# RENEWABLE ENERGY

# Sector Definition

**RENEWABLE ENERGY IS PRODUCED FROM SOURCES THAT ARE NATURALLY REPLENISHING,** such as solar light, wind, waves, underground heat, surface water flows and biomass. The China Greentech Initiative focused on China's solar, wind and bioenergy markets.

## SOLAR ENERGY

Solar Energy is the conversion of the energy from the sun into thermal heat or electricity. The conversion into electricity can be achieved through the use of photovoltaic (PV) cells and solar thermal plants (also known as concentrated solar power or CSP). A photovoltaic cell is a device that converts light into direct current using the photo-electric effect. Building-integrated PV (BIPV) technologies incorporate solar PV materials into the building structure directly. Concentrated solar power technologies include concentrated PV and concentrated solar thermal, using lenses or mirrors to focus sunlight into a small beam to power steam turbines to generate electricity. Solar water heaters (SWH) transform solar energy directly to heat water.

## WIND POWER

Wind Power is the conversion of wind energy into electricity by wind turbines. This energy is mostly generated by wind farms, where many wind turbines are placed together in high wind areas, but can also be generated by stand-alone turbines. The generated electricity is either distributed over the electric power grid or stored before being consumed.

## BIOENERGY

Bioenergy is renewable energy extracted from a variety of materials collectively called biomass. Biomass consists of recently living organisms or their metabolic byproducts, including straw and crop residues, specifically grown energy crops such as sweet sorghum, jatropha and rapeseed, and waste from a range of sources, including food production. The four main bioenergy output types include bioelectricity, bioheat, biofuels and co-products. Bioelectricity is the generation of electricity from various forms of biomass mainly via boiler combustion. Bioheat is the conversion of biogas into heating for industrial and civil purposes. Biofuels are generated from biomass inputs (e.g. bioethanol from cassava or biodiesel from microalgae). Co-products solutions such as biomass pellets support both bioelectricity and bioheat applications, enhance burning efficiency, and improve biomass transportation and storage.

# Market Context

**CHINA'S DRAMATIC INDUSTRIALIZATION HAS LED TO SUBSTANTIAL GROWTH IN ENERGY DEMAND.** Total electricity consumption grew by more than five times from 1990 to 2007, while growing petrol consumption has made China the world's second largest oil consumer after the U.S.[1] An imbalance between demand and supply has led to a heavy reliance on imports of foreign oil, creating national security concerns.

Renewable Energy sources offer very attractive alternatives to conventional energy, with low environmental impacts and opportunities to take advantage of abundant natural resources:

- **SOLAR:** Two-thirds of China's land area enjoys over 2,200 radiation hours annually and has solar resources in excess of 500 KJ/cm$^2$/year (by comparison, Germany and Japan average only 400 KJ/cm$^2$/year and 450 KJ/cm$^2$/year respectively)[2]

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[1] *Economic Relations Between The United States and China, Fact Sheet, (Washington, DC, US: Bureau of Easen Asian and Pacific Affairs, 2006)*
[2] *Charles Bai, "Solar Energy Demand in China," (Rene Sola), 2*

- **WIND:** China also has abundant wind resources, which if fully tapped could generate at least as much electricity as the country's current total installed electrical capacity[3]

- **BIOENERGY:** In 2006, China had 300 million tons of coal equivalent (MTCE) biomass supply; [4] China's accumulated biomass supplies are projected to double in the next ten years and triple in the next 20 years, supporting expansion of the industry.

## SOLAR

China has abundant solar resources and use of these resources bring positive economic effects, promote energy security and reduce the environmental impacts of $CO_2$.

China currently has the world's largest solar PV and SWH production capacity, and the government has set ambitious installation targets to continue this trend. In spite of these positive market and resource considerations, current domestic market uptake of solar energy solutions remains limited, creating huge growth potential for these solutions in China.

Price competitiveness and conversion efficiency are key defining parameters in the solar industry. Solar energy solutions are currently not price competitive with other energy sources, although prices are falling and grid parity for Solar PV is expected within the next four to eight years (with some industry participants believing parity could happen within the next two years).[5]

The manufacturing process of solar PV technologies has a slightly larger carbon footprint than other renewable energy solutions, although the solar sector's carbon footprint is considerably smaller than traditional fossil fuel alternatives.

The market is home to many diffuse and competing technologies. As a result, there is competition among the different solar solutions to determine the most suitable and cost-effective technology to suit different applications.

## BENEFITS OF UTILIZING SOLAR ENERGY

Exploiting the market potential of solar energy in China creates many benefits, including leveraging a free and abundant resource supply, economic benefits through the growth of new markets, and energy security and environmental impact benefits.

China has vast solar resources. This includes cloudless weather, especially in the northern and western regions, long sunshine hours such that two-thirds of the country enjoys over 2,200 radiation hours annually and solar resources in excess of 500 KJ/cm$^2$/ year across 70% of the country.[6]

Use of solar has also had positive economic effects through the jobs the industry creates and the revenues it produces. Around 150,000 jobs are currently linked to the solar PV sector according to Mark Ding, president of SEMI China[7] and nearly 600,000 jobs were provided by the solar water heater sector in 2006.[8] Moreover, the SWH sector generated sales of 32 billion yuan (US$470 million) in 2007.[9]

From an energy security perspective, increasing use of solar energy reduces dependency on imported oil. Solar stand-alone power stations also provide a feasible energy solution for remote rural areas that do not have easy access to traditional energy sources.

Finally, increased use of solar energy will also reduce China's current consumption of coal, resulting in a positive environmental impact in terms of $CO_2$ emissions.

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[3] *Li Junfeng et al., 2007 China Wind Power Report (China Environmental Science Press, 2008)*
[4] *Energy Bureau of National Development and Reform Commission, Energy Research Institute of National Development and Reform Commission, China Renewable Energy Development Overview 2008 (Beijing, China: China Renewable Energy Scale-up Program, 2008), 14*
[5] *Dr. Zhengrong Shi of Suntech*
[6] *Charles Bai, "Solar Energy Demand in China," (Rene Sola), 2*
[7] *PVGroup, "Global Financial Crisis Compels China to Expand Domestic Solar Market," http://www.pvgroup.org/*
[8] *Worldwatch Institute, "China to Push Use of Solar Water Heaters," http://www.worldwatch.org/ (accessed on December 2, 2009)*
[9] *Asia Times Online, "China leads solar home revolution," http://www.atimes.com/ (accessed on December 2, 2009)*

## SOLAR MARKET POTENTIAL

China's utilization of solar energy in its primary energy mix, including both solar PV and SWH, has the potential to grow to 0.8% by 2020 from 0.01% in 2006.[10]

Currently, China has the world's largest solar PV production capacity and in 2007, China's PV cell production was 1,088 MWp (megawatt peak), accounting for approximately 27.2% of the total global output.[11] However, over 90% of China's solar PV cells and PV modules are exported, while China's domestic demand accounts for only 4% of total global PV installations.[12] The government is seeking to stimulate domestic demand through setting a 2010 target of 300 MW and upgrading the 2020 1.8 GW target to 20 GW. [13]

In addition, China is also the world leader in the SWH market for both production and installation, with annual production twice that of Europe and four times that of the U.S.[14] and total installed capacity of 90 million square meters or roughly 60% of the world total.[15]

In contrast, development of CSP technologies is still at an early stage in China while Spain and the U.S. are considered as world leaders in this technology. Over 5,800 MW of solar CSP projects are in planning stages worldwide, and the lion's share is expected to come only by 2012.[16] Chinese companies, such as Himin, have been investing in CSP research and development and promising opportunities are anticipated in this area for China.[17]

## SOLAR PROGRESS AND IMPEDIMENTS

Two key problems that solar energy solutions currently face are price competitiveness and conversion efficiency. At present, solar energy solutions are not yet competitive with other energy sources.[18] However, the trend is for lower crystalline silicon (c-Si) solar PV costs.[19] Manufacturers in China have been successful in reducing the production cost of solar PV cells that has contributed to a gradual decline in the price. It is estimated that by 2010, the electricity generation cost of solar PV systems has the potential to drop to below one yuan per kWh (0.15 $/kWh), reaching or approaching the cost of conventional power

*Fig. 1*: RENEWABLE AND TRADITIONAL ENERGY COSTS, *Cost per kWh to produce (US$)*


***Source:*** *Unlimited Natural Energy, "Cost Comparisons of Energy Supply Technologies," http://www.unenergy.org/ (accessed July 10, 2009)*

[10] *China Greentech Initiative analysis*
[11] *Bharat Book Bureau, "China Thin Film Solar Cell Market Report," http://www.bharatbook.com/ (accessed on October 31, 2009)*
[12] *Ibid*
[13] *China Daily, "China Hikes 2011 Power Target," http://www.chinadaily.com (accessed on July 8, 2009)*
[14] *Asia Times Online, "China leads solar home revolution," http://www.atimes.com/ (accessed on December 2, 2009)*
[15] *Worldwatch Institute, "China to Push Use of Solar Water Heaters," http://www.worldwatch.org/ (accessed on December 2, 2009)*
[16] *Global Concentrated Solar Power Markets and Strategies, 2007-2020 (Cambridge, MA USA: Emerging Energy Research, 2007)*
[17] *Expert interview with Himin*
[18] *Unlimited Natural Energy, "Cost Comparisons of Energy Supply Technologies," http://www.unenergy.org/ (accessed July 10, 2009)*
[19] *Arnulf Jäger-Waldau, PV Status Report 2008 (Ispra, Italy: Joint Research Center, European Commission, 2008), 47*

generation.[20] Suntech estimates that the industry is likely to reach a solar energy generation cost of one yuan/kWh or below by 2012.[21]

Solar companies strive to increase conversion efficiency – the percentage of power converted (from absorbed light to electrical energy) and collected when a solar cell is connected to an electrical circuit – in order to reduce cost and maximize space utilization. Conversion efficiency dictates the required size of installations and becomes increasingly important when two competing technologies have similar prices.

Due to a global drop in solar PV demand, analysts have dampened growth forecasts for 2009, but the long-term outlook in China remains positive. With the announcement of new government initiatives to boost green energy, existing capacity growth forecasts have become obsolete. Market projections for 2009 have suggested China will exceed its original 2020 target of 1,800 MW installed solar capacity, and reports now indicate the government is proposing a new target of 2 GW for 2011 and 20 GW for 2020 under the Renewable Energy Development Plan.[22,23] In addition, global BIPV installations are expecting strong growth. However, uncertainties over the costs of a distributed energy model still exist.

Although solar PV has a larger carbon footprint than wind and hydro energy, its footprint is much smaller than that of traditional energy sources such as coal. In addition, solar's carbon footprint is expected to fall as low as 15g $CO_2$/kWh due to technological improvements leading to manufacturing efficiency gains, reduced use of aluminum in mounting systems and higher rates of conversion efficiency. [24]

Meanwhile, recycling silicon from old solar panels is underdeveloped, and there is little information on costs and techniques. Concerns also exist regarding the high volumes of water consumed during the operation of CSP power plants, although the use of dry cooling systems rather than wet cooling systems, where possible, can mitigate this issue. Even though solar technologies are becoming cleaner, a perception of the negative environmental impact of the solar manufacturing process persists amongst consumers.

