Danish Environmental Technology Adoption in China

October 2008

McKinsey&Company

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To create the report, McKinsey collected and consolidated data and conducted interviews and analyses of the carbon abatement potential and cost of five selected technologies in China. These results should not be used to forecast the real abatement that China can realize on each measure, as social and transaction barriers haven't been fully incorporated. Neither should they be used as basis, or part of the basis, to determine the abatement targets that China should commit to.

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Chapter 6: Wind power technology

INTRODUCTION TO WIND POWER TECHNOLOGY

The power of wind is captured by wind turbine generators (WTG), mammoth structures often exceeding 50 meters in height. Wind turbines are assembled from many different sub-components (e.g., tower, blade, gearbox, generator, etc.) and convert wind power through the spinning of their blades. Many individual wind turbines are placed together to form wind farms; the energy is then transmitted via the electricity grid for consumption.

While the basic technology is centuries old, wind turbines today are high-tech structures. Improvements over the years include variable pitch and speed to maximize wind resources, mechanisms to protect the turbines during high winds, engineering designs to decrease long-term maintenance, and reduced weights to lower material costs.

Wind energy is a permanently-available, renewable resource that does not emit any CO_2 in its generation of electricity. By replacing some of the electricity generation that would have been needed from fossil fuel sources that emit CO_2 (e.g., coal), wind power technology reduces CO_2e emissions.

CARBON ABATEMENT POTENTIAL AND COST

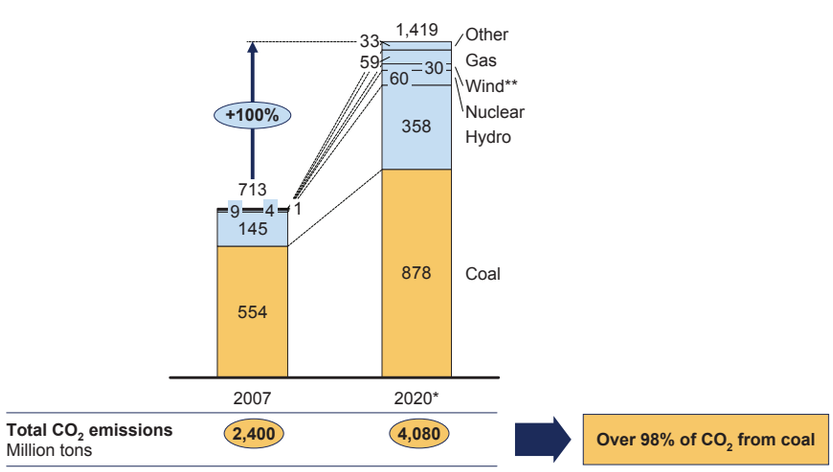
China has huge potential for reducing CO_2e emissions by installing and generating greater and greater amounts of wind energy. Capturing this carbon abatement opportunity makes sense for China, as wind is increasingly cost competitive and provides a number of additional benefits for China.

Large carbon abatement potential

China's power sector is currently dominated by coal, which represents over 75 percent of installed capacity and supplies over 80 percent of electricity generation. Coal is the most CO_2 intensive fuel source, and accounts for nearly 100 percent of the 2,400 MT CO_2e from China's power sector in 2007. In order to feed its economic growth, China's power sector will need to grow 100 percent from now until 2020, as illustrated in exhibit 6.1. The additional 719 GW of capacity (and more than 3,000 TWh of generation) created is equivalent to 7 times the current installed base of Denmark's entire power sector. The resulting rise in CO_2e emissions of 1,680 MT would be more than 30 times that of the entire nation of Denmark, across all sectors.

