side and end-use economics, existing and potential market sectors and geographies, opportunities, motivations, challenges, hurdles to overcome, future growth projections, and implications for industrial development. Nexant’s report, *Solar Photovoltaics: Opportunities for Manufacture and Use*,

provides a unique and valuable perspective on these various aspects of the SPV industry and more.

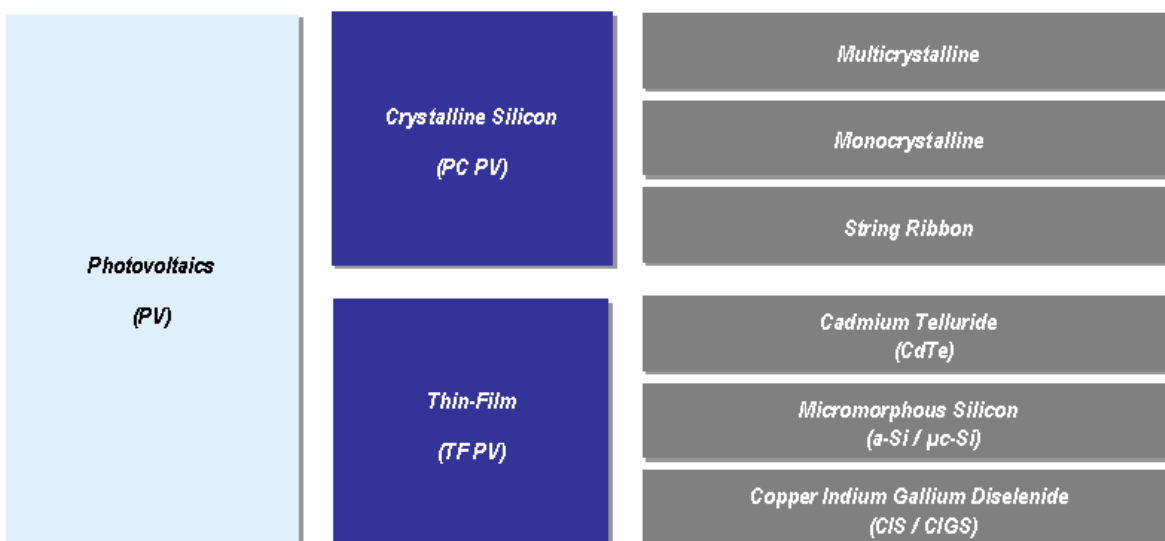
1.2 COMPREHENSIVE STUDY

Nexant's report, *Solar Photovoltaics: Opportunities for Manufacture and Use*, will provide a comprehensive view of the SPV industry and will examine the industry in terms of various technologies, market sectors, and driving market economics, in addition to overarching trends and projected future developments in the industry. The report will also address important implications for industrial development and job creation and for electric power supply, on and off the grid. Moreover, the study will examine case studies of applications of SPV to demonstrate its competitiveness under a number of common commercial situations.