The overall positioning of Chinese companies upstream in the value chain leaves them vulnerable to industry shake-out.[25] Currently, Chinese companies are major producers of solar-grade polysilicon. As a result of polysilicon shortages and surging average selling price, aggressive capacity expansion occurred between 2006 and 2008 creating excess output and falling prices.[26] This oversupply caused the downfall of share prices of some Chinese solar stocks.

There is also a shortfall of skills downstream in the value chain, with little experience or expertise at solar forecasting, planning, installing or maintaining solar arrays in order to achieve high panel output efficiencies. This could limit the uptake and effectiveness of solar solutions and limit the impact of financing and government incentives, as high quality forecasting and planning is needed to design and install a solar array. However, with the expectation of rapid growth in demand in China, numerous companies are building capabilities in these downstream segments of the value chain and given the quick uptake of new skills by the Chinese labor market, this is likely to be a short-term situation.

## WIND

China's wind industry is small but growing rapidly, supported by abundant wind resources and strong government support. China has already surpassed its 2010 installation targets and upward revisions of these targets will ensure that wind remains a "hot" industry. However, systematic and efficient development of these resources remain limited.

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*[20]Ibid*
*[21]Dr. Zhengrong Shi of Suntech*
*[22]China.com, "PV Installation may expand to 20GW in 2020," http://www.china.com.cn/(accessed on July 7, 2009)*
*[23]China Daily, "China Hikes 2011 Power Target," www.chinadaily.com (accessed on July 8, 2009)*
*[24]Gareth Harrison, "Life Cycle Assessment of Renewable Energy Systems," (Presentation given at the Bath University, University of Edinburgh, UK, July 9,2008)*
*[25]According to a news report from SolarPlaza, many analysts predict that a global industry shakeout looms due to the global recession. They anticipate massive consolidation leaving likely leave only strong competitors standing.*
*[26]Expert interview*

Although China is exceptionally rich in wind resources, wind power currently represents a very small percentage of total energy generation. China is the fifth largest global producer of wind power and installed 6,300 MW of wind power capacity in 2008, the second largest newly added capacity in the world.[27] Even so, China's wind energy accounts for only 0.8% of total electricity generation capacity compared with 2% globally.[28,29]

Additionally, wind power is viewed as an important component of China's renewable energy sector development. As such, China's policies and incentives strongly support development of the domestic wind power equipment manufacturing industry and wind farm development by Chinese players.

However, significant impediments continue to hold back development of the wind power industry. Low quality wind generated power, limited adoption of adequate conversion technologies and insufficient financial incentives to improve grid connectivity all undermine the wind industry's power generation potential. Also, real and perceived quality issues for Chinese domestically manufactured turbines and components negatively impact wind farm efficiency and constrain export market opportunities.

## STRATEGIC BENEFITS

Wind is a sustainable and clean energy alternative to conventional energy, and China's wind power generation potential is well positioned to help satisfy the country's fast growing electricity needs.

It is a free and increasingly attractive energy source for China as it is currently cost competitive with all other energy sources, apart from coal. With advances in technology, wind could even challenge coal by 2020, particularly if a $CO_2$ tax is implemented. In addition, as wind power has zero emissions during generation, it has large carbon abatement potential.

The development of the wind industry creates new job opportunities throughout the value chain, including wind turbine generator (WTG) manufacturing and wind farm construction, maintenance and operation. Wind power employs approximately 25% more people than coal on a MWH basis.[30]

## WIND MARKET POTENTIAL

Wind energy has become increasingly attractive worldwide and China is one of the most significant markets, having doubled its total capacity in 2009 for the fourth year in a row.

While China has an abundance of onshore and offshore wind energy resources, the distribution of these resources pose a significant transmission challenge. Rich wind energy resources are distributed primarily along the southeast coastal regions, dry northwest regions and vast offshore areas. Coastal regions, which have the largest demand for power, have well-established power grids but limited usable land for wind energy development. In contrast, northwest regions have large areas suited for wind energy development but lack power grid coverage and voltage capacity.

The National Development and Reform Commission's (NDRC) target of five GW cumulative installed wind capacity by 2010 drastically underestimated actual growth of the market; said growth actually was achieved three years ahead of schedule.[31] Experts predict that the target of 30 GW of cumulative installed wind capacity by 2020 will be achieved by 2012, eight years ahead of schedule.[32] Noticing the rapid growth in the wind power industry, the NDRC is considering increasing its target for 2020 from 30 GW to 100 GW, more than the total global accumulated installed wind energy capacity at the end of 2007.[33]

*[27]Global Wind Energy Council et al., Global Wind Energy Outlook 2008 (October 2008)*
*[28]National Bureau of Statistics, "China Statistical Yearbook 2001-2007"*
*[29]China Greentech Initiative analysis*
*[30]National Wind Coordinating Collaborative, "Direct Job Creation from Wind Power," http://www.nationalwind.org/*
*[31]Global Wind Energy Council et al., Global Wind Energy Outlook 2008 (October 2008)*
*[32]Ibid*
*[33]Ibid*

## COMPETITION IN THE WIND INDUSTRY

State-owned wind farm developers will continue to be the largest participants in the wind farm market, but their domination may be challenged as competitive pressures drive the market. An increasing number of private domestic and international developers are actively looking for opportunities to participate in the market and their market share may rise in the long-term, however SOEs are likely to continue to play a major role for the foreseeable future.

## MAJOR WIND INDUSTRY IMPEDIMENTS

Although trade policies facilitated initial wind development, they have led to some confusing incentives and impediments. Investors are selected through public tender by the government and generally the bidder who offers the lowest price wins the bid. However, state-owned enterprises (SOE) often bid the lowest prices even if it is not cost effective for them to do so. As a result, private and international investors have been unable to compete as the bids are too low for reasonable returns given the level of risk. This has resulted in SOEs holding approximately 88% of the market.

China was the world's second-largest buyer of wind turbines in 2008; however, around 30% of its wind power assets remained not in use, as they were not connected to a transmission grid.[34] Some experts suggest that this could be because Chinese power companies bought wind assets to satisfy, on paper, the government's requirement of increasing renewable energy capacity.[35]

Chinese companies enjoy preferential treatment over foreign participants in terms of access to capital, installation restrictions and certified emission reductions (CERs).[36] Domestic companies also have greater access to domestic commercial banks. Finally, local knowledge is important in navigating project approval procedures. The permits issued by the appropriate governing bodies do not guarantee the final approval to set up wind farms in the desired location.

Domestic wind power generation remains a nascent industry with limited operational experience, thus lacking the ability to create opportunities that will drive improved efficiency and enhancements. Most domestic component providers have less experience, compared to their foreign counterparts who often have much longer experience operating in the industry.

Some additional impediments include the changeability of wind strength dependent on time of day and temperature, lack of financial incentives for grid companies to connect to wind power plants, as well as the slow adoption rate of conversion technologies due to budget constraints and lack of awareness. However, there are technologies that can solve the intermittent issues of wind power and remove the grid's wind power tolerance constraints.

## BIOENERGY

Biomass resources in China offer potential for significant growth of the bioenergy industry. Bioenergy resources in China are rich, diversified and widely distributed. China's potential biomass sources include approximately 3.7 million metric tons of suitable agriculture waste, 1.2 billion metric tons of forestry residue and 150 million metric tons of municipal solid waste (MSW).[37] In 2006, China had 300 million tons coal equivalent (MTCE) of biomass supply; this rate is projected to grow at 4% CAGR over the next 20 years.[38,39]

The government has set ambitious bioenergy generation targets for 2010 and 2020, aiming to double the 2006 figure of total bioenergy generation by 2010, and increasing capacity by up to six times by 2020.[40,41] However, government efforts to

[34] *Forbes, "Weaknesses in Chinese wind power," http://www.forbes.com/ (accessed on December 3, 2009)*
[35] *Ibid*
[36] *Certified emission reductions are climate or carbon credits issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects under the rules of the Kyoto Protocol.*
[37] *Energy Bureau of National Development and Reform Commission, Energy Research Institute of National Development and Reform Commission, China Renewable Energy Development Overview 2008 (Beijing, China: China Renewable Energy Scale-up Program, 2008), 14*
[38] *Ibid*
[39] *China Greentech Initiative analysis*
[40] 国家发展和改革委员会，可再生能源中长期发展规划"，*2005*年*10*月*18*日*[National Development and Reform Commission, "Medium and Long –Term Development Plan for Renewable Energy in China,"October 18, 2005] 2*
[41] *Ibid*

stimulate growth of the bioenergy industry have led to the majority of the market being held by SOEs, as subsidies have been insufficient for private operators to compete.

### STRATEGIC BENEFITS

Development of bioenergy offers several strategic benefits to China. The bioenergy industry has the potential to create new jobs and generate new income streams in rural areas where most biomass resources are located. Bioenergy generation reduces dependence on conventional energy sources and the use of biomass and waste for energy generation has significant environmental benefits.

As the vast majority of biomass resources are located in rural areas, the development of the bioenergy industry has the potential to create millions of new jobs and increase the incomes of hundreds of millions of farmers. It is estimated that this sector may generate income for the central and local governments of up to 100 billion yuan per year.[42]

Development of the bioenergy industry will also help improve national security as it reduces China's dependency on oil imports. Finally, biomass utilization has significant positive environmental impact, including the reduction of agricultural residue and utilization of animal excrement, in addition to significant commercial benefits if carbon regulations, such as carbon taxes, are implemented.

### BIOMASS MARKET POTENTIAL

Bioenergy generation accounted for 12 MTCE in 2006, most of it generated in the form of biofuels, electricity and bio-based gas from biomass.[43] At the beginning of the 11th Five Year Guidelines period, the government set forecasts for bioenergy in the form of tons of coal equivalent (TCE).[44,45] In order to increase the demand for and supply of bioenergy, the government has set targets to double the 2006 figure of total bioenergy generation by 2010 and increase capacity by up to 14 times by 2020.[46, 47]

### MAJOR INDUSTRY IMPEDIMENTS

In contrast to wind and solar, biomass resources have owners. As a consequence, rising demand has led to sky-rocketing input costs for bioenergy. Bioenergy suppliers regard securing sustainable feedstock supply as the key success factor for operation. The development of the bioenergy industry, along with a generally low elasticity of demand for biomass, has transformed "costly wastes" into an expensive commodity. Biomass now sells at approximately 300 yuan/metric tons, after reaching a peak price of around 400 yuan/metric tons.[48]

In addition, as a result of seasonal and storage constraints, securing and storing continuous feedstock supply is a significant challenge for the industry. For example, sweet sorghum loses most of its sugar content, an important ingredient in ethanol production, within a few days of harvest thus reducing its worth.