Exhibit 6.1

CHINA POWER SECTOR INSTALLED CAPACITY
GW

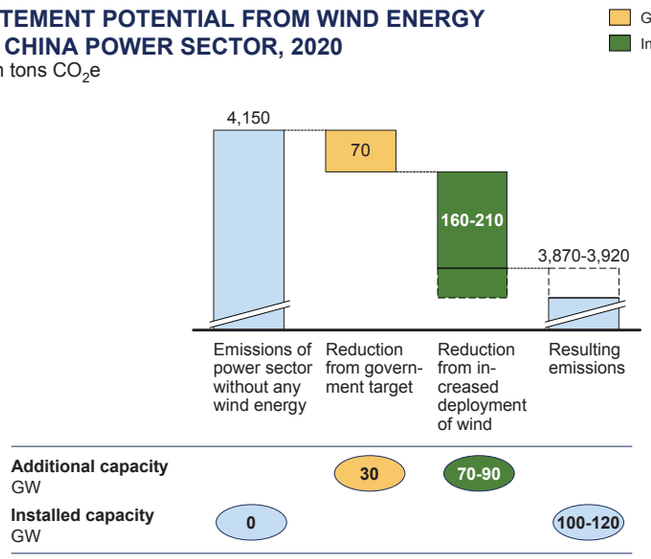


* Forecast based on NDRC targets for renewable sources and electricity growth coupled with McKinsey analysis on energy efficiency gains
** Of the total 6 GW installed, only 4 GW were connected to the grid
Source: China Electricity Council; NDRC; McKinsey analysis

Wind energy has the potential to supply a portion of this electricity growth and reduce CO_2e emissions in the process. Current government target of 30 GW by 2020 is conservative; numerous experts cite 100 to 120 GW as a reasonable or even conservative target. In terms of wind resources, growth rates, supply chain capacities, and penetration levels, 100 to 120 GW is attainable and not aggressive. Achieving this target of installed wind capacity would result in 230 to 280 MT CO_2e abated, as illustrated in exhibit 6.2, 3 times more than the government targets would achieve and 4 to 5 times the entire annual emissions of Denmark.

Exhibit 6.2

ABATEMENT POTENTIAL FROM WIND ENERGY FOR CHINA POWER SECTOR, 2020
Million tons CO_2e



Source: ERI; literature research; McKinsey analysis

Attractive energy source for China

Wind is an increasingly cost competitive energy source for China. Energy costs should be compared on the basis of an average cost of electricity power metric (RMB/MWh) – i.e., the total cost required to deliver each unit of energy to the consumer. This incorporates all relevant costs over the lifetime of the power plant as well as its performance output. In wind energy for example, a turbine with a lower initial capital cost could actually have a higher cost of energy due to decreased availability, lower capacity factors, and/or a shorter lifetime, as illustrated in exhibit 6.3.

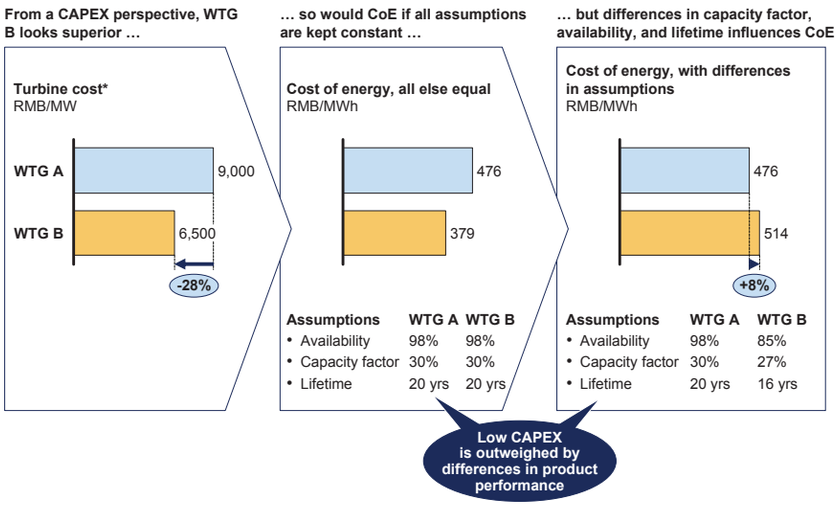
The cost of energy from different power plants varies in practice based on performance, fuel prices and uncertain capital costs. Based on this energy cost metric, a new wind farm is cost competitive with all other energy sources with the exception of coal today, as illustrated in exhibit 6.4.