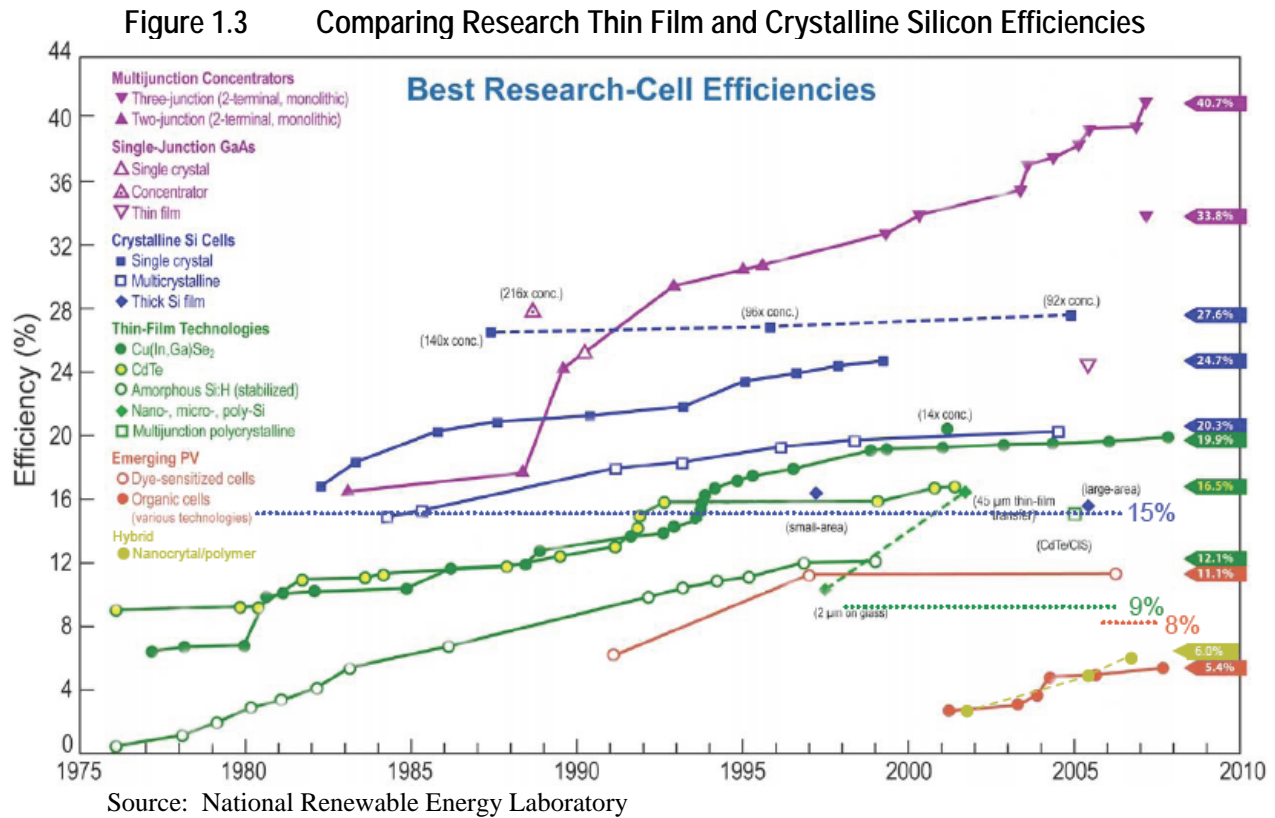
1.2.1 Technology

SPV technologies are of two main types: crystalline silicon (c-Si) wafer and thin film. Within these two categories, various technologies have been developed to use differing substrates. This report will explore and analyze various aspects of these technologies.

Figure 1.2 SPV Technologies

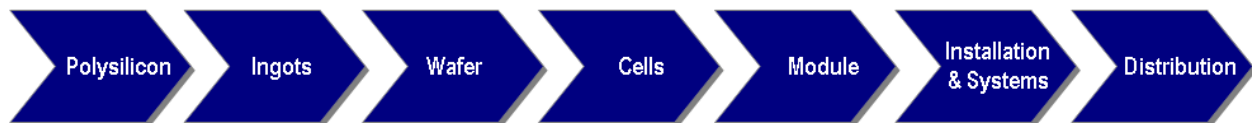


Crystalline silicon (c-Si) wafer technologies are far more mature, have the majority of current market share, and are more efficient. Thin film technologies have a significantly lower cost structure and have achieved higher growth rates in recent years. Thus, investors must consider trade-offs between higher cost (c-Si) and lower efficiencies and shorter shelf-life (thin film). Relative efficiencies of various thin film and c-Si technologies are significant and in general been improving over time. Nexant's report will analyze, in depth, the dynamics between these two leading technologies, as well as their strengths and weaknesses.



In addition to offering different technologies, players in the SPV industry have varying levels of integration and product technology focus within the SPV value chain. Nexant’s report *Solar Photovoltaics: Opportunities for Manufacture and Use* will examine each of these segments and will show the involvement of major players in the various aspects of the SPV value chain.

Figure 1.4 Solar SPV Value Chain



1.2.2 Economics

Silicon accounts for approximately half of raw material costs for c-Si wafers, and therefore is a key determinant of economics for SPV technologies. Driven mainly by the semiconductor industry, silicon costs are highly volatile and have oscillated between factors of up to ten from highest to lowest cost within the last few years. Therefore, addressing and managing silicon cost is crucial to the advancement of the solar SPV industry.

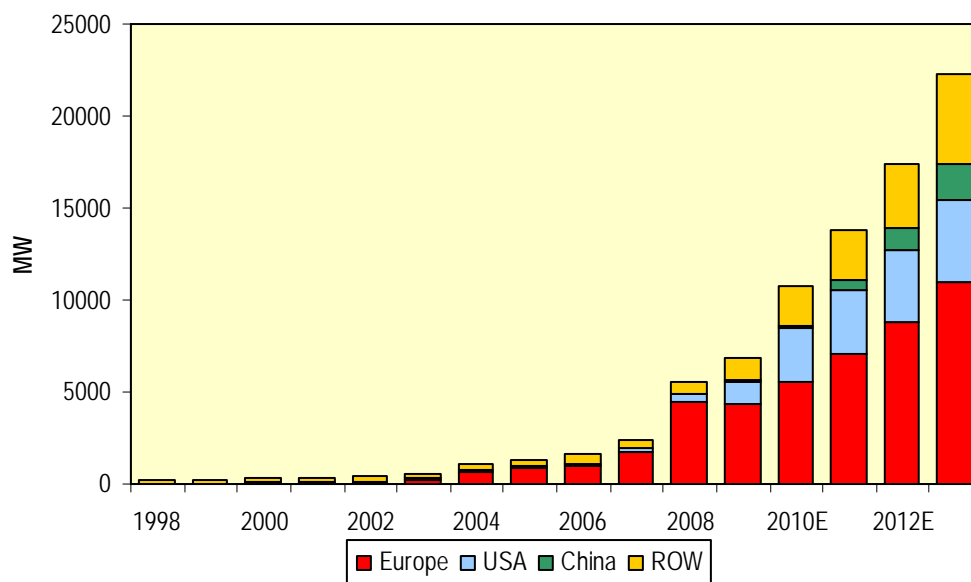
Different SPV technologies produce different unit levels of energy. Therefore, the average selling price (ASP) of the module is not a meaningful comparison between different SPV technologies. To effectively compare the cost of an SPV system, the Levelized Cost of Electricity (LCOE) is used instead of the ASP. The LCOE is the net cost of electricity generated by the SPV system throughout the life cycle of the system, defined as the total life cycle cost divided by the total lifetime energy production.

Nexant's study will evaluate the economics of SPV modules from both ends of the value chain: the raw material costs (silicon and other raw materials) and the final end-use value (LCOE) of the system.

1.2.3 Markets

Currently Europe, mainly Spain and Germany, accounts for the vast majority of the SPV market. At the national level, the United States is the third largest market in the world, with high forecast growth rates. Although China and other emerging countries currently have a very low presence in SPV, it is expected that these emerging regions will have the highest growth rates and are expected to achieve significant market share over the next decade. Nexant's study will focus on the United States, Europe, and China, but it will also analyze demand opportunities in other regions such as Northern Africa, the Middle East, Southern Europe, and Australia.