As a consequence of these challenges, most bioenergy power plants today are experiencing difficulties, despite government support. In order to enable bioenergy suppliers to survive without considerable financial support from the government, as well as to encourage further private investment, it is necessary to develop more efficient and cost effective technologies.

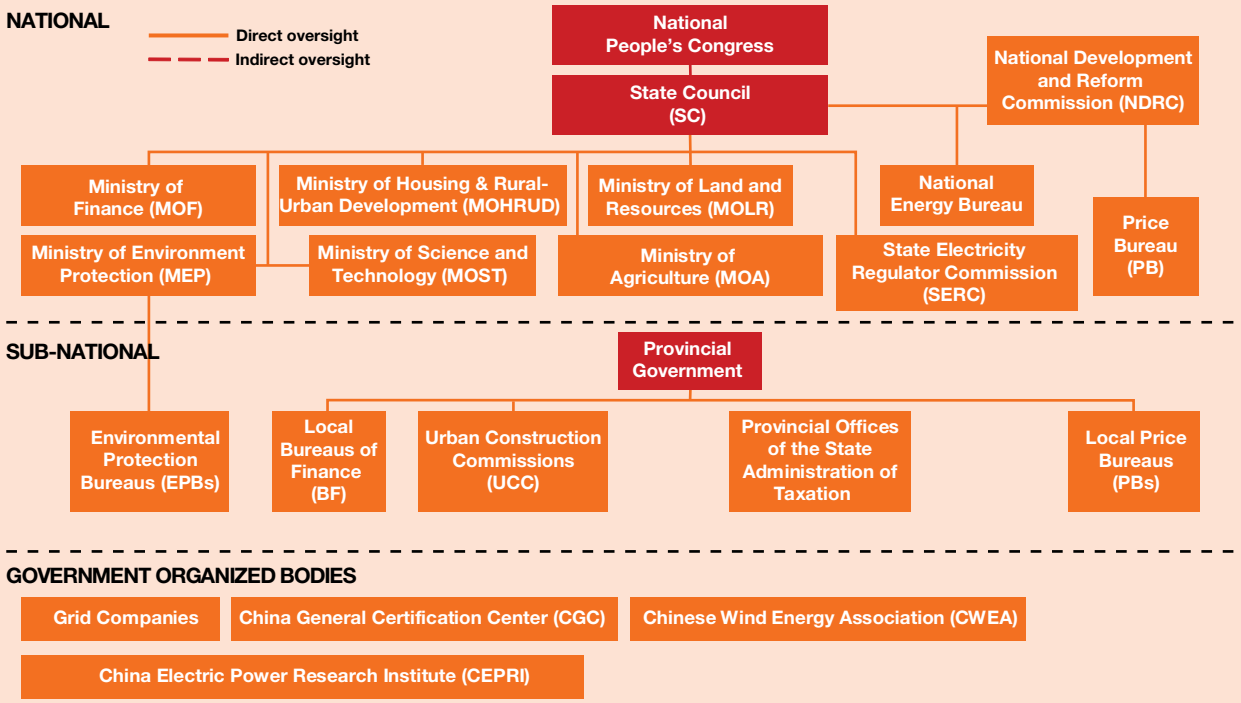
Some of the development setbacks stem from an absence of national standards for biomass and transparent market data. Currently, bioenergy operators are forced to set their own resource standards based on experience. This has resulted in an over estimation of available resources and an undervaluing of biomass.

## Regulatory Response

**CHINA IS FOCUSED ON MITIGATING THE IMPACT OF CLIMATE CHANGE.** China's National

[42] *Novozymes, Bioethanol and the Need for Sustainable Energy -A Contribution to the Debate (Copenhagen, Denmark: Novozynes)*
[43] 国家发展和改革委员会，可再生能源发展"十一五"规划"，*2005年10月18日[National Development and Reform Commission, "Renewable Development in 11th Five Year Plan,"October 18, 2005]*
[44] 中华人民共和国发展和改革委员会
[45] *Ibid*
[46] *Ibid*
[47] *Ibid*
[48] *Expert interview*

*Fig.2*: INSTITUTIONAL ARRANGEMENTS FOR RENEWABLE ENERGY




Climate Change Program (June 2007) outlines the country's strategic priorities for addressing climate change and the key policies that need to be developed. This was the first such plan issued by a developing country to moderate greenhouse gas emissions and adapt to changing environmental conditions.[49]

Recognizing the dual need to both address climate change and improve energy security, China has, under its Renewable Energy Law (2005) and subsequent policies, put in place numerous regulations, incentives and subsidies to support the utilization of renewable energy. As directed by China's Medium and Long-Term Development Plan for Renewable Energy (2007-2020), China's power generators are working to build up non-hydro renewable energy generation capacity so that it comprises 3% of their total energy mix by 2010 and 8% by 2020.[50]

Numerous regulatory agencies are involved in the management of China's renewable energy resources.[51,52]

Twelve key national regulatory entities with dedicated resources have responsibility and accountability for renewable energy policy development, and almost every major national administrative body has an equivalent at local levels that reports directly to provincial governments.

China's desire to increase the use of renewable energy has supported the development of a wide range of subsidies to encourage investment in the sector, including projects to build access roads and electricity transmission infrastructure, tariff and VAT rebate programs for imports of parts and raw materials, and direct subsidies to renewable energy plant owners to compensate for losses. These policies, which have supported the growth of domestic renewable energy companies, have, however, also prompted some foreign companies to wonder whether the evolution of local conditions will allow them to continue to participate in these markets.

[49] *National Development and Reform Commission (NDRC), National Climate Change Programme, (Beijing: NDRC, June 2007)*
[50] *中国国家发展和改革委员会, 可再生能源中长期发展规划,2007年8月, [China Climate Change Info-Net, Medium and Long-Term Plan for Renewable Energy Development (2007-2020)], (Beijing, China: National Development and Reform Commission, August, 2007)*
[51] *China Greentech Initiative Analysis*
[52] *NDRC, "National Development and Reform Commission," http://en.ndrc.gov.cn/ (accessed on July 16,2009)*

## SOLAR

In the solar sector, the government has been proactive in providing incentives and subsidies to stimulate the domestic industry. Aspects of the Renewable Energy Law and the Long-term Development Plan (which acts as the implementation plan for Renewable Energy Law), as well as other laws and regulations which are specific to the solar industry, all support growth of the sector. Examples include a mandate for provincial governments to develop renewable energy feed-in tariffs and quotas for the purchase of renewable energy within their locality; solar incentives in the 2009 stimulus package; nascent solar building codes; trial provincial public benefit funds; electric tariff reform; and the introduction of related policies in order to provide development guidance.

## SUCCESSFUL SUPPORTING POLICIES AND PROGRESS

In practice, the effectiveness of the Renewable Energy Law is restricted by a lack of transparency and consistency in its application. For example, the Law (Article 14) states that grid companies must buy grid-connected renewable power where an administrative license has been obtained and must pay grid connection expenses (Article 21).[53] However, grid companies often use technical reasons for not complying with their grid connection obligations,[54] transmission networks are not technically able to support large-scale renewable energy facilities and there is limited training for grid controllers with regards to management of this kind of electricity production.

Another problem exists with price setting and bidding. The law states that electricity prices need to be set on a project-by-project basis, either by feed-in tariff or concessionary bidding. This results in uncertainty over whether or not the project will be approved, as well as whether or not the feed-in tariff will be profitable. In reality bidding activity sometimes has been opportunistic and unsustainable as developers chase idiosyncratic tariff benchmarks. For example, in August 2008, the NDRC approved a four yuan/kWh tariff for an Inner Mongolia-based project, but a recent Dunhuang project announced its tariffs at a much lower rate of 1.09 yuan/kWh.[55] One possible solution to this would be to introduce predictable and consistent feed-in tariffs, as well as tax incentives.

In contrast, the green portion of China's stimulus package is regarded as very positive policy support for the renewable energy industry. Although only 210 billion yuan (US$30 billion) of the four trillion yuan (US$586 billion) package is directly earmarked for green investments, HSBC estimates that US$221 billion has green features, including grid and infrastructure investments, making this the largest green stimulus package in the world.[56]

However, as with the Renewable Energy Law, the effectiveness of these measures will depend on ensuring sufficient detail and transparency to remove uncertainties and improve spending quality.

Provincial governments are also playing a central role in introducing specific measures to incentivize solar uptake, although existing provincial regulation can

### JIANGSU PROVINCIAL GOVERNMENT HAS IMPLEMENTED A NUMBER OF SUCCESSFUL INCENTIVE PROGRAMS

Jiangsu Province is home to leading Chinese solar PV manufacturers and in 2008 accounted for 1.58 GW of China's 2.54 GW PV production capacity. In response to the 2006 Renewable Energy Law, incentives were announced for solar projects with a 240 MW cap. The Jiangsu Development and Reform Committee set ambitious PV installation targets of 10 MW in 2009, 50 MW in 2010, 200 MW in 2011 and considered an annual PV fund of one billion yuan, potentially for feed-in tariffs, from 2009-2011. This would translate to a 200-250 MW market in Jiangsu alone (the national target for 2010 is only 300 MW). The new provincial energy plan includes annual targets by 2011 for production of 10 GW solar cells and modules to generate 350 billion yuan in revenue.

*Source: 1. JLM Pacific Epoch, "Jiangsu Targets RMB 450B From Clean Energy," http://www.jlmpacificepoch.com/ (accessed on July 14, 2009)*
*2. Green Leap Forward, "Jiangsu Kicks Off Domestic Solar Market Race with Provincial Subsidies," http://greenleapforward.com/ (accessed on July 14, 2009)*

[53] *China Climate Change Net-Info, "The Renewable Energy Law of the People's Republic of China," http://www.ccchina.gov.cn/ (accessed on July 20, 2009)*
[54] *EU Chambers of Commerce, Energy Working Group ( Beijing, China, EU Chambers of Commerce,2008), 178-9*
[55] *The Green Leap Forward, "Dawn of a New Era: The Gansu Solar Concession and Landmark Solar Roofs Program, "http://greenleapforward.com/ (accessed on July 16, 2009)*
[56] *Nick Robins, et al., A Climate for Recovery: The Colour of Stimulus Goes Green (HSBC, February 25, 2009)*

sometimes be inconsistent and sporadic. In Inner Mongolia, the government has announced a planned 1:1 ratio for central and local solar energy subsidies, but results are yet to be seen.[57] In Qinghai, the government uses 5-10% of its annual budget to fund solar projects.[58] This includes a positive tax policy for related solar businesses as well as plans for a one GW crystalline silicon (c-Si) PV and amorphous silicon (a-Si) thin film PV solar plant in the Qaidam Basin.[59] In February 2009, Yunnan DingXing New Energy Development Co. signed an agreement to build the largest solar PV power plant in Yunnan with four billion yuan total joint investment and 360MW completed capacity.[60] The Shaanxi provincial government, the Shizuishan city government, Ningxia Province, the Qinghai provincial government and the Panzhihua city government, Sichuan Province are other examples of new city and provincial-level governments committed to driving growth in the solar industry.[61]

## WIND

While central government policies have been critical to the development of China's wind industry, there remains room for further enhancements.

