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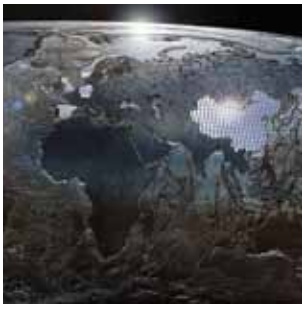
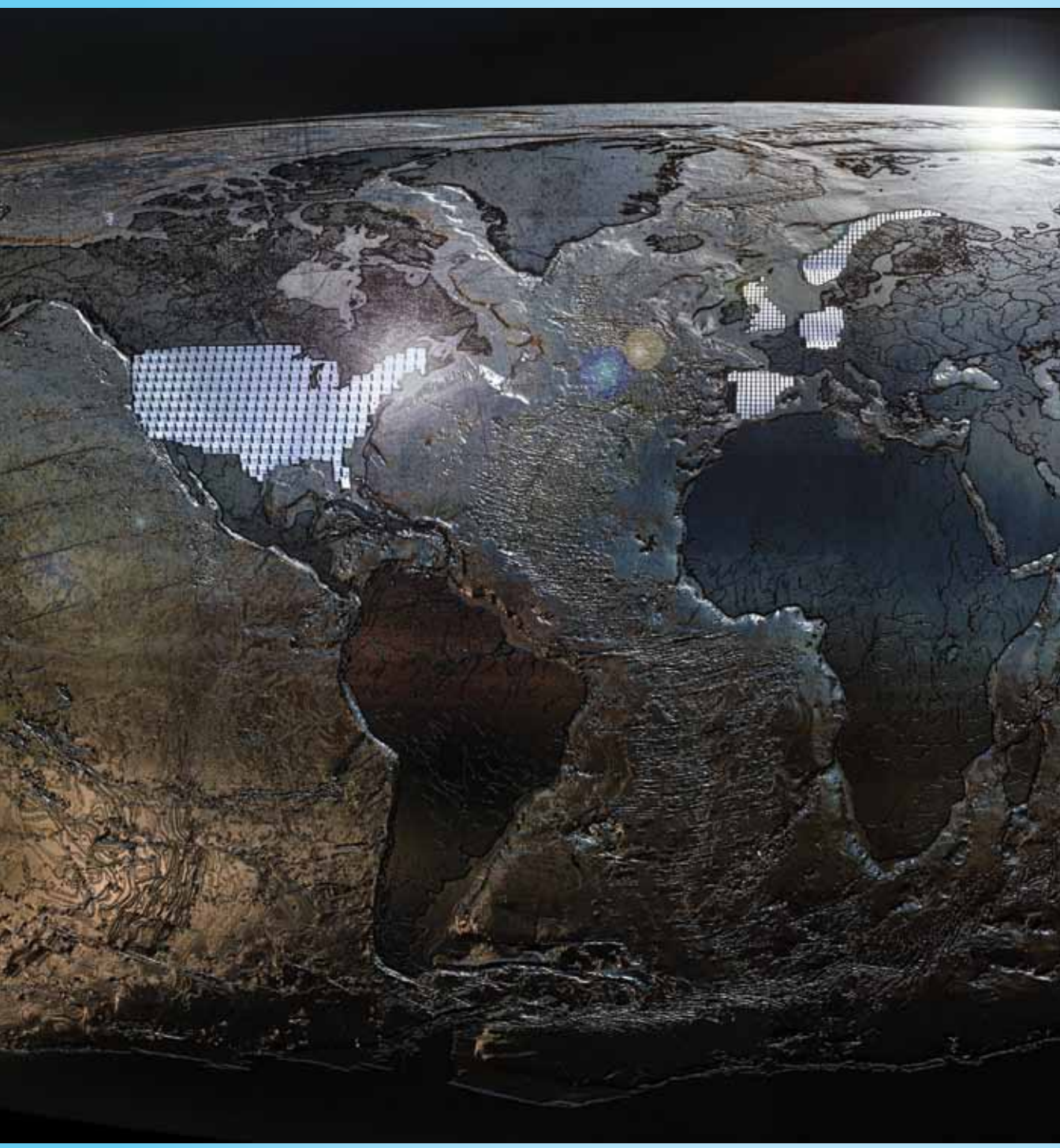