Figure 1.5 Global Annual SPV Market Outlook



Source: EPIA

Nexant will also consider key factors and infrastructure conditions that will impact successful development of SPV. For example, the state of industrial infrastructure and the electrical grid in the United States and other key nations and its ability to accommodate SPV will be examined.

The United States transmission system is in need of fundamental improvements to increase efficiency and provide a sustainable platform for growth. Nexant will assess how SVP's characteristics, which include daytime-only availability, DC electricity generation, geography-specific advantages, modularity, and passive nature, can be balanced with the availability of appropriate electricity storage and power management technologies so that it can be effectively integrated within the grid or operated off-grid.

1.3 MOTIVATIONS FOR PERFORMING THIS STUDY

Nexant's report, *Solar Photovoltaics: Opportunities for Manufacture and Use*, will be a comprehensive study covering all the main aspects of SPV. This report will not only be beneficial for those directly involved in the solar industry but will also be useful for industry players in the utility, oil and gas, petrochemical, chemical, polymers, bio-renewables and government sectors. Listed below are a few factors that we believe will make this report of interest to this broad range of industries:

- **Significant growth opportunities within the solar SPV industry** - Due to substantial R&D and manufacturing investments in a relatively small industry, solar SPV has experienced very high growth rates over the last few years, and this trend is expected to continue. United States Department of Energy (DOE) Secretary Steven Chu announced in April, 2010, that over the next five years, the DOE will spend over \$200 million to invest in the expansion and acceleration of R&D, commercialization and use of solar and water technologies.
- **Opportunities for all energy industry players** - As the United States and other nations move forward with increasingly greater shares of solar energy and other renewables on their national grids, and renewables start supplying individual facilities around the world, both opportunities and potential threats need to be assessed and managed by players across all energy sectors, regardless of whether or not they will participate actively in SPV businesses. The growth factors in the solar SPV sector are tremendous, and solar technology is more chemically intensive than most other renewables. The oil and gas, chemicals, and ag-biotech sectors, as well as logistics systems, operate many remote, off-grid facilities around the world that need to consider the potential practical role of SPV in supplying power needs and mitigating power costs. The case studies of this report will assist in understanding some of the value propositions of SPV.
- **Carbon footprint** - As global climate change concerns become increasingly pressing, companies have a growing need to reduce their carbon footprint by using more renewable energy, along with conservation measures. SPV is a renewable energy source with a very small relative carbon footprint.
- **Control of Greenhouse Gas (GHG) Emission Levels** - Although a global GHG consensus has not yet been achieved, local programs at the state and regional level are pushing forward and spearheading initiatives to manage and decrease GHG emissions. In the United States, an electricity-specific cap-and-trade program in ten northeastern states called the Regional Greenhouse Gas Initiative (RGGI – pronounced “reggie”) generated a half-billion dollar auction in energy-saving projects in 2008-2009. In addition, programs

such as the Western Climate Initiative, the Global Warming Solutions Act in California, the Midwestern Greenhouse Gas Reduction Accord, and others are expected to soon cover over 50 percent of the U.S. population and over half of U.S. greenhouse gas (GHG) emissions. SPV is a renewable energy source with a very small relative GHG footprint, and is an attractive option to meet the objectives of these programs.

- **Materials, energy, and systems supply opportunities** – As SPV gains critical mass, opportunities will grow for materials supply and/or manufacturing for technologically-based manufacturing companies and raw material suppliers. This may be in conventional silicon materials, or in advanced thin film systems.

1.4 TECHNICAL AND PRACTICAL CHALLENGES FACING THE SPV INDUSTRY

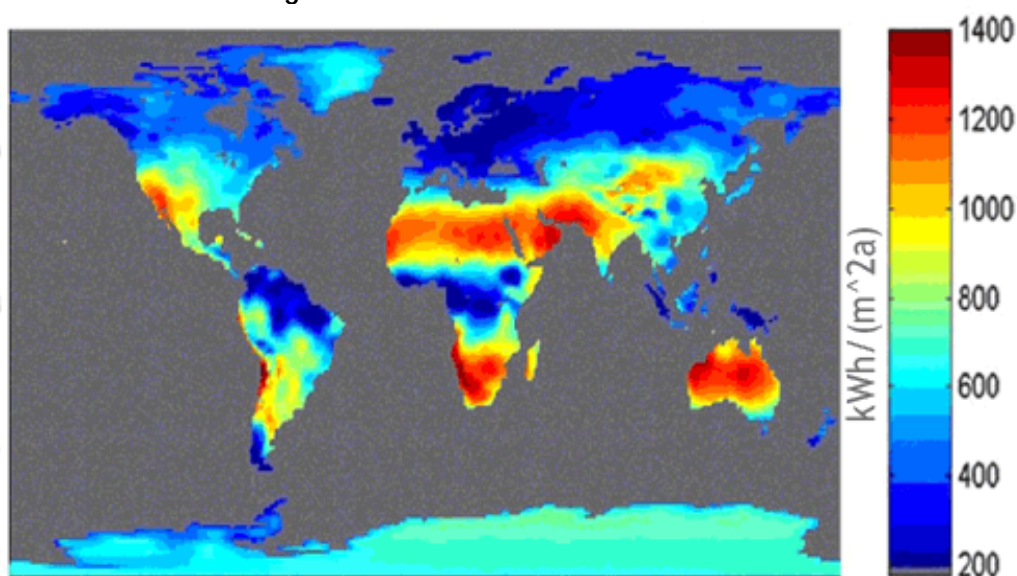
SPV technology has made great strides and continues to improve. Prices to end users are on a steady decline, and production capacity is regularly increasing. However, there are several challenges facing SPV which will be analyzed in depth in this report, including:

- **Polysilicon Costs** – One of the main hurdles to SPV growth is the cost of polysilicon which accounts for approximately half of total production costs of an SPV module. Polysilicon has been highly volatile in the last few years, with prices varying by up to a factor of ten. Additionally, only the very top surface of the silicon wafer generates the current, while the rest of this expensive material in the wafer is wasted by only functioning structurally. Although manufacturers are developing increasingly thinner silicon wafers, advancement is slow, and available current technology places limitations on how thin the wafers can be manufactured. Solutions to minimize the use of silicon will reduce production costs and improve overall efficiency.
- **Grid Parity** - Although the SPV industry has been steadily decreasing costs while concurrently increasing efficiency and production volume, power from SPV is still above grid parity, which means solar energy is still dependent upon governmental support such as subsidies and incentives to be competitive with conventional electricity supply. As producers aim for and achieve prices closer to grid parity, SPV will become increasingly competitive with other electricity sources.
- **Partial Shading** - Obstructions either on the solar panel or between the solar panel and sunlight create the effect of partial shading, which impairs the performance and efficiency of SPV panels. Advancements are being made to minimize partial shading and increase efficiency.
- **PV Efficiency** - Although efficiencies of the conventional and still dominant polysilicon-based technology have increased, SPV efficiencies are still relatively low compared to the potential for utilization of the sun's energy. Additionally, polysilicon material production is energy-intensive, and there are physical limits to materials utilization efficiency inherent in the wafer fabrication process.
- **DC Generation** - Solar SPV generates DC electricity, which can be stored and recovered as DC using batteries, capacitors, etc. Some other storage technologies, and integration with the grid, involve conversion to AC power. In addition, some uses require different

voltages than can be generated by SPV. AC/DC conversion systems and voltage transformers add costs. Solutions need to be developed to maximize electricity generation and control costs.

- **Insolation Implications** – “Insolation” is the incident sunlight over time at any location and is influenced by a number of different factors including: the diurnal (day-night) cycle, seasonal daylight cycles, cloud cover, dust, snow, leaf fall and other solids accumulations at various times and places. The vast majority of current solar capacity is located in Europe, which has relatively low insolation levels. Figure 1.6 shows that there are great possibilities to develop solar energy in many parts of the world where there is a high potential to harness solar energy based on good insolation. Most of these regions do not have much SPV presence, and there is a significant opportunity to expand into these regional markets. Also, solutions are being developed to enhance insolation mechanically, such as with mirror arrays, sun-tracking systems, and surface coatings that help collect light arriving at different incident angles.

Figure 1.6 Global Solar Insolation



Source: Solenco, Australia

- **Dispatchability** - The limited dispatching capability of SPV (ability to supply electricity to a local user or the grid when demanded) is related to insolation patterns. The solution and challenge, as with most other renewable electricity sources, is to develop appropriate storage systems and integration with a multi-faceted grid system.

1.5 NEXANT IS HIGHLY QUALIFIED

Nexant is a leading, multi-faceted, global energy consultancy, expert in the “well to wire” value chain, with in-depth expertise in SPV gained from a range of technical and commercial engagements. Specifically, over the last five years Nexant has participated in government and private development of solar renewable systems on several fronts and has performed a number of private industry feasibility and technology screening studies for solar photovoltaics. Supporting this experience is Nexant’s 45 plus years of experience in evaluating emerging technologies of many types, and in assisting the major players in the global energy sector to understand the techno-economics and market dynamics of diverse new technologies.

1.6 STUDY COST

The cost of the study is US\$14,000 (fourteen thousand U.S. dollars). A discount will be offered to companies who subscribe before the report is published.

Information concerning the focus of the report is presented in Section 2 (Scope) and Section 4 (Proposed Table of Contents).

The objective of this study is to profile and assess the technical and business status of the development, manufacture, and use of solar photovoltaics (SPV), including newer thin film options. The study will also assess the economic viability of implementing the technology in case studies relevant to the subscriber base, which includes the utility, petroleum, chemicals, and materials sectors. Nexant will consider the following topics:

Overview of SPV Systems and Issues

Key systems and issues that will be addressed include:

- Polysilicon supply chain materials, technologies, manufacturing economics, and market dynamics
- Silicon wafer technology, polysilicon, amorphous silicon
- Power modules - cells, controls, installed SPV systems
- Thin film technologies – definition and profiles of the types, motivation, cost, weight, substrates, flexibility, deployment, progress, prospects
- Concentrating Photovoltaics (CPV) for utility and commercial/industrial-scale use
- Grid Integration – Smart Grid, storage, back-up, geography (insolation)
- Monetization of renewable power – power cost savings, government incentives, subsidies, carbon cap and trade, other local programs
- Implications for the Chemical and Oil and Gas Industries
- Emergence of China as a dominant player
- Advanced Technology Issues - increasing photon absorption, reducing module costs

Technology Evaluation

Nexant will perform a review and status assessment of the various SPV technologies. The status of commercial development will be profiled, including the types of projects operating and being planned. Selected key developers and their unique approaches will be analyzed. Technical issues will be identified, and estimates will be made of the impact of potential improvements.

Economic Evaluation

Nexant will examine the economics of SPV modules from both ends of the value chain: the raw material and final end-use costs of the completed system. Cost of production estimates for silicon metal and polysilicon, which is the key driver of raw material costs, will be developed for the various technologies. Leading SPV technologies and enabling electric power storage technologies will also be evaluated and compared. Sensitivities to key cost factors will be modeled. A high level estimate of the costs of various SPV systems as defined by the LCOE will be analyzed.

Commercial Evaluation

Nexant will perform an analysis of how SPV could be used by relevant industrial facilities under various site-specific conditions. Capital costs, grid power costs, and carbon monetization scenarios will be discussed. This evaluation will consider projected progress in CPV and thin film SPV technology development and cost reductions. The technologies to be evaluated will represent the key global offerings from the United States, China, and elsewhere.