### KEY OBSERVATIONS

Regulatory instruments are essential for resolving key wind industry impediments. Although the government provides some guidance and restrictions to address the impediments, many hurdles remain in execution.

Key challenges include an inadequate market mechanism where low bidding prices focus on installation targets rather than power generation, resulting in confusing incentives, expensive, nascent wind technologies, quality concerns for domestic components, high infrastructure costs and renewable energy access limitations to the grid.

Potential regulatory solutions include raising funds from conventional energy SOEs via taxation to support wind development, friendly and transparent cooperation between government and business, and the establishment of generation targets instead of installation targets. Potential technology solutions include certification enforcement. Potential grid-related solutions include total purchase enforcement and a more active government role in infrastructure building and in the provision of clearer and more structured development guidance.

### CURRENT SITUATION

The government supports domestic wind turbine and component manufacturing through fiscal incentives and regulations favouring local companies. For example, all new wind power projects are required to have at least 70% local Chinese made components.[62] Grid companies are mandated to purchase all electricity generated, and the government guarantees a fixed price for the electricity (30,000 full load hours) in the first operational stage of a project, after which the average market price for electricity is used.[63] For wind turbine generator suppliers there is a 50% discount on value added taxes (VAT) payable in China, and a tariff and VAT rebate program for imports of parts and raw materials used in the manufacture of wind turbines which became effective January 1, 2008.[64] Further, VAT on domestically produced generators is refunded after two years.[65] Finally, a new tariff on imported wind turbines of less than 2.5 MW came into effect on May 1, 2008.[66] There are also subsidies available: Chinese controlled turbine manufacturers are eligible for a payout of 600 yuan per kW for the first 50 units they produce for any new turbine with capacity of 1 MW or more.[67]

Despite this political support, implementation of incentives and regulations remains difficult. In the first instance, there is insufficient enforcement of policies and grid development. While the grid company is mandated to purchase wind

[57] 中华人民共和国住房和城乡建设部,"中华人民共和国住房和城乡建设部,"[*Ministry of Housing and Urban-Rural Development of People's Repulic of China, " MOHURD"] http://www.cin.gov.cn/ (accessed on July 12, 2009)*
[58] *Ibid*
[59] *Ibid*
[60] *Ibid*
[61] *Ibid*
[62] *Renewable Energy World, "China's Wind Power Industry: Localizing Equipment Manufacturing," http://www.renewableenergyworld.com/ (accessed on February 10, 2009)*
[63] *Ibid*
[64] *Ibid*
[65] *Ibid*
[66] *Ibid*
[67] *Ibid*

power, the lack of a fully developed grid makes this difficult. Also, pricing is decided on a project-by-project basis, and prices high enough to be acceptable to private domestic and foreign wind farm developers have not yet been established. There is also a strong focus on installed capacity rather than electricity generation. This misaligns incentives and has resulted in underperforming wind farms. Also, the failure to create a more standardized approach for connecting wind farms to national electricity grids threatens to slow the growth of wind energy applications. Finally, international project developers are not entitled to apply for Clean Development Mechanism[68] credits in China unless they form a joint venture with a domestic Chinese partner in which they can only hold a minority share (less than 50%).

### INTERNATIONAL COMPARISON

International practices can provide reference for policy makers in China to help drive successful wind development. First, the implementation of nationwide industry quality standards requires the government's immediate attention. Key issues to be addressed include certification for turbine design, manufacturing evaluations, foundations, type testing and type characteristic measurements, and implementation and enforcement to ensure that licensed turbines have valid certification.

Other areas that need to be addressed include quality concerns with respect to domestic components (as the performance of locally manufactured wind turbines tends to be lower than that of international companies), grid connectivity (since the unsustainable wind power supply due to wind turbine generators' frequent break-downs places limitations on the amount of wind power that the grid can guarantee) and adaptation of international best practices in a scope that extends beyond turbine component manufacturing.

## BIOENERGY

For bioenergy, the government has laid down a general regulatory framework to guide and manage the sector's overall development.

### KEY OBSERVATIONS

Guidance and regulations are required to deal with impediments affecting the bioenergy industry. Challenges include the ability to secure sustainable supplies of resources, managing resource price risk and high up front costs for technology.

Possible regulatory solutions could include setting up and enforcing national-level resource standards, providing plans for securing feedstock supply and regulation of feedstock price, providing more financial incentives such as subsidies and tax exemptions to encourage R&D and ensuring that total output purchase schemes and mandatory consumption requirements work as they should.

A number of subsidies currently exist for bioelectricity, bioheat, biomass and bioethanol. However, these may not be sufficient or enforced effectively enough to ensure successful commercial operations across the bioenergy value chain. First, a lack of resource standards has led to an undervalued bioenergy price. Further, biomass prices have been sky-rocketing as a result of increasing demand, a factor which has forced many power plants to shut down. In general, fiscal policies lack detailed implementation and enforcement guidance and tax exemptions have created uncertainties for investors and hindered development. For example, electricity tariffs and subsidies are still insufficient to ensure commercial operation of biomass power plants, especially as those in central and west China have very low local electricity tariffs.

Although the government has imposed mandatory electricity purchase schemes to secure demand, these schemes have not been rigorously enforced. According to regulations, grid companies should purchase electricity generated by biomass power plants without any reservation and the electricity network was to be built and managed by the grid companies. However, in reality, the grid often lacks financial incentives for connection, meaning that this aspect is not always implemented properly.

Support from the Renewable Energy Fund, in the form of interest-free or

[68] *Clean Development Mechanism (CDM) is a mechanism by which countries that are signatories to the Kyoto Protocol can invest in emission reduction projects in developing countries instead of implementing similar projects in-country.*

discounted loans, has been made available to finance a number of biofuel research and development activities. The government has also engaged with laboratories, universities and businesses to collaboratively develop appropriate technologies that could become commercially viable.

### INTERNATIONAL COMPARISON

Practices abroad may provide reference for policy makers in China to help drive successful bioenergy development. In particular, China can look to the U.S. and Europe for examples of successful bioenergy projects. Meanwhile, the government can be very effective in supporting the industry through the implementation of nationwide industry quality standards, particularly for bioelectricity and biodiesel.

## Existing and Emerging Solutions

**THE CHINA GREENTECH INITIATIVE EVALUATED OVER 35 RENEWABLE ENERGY SOLUTIONS.** These solutions are split nearly equally across three segments: Solar, Wind and

*Fig. 3:* RENEWABLE ENERGY SOLUTIONS

| | |
|---|---|
| **SOLAR - PHOTOVOLTAIC SOLUTIONS** | ■ **Amorphous Silicon Thin Film Photovoltaic Cell (a-Si PV)**<br>Type of thin film solar cell based on amorphous silicon chemical compound<br>■ **Building Integrated Photovoltaic (BIPV)**<br>Application of solar photovoltaic materials, whether crystalline or thin film, into actual building structures, normally replacing conventional building materials in parts of the building envelope such as the roof, skylights or facades<br>■ **Cadmium Telluride Thin Film Photovoltaic Cell (CdTe PV)**<br>Type of thin film solar cell based on cadmium telluride chemical compound<br>■ **CIGS Thin Film Photovoltaic Cell (CIGS PV)**<br>Type of thin film solar cell based on copper iridium gallium selenide chemical compound<br>■ **Crystalline Silicon Photovoltaic Cell (cSi PV)**<br>Type of solar cell made from a single crystal or a polycrystalline slice of silicon that was the first type to be widely commercialized |
| **SOLAR – CONCENTRATED SOLAR POWER SOLUTIONS** | ■ **Concentrated Photovoltaic (CPV)**<br>Devices that concentrate sunlight onto photovoltaic surfaces to produce electricity<br>■ **Fresnel Mirror**<br>Solar thermal energy collector that consists of a series of long, narrow, slightly curved mirrors that focus the light onto linear receivers positioned above the mirrors to be eventually converted into electricity<br>■ **Parabolic Dish Stirling Engine**<br>Device that concentrates sunlight at a single focal point via a parabolic dish to produce electricity that can track the sun along two axes by automatically adjusting the direction of the dish<br>■ **Parabolic Trough**<br>Solar thermal energy collector that consists of a long parabolic mirror and a Dewar tube running its length at the focal point that absorbs energy from the sunlight which is converted into electricity<br>■ **Power Towers**<br>Type of solar power plant that uses a tower and a high heat capacity component to receive the sunlight focused by an array of flat movable mirrors and convert it into electricty |
| **SOLAR - WATER HEATER SOLUTION** | ■ **Solar Water Heater (SWH)**<br>System that heats water by absorbing energy from sunlight, normally consisting of solar thermal collectors, fluid systems to transport the heat and a water tank where water is heated and stored |
| **WIND COMPONENT MANUFACTURING SOLUTIONS** | ■ **Offgrid / <1 MW/Horizontal**<br>Horizontal wind turbine with under 1 MW capacity that generates electricity to be used locally and does not require connection to the power grid<br>■ **Offgrid / <1 MW/Vertical**<br>Vertical wind turbine with under 1 MW capacity that generates electricity to be used locally and does not require connection to the power grid<br>■ **Ongrid / 1-3 MW/Onshore** |

| | |
|---|---|
| | Horizontal wind turbine with capacity between 1 and 3 MW that is located onshore and feeds the generated electricity onto the power grid<br>■ **Ongrid / >3 MW/Onshore**<br>Horizontal wind turbine with capacity over 3 MW that is located onshore and feeds the generated electricity onto the power grid<br>■ **Ongrid / >3 MW/Offshore**<br>Horizontal wind turbine with capacity over 3 MW that is located offshore and feeds the generated electricity onto the power grid |
| **WIND DEVELOPMENT SOLUTIONS** | ■ **Micrositing**<br>Consideration of an array of factors related to wind flow, terrain, local power demand, environmental and land-use issues carried out during site selection for wind turbines to maximize wind farm's operational efficiency and economics<br>■ **Wind Assessment**<br>Process of assessing the quality of wind at a particular location for the purpose of estimating future potential energy production of a wind farm if it were to be installed at that location |
| **WIND MAINTENANCE SOLUTIONS** | ■ **Control System**<br>System that monitors and controls the behavior of other devices or systems to ensure optimal operation of the wind turbine<br>■ **Conversion Technology**<br>Device that converts electricity received from a set of wind turbines to the standard required by the power grid before feeding the electricity onto the grid<br>■ **Maintenance**<br>Set of inspections, repairs or modifications of individual wind turbines or wind farms to ensure optimal operation<br>■ **Standard Operating Procedures (SOPs)**<br>Set of prescriptions for employees, often mandated, on how to execute specific tasks or how to react to circumstances in the most efficient and effective ways |
| **WIND ENERGY STORAGE SOLUTIONS** | ■ **Battery Storage**<br>Electrochemical cells that can be used to store energy and be charged using electricity and discharged to produce electricity<br>■ **Compressed Air Energy Storage (CAES)**<br>System that can store energy by compressing air in a compartment, such as airtight underground cavern, and then generate electricity by releasing the air from storage through a combustion turbine<br>■ **Pumped Hydro Storage**<br>Method under which energy can be stored by pumping the water to a high reservoir and then released back into a lower reservoir to generate electricity when passing through power generating turbines |
| **BIOENERGY - ELECTRICITY SOLUTIONS** | ■ **Biomass Co-Firing**<br>Combining biomass with coal to be burned to generate electricity at a power plant<br>■ **Biomass Combustion**<br>Burning of biomass to generate electricity at a power plant |
| **BIOENERGY - HEAT SOLUTIONS** | ■ **Civil Heat**<br>Burning of biomass to generate heat to be used for civil purposes<br>■ **Industrial Heat**<br>Burning of biomass to generate heat to be used for industrial purposes |
| **BIOENERGY - FUELS SOLUTIONS** | ■ **Cassava Bioethanol**<br>Bioethanol produced from cassava crop<br>■ **Cellulosic Bioethanol**<br>Bioethanol produced from wood, grasses or other plants<br>■ **Jatropha Diesel**<br>Biodiesel produced from jatropha crop<br>■ **Microalgae Diesel**<br>Diesel produced from microalgae,photosynthetic organisms that can be farmed in water<br>■ **Sweet Sorghum Bioethanol**<br>Bioethanol produced from sweet sorghum crop<br>■ **Waste Vegetable Oil Biodiesel**<br>Biodiesel produced from waste vegetable oil |

Bioenergy. While the Renewable Energy sector is defined to include hydroelectricity, wave and geothermal segments, these solutions are not covered in this report.