Solar's Push to Reach the Mainstream

BY OLAF BABINET, DUSTIN GELLMAN AND JOVANA TRKULJA
WITH PHIL SCHNEIDER
> ILLUSTRATION BY KEV JENKINS



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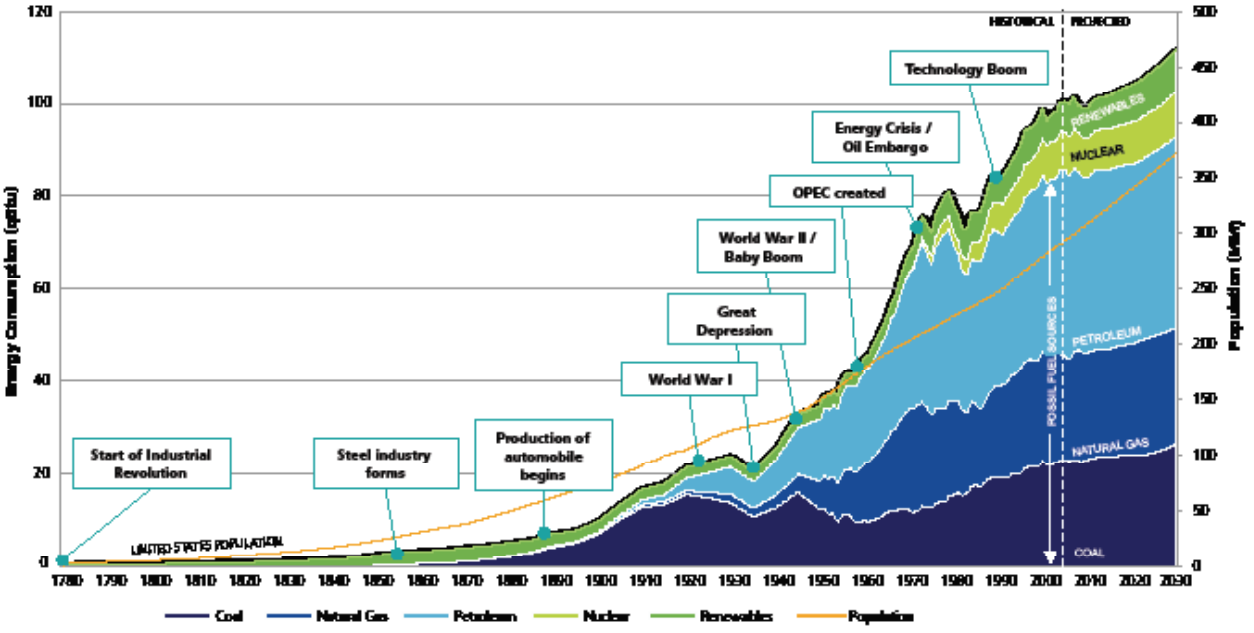
IN THE COMING DECADE, SOLAR ENERGY WILL IMPACT YOUR LIFE AND BUSINESS. IN THIS ARTICLE, WE EXPLORE CHALLENGES CONFRONTING THE SOLAR INDUSTRY IN THE RACE TO GRID PARITY AND PUSH TO EXPAND GLOBAL ADOPTION.

LOOMING ENERGY CHALLENGES

Hardly a day goes by without a news story, article or academic finding that suggests energy will be among the world's most significant challenges in coming decades. By 2030, global energy consumption is expected to nearly double 2005 levels.[1] Put simply: it will likely be difficult to meet projected energy demand with available supply — a situation that could present dire economic and environmental consequences. As countries across the world strive for energy independence and environmental stewardship, demand for clean, affordable, renewable power is expected to increase dramatically.

How will we meet rising demand for energy?



U.S. demand for energy is expected to increase 14-28% from 2005 to 2030

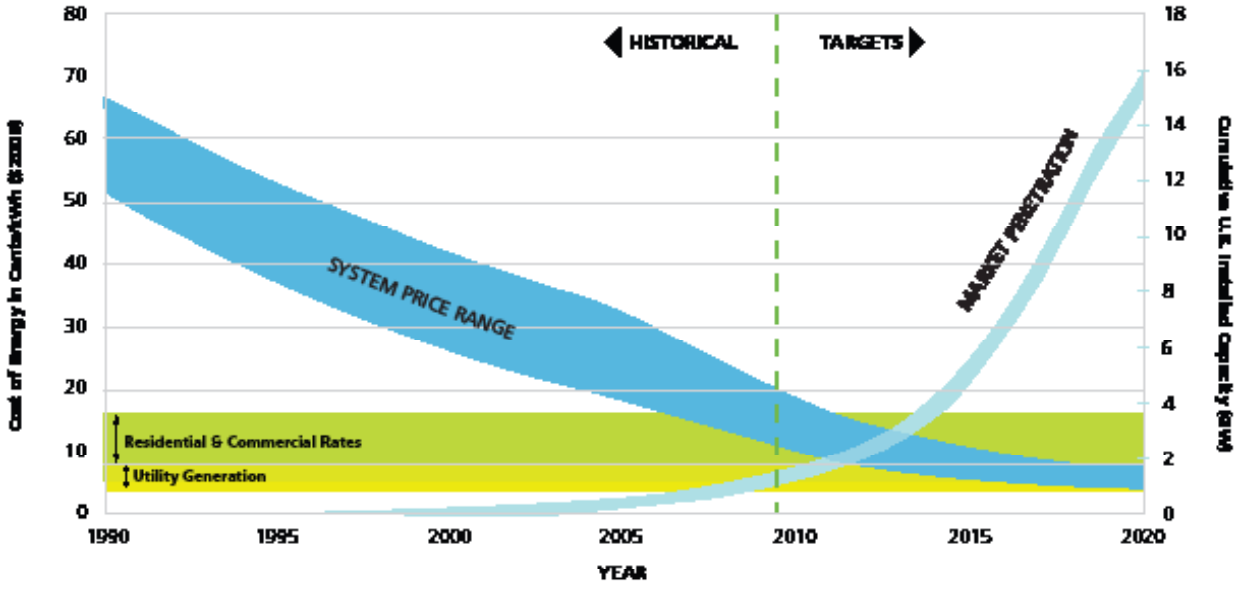
Source: Energy Intelligence Administration. International Energy Outlook (2008)

After decades relegated to powering calculators, parking meters and roadside telephones, solar energy[2] is now positioned to deliver abundant clean energy at an industrially scaled level. While more energy from sunlight hits the earth in an hour than is consumed in an entire year, solar currently constitutes less than half of one percent of the United States' overall generation portfolio and is projected to reach just over three percent by 2030.[3] The data underscore a critical issue: without more dramatic action, solar's great potential will go unrealized. So how can solar companies and governments accelerate the growth of this industry, ultimately to benefit society?