By 2020, advances in technology and decreasing capital costs could allow wind to even challenge coal, especially if fuel prices continue to rise. If a \$30/ton (210 RMB/ton) CO_2 tax is incorporated, wind becomes even more attractive than coal, as illustrated in exhibit 6.5.

Exhibit 6.3

COST COMPARISON OF DIFFERENT TURBINES

EXAMPLE ESTIMATES



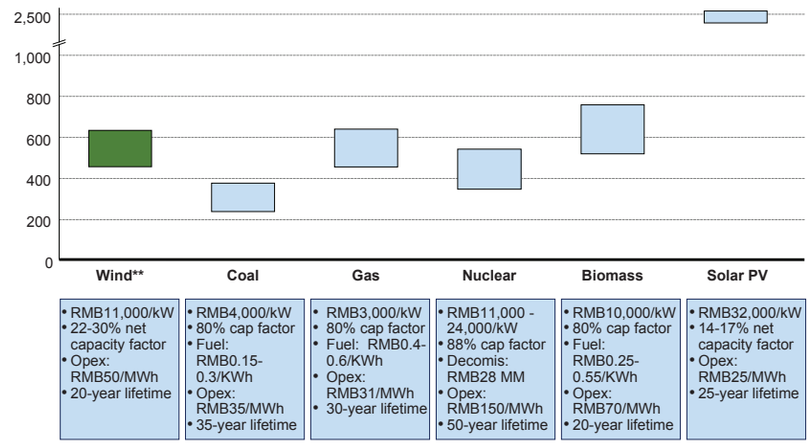
* Only represents the turbine cost, full CAPEX cost is often 25-30% higher; assuming park size of 50 MW; WTG size of 1.5 MW; WACC of 8%; does not include subsidies, taxes or VAT

Source: Expert interviews; McKinsey analysis

Exhibit 6.4

LEVELIZED COST OF ELECTRICITY FROM NEW FACILITIES, CURRENT OUTLOOK*, 2008

RMB/MWh



* Reflects current capital costs, operational costs, fuel costs, etc.; WACC of 8%; does not include subsidies, taxes, VAT or externality costs

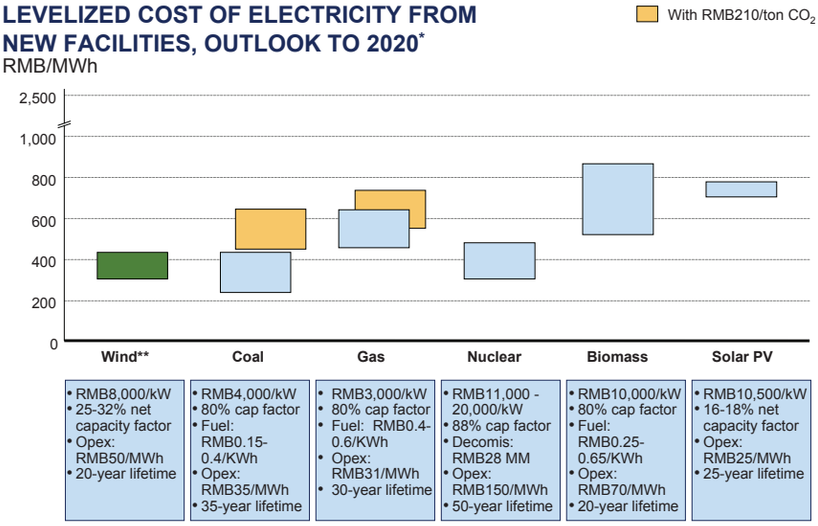
** Integration costs not included; McKinsey analysis suggests such costs would be less than RMB14/MWh with penetration <6%