Industry Structure

Key players in the field will be identified and profiled. As relevant, technology position, intellectual property, and other commercial factors will be discussed.

Market Assessment

The renewable energy market, SPV's position in it, and factors impacting it will be identified and characterized. These include policy drivers and their mechanisms, cost points of technology adoption, and costs of ancillary and enabling systems such as storage. Forecast growth of the overall solar market, as well as Nexant's views of potential penetration of SPV under several scenarios, will be presented.

Case Studies

Nexant will present relevant generic case studies for implementation of SPV systems, including the following:

- Fuel Terminal
- Plastics Fabricator
- Chemical Plant
- Office Complex

The deliverable for the study will be a full text report of findings. The Proposed Table of Contents is shown in Section 4.

The evaluation of SPV technologies, economics, and markets will be grounded on Nexant's in-house knowledge and information, augmented by contacts with government and academic researchers, SPV developers and manufacturers, investors, engineering contractors, government regulators, trade associations, and other experts and stakeholders in the area. Analyses of these technologies will be built up from internal and field-derived information, reviews of patents, other public domain information, and discussions with the entities involved in developing and implementing SPV.

Nexant will utilize non-proprietary aspects of data and analyses from assignments that Nexant has performed for a number of clients in the SPV sector.

Additionally, Nexant will use proprietary and commercial state-of-the-art software tools to develop its estimates of technology and economic performance. These are well-established engineering tools in the process industries. Commercial information and forecasts will be developed from Nexant's extensive in-house databases, augmented with selected fieldwork.

Market projections will be developed with the aid of Nexant's supply/demand computer modeling systems.

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- 2. Introduction**
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 - 2.2 STUDY OBJECTIVES AND ORGANIZATION – SOLAR SPV VERSUS SOLAR THERMAL HEATING AND POWER
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 - 2.4 HISTORY OF DEVELOPMENT OF SOLAR SPV – SPACE PROGRAM, COST REDUCTIONS, ETC.
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 - 2.6 MARKET ISSUES – SILICON SUPPLY/PRICE
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 - 2.10 GRID INTEGRATION – SMART GRID, STORAGE, BACK-UP, GEOGRAPHY (INSOLATION)
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 - 3.2.3 Copper Indium Gallium Diselenide (CIS/CIGS)
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 - 5.1.3 Infrastructural (off-grid, remote)
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- 7. Facility Case Studies**
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 - 7.2 CHEMICAL PLANT
 - 7.3 OFFICE COMPLEX
 - 7.4 FUEL TERMINAL

Please visit www.chemsystems.com to authorize engagement of the study or return the following authorization form to one of the Nexant offices listed below.

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1. The undersigned (hereafter "Client") hereby subscribes to purchase from Nexant, Inc. ("Nexant"), Nexant's study, ***Solar Photovoltaics: Opportunities for Manufacture and Use***. Nexant will provide to Client access to electronic downloads of the report via a password-protected area from www.chemsystems.com
2. While the information supplied by Nexant to Client will represent an original effort by Nexant, based on its own research, it is understood that portions of the report will involve the collection of information available from third parties, both published and unpublished. Nexant does not believe that such information will contain any confidential technical information of third parties but cannot provide any assurance that any third party may, from time to time, claim a confidential obligation to such information.
3. The information disclosed in this report will be retained by Client for the sole and confidential use of Client and its 51 percent or greater owned affiliates in their own research and commercial activities, including loaning the reports on a confidential basis to third parties for temporary and specific use for the sole benefit of Client.
4. Client further agrees that it will use reasonable efforts to keep the information in the reports for its sole use; however, this restriction shall not apply to information which is or becomes generally available to the public in a printed publication, which is already in the possession of Client, or which is received by Client in good faith from a third party without an obligation of confidentiality.
5. Client shall not republish any of the report except within its own organization or that of its 51 percent or greater owned affiliates. Client further agrees to refrain from any general publication of the report, either directly or through its affiliates, so as to constitute passage of title into the public domain or otherwise jeopardize common law or statutory copyright in said report.
6. The study is scheduled to be completed by the end of 2010. Until October 31, 2010, upon authorization, Client will be billed by and shall pay to Nexant a total of US\$11,000 (eleven thousand U.S. dollars). After October 31, 2010, but prior to publication, the price will be US\$12,000 (twelve thousand U.S. dollars). The price after publication will be US\$14,000 (fourteen thousand U.S. dollars). Amounts are due upon receipt of invoice and payable within thirty (30) days. Late payments shall accrue interest at the rate of 1.5 percent per month. Fees quoted do not include any applicable sales tax, or use or value added tax, all of which are for the account of Client.
7. The report will be provided in electronic format (Adobe Acrobat .pdf file) to all subscribers, and this version of the report will be the deliverable for the subscription. Printed copies of the report also are available to subscribers at an additional US\$500 each.
8. The obligations of paragraphs 3 and 4 shall terminate five (5) years from receipt of reports.
9. Unless specified otherwise, there are no warranties of any kind for reports and consulting services provided under this Agreement. Nexant's total liability under this Agreement is limited to the total amount paid to Nexant for the reports.
10. This Agreement will be governed by the laws of the State of New York.

AUTHORIZATION FORM

AGREED TO AND ACCEPTED BY:

AGREED TO AND ACCEPTED BY:

CLIENT: _____

NEXANT, INC.

Name: _____

Name: _____

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Signature: _____

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Title: _____

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Web: www.nexant.com

7.1 GENERAL

Nexant uses multidisciplinary project teams drawn from the ranks of our international staff of engineers, chemists, economists and financial professionals, and from other Nexant groups to respond to the requirements of each assignment. Most of the consulting staff possess credentials in both scientific and commercial disciplines plus substantial industrial experience. The collective talents of our staff are strategically located and closely linked throughout the world, resulting in valuable insights gained through a variety of perspectives.