Solar Incentives: a Pareto Improvement

In most areas of the world, solar energy is too expensive to compete directly with traditional fossil fuels — primarily because the industry is relatively immature and lacks economies of scale. Grid parity refers to the point at which the cost of solar electricity (or other alternative energy source) rivals that of our more traditional sources, such as coal, oil, natural gas or nuclear. While many areas of the United States are expected to reach this point for solar by 2015, grid parity actually varies geographically as a function of local climate, utility rates and government support, to name a few. In the United States, residential electricity rates vary between about $0.07 to nearly $0.25 per kWh;[4] consequently, different areas will reach grid parity at different times. Globally, the variance is even more pronounced, with a significant portion of the world's population not served by a grid at all.

Projected PV Solar Market Penetration



Falling PV system prices will spur a sharp increase in demand from 2010 to 2020

Source: U.S. Department of Energy. Solar Energy Industry Forecast (2008)

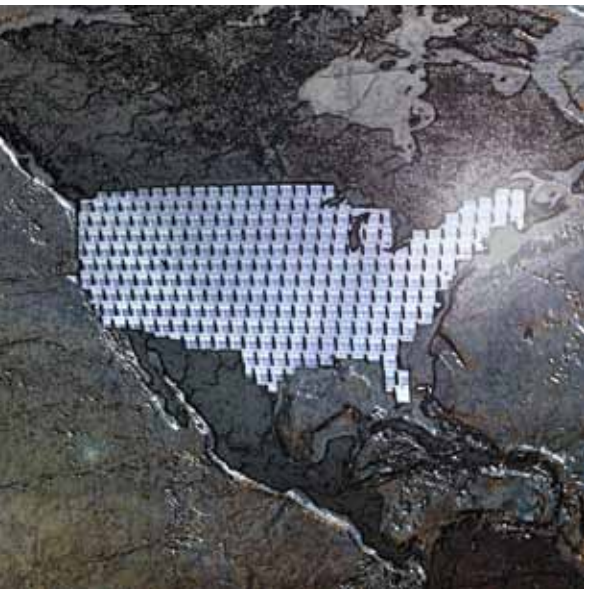
The solar industry faces a chicken and egg dilemma: lower costs will stimulate demand and increase economies of scale, but achieving lower costs now requires scale — or market subsidies. To achieve grid parity, industry players need to survive the current economic recession, reduce operating costs, and pursue technological advancements. Simultaneously pursuing all three initiatives will be difficult;

therefore, governments should consider whether or not to support the industry by subsidizing supply and demand and providing the necessary electrical grid infrastructure. Additionally, capital markets and governments should consider making available the necessary funding for solar companies to invest in R&D, expand production, and deploy solar energy projects. These actions would likely help expedite solar industry technology, innovation, and production scale — which should accelerate the industry toward grid parity.

Growing Pains Ahead

The road to grid parity is fraught with potholes; and beyond parity, mass market adoption poses new challenges. Manufacturers that fail to innovate and lower costs may face extinction. From a revenue growth perspective, numerous solar energy business models — from complex leases to retail dealers — exist today with no clear winner. In the realm of public policy, the United States trails both Western Europe and China in stimulating consumer demand and has a burdensome corporate tax structure. Further, America's electric grid infrastructure is a patchwork of antiquated technology with conflicting stakeholder interests and intricate governance.

Compounding these issues, consumers are mostly unfamiliar with solar products; and those that desire the technology often lack sufficient capital to finance projects. For all of its promise, solar faces an uphill climb to mature and deliver its potential. While the industry may eventually create billions of dollars of investments (and tax revenues) and millions of jobs, the timeline for solar-driven prosperity is uncertain, and the winners and losers remain undetermined.



THE ROAD TO GRID PARITY

In 2009, the solar industry witnessed two milestones: First Solar announced that it produced thin film solar modules for less than $1.00/watt,[5] and the U.S. government passed the American Reinvestment and Recovery Act (ARRA) with significant incentives for both consumers and producers of renewable energy. These are important steps toward making solar systems more cost competitive, thereby fueling innovation and bringing solar closer to grid parity

and mass market adoption in more regions of the United States. But these are early steps in a long journey that includes surviving the current economic crisis, lowering production costs across the value chain, and developing new technologies.