Source: Literature search; industry; academic and association expert interviews; McKinsey analysis

Exhibit 6.5

LEVELIZED COST OF ELECTRICITY FROM NEW FACILITIES, OUTLOOK TO 2020*

RMB/MWh



* Reflects projected capital costs, operational costs, fuel costs, etc.; WACC of 8%; does not include subsidies, taxes, VAT or externality costs

** Integration costs not included; McKinsey analysis suggests such costs would be less than RMB14/MWh with penetration < 6%

Source: Literature search; industry; academic and association expert interviews; McKinsey analysis

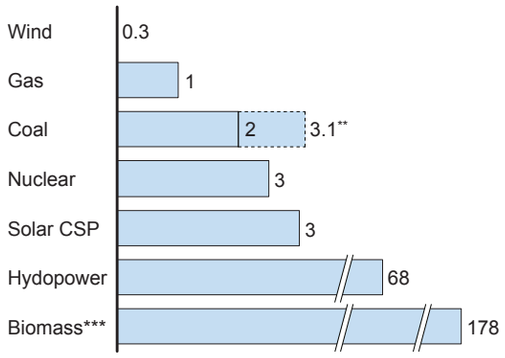
Wind power is strategically important to China as it provides China with increased energy security. Energy security is of outmost importance to China as it seeks to keep its economy booming and its population content. Many experts predict that China will become a growing net importer of coal in the coming years. 100 to 120 GW of wind power generation could reduce these imports of coal by 78 to 95 MT per year. Additionally, having diversified energy sources such as wind reduces China's overall reliance on coal for power generation, which is of great importance in constrained situations such as the recent winter storms that caused numerous blackouts across southern China.

Wind power is also attractive to certain water scarce regions in China, as it consumes far less water than most other energy sources – 1,000 times less than gas and 2,000 times less than coal or nuclear, as illustrated in exhibit 6.6.

Exhibit 6.6

WATER CONSUMPTION FROM POWER GENERATION

M^3/MWh*



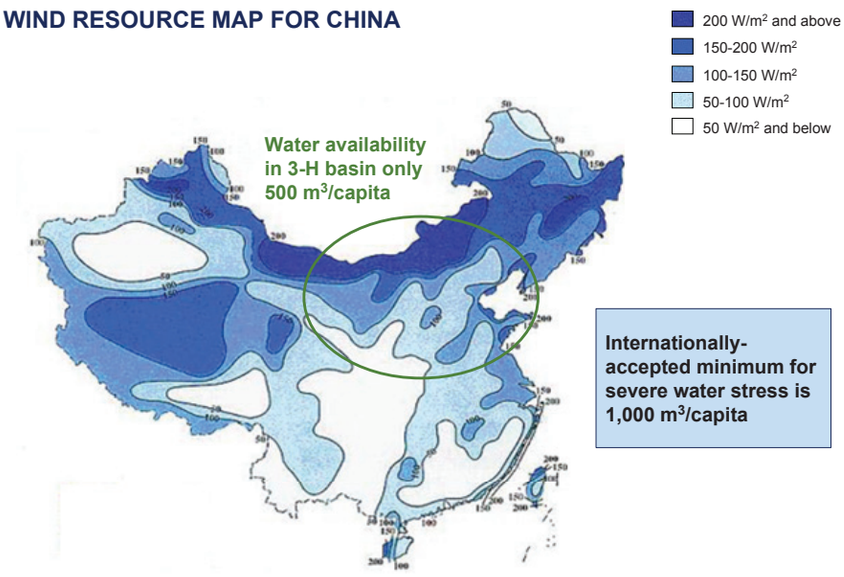
* Represents water consumption from raw material extraction/refining as well as energy generation
** China's coal power generation uses more water than normal, in 2005, this figure was 3.1 m^3/MWh though it has been declining
*** Assumes that the feedstock used is ethanol, which requires corn or sugar crops
Source: Department of Energy; DHI; EIA; China Infobank; China Urban Construction Statistical Yearbook; China Regional Statistic Yearbook; World Bank