Due to the abundance of solutions in this sector, they have been grouped into ten areas to facilitate analysis. The Solar segment includes three solution areas: Photovoltaic, Concentrating and Water Heaters. Wind Power encompasses four areas: Turbines, Development, Maintenance and Energy Storage. The three Bioenergy solution areas are: Electricity, Heat and Fuels.

## SOLUTIONS SCREENING AND PRIORITY SOLUTIONS

In order to compare solutions (see Figure 3) across these areas, two key criteria were used: environmental impact potential and overall commercial potential.

Environmental impact potential focuses on operational negative impact abatement of the primary pollutant (e.g. $CO_2$, $SO_x$, COD, landfill) or decreases in resource intensity (e.g. energy, water, raw material). It is measured on a unit basis (e.g. negative environmental impact abatement achieved in the process of generating one MW of electricity or delivering one unit of benefit).

Commercialization potential refers to the potential of the solution or technology to successfully penetrate the market without subsidies or incentives. The criterion considers technological maturity in short to medium-term, favorable economics (i.e. financial benefits greater than costs at net present value) and large addressable market. Commercialization potential is not influenced by the regulatory environment or government incentives.

## SOLUTIONS EVALUATION FRAMEWORK

The Solution Evaluation Framework (SEF) was developed to assess solutions in a comprehensive, consistent, rigorous and flexible manner. It provides a structure in which to capture relevant available qualitative and quantitative information, apply judgment in a structured way and compare results both within and across sectors.

The SEF evaluates solutions across four dimensions: unit environmental impact potential, solution attractiveness, addressable market size and market accessibility. The last three criteria collectively represent the overall commercial potential of a given solution in China. Solutions were evaluated according to three time periods: Short (under one year), Medium (1-5 years) and Long (5-10 years).

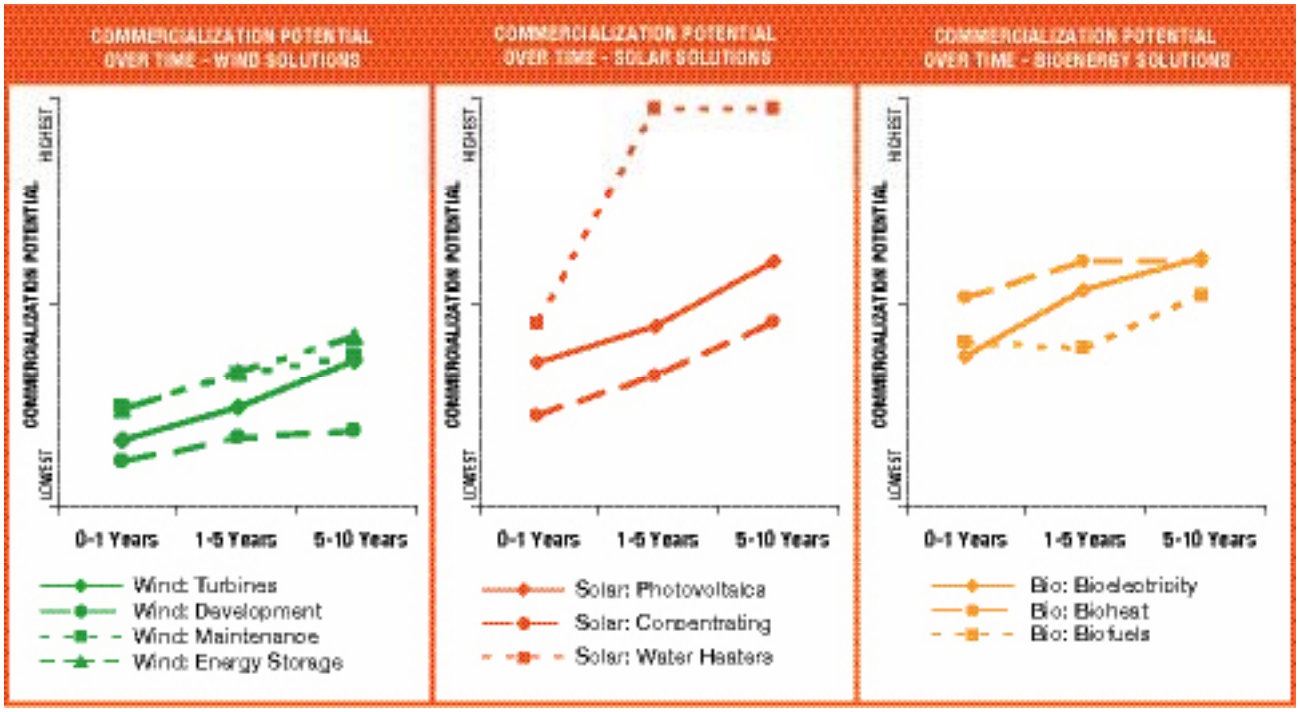
*For more detailed information on the Solution Evaluation Framework, please refer to the Solutions chapter of this report.*

**RENEWABLE ENERGY SOLUTIONS EVALUATION SUMMARY**

| WIND SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL | SOLAR SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL | BIOENERGY SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL |
|---|---|---|---|---|---|
| **WIND - TURBINES** | | **SOLAR - PHOTOVOLTAICS** | | **BIO - ELECTRICITY** | |
| Offgrid / <1MW / Horizontal | ● | Crystalline Silicon PV | ● | Biomass Combustion | ● |
| Offgrid / <1MW / Vertical | ● | Thin Film PV - Amorphous Silicon | ● | Biomass Co-Firing | ◑ |
| Ongrid / 1-3 MW / Onshore | ● | Thin Film PV - Cadmium Telluride | ● | **BIO - HEAT** | |
| Ongrid / >3 MW / Onshore | ● | Thin Film PV - CIGS | ● | Industrial Heat | ● |
| Ongrid / >3 MW / Offshore | ● | Building-Intergrated PV | ● | Civil Heat | ● |
| **WIND - DEVELOPMENT** | | **SOLAR - CONCENTRATING** | | **BIO - FUELS** | |
| Micrositing | ◑ | **Parabolic Trough** | ● | **Sweet Sorghum (ethanol)** | ● |
| Wind Assessment | ◑ | **Fresnel Mirror** | ● | **Cassava (ethanol)** | ● |

**RENEWABLE ENERGY SOLUTIONS EVALUATION SUMMARY CONTINUED...**

| WIND SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL | SOLAR SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL | BIOENERGY SOLUTION | UNIT ENVIRONMENTAL IMPACT POTENTIAL |
|---|---|---|---|---|---|
| **WIND - MAINTENANCE** | | Power Towers | ● | Cellulose (ethanol) | ● |
| Control Systems | ◔ | **Parabolic Dish -Stirling Engine** | ● | **Waste Vegetable Oil (diesel)** | ● |
| Maintenance | ◔ | **Concentrating PV** | ● | **Jatropha (diesel)** | ● |
| Standard Operating Procedures (SOPs) | ◔ | | | **Microalgae (diesel)** | ● |
| Conversion Technology | ◕ | | | | |
| **WIND - ENERGY STORAGE** | | **SOLAR WATER HEATERS** | | | |
| Compressed Air Storage | ● | Solar Water Heater | ● | | |
| Battery Storage | ● | | | **LEGEND** | |
| Pumped Hydro Storage | ● | | | Unit environmental impact potential of solutions: | |
| | | | | ● = More than 40% ○ = Less than 10% | |




*Commercialization potential is a product of average addressable market size, solution attractiveness and market accessibility for all solutions within each displayed category.*

## SOLUTION AREA COMPARISON

Most renewable energy solutions score high for environmental impact potential since renewable energy generation produces zero or minimal greenhouse gas emissions, a substantial advantage over conventional generation. Within certain renewable energy market segments, however, there are environmental impact differences (e.g. the greater $CO_2$ abatement potential of cellulosic biofuels compared to first generation biofuels). In addition, there are several individual renewable energy solutions which have life cycle environmental concerns due to the resources used or waste generated in their manufacturing, maintenance or disposal.

With respect to commercial potential, solar water heaters, wind energy storage solutions and biofuel solutions were found to have the highest average 10-year commercialization potential in their respective segments of China's renewable energy landscape. Across renewable energy segments, many wind solutions, particularly those related to the development, operation and maintenance of wind farms, were found to be more attractive to adopters than many bioenergy or solar solutions. This is partially due to the relative technological maturity and attractive

economics, driven by the potential to improve operating efficiency, of these wind solutions. At the same time, the bioenergy and solar solutions analyzed were found to have significantly larger addressable market sizes due to the type of solutions selected, which in aggregate resulted in higher evaluations of overall commercial potential for these two segments.

## SOLAR

### PHOTOVOLTAIC SOLUTIONS

Solar PV technologies scored high in their environmental impact potential since they do not emit $CO_2$ during electricity generation. However, further technological development is needed to improve their energy-intensive manufacturing process.

Technological improvements that drive down costs are expected to drive the commercialization potential of PVs. The low levelized cost of electricity (LCOE) and high conversion efficiency potential of newer PV solutions such as Cadmium Telluride Thin (CdTe) Film PV cells will also drive the future growth of these technologies.

### CONCENTRATED SOLAR POWER (CSP) SOLUTIONS

CSP technologies scored high in their environmental impact potential since they do not emit $CO_2$ during electricity generation. However, it should be noted that large quantities of water are required to cool and maintain most CSP technology. The initial manufacturing process is also resource-intensive.