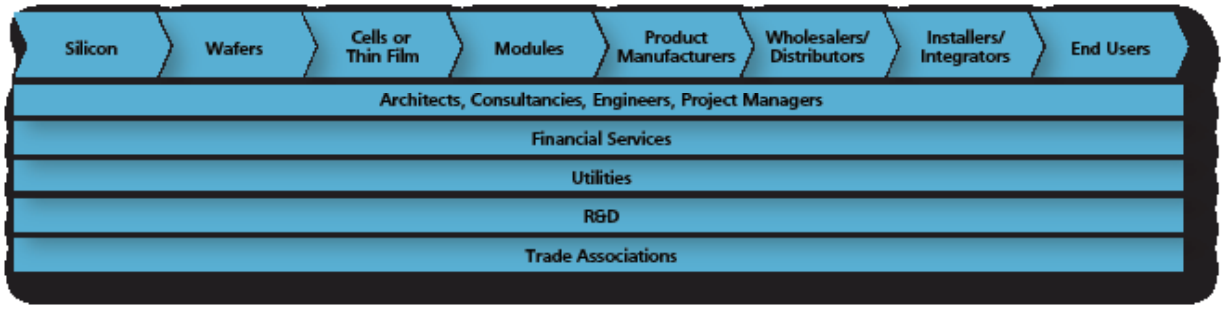
Survive the Global Recession and Solar Shakeout

In recent years, a global shortage of polysilicon — feedstock for crystalline silicon (c-Si) solar modules — drove up system prices. More recently, the global economic crisis and falling fossil fuel prices resulted in weakened demand for solar solutions. Consequently, many solar companies postponed or delayed expansion projects, cut jobs, and carried bloated inventories across much of the value chain. With a shakeout underway, companies were forced to reduce variable costs and delay expansion plans in order to survive.

Reduce Operating Costs

The solar value chain is complex and has numerous stakeholders. The illustration below highlights key steps in the process from raw materials (e.g., solar grade silicon) to building rooftops or solar farms.

PV Solar Value Chain



Source: Deloitte Research, SolarPlaza.com

According to REC, an integrated solar company and industry pioneer, the aim of every solar producer is to move toward grid parity by reducing costs at each step of the value chain. Companies are under enormous pressure to identify areas where costs can be most effectively reduced within each step, while simultaneously improving operational efficiency, driving innovation, and managing business risks.

Balancing such a broad set of operational challenges requires solar companies of all sizes to think and act globally. At each step in the value chain, producers must

simultaneously maintain access to suppliers and customers, attract and retain qualified talent, reduce execution and operational risks, and lower costs — all the while anticipating rapid market evolution. For example, in March 2009 the Chinese government announced some of the most aggressive solar subsidies in the world that, if implemented, may amount to nearly half of the cost of installation for medium-sized projects.[6] While industry analysts may debate the long-term impact of China's actions, it is clear that solar companies must remain nimble to adapt to changing global market conditions.

The United States consumes more energy than any other country in the world and has the largest potential market for solar installations. From this standpoint, U.S.-based companies are well positioned to lead the solar industry — and reap considerable economic and social benefits as a result. However, the United States significantly lags Germany, Japan and Spain in terms of solar installation and manufacturing companies and risks missing significant wealth and job creation opportunities.

Pursue Technological Innovation

Crystalline silicon (c-Si), sometimes referred to as First Generation solar, presently accounts for 90 percent of industry demand.[7] First Generation modules require solar-grade silicon, which is processed into solar cells. Securing adequate silicon feedstock and using it efficiently is key in reducing end product costs. Technological advances may reduce the industry requirements for this raw material by cutting thinner wafers or reducing cell breakage during the manufacturing process. These technological advancements should improve efficiency and contribute to creating economies of scale. Despite these technology innovations, some analysts predict that it will be difficult to drive First Generation solar manufacturing costs below $1.00/watt.[8]

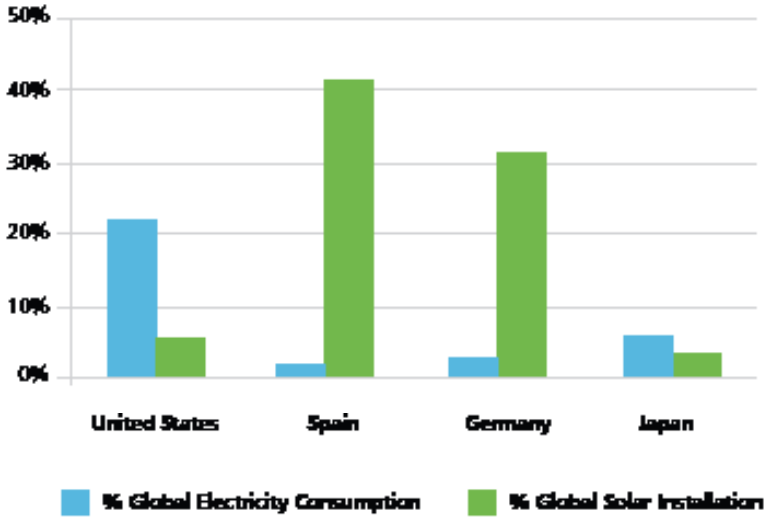
According to Austin-based HelioVolt's founder, Dr. B.J. Stanbery, the solar industry is at the cusp of rapid growth of its next generation technology. Between 2008 and 2012, thin-film technology is expected to grow ninefold.[9] Thin-film, sometimes referred to as Second Generation solar, uses sophisticated equipment to coat a surface (e.g., glass or plastics) with a layer of photovoltaic material—a process that lowers manufacturing costs by reducing or eliminating the need for