In the highly populated 3-H basins in northern China (Huai and Huang river basins), per-capita water availability is only 500m^3/person, well below the internationally-accepted minimum of 1,000m^3/person for severe water stress. Conveniently, many of the provinces in this water-scarce region have abundant wind resources (e.g., Hebei, Ningxia and Shandong), as illustrated in exhibit 6.7. The total water consumption that would be saved from having 100 GW of wind instead of coal generation amounts to about 525 million m^3 – sufficient to supply an urban population of more than 3 million people.

Finally, wind power is attractive for its rapid construction time and immediate scalability. A typical 50 MW wind farm can be built in only a year's time. The technology is ready for large-scale build-out today; additional R&D improvements or cost declines will only further increase its competitiveness.

Exhibit 6.7

WIND RESOURCE MAP FOR CHINA



Source: Department of Energy; DHI; EIA; China Infobank; World Bank

CHALLENGES TO ADOPTING WIND POWER TECHNOLOGY IN CHINA

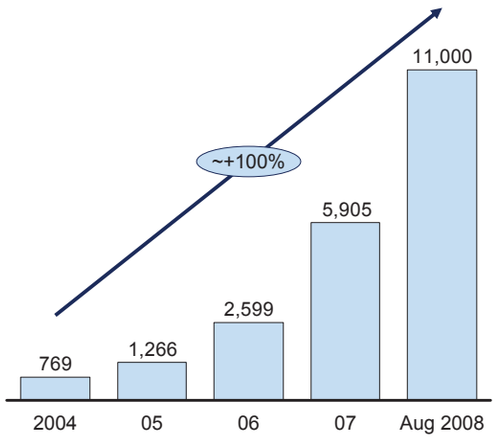
China is well aware of the many benefits of wind energy and has already done well to spur explosive growth in the sector. From less than 1 GW in 2004, China's installed wind capacity grew to 11 GW in August of this year – a yearly growth rate of nearly 100 percent, as illustrated in exhibit 6.8. In addition, a vibrant domestic manufacturing industry has arisen, with over 50 turbine suppliers now in the market. Government policy has been the driving force behind this growth, most notably through:

- **Concession projects**

  Begun in 2003, these government-arranged wind farms select developers based on a competitive bidding process. The program is designed to encourage build-out in attractive wind resource areas at scale (more than 50MW) and guarantees the grid company will pay for transmission.

Exhibit 6.8

CHINA WIND INSTALLED CAPACITY
GW



Source: CWEA; literature search; expert interviews

- **"Renewable Energy Law"**

  Passed in 2006, China has set up a comprehensive plan to encourage renewable energy development, including targets, mandatory grid connection, pricing arrangements and cost sharing arrangements. Subsequent legislation (e.g., Mid and Long-term Renewable Energy Implementation Plan) has further elaborated and codified specific areas.

Despite the wind industry's remarkable growth over the last few years, there are a few troubling signs. For example, by the end of 2007, over 2 GW of the 6 GW installed wind capacity was unconnected to the grid, and reports of difficulty gaining grid connectivity exist today. Additionally, uncertified/untested turbines are being installed, some of which have encountered technical challenges.

These challenges will need to be addressed to secure the future success of wind energy in China. By 2020, China could potentially become the world's largest wind power generator and also a leading exporter of wind turbines and wind technology. Alternatively, grid connection and turbine performance issues could cause the industry to fall short of its potential. The next few years will shape the long-term trajectory of the industry.

The current challenges in the industry can be grouped into two fundamental categories: imperfect incentives (leading to unhealthy demand) and supply-side shortfalls (unable to fully keep up with demand).