Nexant is an international consultancy and is dedicated to assisting businesses within the global energy, chemical, plastics, and process industries by providing incisive, objective, results-oriented management consulting. Over four decades of significant activity translates into an effective base of knowledge and resources for addressing the complex dynamics of specialized marketplaces. By assisting companies in developing and reviewing their business strategies, in planning and implementing new projects and products, diversification and divestiture endeavors and other management initiatives, Nexant helps clients increase the value of their businesses. Additionally, we advise financial firms, vendors, utilities, government agencies and others interested in issues and trends affecting industry segments and individual companies. Whether identifying opportunities, managing change or confronting competitive challenges, we adhere to the highest ethical and professional standards.

Nexant, Inc. maintains fully integrated operations in White Plains, New York; London, England; San Francisco, California; Bangkok, Thailand; and Washington, D.C., Boulder, CO and Phoenix, AZ, Tokyo, Beijing, Shanghai, Seoul, and Houston. We also work with representatives located throughout the world.

From major multinationals to locally based firms and governmental entities, our clients look to us for expert judgment in solving compelling business and technical problems and in making critical decisions.

Nexant's clients include most of the world's leading oil and chemical companies, financial institutions, and many national and regional governments. Nexant, Inc. is active in most of the industrialized countries of the world, as well as in most of the developing areas including the Middle East, Africa, and East and Southeast Asia.

Major annual programs are:

- Process Evaluation/Research Planning[®] (PERP)
- *ChemSystems* Online[®]/Petroleum and Petrochemical Economics (CSOL/PPE) – United States, Western Europe, and Asia

The PERP program covers technology, commercial trends, and economics applicable to the chemical industry. The program has more than 40 subscribers, including most of the major international chemical companies. Many of the processes to be analyzed in this multiclient have been assessed in the PERP program.

CSOL/PPE covers the market and manufacturing economics for major petrochemicals.

Over the past eight years, the program has been completely overhauled and upgraded. The models and databases that run the analysis have been replaced with a start-of-the-art industry simulation program that has taken the 40 years of industry knowledge and experience of our consultants and enhanced it to a proven new level of forecasting expertise.

The simulation model is used to generate the PPE reports and also an internet serviced brand *ChemSystems Online*[®] that provides global data, analysis, and forecasts of:

- Plant capacity
- Production
- Consumption
- Supply/demand and trade
- Profitability analysis
- Forecast
- Price forecast
- Techno-economic analysis

A subscription to *ChemSystems Online*[®] includes both written reports (the PPE program) on the petroleum and petrochemical industry and internet access to all data analysis and forecasts. Your subscription may be tailored to meet your specific company requirements and the fees reflect the value brought to your business. Insightful analysis and a reliable forecasting methodology provide the means to significantly improve your business performance through better investment decisions and improved competitive position.

7.2 SPECIFIC SINGLE-CLIENT EXPERIENCE RELEVANT TO SOLAR RENEWABLES

Nexant is exceptionally qualified to perform this comprehensive analysis based on our multidisciplinary business approach and has been carrying out studies of this type throughout our more than 45-year history.

RELEVANT CHEMSYSTEMS PERP PROGRAM MULTICLIENT SUBSCRIPTION REPORTS

Relevant recent reports from the Process Evaluation/Research Planning (PERP) program include:

Stationary Fuel Cells – This report provides an overview of fuel cell technology with an emphasis on the best technologies for stationary power production applications. The study considers SOFCs, MCFCs, PEMFCs, and other types, but concludes that SOFCs and MCFCs are most attractive for stationary use in industrial, utility, and commercial systems, in both large and distributed systems, in contrast to vehicle and residential applications where PEMFCs are more highly supported by government and private investors, and therefore may be more successful.

Ceramic Membranes – This report is a broad review of the fabrication technologies and economics of different ceramic membrane fabrication systems and applications (reverse osmosis, gas separation, pervaporation, etc.) in food, chemicals, and high tech industries. It traces the corporate/government development arc of the various physical designs and chemistries of this field.

Crystalline High Temperature Polymers – This is primarily a techno-economic and market analysis of PEEK (polyetheretherketone), which is a high temperature, high performance polymer with properties and applications similar to polyethersulfone (PES). This easily processed plastic is resistant to heat, acid, caustic, and radiation.

“Green” Polyethylene – Analysis of the technology and economics of converting ethanol to ethylene by catalytic chemical dehydration, and then to polyethylene by conventional polymerization technology, including comparisons with the incumbent routes from hydrocarbon feeds.

Biomass Gasification – A review of developments in gasification of biomass and technology, economics, and commercialization initiatives, including making liquid biofuels by catalytic processes.

Refinery of the Future as Shaped by Environmental Regulations – Reviews issues of supply and quality of crude oil feeds to refineries, trends in quality and volume requirements for refined products, and environmental drivers for both refinery operations as well as fuel specifications.

Biodesulfurization of Petroleum Fractions – Compares various versions of conventional refinery hydrodesulfurization with developments in fermentation-based biodesulfurization.

RENEWABLES - RELEVANT SINGLE TOPIC MULTICLIENT STUDIES

Carbon Management: CO₂ Capture, Transport and Sequestration - This milestone multiclient study considers a wide range of chemical and physical solvent carbon capture systems, policy drivers and ramifications, and discussions on a number of leading applications.

Algae: Emerging Options for Sustainable Biofuels - Techno-economic analysis of this emerging field, including open pond and PBR systems, for biodiesel lipid feeds, ethanol, or other fuel products; all process steps, co-products and other cash flows, CO₂ recycle, oleochemicals, foods, animal feeds, specialty chemicals, and nutraceuticals, wastewater treatment, and fresh water production.