solar grade silicon and bypassing several production steps.[10] This cost advantage is expected to be an important contributor toward reaching grid parity. Additionally, Second Generation thin-films can be applied to a variety of surfaces, such as building materials and consumer products, opening up new markets for the industry. Incumbent First Generation producers must strike a delicate balance between improving existing processes and investing in disruptive (and potentially cannibalistic) new technologies. For example, Q-Cells, the world's largest solar cell manufacturer, is actively investing in emerging thin-film technologies while continuing its traditional silicon-based cell production.[11]

Effect Public Policies

The United States consumes more energy than any other country in the world and has the largest potential market for solar installations. From this standpoint, U.S.-based companies are well positioned to lead the solar industry — and reap considerable economic and social benefits as a result. However, the United States significantly lags Germany, Japan and Spain in terms of solar installation and manufacturing companies and risks missing significant wealth and job creation opportunities. To help accelerate the U.S. solar industry, federal, state and local governments might consider new policies in four key areas: market subsidies, renewable electricity standards, carbon regulations, and corporate taxation.

Public Policy Drives Solar Installations



While Germany consumes only 15% as much electricity as the U.S., it has about five times as many solar panels installed.[12]

Source: CIA World Fact Book, SolarBuzz.com, *New York Times*

Market Subsidies

In March 2009, Gainesville, FL became the first city in America to adopt feed-in tariffs (FiT), a subsidy that effectively pays homeowners to install solar modules on their rooftops. By contrast, Germany implemented its FiT program on a *national* basis in 2000. Unfortunately, nationwide programs are difficult to implement in America because most utilities are regulated by states. Alternatively, the federal government could consider offering aggressive federal tax credits and other incentives for solar manufacturing and installation like the recent changes enacted in the federal stimulus (ARRA). For example, industry analysts expect that the $6 billion of federal loan guarantees for renewable energy projects could help stimulate $60 billion of lending for renewable energy companies. However, industry executives note that to compete with the leading European and Asian countries, the solar manufacturing industry will need additional financial support.

Renewable Electricity Standards

More than half of U.S. states have enacted Renewable Electricity Standards[13] (RES) legislation, which mandates that a minimum percentage of a state's electricity come from renewable energies by a specific date (e.g., 20 percent by 2020) — a system that effectively *imposes* demand. However, increased costs are passed along to consumers in the form of higher rates, which critics argue is akin to a regressive tax. Proposed legislation for a national RES has previously failed to pass but is expected to resurface in Congress. Such legislation could be a boon for renewable energy manufacturers.

Carbon Regulations

Fossil fuels such as coal and natural gas power most American utilities — 50 percent and 20 percent of total generation, respectively — and emit carbon dioxide (CO_2) during the process.[14] CO_2 emissions are generally accepted to have a negative impact on the environment, although this impact or societal cost is not presently accounted for in the price of electricity in the United States, consequently understating actual costs. At the time of writing, U.S. lawmakers are preparing to debate carbon regulations, economic measures designed to reduce CO_2 emissions through taxation, auctions, trading schemes and other methods. If passed, such regulation is expected to increase electricity prices in most areas of the country and accelerate alternative sources such as solar power toward grid parity.[15] The economic impact is expected to vary by program structure, with some experts predicting residential electricity rate increases of up to 40 percent in Midwestern states.[16]

Corporate Taxation

The U.S. average combined federal and state corporate income tax is close to 40 percent, second only to Japan. High income taxes have deterred foreign solar companies from locating in America. Most solar companies are startups and, given industry growth prospects, expect healthy profit margins to fund expansion, maintain aggressive R&D, and attract investment capital. As the industry matures and margins compress, manufacturers will weigh the tradeoff between increased logistics costs to ship products to the United States from low tax countries and higher corporate income taxes from locating in America closer to the market. Corporate income tax credits could stimulate growth of the domestic solar industry, including both manufacturing and installation.

Upgrade America's Century-Old Grid

In the United States, electricity is usually generated at central power plants and transmitted to consumers. Based on century-old technology, the transmission networks in certain areas of the country are often outdated, strained and poorly suited for renewable energy. High-voltage lines — necessary to carry electricity from remote solar or wind farms to consumers — simply are not as developed in areas where the sun shines brightest or the wind blows strongest.[17] The ARRA economic stimulus directed over $40 billion toward improving the grid, but related projects will take years to reach fruition.

In contrast to traditional electricity generation, solar power collection may be distributed across numerous rooftops or centralized in utility-scale farms. Distributed solar will require grid operators to install technology to monitor power supply and demand, balancing thousands of individual generators with central power plants. Connecting remotely located solar farms will require building new high-voltage transmission lines and routing them to the grid. The ultimate goal among public policymakers and industry insiders is to develop a *smart grid*—a modern electricity network driven by digital technologies, capable of monitoring activity in real time, detecting and healing issues, increasing efficiency through demand management, and accommodating interconnected distributed generators, such as solar and wind farms.