- **Imperfect incentives**

  Currently, growth in the industry is primarily fueled by portfolio requirements that require generation companies with more than 5 GW of capacity to have 3 percent non-hydro renewables (mostly wind) by 2010 and 8 percent by 2020. As this target is measured in installed capacity, not generation output, generation companies are incentivized to increase installed capacity, but not necessarily energy output. This focus on installed capacity translates into demand for low-cost, immediately-available turbines, without placing sufficient emphasis on quality output or even grid connectivity.

  Additionally, as concession-tendered pricing is often too low to be profitable and may be renegotiated later on, what becomes important for developers is securing the best site locations, and not necessarily generating energy on them right now. Thus, many wind farms are being developed by those without any incentive to actually produce energy in the near term (i.e., secure land now, wait until prices rise later on or sell land to someone else, install cheapest turbines available if forced to build).

- **Supply-side shortfalls**

  Driven by explosive demand often more concerned with low cost and immediate availability rather than product quality, over 50 domestic turbine manufacturers have begun production while testing and certification of turbines have not yet made their way into the industry. This has led to the installation of many uncertified and untested turbines whose productivity is uncertain.

  Furthermore, qualified human resources appear strained in keeping up with the astounding pace of demand, both in terms of quantity and quality. This capability gap is apparent throughout the value chain, leading to component bottlenecks, project management missteps, grid connection issues, as well as delayed project approvals.

  Lastly, the supporting infrastructure for wind industry development appears lacking. Grid connection is often perceived as difficult due to the relative

weakness of the grid in attractive wind areas, and the complexities of securing grid data and buy-in. Comprehensive wind resource mapping, though underway, is also currently not available for public use.

OPTIONS TO ADDRESS THE CHALLENGES

In order to continue the maturation of the wind industry and capture the full carbon abatement potential of wind power, several options are available which could address the imperfect incentives and supply-side shortfalls. Quickly adjusting demand-side policies could create healthy demand, while supply-side improvements will take longer to show results, but would be critical to the long-term development of the industry

Options for policy makers

- **Create improved incentives schemes**

  Refining incentives to ensure that focus is placed entirely on the ultimate end product and generation output. Transforming the mindset of the industry, away from cheap capex and towards quality output will go a long way in forcing supply-side improvements. Specifically:

  — Reform portfolio requirements for generation companies to create targets for generation output not installed capacity.

  — Clarify penalties for not reaching targets.

- **Create a stable investment environment**

  A stable and secure investment environment reduces uncertainty in the industry and encourages healthy investment. Some potential measures developed in other countries include:

  — Move from a de-facto tariff regime to a formalized tariff structure.

  — Extend or clarify pricing beyond 30,000 hours of operation for wind farms.

  — Streamline government approval and grid connection procedures.

- **Raise turbine quality**

  Adjusting the demand drivers and changing the mindset of the industry will already go a long way toward upgrading turbine quality. Still, the government could consider a role in supporting this change:

  — Ensure qualified testing and certification agencies are in place as demand for such services increases.

  — Engage industry leaders (both foreign and domestic) to collaborate on standards.

  — If mandatory standards are adopted, ensure adequate attention is placed on enforcement of the standards.

  — Facilitate the anticipated consolidation in the industry so that suppliers, in an effort to stay afloat, are not forced to drastically slash prices and reduce quality.

- **Build local capabilities**

  Building local capabilities will be critical to the long-term development of the wind industry. Ultimately, skilled personnel will be required at each step of the value chain (from mapping wind resources to ensuring component/turbine quality, from locating wind farms to operating them, from establishing grid connectivity to devising standards/policies) in order to keep pace with the torrid rate of growth. To accelerating this process, the government could consider the following two key elements:

  — Attract and retain foreign developers and manufacturers with relevant expertise to China. Already, foreign manufacturers have been raising domestic capabilities through their very presence in China – raising the qualifications of suppliers, introducing leading manufacturing processes, and working with first-time project developers. Drawing foreign project developers to China, many of which are utilities themselves, could elevate local capabilities in grid management, project development and wind farm operations. In order to encourage continued and increased investment by foreign entities, the government could consider:

    - Ensure a stable, transparent and fair investment environment for all.
    - Loosen the domestic majority ownership requirement for CDM credits on wind farms while still encouraging collaboration between foreign and domestic developers.

