Danish Environmental Technology Adoption in China

October 2008

McKinsey&Company

Disclaimer

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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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Executive Summary

Consensus is growing among scientists, policy makers and business leaders that concerted action will be needed to address rising greenhouse gas (GHG) emissions. The discussion is now turning to how to do it. Since early 2007, research teams from McKinsey & Company have been working to develop a detailed fact base estimating the cost and potential of different options to reduce GHG emissions. This effort has extended to China, with a team working with leading companies, industry experts, academics, and environmental NGOs.

On the occasion of the Danish-Chinese Conference on Climate Change, the McKinsey team extends its research to understand the potential for abatement opportunities through technology cooperation between China and Denmark. Though we have assessed only five technology examples, we hope that the fact base provided here will help policy makers, business leaders, academics and other interested parties make better informed decisions and develop sensible policies and strategies to address the rising GHG emissions.

TECHNOLOGY COOPERATION OPPORTUNITIES BETWEEN CHINA AND DENMARK

China has significant GHG or CO_2e (CO_2 equivalent) abatement potential in the areas of sustainable buildings and renewable energy. Denmark, with over 30 years of focused research and application experience, possesses many world leading technologies in these two fields.

This compatibility leads to significant potential for technology cooperation between these two countries. To better understand this potential, we selected five leading Danish technologies within these two fields for further analyses: passive building design, energy-conserving temperature control systems and high-efficiency pump technology for sustainable buildings; enzyme-enabled biofuels and wind power technology for renewable energy.

GHG ABATEMENT POTENTIAL AND ADOPTION CHALLENGES

With full adoption, the three building-related technologies can contribute up to 280 million tons of carbon emissions (MT CO_2e) abatement from the building sector alone in 2020. That is equivalent to 20 to 25 percent of the energy savings target set by the Ministry of Housing and Urban and Rural Development. If applications outside of the building sector are included (e.g., pumps used in the industrial sector), the total abatement potential can reach 380 MT CO_2e.

More importantly perhaps, these technologies are economically attractive, often with payback periods of only 1 to 3 years if properly applied in buildings.

Though the Government is taking important steps to address energy consumption within buildings, wide adoption of the three building technologies still faces many challenges. Issues such as limited public awareness, under-developed standards and codes, misaligned incentives along the value chain, and implementation capability gaps are preventing the technologies from reaching their full potential.

The two renewable energy technologies could potentially bring 370 MT CO_2e abatement to China. If combined with enzyme applications in other sectors, the total could become 420 MT.

Enzyme technology leads to huge cost savings through the replacement of fossil fuels with biofuels. But its wider adoption requires a solid and comprehensive national strategy and regulatory framework for biofuels to ensure greater technology adoption and proper setup of the feedstock value chain. Fast-growing wind energy has exceeded many people's expectations, and if measured by a true cost of energy metric (RMB/MWh), wind is comparable with most other energy sources. It is currently hampered though by incentive issues on the demand side and capability gaps on the supply side.

A CASE FOR COLLABORATIONS AMONG STAKEHOLDERS

Concerted and sustained efforts from key stakeholders and leading companies, will be critical to unlocking the total 800 MT CO_2e abatement potential, equivalent to nearly 10 percent of China's total emissions in 2005, or emission from 2,400 100 MW coal-fired power plants a year.

The potential is also significant in terms of energy security. For instance, by using biofuel to replace gasoline/diesel, 0.3 billion barrels of crude oil could also be saved in 2020, or 7 percent of projected imports.

Experiences and lessons learned from Denmark and other countries offer a variety of options for the Chinese government to get more leverage from the green technologies. Some examples could include: 1) cascade energy efficiency measures into government KPIs at the city/sector level; 2) set detailed implementation guidelines and mobilize the relevant government agencies to capture the window of opportunity in emerging industries such as biofuel; 3) allocate sufficient administration resources to enforce industry standards (e.g., for building inspection and quality auditing); 4) leverage empirical evidence from Denmark and other countries in China's own effort to reform pricing of energy, fuel, heat and other utilities; and 5) create appropriate mechanisms to encourage localization of technology (e.g., jump-start local market via government buying).

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.

At the same time, the private sector has a significant role to play in market cultivation and capability building across the value chain. Particularly, as technology providers, the leading Danish companies should 1) continue to raise awareness both within industries and among consumers; 2) proactively contribute their industry expertise to pilot programs and help government in industry standard setting; 3) facilitate know-how and expertise transfer to local channel and supply chain partners, build local talent base through various training programs and off-shoring R&D, sourcing and production activities to China; and 4) tailor products and technologies for China market conditions.