Today, electricity is a just-in-time commodity, routed to consumers as it is produced. When the sun stops shining, solar cells cease generating power. For solar to truly have a meaningful role in the electric power generation mix, in addition to extending and improving the country's transmission network, a power storage infrastructure is required. To maximize efficiency, utilities can use advanced batteries to store up energy from solar as it is generated for future use ondemand. However,

broadscale deployment of this technology is immature and, to date, limited in the United States.

Secure Access to Capital

Less restricted capital markets are necessary to expedite solar industry's growth. Between 50-70 percent of solar projects are financed by debt, which makes the industry particularly susceptible to the current credit crisis.[18] And when customers can't secure financing, demand weakens, prices fall, and solar companies are forced to reduce production, alter payment terms, or postpone projects. According to Germany's Commerzebank, tight credit conditions impact solar project returns to a much greater extent than falling module prices.[19]

HelioVolt, considered a leader in thin-film solar technology, illustrates the financing challenges faced by many technology startups: its 20 MW pilot factory cost nearly $40 million to equip, and commercial production won't begin until 2010. Building larger-scale factories will deliver dramatically lower capital cost per unit output but requires additional capital from investors with a longer-term outlook and appetite for risk — rare characteristics in today's economic climate but essential for HelioVolt to gain speed to market.

ACHIEVING WIDESPREAD ADOPTION

The U.S. Department of Energy anticipates that by 2020, solar will achieve widespread grid parity, with worldwide installations reaching a cumulative 200 GW. While the implied growth rate to achieve this level of installation over the next decade is impressive, this figure represents only one percent of projected global energy demand. Harvesting the sun to make a more significant impact on energy independence and environmental leadership will require far greater adoption. For solar power to account for more than a token portion of the world's energy portfolio the industry must drive costs even lower and pioneer new business models, and governments must continue to deliver supportive public policy.

Drive Costs Even Lower

Driving costs significantly lower will likely accelerate adoption, especially in light of solar's environmental and energy independence benefits. Solar energy prices have declined by about four percent annually since the mid-1990s[20] and are expected to continue downward at a rate of five to six percent.[21] The commodity nature of solar modules will force producers to continuously lower costs to gain competitive advantage and improve margins. Economies of scale will be a major driver. Solar Revolution author Travis Bradford estimates that solar production costs decline 18 percent each time output doubles.[22] From this perspective, it certainly pays to be bigger.

Solar manufacturers can optimize their global R&D and manufacturing footprint to lower production costs by strategically deploying these assets across facilities, functions and geographies. Similar to the semiconductor industry, solar wafer and cell manufacturers will need to leverage production locations with lower variable cost inputs such as taxes, labor and utilities while maintaining reasonable access to markets for final module assembly. Stanbery notes that as solar module prices fall, shipping costs relative to product value will rise. Consequently — and contrary to popular opinion — module manufacturers may actually relocate production closer to customers in large markets to minimize distribution costs; likewise for other next generation solar products, such as solar-integrated building materials.

Today, the majority of solar modules produced are sold to a relatively small number of customers. Beyond grid parity, both the type and number of customers will fundamentally change, with commercial and residential segments increasing dramatically. To capture a larger portion of the value chain and streamline costs, today's savvy manufacturers will likely seek to vertically integrate by moving either further up or downstream from their current core competency. Thin-film leader First Solar exemplifies this idea, having recently purchased solar integrator OptiSolar's entire portfolio of utility projects.

Solar companies can also drive production costs lower through innovation and

technological advancements at any stage of the value chain. For example, Elkem Solar has pioneered a process to produce a tailor-made solar grade silicon through metallurgical refining with performance equivalent to polysilicon for a fraction of the cost of traditional production methods. Numerous companies have made great strides toward module manufacturing automation. Dramatic raw materials savings are already inherent in both thin-film and silicon manufacturing, and wafer producers continue to make strides toward thinner wafers. Both silicon and thin-film will likely continue to improve efficiency yields of solar cells, further lowering the total cost/watt. Regardless of technology, solar manufacturers in a post-parity world must maintain a distinct competitive advantage by driving to an ever lower cost structure, dominating a specific application, or vertically integrating to achieve production and cost efficiencies across the solar value chain.

To dramatically increase adoption, the solar industry must develop new products, enter new markets, and expand financing options. The industry may evolve across a spectrum: On one end, a smaller number of high-volume producers will produce cells and modules at relatively low margins. On the other end, numerous smaller product developers will produce lower volumes of specialized, higher-margin products.

Deliver Supportive Public Policy

When solar electricity costs are comparable to fossil fuels such as coal, will governments continue to offer subsidies and favorable legislation? It depends on public policy goals and to what extent the environment and energy independence remain in focus. To accelerate solar adoption beyond a tiny fraction of total energy demand, governments will need to continue to play a proactive role.