*Fig. 4*: PHOTOVOLTAIC SOLUTIONS EVALUATION DYNAMICS

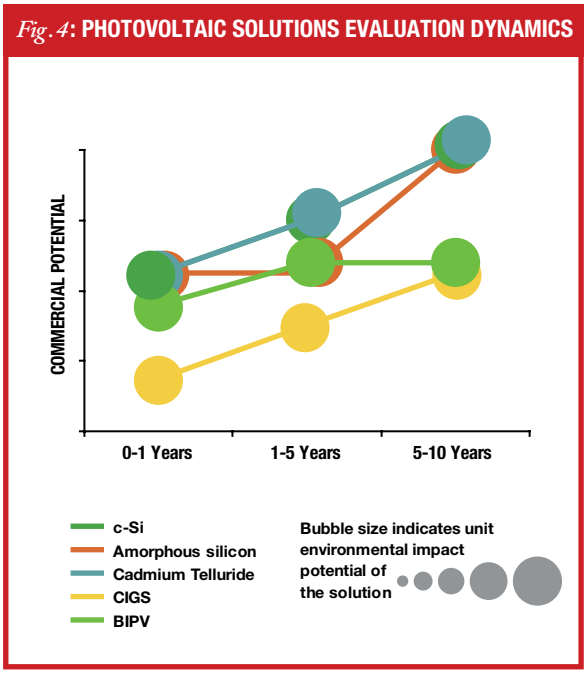
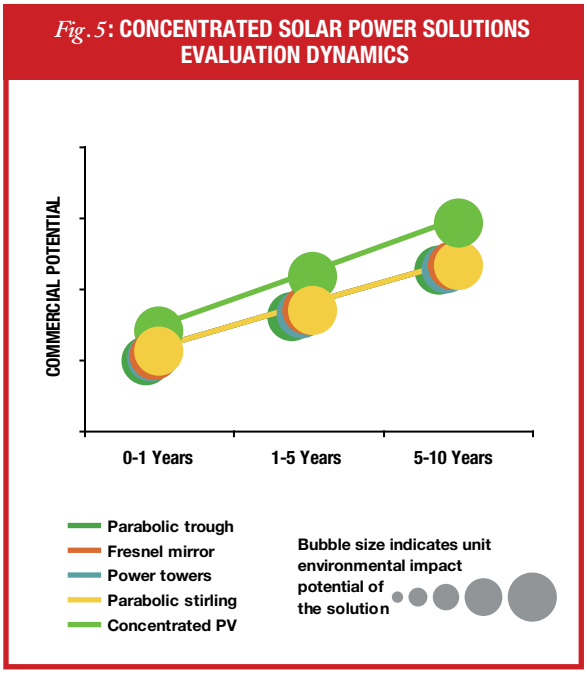



*Fig. 5*: CONCENTRATED SOLAR POWER SOLUTIONS EVALUATION DYNAMICS




Difficulties in financing and low regulatory support make this group of solutions less attractive initially, thereby reducing their commercial potential in the short-term. However, as the technology develops and matures, adoption is likely to rise, driving improvement in commercialization potential.

It should be noted that the market size of Concentrated PV is larger than that of other CSP technologies as it capitalizes on relatively mature existing technologies, giving it "first mover" advantage in the market.

### SOLAR WATER HEATERS (SWH)

SWH scored high in their environmental impact potential since they do not use coal in their operation. However, the manufacturing process still encounters the same negative carbon footprint issues as other solar solutions.

As awareness and implementation of SWH gains further momentum in China, the commercial potential of the Solar Water Heater market will likely continue to grow and become more attractive to investors.

*Fig. 6*: SOLAR WATER HEATER SOLUTIONS EVALUATION DYNAMICS

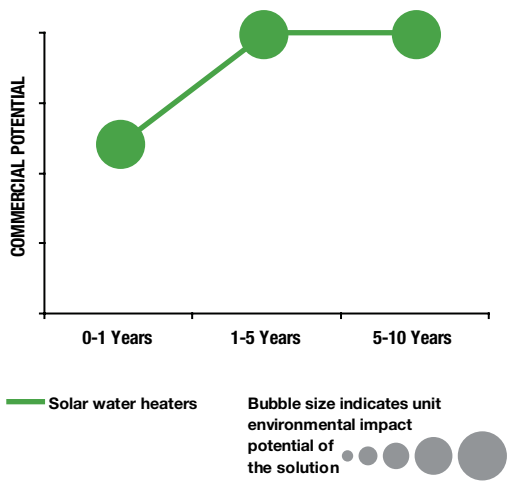
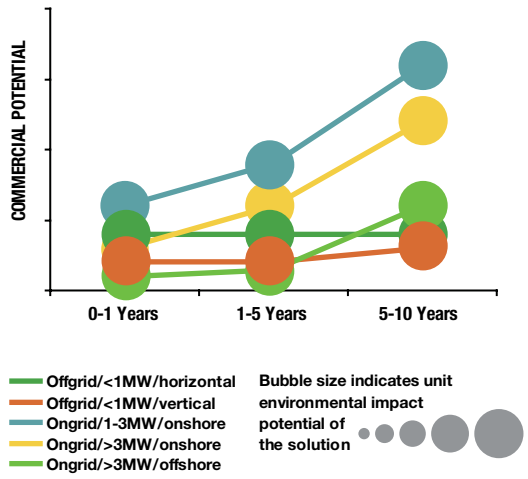



*Fig. 7*: COMPONENT MANUFACTURING SOLUTIONS EVALUATION DYNAMICS




## WIND

### COMPONENT MANUFACTURING

Similar to most other renewable energy solutions, wind has huge $CO_2e$ abatement potential as it does not generate emissions during electricity generation.

Due to substantial onshore wind resources and available designs and technologies, the Ongrid/1-3MW/Onshore turbine has the highest current commercial potential and is likely to remain popular over the course of the next 10 years.

Offshore wind energy generation, although a relatively new concept, appears promising and has already been utilized abroad. However, China currently has only one such project under construction. In the final analysis, the Chinese market needs additional time in which to build experience and capacity in order to fully utilize the country's rich offshore wind resources.

### WIND DEVELOPMENT

Adequate and sufficient Micrositing processes, coupled with comprehensive Wind Assessments during site selections, typically result in enhancements to wind farms' operational efficiencies while also reducing wind power waste and other associated risks.

Until now, most Wind Assessment activities have been in-sourced by wind project developers. However, due to increasing concerns and demands from third parties for accurate wind data, there is rising commercial potential for Wind Assessment activities.

### WIND MAINTENANCE

Expert interviews suggest that the adoption of Conversion Technology could solve intermittency issues with wind power and save wind power wastage. Control Systems, Standard Operating Procedures (SOPs) and Maintenance collectively ensure efficient and continuous operation of wind farms. However while robust conversion technology exists, low awareness and limited budgets means that there has been almost zero adoption.

Additionally, although China is capable of manufacturing all the hardware for Control Systems today, it is almost totally reliant on foreign imports of software; due to IPR protection issues, this state of affairs is likely to persist.

### WIND ENERGY STORAGE

Storage solutions can effectively solve energy consumption and production mismatch problems and prevent enormous energy wastage. For example, although

*Fig. 8*: WIND FARM DEVELOPMENT SOLUTIONS EVALUATION DYNAMICS

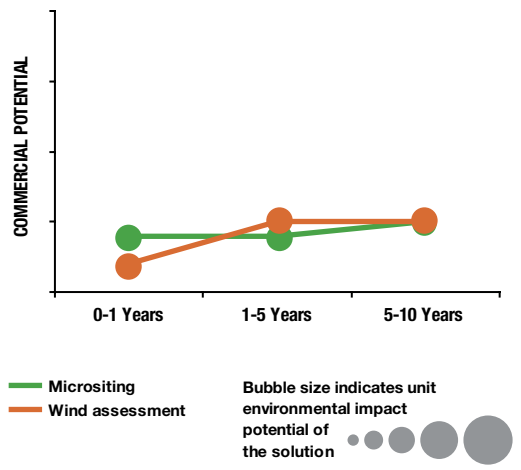
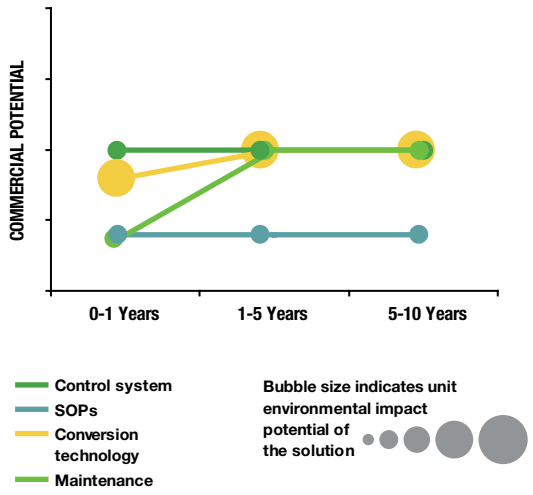



*Fig. 9*: MAINTENANCE SOLUTIONS EVALUATION DYNAMICS




Compressed Air is only a concept at the moment, as technology advances, it will have increasing commercial potential. This application does, however, carry with it geographic, health and safety concerns.

Hydro is currently the most readily available technology but, due to water security concerns, its commercial potential is likely to remain limited to SOEs.

Even though large-scale battery storage does not exist yet, it appears to have the lowest risk of excessive state intervention. This factor alone gives it the greatest commercial potential for private and international investors.

## BIOENERGY

### BIOELECTRICITY

As agriculture and forestry products absorb $CO_2$ during cultivation, Biomass Combustion is often regarded as carbon neutral. However, agriculture residue left in the field generates odors and bug infestations, leading farmers to often dump these byproducts into rivers instead, thereby causing serious water pollution. In a Co-firing plant, up to 20% of biomass can be mixed with conventional energy