Liquid Biofuels: The Next Generation – This report updates the earlier study, **Liquid Biofuels: Substituting for Petroleum**, but is organized somewhat differently, with a broader viewpoint on biogasoline and biodiesel beyond ethanol and FAME. It also has a more extensive analysis of policy and sustainability issues, and the status of development of second and third-generation feedstocks, biofuels, and process technologies.

INDIVIDUAL CLIENT STUDIES

A partial list of relevant projects includes:

Biodiesel Glycerine Byproduct - Market Dynamics – For a major U.S.-based multi-national agricultural and food company with a growing stake in biofuels, Nexant analyzed the market demand/price elasticity (with a growing glut of biodiesel glycerine byproduct), existing uses of glycerine, potential substitutions for other polyols such as propylene glycol and sorbitol, and potential future applications, including reaction derivatives of glycerine in various applications and fuel uses. Nexant considered the near term, emerging, and long-term market outlets for USP and other refined grades of glycerine, as well as for crude biodiesel glycerine byproduct, which is of a more problematic quality than soap and oleochemical byproduct. The study required developing views of biodiesel growth, and pricing scenarios under various assumptions.

Biobased Fuel Cells – At the BIO World Congress on Industrial Biotechnology and BioProcessing, Orlando, FL, April 20-22, 2005, Nexant presented a paper on biofuels use in fuel cells based on a study of Stationary Fuel Cells for Nexant’s PERP program, and also chaired a panel on Bio-based Fuel Cells, which included discussions of enzyme-based fuel cell membrane and electrode technologies to utilize hydrogen or biofuels.

Ultra Clean Fuels Study – For Conoco, under U.S. DOE sponsorship, Nexant performed a comprehensive review of the future for ultra low sulfur diesel (ULSD) and other petroleum distillates in transportation, considered regulatory and market drivers, production technology and economics, petroleum refining impacts, environmental/resource depletion impacts, vehicle engine and performance, consumer acceptance, distribution and refueling logistics, diesel and gasoline ICE operational issues, stationary combustors, and fuel cells. The objective was to determine the feasibility of using GTL fuels – Fischer-Tropsch distillate, naphtha and methanol (comparisons to hydrogen, ethanol and biodiesel included). At issue was the use of biodiesel as a lubricity additive to counter the reduced lubricity with loss of sulfur in ULSD and GTL.

Synthesis Gas (Future Sources) - This report reviewed the technology for production of synthesis gas (H₂, CO mixtures) from a number of sources. Most emphasis was devoted to coal and biomass gasification (municipal solid waste and wood) and new gasification technology. The report discussed downstream processing requirements and examined coal and biomass properties and their impact upon gasifier design. The economics of producing industrial fuel gas (gasifier effluent after acid gas removal) via different routes were compared to the direct use of natural gas and low sulfur fuel oil.

LNG Competition with Clean Diesel – For a multinational industrial gas company with a stake in technology for LNG as an alternative vehicle fuel/CNG refueling strategy, Nexant studied the current status of “clean diesel” (e.g., engine modifications along with ultra low sulfur diesel fuel enabling use of particulate traps and catalytic tailpipe controls to reduce soot and NOx emissions), and assessed the competitiveness of biodiesel in this context.

Global Finished Automotive Lubricants Market Drivers – For a leading U.S.-based multinational lubricants additives maker, Nexant studied the current and projected global market

dynamics for finished automotive lubricants for the next two decades. Market segments/products included passenger car and diesel/heavy-duty crankcase, gear oil, automatic transmission, tractor, off-road and small engine lubricants. Fleet growth in various regions, ultra low sulfur diesel, and trends to “dieselization” of fleets in various regions were relevant issues examined. In this and other related work, Nexant has opined that a key vector for use of biodiesel, aside from as a fuel, will be as a lubricity additive to ultra low sulfur diesel. In addition, key will be demand for biodegradable, non-toxic biodiesel fuel in small boats in place of other marine fuels.

Synthetic-Based Drilling Fluids (SBFs) – For a multinational specialty chemicals company with a stake in oleochemicals and GTL, Nexant studied market issues and projected markets for SBFs in deepwater drilling, as driven by recent U.S. EPA regulations of these oil-based systems with respect to disposal of drilling spoils (especially in the Gulf of Mexico, but in other seas as well). The only systems allowed, by consensus in a stakeholder-involved regulatory development process, are those based on Internal Olefins (IOs) and vegetable esters (essentially, “biodiesel”). These alternatives strike a balance in meeting both toxicity and biodegradability limits.

M2M Feasibility for Developing Economies – For USAID, Nexant studied the feasibility of capturing various streams of fugitive methane and bringing them to market (“methane-to-market”, or M2M), including anaerobic biodigestion of agricultural waste biomass.

PHOTOVOLTAICS

Nexant has conducted a wide variety of technical and commercial consulting activities in photovoltaics and its precursor materials for multiple clients since 2006.