— Facilitate transfer and dissemination of skills, know-how and expertise to cultivate local talent. Already, the government has successfully encouraged manufacturers to build production in China and thus developed a dynamic industrialized base; further measures could accelerate the pace of knowledge diffusion:

  - Encourage establishment of R&D facilities (foreign and domestic) in China to increase local engineering and design capabilities.
  - Engage industry leaders (foreign and domestic) to collaborate on panels, information sharing networks and other public programs where they'll have the opportunity to work hand-in-hand with local institutions and businesses.

- **Strengthen supporting infrastructure**

  A solid supporting infrastructure is a prerequisite to capture the full potential of wind power and reduce the risk of investment. Wind resource mapping and the transmission grid play essential roles in providing the foundations for the expansion of the wind industry. To bolster these areas, government could consider the following:

  — Make comprehensive wind resource data accessible to the public as they become available.

  — Incentivize grid companies to take a more active interest in increasing wind penetration. The grid is needed to provide grid data and work with project developers from the very beginning of project development. The grid should also be encouraged to produce a long-term build-out strategy, and invest in smart grid and storage technologies, which would help accommodate a higher penetration of wind power.

In addition to fine-tuning policy direction, private sector efforts will be essential in producing a world-leading industry.

Options for leading companies

- **Raise turbine quality**

  While adjustments in policy drivers may naturally raise the demand for quality turbines, manufacturers should not wait to be pushed, but rather should proactively aim to improve their turbines. Ensuring the proper performance of their turbines is vital to sustaining the momentum and interest in the industry. Ultimately, it will serve the manufacturers well as they seek to enter overseas markets. Leading companies should take the lead in providing an example to newer entrants. Some potential actions include:

  — Apply for testing and certification of turbine quality.

  — Provide margin for error in design and manufacturing to protect against product defects and to guarantee long-term durability.

  — Invest heavily in R&D for the long-term.

  — Transform customer mindset by focusing sales message on total cost of energy, rather than just initial capital costs.

- **Adapt products to China**

  While balancing the need for quality, manufacturers should also continue to adapt their products to China. This can lead to reduced costs without declines in performance. Some possible actions:

  — Design tailored turbines to suit the specific wind resources and environmental conditions in China, adding functionalities where appropriate and removing unnecessary costly components.

  — Continue to develop and source from local suppliers and build local manufacturing bases that will produce quality at lower costs.

- **Build local capabilities**

  The importance of having sufficient trained and knowledgeable personnel in the industry cannot be over-emphasized. While through their normal course of commerce, leading companies are already significantly contributing to the building up of local capabilities, they will also need to pursue additional opportunities to cultivate domestic know-how and transfer necessary skills and expertise. Their contributions will be critical to establishing a robust, healthy and sustainable wind industry. Some possibilities include:

  — Establish R&D centers in China and partner with local universities in developing local R&D capabilities

  — Establish vocational universities, training centers, and apprenticeship programs.

  — Provide technical assistance to grid operators to improve grid connectivity of wind energy.

Conclusions

As the preceding chapters have illustrated, there are tremendous opportunities in China for the cost effective reduction of carbon emissions, particularly in the buildings and renewable energy sectors. The 5 technologies assessed, in total, would enable annually 800 MT CO2e reductions by 2020. As is typical for any significant feat worth achieving, considerable collaboration will be required among public and private sector stakeholders.

Both Chinese and Danish governments can share experience in policy setting and creating conducive environment for technology adoption, and industry players, particularly the leading technology providers can go a long way in raising awareness, building local capabilities along the value chain, and making the technologies more cost effective by leveraging China's volume and cost advantage

GOVERNMENTS

Experience from Denmark shows that it is powerful to breakdown the country aggregate level energy efficiency measure to state/city/sector level, and translate into an elaborate set of KPIs for local government agencies.