The Obama administration has targeted renewable energy as a catalyst for economic growth and prosperity. Manufacturing and installing solar power systems creates jobs. According to a recent EPIA study, 10 jobs are created per MW of modules manufactured, and 33 jobs are created per MW during installation. Adjusted for varying project types, if global demand reaches the projected 200 GW by 2020, and not controlling for likely labor efficiencies, this would translate to over one million installation jobs globally. According to the University of California at Berkeley's Renewable and Appropriate Energy Laboratory, over the course of

a 10-year period the solar industry creates 5.65 jobs per million dollars in investment, the wind energy industry 5.7 jobs, and the coal industry only 3.96. Research from the University of Florida estimates solar creates more than fifteen times the number of jobs per MW installed when compared to nuclear.

Which countries capture the lion's share of solar-related economic growth and jobs remains in play and will be driven in large part by public policy. Countries that offer aggressive incentives, develop modernized infrastructure, and streamline the regulatory environment will be well-positioned to lead in both the manufacture and installation of solar modules. The ARRA federal stimulus incentives and state-mandated Renewable Electricity Standards will help the United States gain market share, but recent announcements of aggressive solar subsidies by China and Ontario, Canada underscore the reality that the race to lead the industry will be hotly contested.

While solar installations are inherently local, solar cells, modules and other system equipment can be manufactured nearly anywhere. This bodes well for tax holiday and otherwise low cost manufacturing countries such as Singapore and Malaysia, but less well for the United States, Japan and Western Europe. However, module assembly is becoming rapidly automated. So unless the entire supply chain is optimized in a low labor cost region, the tradeoff between labor, taxes and logistics and other favorable operating conditions will likely be evaluated on a case-by-case basis. In the short run, to be globally competitive in solar manufacturing, countries with high taxation and labor costs will likely need to compensate with supportive public policy that provides tax credits for capital investment, R&D and technical training.

Pioneer New Business Models

To dramatically increase adoption, the solar industry must develop new products, enter new markets, and expand financing options. The industry may evolve across a spectrum. On one end, a smaller number of high-volume producers will produce cells and modules at relatively low margins. On the other end, numerous smaller product developers will produce lower volumes of specialized, higher-margin products. Instead of opening expensive factories, smaller companies may outsource production to larger fabrication plants, in similar fashion to the semiconductors. The localized nature of solar installations raises the prospects of specialized retail stores, dealerships and franchises.

There are presently three distinct market segments for solar: industrial, commercial and residential. Industrial solar generates electricity centrally, usually in large-scale farms. Pre-grid parity, utilities such as Pacific Gas & Electric and Duke

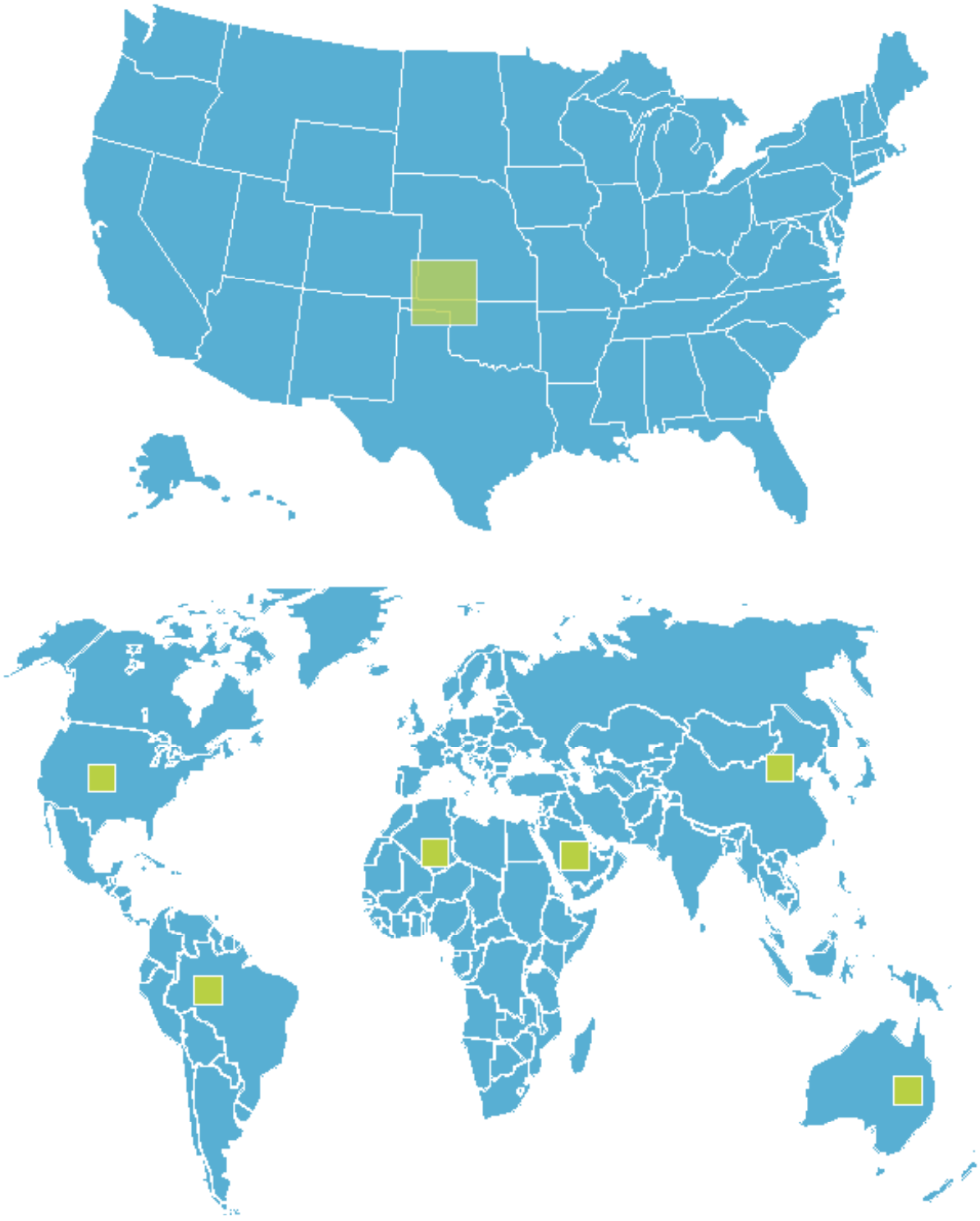
Energy are using large-scale solar projects to help meet state-issued standards.[23] By contrast, commercial and residential solar segments put solar panels on individual rooftops and generate electricity in distributed fashion. Beyond grid parity, a new segment of building integrated products (BIPV) will emerge, with solar cells built directly into windows and roofing materials, fixtures and consumer electronics. These products require sophisticated engineering and will command higher margins compared to commoditized solar modules. Industry analysts estimate the global potential market size for BIPV in the tens of billions.