*Fig. 10*: WIND ENERGY STORAGE SOLUTIONS EVALUATION DYNAMICS

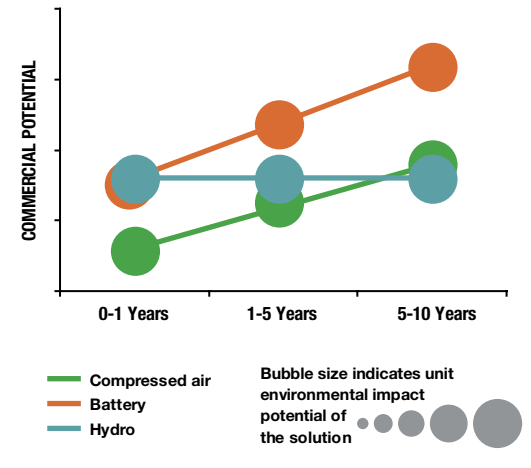



*Fig. 11*: BIOELECTRICITY SOLUTIONS EVALUATION DYNAMICS

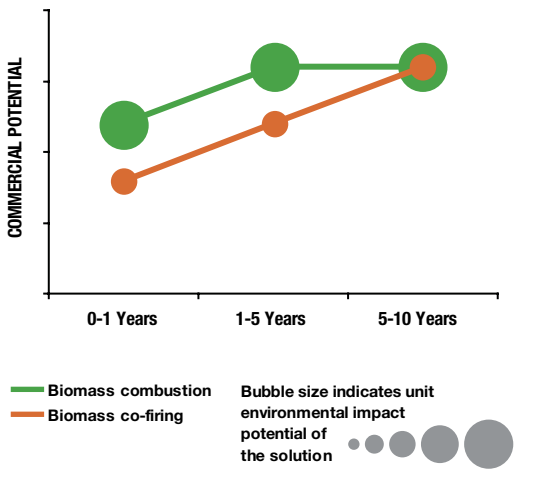


*Fig. 12*: BIOHEATING SOLUTIONS EVALUATION DYNAMICS

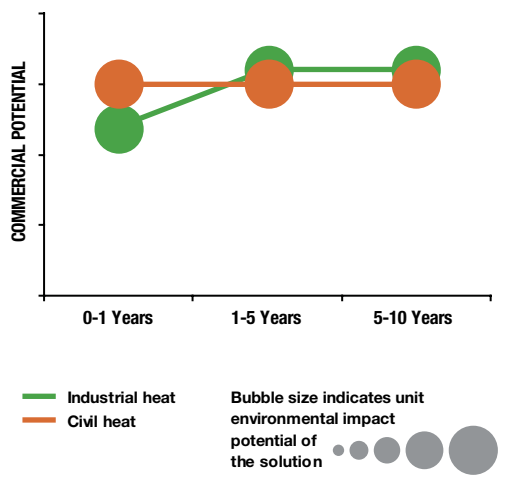
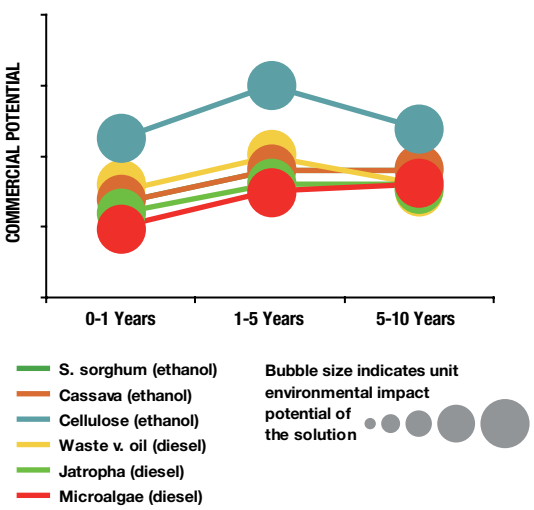



*Fig. 13*: BIOFUELS SOLUTIONS EVALUATION DYNAMICS

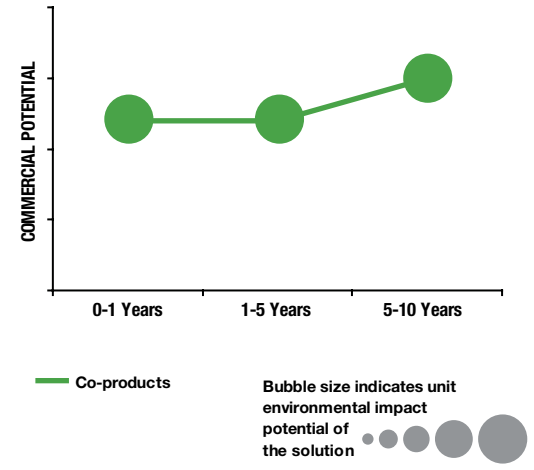



sources with minor boiler changes required. In the process, $CO_2e$ can be abated by 20%.

Despite recent sky-rocketing feedstock prices, Biomass Combustion is still the most economical technology for bioelectricity generation in China today. Some innovative new ideas for bioelectricity generation include burning chemical residues from cellulose-based bioethanol and the vertical integration of farms with other applications.

Although there are very few co-firing plants at present, growing awareness of the environmental benefits of introducing Co-firing into the coal power generation process supports promising commercial potential.

*Fig. 14*: CO-PRODUCTS SOLUTIONS EVALUATION DYNAMICS




## BIOHEATING

Manufacturers can effectively substitute conventional energy sources with biomass heating for industrial applications which have significant $CO_2e$ abatement potential. Whether directly burning loose biomass or biogas, bioheating processes are significantly less polluting and much safer from a health perspective than burning coal.

Industrial Heating is a relatively new concept. Although it does not appear as attractive as bioelectricity, it has proven to be more profitable when there is limited demand and sustainable nearby feedstock supplies due to its moderate technology and infrastructure requirements.

As more people start paying attention to their carbon footprint and organizations work to enhance their environmental image, there are substantial new opportunities for Industrial Heating from biomass in China.

## BIOFUELS

Novozymes, a Danish bio innovation company, estimates that first generation bioethanol fuels can abate $CO_2e$ by up to 60% (up to 90% with second generation applications). Furthermore, some studies indicate that biodiesel can reduce $CO_2$ emissions by up to 78%. Biomass feedstocks also absorb $CO_2$ during cultivation.

The government regards Sweet Sorghum and Cassava as the most promising first generation bioethanol energy sources. However, in addition to seasonal

constraints, it is practically impossible to store sweet sorghum without losing most of its value in a few days. At the same time, rising cassava prices have forced the mandatory adoption of this solution in Guanxi in 2008 to be suspended.

Cellulose-based bioethanol has exciting commercial potential. Yet due to an unsustainable supply of agriculture residue at present, there is likely to be a slight reduction in its commercial potential.

As technology for Microalgae gradually advances, it has the potential to replace waste oil as the main, if not sole, feedstock for biodiesel.

Despite excitement over Jatropha as a key feedstock for biodiesel, it has proven to be unprofitable. Nevertheless, with better planting, planning and easier access to sources, its commercial potential might improve.

### CO-PRODUCT

Biomass pellets enjoy the benefits of easy transportation, storage and excellent burning efficiency with less erosion to boilers compared to loose biomass. Indeed, loose biomass sometimes loses up to 60% of its value during transportation, is expensive to store with significant health concerns and has low burning efficiency and high boiler erosion issues from unburned ashes.

## Key Challenges

**ALL THREE RENEWABLE ENERGY SEGMENTS ANALYZED FACE SIGNIFICANT CHALLENGES WHICH IMPEDE MARKET GROWTH OPPORTUNITIES AND UPTAKE.** Challenges the solar industry faces include the ability to achieve grid parity and power generation competitiveness in its cost structure. Wind farm capacity has grown rapidly but grid connectivity issues remain a problem. Finally, the commercial potential of biofuels is substantially constrained by the high price and irregular supply of feedstock and the slow development of key technologies.

### SOLAR

The extensive uptake of solar technologies in China is inhibited by a number of market, technology, financing and regulatory challenges.

*Fig. 15:* SOLAR INDUSTRY CHALLENGES

| CATEGORY | CHALLENGES |
|---|---|
| MARKET | ■ Presence of negative environmental impacts such as large carbon footprint and recycling limitations<br>■ Lack of price competitiveness |
| TECHNOLOGY | ■ Lag in new solar technology acquisition and development<br>■ Presence of quality concerns |
| FINANCING | ■ Restricted foreign investment<br>■ Limited financing vehicles |
| REGULATORY | ■ Inadequate brand protection<br>■ Insufficient government policy support<br>■ Lack of enforcement |

Market challenges include lack of price competitiveness and presence of negative environmental impacts. Currently, existing solar technologies are not competitive with other renewable energy sources or grid electricity in the short-term; although prices are falling and grid parity for solar PV is expected within the next four to eight years (as mentioned previously, some industry participants believe parity could be achieved within the next two years).

Also, solar technologies have a larger carbon footprint compared to wind and hydro energy. Although an operating solar panel is non-polluting, it has a very intensive manufacturing process and requires hazardous materials like cadmium

and arsenic. Additionally, CSP power plants require huge amounts of water for cooling, said to be four times more than a natural gas plant. Technology for recycling silicon from old solar panels is also underdeveloped and there is little information available regarding its costs and techniques.

Technology deficiency and quality issues undermine the competitiveness of some manufacturers in China's solar industry. Some manufacturing companies do not have yet technologies capable of producing solar panels with high conversion efficiency and/or made up of new thin film technologies, considered to have lower environmental impact potential compared to conventional solar panels. The country's solar industry is also behind in CSP development, the cheapest electricity generating solar technology.

Limited financial assistance challenges the growth of China's solar industry. Foreign investments in the industry are restricted. In practice, large-scale foreign investment has been constrained by complicated regulatory approvals and lack of policy transparency regarding bidding and subsidy claims creating uncertainty.

Limited government support restricts the potential growth of China's solar industry. There is insufficient brand protection and the lack of a robust and enforceable intellectual property rights protection framework constrains capital investment and technology transfer of new technologies. There is also often a lack of enforcement of the laws already in place. An absence of consistent feed-in tariffs, effective grid connectivity regulations and regulatory approval processes for foreign investors limit implementation of solar solutions and downstream integration of Chinese solar companies. In other countries, feed-in tariffs are a proven tool to subsidize solar installations and promote industry price competitiveness; this incentive can be reduced as LCOE moves towards grid parity.

## WIND

The wind industry faces a number of market, technology, financing and regulatory challenges.

*Fig. 16:* WIND INDUSTRY CHALLENGES

| CATEGORY | CHALLENGES |
|---|---|
| **MARKET** | ■ Preferential policies for Chinese providers<br>■ Grid connectivity issues |
| **TECHNOLOGY** | ■ Further cost reduction required to reach grid parity<br>■ Quality concerns |
| **FINANCING** | ■ Low bidding prices<br>■ Inadequate financing and incentives |
| **REGULATORY** | ■ Confusing incentive policies<br>■ Limited transparency<br>■ Issues with enforcement |

Preferential policies for Chinese providers, particularly SOEs, have created an uneven playing field, discouraging foreign competition and investment. Grid connectivity remains a key challenge as high infrastructure costs, remote wind farm locations and technology issues have resulted in wind generation remaining under-capacity. The state grid has a natural monopoly and generates virtually all its revenue from conventional energy sources, and so has had limited incentive historically to enable wind farm connectivity. Also, despite the existence of PPAs, there is a lack of financial incentives for the grid to prioritize connection for wind projects.

Technology challenges include the need for technology cost reductions to reach grid parity, as well as quality concerns associated with domestically manufactured WTGs. As the cost of coal-fired power remains relatively low, technology cost reduction is crucial if wind power is to achieve parity with the grid. As a result of continual technology development and the introduction of $CO_2$ taxes, wind is already almost competitive with coal. However, while Chinese domestically

manufactured WTGs are generally cheaper than international ones, they have often been of substandard operating quality leading to considerable maintenance costs.

Financing challenges include competition constraints caused by low bidding prices and inadequate financing and incentives. Conventional energy SOEs dominate today's wind market, as they are able to make the lowest bids during the project tender process. These bids are too low for concession projects to be profitable for private players, thereby driving out private and international investors. In addition, China lacks a robust system of incentives for all developers as several key incentives, such as CDM and VAT, limit opportunities for private and foreign firms. Most tax incentives introduced to promote investment in the renewable energy sector have now been revoked.