- For a large Arabian Gulf investor, Nexant conducted a multi-faceted feasibility study for the production of purchased Si metal polycrystalline silicon for SPV wafer manufacture, including for export of product to European, North American, and Asian customers, and considered drivers such as feed-in-tariff and competition from growing thin film PV. The developer was seeking to exploit a strong financial position and low energy costs to become a major player in the global polysilicon market. Nexant modeled costs of production in key market regions and potential producer locations around the world.
- Performed an independent commercial due diligence evaluation of a thin film SPV solar business.
- Performed a global market analysis of photovoltaic grade polysilicon.
- Nexant assessed commercial and technical competitiveness for a 7.5 KT Siemens polysilicon plant located in the Middle East.
- Prepared a presentation of Sustainable Policy Structures for the European Union, given to the World Future Council.
- Nexant was a contributor to Strategic Summit on Feed-in Tariffs versus Renewable Portfolio Standards, hosted by the Solar Industry Energy Association.
- Established the path-forward business plan for Europe's largest installer of SPV polysilicon panels.
- Performed a strategic assessment of renewable portfolio standards in the United States.
- Made an impact study on feed-in tariffs for stimulating industry for a Florida municipality.
- Performed a Material Replacement Study for Aluminum versus Plastic – jointly co-sponsored by a major North American producer of SPV panels and a major specialty polymer company.
- Performed a competitive analysis between polysilicon and thin-film SPV for a producer of thin film photovoltaics.
- Provided a Market Assessment of photo-reactive polymers and photovoltaics to an advanced polymer company in France.
- Assessed opportunities for a leading Korean chemical manufacturer to participate in the global thin-film PV market.

Thermal Solar

Project: Project development of a solar power plant

Client: eSolar, Inc. Nexant provided project development services for start-up of the 7 MWe Sierra demonstration solar power plant and eSolar's first commercial solar utility scale power plant, the 245 MWe Longview SunTower facility in southern California. Nexant's services have included site selection; permitting support for local, state and federal approvals; interconnection studies; and engineering review for plant design, plant operation and equipment selection and specifications. We have also provided procurement support which included bidding documents, bid evaluation, negotiations and award for the purchase of steam turbines for the Longview Project. Nexant will be involved in the engineering and financial due diligence required to support eSolar's future international projects.

Project: Engineering and procurement services for a demonstration project for a solar plant in California

Client: Solar Millennium, LLC. Nexant is providing engineering and procurement services to Solar Millennium for the supply of their third generation solar parabolic trough collectors at the Kramer Junction solar plant. To date, Nexant has facilitated the design, purchase and fabrication of 40 parabolic collectors from the People's Republic of China to Solar Millennium's very strict specifications. Nexant has continued its support of this project with permitting and interconnection approvals and the development of the site construction contracts.

Project: Solar collectors for low temperature process heat

Client: Sociedad Contractual Minera El Abra. The El Abra copper mine in Chile uses approximately 19 MW of low temperature energy for extracting copper metal from copper ore. This energy is supplied by water heaters fired with distillate fuel oil. The study examined the potential for various combinations of flat plate, parabolic trough, and evacuated tube solar collectors to reduce its fuel use by 30 to 70 percent. Nexant evaluated the annual performance of the solar collectors, and is developing system capital cost estimates to estimate the net present values of the various solar options.

Project: Rankine cycle, steam generator, and thermal storage analyses

Client: Pratt & Whitney Rocketdyne. Nexant provided technical and economic information to Pratt & Whitney Rocketdyne on the steam generator and thermal storage systems for use in commercial nitrate salt 85 MWe central receiver power plant with 4 hours of thermal storage. Study increased plant capacity to 100 MWe with 6 hours of thermal storage, and generated as many as 4 proposals to various public utilities in the Southwest.

Project: Parabolic trough and central receiver technology and economic comparison

Client: Electric Power Research Institute (EPRI). Nexant conducted a technical and economic assessment for EPRI on parabolic trough and central receiver power plants in New Mexico. A

range of design options was considered including plant size (50 MWe and 125 MWe), plant location (Albuquerque and Lordsburg), thermal storage (3, 6, and 9 hours), heat rejection (dry, wet, and hybrid), natural gas hybridization (10, 15, and 20 percent of annual solar thermal input), and annual solar radiation (plus and minus 5 percent from long term average).

OTHER RELEVANT EXPERIENCE

GREENHOUSE GAS (GHG) MANAGEMENT AND CERTIFICATION

The GHG experts at Nexant have over 50 years combined experience with climate change and clean energy, and have delivered credible services for over 100 GHG assignments since 2001. Nexant team members continue to offer innovative GHG management services to numerous large and multi-site clients:

- GHG program design and methodology development
- Corporate management plans and strategies
- Regulatory compliance strategic plans and management systems
- Inventory development, reporting and verification
- Needs analysis and implementation of GHG Information Management Systems
- Clean technology assessments
- Carbon neutral product evaluation
- Offset project advisory services, validation and verification
- GHG Training

Nexant helps companies achieve double dividend results on their GHG investments by capitalizing on carbon market opportunities, managing GHG inventories more efficiently, and investing in clean technologies with the right standards and strategies.

Where others see costly risk mitigation processes, we see business opportunities for generating non-conventional revenue streams. Our team can help do much more than document and manage a company's GHG emissions. Whether a company is invested in clean technologies, carbon neutral products, or offset projects, Nexant assists in optimizing the return on investment.

MARKETER OF RECS AND EECs

Nexant is the largest and oldest independent retail marketer of environmental credit products including Renewable Energy Certificates (RECS), Energy Efficiency Certificates (EECs) and Carbon Dioxide (CO₂) Offsets. Principals in Nexant's Clean Energy Solutions practice created and transacted the very first EEC in the U.S., developed one of the first corporate Greenhouse Gas (GHG) programs, created the first renewable energy credits from Combined Heat & Power (CHP) in Pennsylvania, and transacted over 1 billion kWhs of EECs in the state of Connecticut.

Nexant has extensive experience in providing REC and EEC products and services to utilities, businesses, and universities. In just the last six months, Nexant has sold almost 2 billion kWhs of renewable energy nationally and transacted over 1 billion kWhs of energy efficiency. Three of the top EPA Green Power Partners recently purchased RECs from us. We have developed EECs for projects of Fortune 500 companies, including the world's largest package delivery company and the world's leading producer of glass fiber materials.

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