Denmark's experience also shows that a coherent national energy efficiency/ climate change agenda would not only cover the proven technologies in traditional sectors, e.g., building, it also gives clear guideline to emerging technology, e.g., bio-fuel. The bio-ethanol strategy in the US and Brazil are more examples where clear national strategy and detailed implementation guideline effectively created market for green technologies.

With good regulation framework, it also takes adequate administrative resources to enforce and ensure compliance, particularly in dispersed industries such as building/construction.

We understand that Chinese government is working on gradually phasing out price distortions, while clearly balancing many competing concerns (e.g., maintaining employment, ensuring the welfare of the needy, etc.). The empirical evidence from Denmark's experience of energy price reform offers good base of policy deliberation and balancing tactics that China can learn from.

In addition, in the broad context of technology transfer to China, appropriate mechanisms to encourage localization of technology are important. Government

can jump start the development of local markets via government buying schemes and encouraging measures to attract continuous investment and R&D in China.

Denmark, as the host of the United Nation's conference on climate change, is a prominent leader in the arena of carbon abatement and international cooperation. As the originator of many of the leading technologies for energy efficient buildings and renewable energy, Denmark has a lot to share.

In addition to passing on the experiences in policy making and industry development, the Danish government could act on its own and in concert with others to mitigate current barriers to technology transfer: 1) restrictions on Chinese investments in Danish/EU companies; 2) lack of a global deal wherein technology transfer restrictions from developed countries are reviewed and adjusted; 3) bottlenecks in the flow of talent and knowledge, e.g., difficulties in obtaining visas for scientists; 4) labor and financing hurdles for Danish companies to establish production and R&D in China.

LEADING COMPANIES

Awareness of energy efficiency must be raised within industries and amongst consumers. While the primary goal of any company remains to generate profits, the leaders of these industries have the benefit of being able to take a long term perspective and should recognize that increased awareness will bear financial and societal benefits over the long run.

Government's standard-setting efforts and pilot programs have to be supported by the industries. Leading companies are the most aware of the complex changes occurring within their respective industries, including advances in technology, shifts in demand, and the evolutions of end-user behavior. To ensure that the government utilizes this collective wisdom gathered in each industry in the form of good policies, leading companies need to participate in standard-setting and pilot program efforts.

Leading companies, particularly Danish companies who own the technologies, must seek to strengthen the value chains they play in, through capability building and technology collaboration. These leading companies do not exist within a vacuum in China. Underlying the tremendous GDP growth in China are entire industries that have often adopted practices that were easiest to scale,

though were not necessarily the most efficient. Facilitating the absorption of best practices is a responsibility that falls upon leading companies not just as good corporate citizens, but as competitive companies that benefit from smarter, faster, more efficient value chains. At a basic level, leading companies can contribute by training the local labor force to work within their system. To increase their commitment to developing the local value chain, leading companies may consider co-developing products with upstream and downstream players.

TOWARDS CLOSER PARTNERSHIP

Both countries are well-positioned to commit to greater interaction. China, as a responsible stakeholder in the international system, will put forth a serious effort to reduce its emissions, potentially in the form of an ambitious reductions target. Accomplishing such a task requires that China integrate external technical and financial support and internally foster best practices observed in both government and industry.

This Conference provides a great platform to ensure an effective first step towards translating the broad policy directions mentioned above into implementable action plans in reality. More importantly, to sustain and expand on current successes, this conference will ideally serve as a springboard for regular dialogue and sustained collaboration. Bringing these two natural partners closer together on this issue of global significance will yield benefits for both countries and also for the world.

Acknowledgements

This report is produced by McKinsey & Company for the Danish-Chinese Conference on Climate Change (Beijing, October, 2008) jointly held by the Danish Embassy and the China National Development and Reform Committee. We hope that the fact base provided here will enable better informed decisions and the development of economically sensible strategies to address the nation's rising GHG emissions.

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