Regulatory transparency issues and uneven enforcement of regulations increase regulatory risks for market players. There is a lack of transparency and specificity in the formulation and development of supporting policies such as installation targets and renewable energy goals. There is also often an absence of enforcement. National level certification and enforcement of standards and laws are vital for ensuring quality, developing a competitive market and driving research and development. There is also no clear enforcement structure in place for China's wind power targets, and national grid development lags behind the wind power industry's demand.

## BIOENERGY

The adoption and diffusion of technologies and best practices is inhibited by a number of market, technology, financial and regulatory challenges.

*Fig. 17:* BIOENERGY INDUSTRY CHALLENGES

| CATEGORY | CHALLENGES |
|---|---|
| MARKET | ■ Unreliable biomass feedstock supply<br>■ Inconsistent purchase requirement enforcement |
| TECHNOLOGY | ■ Unproven technologies<br>■ Persistence of environmental concerns |
| FINANCING | ■ Competitive fossil fuel prices versus rising biomass prices<br>■ Intensive up-front capital investment requirement |
| REGULATORY | ■ Lack of transparent, enforced and consistent policies<br>■ Absence of standards |

Market challenges include the availability of biomass feedstock, as well as low awareness and inconsistent mandatory purchase enforcement. Although China has one of the richest biomass resources in the world, securing regular biomass feedstock supply is very difficult. Seasonal changes in biomass supply affect the reliability of bioenergy supply and most feedstock can only be stored for a very short period without losing much of its value. The increasing competition caused by biomass usage has resulted in rising prices and supply shortages.

While mandatory purchase requirements for bioethanol and total purchase requirements for bioelectricity exist, enforcement is difficult and public awareness of bioenergy products remains low.

Despite great potential, most key technologies are still in the trial stage without clear proof of environmental benefits. Also, there are some environmental concerns that cannot yet be mitigated by technology. Industry growth is also constrained by the absence of a clear technology development roadmap. Although the bioenergy life cycle is meant to be carbon neutral, there are substantial concerns with the environmental impact of biomass feedstock generation and processing.

Financial challenges include competitive oil prices, rising biomass feedstock costs and intensive sunk costs, all of which discourage private investment. While fossil fuels remain competitive, there is little incentive to invest in and develop

biofuels. At the same time, as the price for feedstock remains high, securing it at a reasonable price has become very difficult and has resulted in many bioenergy plants closing down. There are also high up-front costs and long payback periods associated with bioenergy. This discourages private investment, as does the lack of an adequate planning system to regulate the feedstock market.

Government policies have lacked enforcement and consistency, and there is an absence of standards for biodiesel and electricity. Although subsidies and other supporting schemes exist, there is a lack of clear and detailed implementation guidance and enforcement processes. The tax exemptions that exist lack detailed guidance and have been changed so frequently that uncertainty and distrust exists among investors. Also, with no set standards for biodiesel and bioelectricity, there is no quality control and a lack of encouragement for continued investment in research and development. A lack of clear standards for feedstock has resulted in a general over-estimation of suitable biomass feedstock supply, and thus an under-estimation of price.

## Opportunities to Accelerate Market Development

**WHAT CAN STAKEHOLDERS DO TO OVERCOME THE CHALLENGES FACING THE COMMERCIALIZING OF GREENTECH SOLUTIONS** which accelerate the sustainable development of China's Renewable Energy sector? The China Greentech Initiative posed this question to its partners and advisors who helped develop the set of opportunities outlined below. These opportunities are not meant to be explicit recommendations, but rather

*Fig.18:* SOLAR INDUSTRY OPPORTUNITIES

| STAKEHOLDERS | OPPORTUNITIES |
|---|---|
| **SOLUTION ADOPTERS** | ■ Seek financing partners and develop power purchase agreements (PPAs) and other funding models to help overcome initial financing burdens within the constraints of China's electricity regulations<br>■ Stay abreast of technological developments and support the use of quality technologies and brands that meet national and international accreditation standards<br>■ Provide demonstration projects to show the feasibility of solar technology solutions at different scales |
| **SOLUTION PROVIDERS** | ■ Consolidate presence downstream in the value chain to deliver "Solar Solutions," including developing balance of system (BOS) technologies to meet installation challenges<br>■ Diversify to new technologies with low LCOE potential<br>■ Encourage greater R&D focus in China and manufacturing guidelines to minimize environmental impact during the manufacturing stage of solar products |
| **FINANCIAL INVESTORS** | ■ Use PPAs and other funding models to drive existing technologies to market and offset high initial capital installation costs for solar adopters<br>■ Evaluate investments on ROI/value basis rather than cost only, thereby adopting a long-term cost-benefit analysis<br>■ Promote transparency in the project bidding process and equal access to capital for foreign companies |
| **GOVERNMENT REGULATORS** | ■ Set stable and consistent feed-in tariffs to incentivize solar installations<br>■ Restructure PPA regulation to permit signing at project financing stage, expanding both private and foreign investment in solar projects<br>■ Improve monitoring, enforcement and regulation of grid company compliance to ensure grid connection, feed in tariffs and other incentive schemes |
| **OTHER STAKEHOLDERS** | ■ Establish an independent quality commission to monitor industry quality standards, including BOS components and installation<br>■ Create forums for dialogue on solar regulation and industry best-practice with public and private sectors, including successful funding models and policy reform recommendations<br>■ Teach market actors how to improve sustainability throughout the value chain; collaborate on guidelines and reporting. |

suggestions of concrete steps different stakeholder groups may take to accelerate greentech markets and enable China's further evolution to a sustainable economy.

## SOLAR

The Chinese government has set a solar target of 5% of total energy consumption by 2050 presenting huge opportunities for the solar industry stakeholders. As solar energy falls in price, adopters are set to gain from solar power if they can overcome initial financing burdens. At the same time, the development of the industry can be accelerated with the availability of innovative funding mechanisms, feed-in tariffs and improved product quality.

## WIND

Similar to the solar industry, there are also various opportunities present to help accelerate development of China's wind industry. Government regulators can play a big role in the advancement of the industry through increased transparency in concession models and the promotion of a level playing field. Providers, adopters and investors, just like in the solar industry, can work together to develop financing mechanisms that will make it easier for everyone to advance research and adopt wind technologies.

*Fig.19:* WIND INDUSTRY OPPORTUNITIES

| STAKEHOLDERS | OPPORTUNITIES |
|---|---|
| **SOLUTION ADOPTERS** | ■ Work with providers to realistically assess project suitability to ensure quality and sustainability of projects<br>■ Set up and participate in industry associations to drive the improvement of wind power generation quality<br>■ Facilitate the set-up of a market mechanism to encourage the development of a competitive market |
| **SOLUTION PROVIDERS** | ■ Understand license approval execution procedures with the government at both national and local levels<br>■ Focus on IRR maximization for the entire 20-25 year life cycle of a project instead of using payback period as the key investment benchmark<br>■ Set up and participate in industry associations to facilitate competition and cooperation among key stakeholders |
| **FINANCIAL INVESTORS** | ■ Develop and promote innovative financing mechanisms<br>■ Set up specialist wind sector investment teams<br>■ Invest in understanding the maturity and associated risks of wind technologies |
| **GOVERNMENT REGULATORS** | ■ Set requirements on generation rates over the entire 20-25 year life cycle of WTG as well as installation capacity targets<br>■ Ensure PPAs are implemented with adjusted tariffs to reflect local wind resources<br>■ Increase transparency in concession models and provide a level playing field to allow developers to choose freely among all available turbines |
| **OTHER STAKEHOLDERS** | ■ Identify gaps in the process, raise awareness and provide potential solutions with reference from abroad<br>■ Set up industry associations to facilitate transparency, technology transfer and develop industry benchmarks<br>■ Liaise with the government to provide guidance, raise awareness and provide appropriate training |

## BIOENERGY

China's bioenergy industry also presents significant opportunities as it continues to become an important source of alternative energy. The full potential of the industry, such as creation of millions of jobs and additional stream of revenue for millions of farmers, can be achieved if the stakeholders take hold of the opportunities available to each of them.

Providers, adopters and regulators can work together to develop industry standards. Financial investors can create effective collaborations among key stakeholders to formulate an appropriate financial support level as well as implementation guidance.

*Fig.20:* BIOENERGY INDUSTRY OPPORTUNITIES

| STAKEHOLDERS | OPPORTUNITIES |
|---|---|
| **SOLUTION ADOPTERS** | ■ Work with providers to realistically assess a project's local suitability, to drive the quality and sustainability of the final output<br>■ Help draft and implement standards<br>■ Provide assistance to or be actively involved in technology development to ensure the quality of products |
| **SOLUTION PROVIDERS** | ■ Work closely with local stakeholders to realistically assess the availability and suitability of local biomass supplies for continuous business development<br>■ Incorporate accumulated experiences to help establish government standards<br>■ Strengthen local industry associations |
| **FINANCIAL INVESTORS** | ■ Work closely with local governments to meet increasing bioenergy targets set by the government<br>■ Sign a set time contract with local biomass providers with fixed demand for and price of feedstock<br>■ Create effective collaborations among key stakeholders to formulate the most appropriate financial support level and implementation guidance |
| **GOVERNMENT REGULATORS** | ■ Draft compulsory national standards for biodiesel and bioelectricity<br>■ Provide guidance on cultivation, distribution and conversion processes taking into account local conditions<br>■ Strengthen PPA enforcement at local levels with strict breaching punishments |
| **OTHER STAKEHOLDERS** | ■ Identify vital gaps and flaws in the process, and provide potential solutions or suggestions through experience<br>■ Organize on-going collaboration amongst key stakeholders to draft appropriate input and output standards<br>■ Liaise with the government to provide guidance, raise awareness and provide relevant industry training |

## Path Forward

**THIS CHAPTER PROVIDES AN OVERALL PICTURE OF CHINA'S GREENTECH MARKETS,** challenges and opportunities related to the Renewable Energy sector as of the middle of 2009. Intended to be a starting point that defines and frames market issues and opportunities, the Initiative recognizes that the chapter doesn't answer every question that market participants have. Given the complexity of the Renewable Energy sector and the intense speed at which regulatory, end user, competitive and technology markets are changing, certain aspects of this chapter will become dated relatively quickly. Moreover, important questions remain to be answered at more detailed levels than has been possible in this chapter.

Readers of *The China Greentech Report 2009* are invited to join the conversation by visiting www.china-greentech.com. The Initiative's website allows people to:

- Download electronic copies of the Executive Overview, full report and individual sector chapters
- Order a printed version of the report
- Access additional content created by the Initiative
- Participate in interactive discussion forums to create, uncover and promote greentech solutions for an environmentally sustainable China and the world.

*The China Greentech Initiative looks forward to welcoming readers to its extended community. Suggestions on improving the content in this report are also welcome at feedback@china-greentech.com*

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**Additional sector-specific sources are included in the full version of the Report.**


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