While current costs for solar largely limit the technology to wealthier nations, falling prices present opportunities to enter developing countries. Distributed solar is particularly promising for areas that lack a modern grid infrastructure, particularly Africa and much of Southeast Asia. Increasing adoption in non-OECD countries carries the added benefit of mitigating some of the world's dirtiest power plants.

The 30 member countries of the OECD presently consume 47.3 percent of the world's energy.[24] The next wave of demand will be driven by developing countries that have a less developed grid. The Energy Intelligence Administration projects that between 2005 and 2030, the demand for energy in non-OECD countries will increase by 85 percent, while demand for energy in OECD countries will increase by 19 percent.[25] While current costs for solar largely limit the technology to wealthier nations, falling prices present opportunities to enter developing countries. Distributed solar is particularly promising for areas that lack a modern grid infrastructure, particularly Africa and much of Southeast Asia. Increasing adoption in non-OECD countries carries the added benefit of mitigating some of the world's dirtiest power plants. In similar fashion to mobile phone companies, solar companies must adapt their business models to sell technology that fits with local incomes, infrastructure and regulations in developing countries, allowing them to bypass grid technology.

Purchasing a solar system to power the average American home currently costs about as much as buying a new car. Even when prices fall, the investment will remain a stumbling block for most households. To increase adoption, solar companies will need to develop a broader range of financing options. Companies such as Solar City — which purchases and installs panels on rooftops, then leases them to customers — will likely grow in popularity. Banks may present the option to

Solar's Potential: Mass Scale Clean Energy



America's entire energy needs could be met by tiling a 400 x 400 KM tract of land in the sunny Midwest with solar panels. Six comparable sites, properly located, could power the entire world.[26]

Source: The Lewis Group

finance solar systems alongside home purchases or refinancing mortgages, while solar retailers may follow the path of the auto industry by offering financing. Utilities are already using their balance sheets to purchase and operate larger-scale projects, and the trend will likely continue. Commercial property owners and tenants may partner with financiers offering purchase power agreements — long-term contracts to lease installed equipment at fixed rates.

SOLAR FUTURE

In the coming decades, the world will likely confront a new energy crisis: combining rapid demand growth and strained supply with increased environmental and independence concerns. The rise of renewable energy sources is inevitable, and solar is particularly well suited for rapid growth as a result of its abundance and broad availability. Unfortunately, today's solar power is too expensive to compete with energy generated from fossil fuels in most areas of the world — a situation that demands solar companies pursue aggressive cost reduction and governments consider supporting the industry with market subsidies, even in the midst of a weakened global economy.

Beyond grid parity, the United States, Europe and Asia will compete for solar's economic prize — estimated worth billions of dollars and millions of jobs. Public policy will likely play a significant role in defining the winners and losers. As the industry matures, producers will compete globally and seek locations that balance production costs, logistics, talent availability, and market access. Integrated products — from buildings clad in "solar skin" to portable power applications — will complement existing market segments. From the consumer's perspective, sun power will eventually become as commonplace as the sun itself, with a global impact of equal magnitude to the industrial revolution or rise of the Internet.

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Endnotes

1. http://www.eia.doe.gov/oiaf/ieo/electricity.html
2. The solar industry is comprised of several technologies, including photovoltaics, concentrating solar, and solar thermal. The focus of this article is on *photovoltaics* (PV) — a process which converts sunlight directly to energy using solar cells. For convenience, this article uses the terms *solar* and *PV* synonymously.
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4. U.S. Department of Energy: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.htm
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10. In contrast to First Generation silicon module production, thin-film solar modules are deposited directly onto a surface for mechanical support and patterned like flat panel displays to form a circuit, eliminating traditionally labor-intensive portions of the manufacturing process.
11. Oliver Beckel, Q-Cells
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