Last but not least, we hope that this Conference provides a platform to generate positive ideas and a concrete agenda for stakeholders to act together.

Contents

Preface: Technology collaboration will be key in tackling climate change

As temperatures continue to rise, the world is witnessing the damage that climate change can unleash on the environment, the global economy and human life. In an effort to avert dire scenarios, closer collaboration is taking place on a global scale, and international communities, including China and Denmark, are working closely together to find a solution.

IMPACT OF CLIMATE CHANGE

Climate change has severe impact on the environment, the global economy and human life. The late 20th century has been warmer than any period in the past 1,000 years. Looking ahead, temperatures are expected to rise even faster by about 0.2°C/decade over the next two decades. A temperature increase of more than 2°C will have catastrophic impact on all areas of human life: intense weather will impact crop yields and lead to worsening water shortages; rising sea levels could cause social unrest as billions of people face migration; and economies will falter significant impact on global GDP.

China has also recognized the impact of climate change in the past 50 years, and is expected to suffer significantly with continued rising temperatures. As stated in the National Climate Change Programme, the average air temperature has increased by 0.5 to 0.8°C and sea-levels in coastal regions have risen at 2.5mm/annually. By 2020, the temperature increase will cause worsening droughts in northern China. Heat waves and extreme weather will then bring a greater risk of desertification and impact China's long-term grain security. Production of rice, corn and wheat could fall by 10 percent by 2030 and up to 37 percent by the second half of the century.

EFFORTS TO TACKLE CLIMATE CHANGE

International communities are mobilized and working together to raise awareness and control climate change. Under the Kyoto Regime, 35 countries are working to reduce their GHG emissions to below 1990 levels, while companies are reducing their carbon footprints and developing low-carbon solutions, and international NGOs are leading awareness-raising initiatives.

Efforts by China

As the Chinese government has realized the dangers of climate change, it has been determined to set clear goals to fight with it and has already made serious efforts on many fronts.

The biggest shift has been the move away from a relentless pursuit of GDP growth alone to a more balanced and sustainable pace of growth, with energy efficiency and the environment added to the development targets.

The Chinese government aims to optimize the structure of the economy growth: In the 11th 5-year Plan (from 2006 to 2010), the government set an ambitious goal to decrease energy consumption per unit GDP by 20 percent and to reduce investment overcapacity in energy-intensive fields. This goal demonstrates China's aspiration to build a resource conservative and environmentally friendly society. It will also enhance national capacity to mitigate and adapt to climate change.

Furthermore, China has implemented a series of policies and legal guarantees to further enhance its capability to address climate change, including enacting the Law on Energy Conservation of the People's Republic of China, adopting the Renewable Energy Law, and establishing the NCCCC and Energy Leading Group. More importantly, the proactive stance taken by China won it huge praise at the Bali climate change conference in 2007.

The road ahead will be far from smooth, however, as China tries to sustain its rapid economic growth while shouldering a fair share of responsibility in containing global GHG emissions. Greater international cooperation on mitigation or adaption measures could enhance China's aspirations to realize its GHG abatement potential. Countries with advanced environmental technologies, such as Denmark, for example, are well-positioned to offer opportunities of such cooperation.

Efforts by Denmark

Denmark, a pioneering country in fighting climate change, has made great progress at home, as well as actively promoting international cooperation in relevant fields.

After the 1973 oil price shock, the Danish government recognized the critical importance of energy security and the danger in continuously relying on oil imports from politically unstable regions. It has since created an enabling regulatory environment comprised of regulations, subsidies and taxations, all of which has led to the development of many world-leading technologies in tackling energy efficiency and climate change. Along with this effort, Denmark has successfully decoupled economic growth and energy consumption, meanwhile keeping its GHG emissions low. Since 1980, although Danish GDP has grown more than 60 percent on the constant price level in year 2000, the gross energy consumption has remained at about the same level as 1980. It now ranks second only to Japan in energy consumption per unit of GDP.

Denmark has also been an active promoter of international cooperation in the climate change efforts. Its export of energy efficient technology and equipment has increased by 195 percent from 1996 to 2006. Its share of energy-efficient technology exports is now almost 50 percent more than the EU-15 average. Moreover, Denmark has continuously provided environmental aids and technological assistances to developing countries. In 2009, Copenhagen will host the United Nations Climate Change Conference (COP15), which will be key in regulating the global efforts in GHG abatement after the expiration of the Kyoto Accord.

Efforts by McKinsey & Company

McKinsey & Company has acquired distinctive expertise in the global climate change effort through comprehensive work on global abatement means, volume and cost. As a leading institution, McKinsey has taken an active role in the economic research of climate change abatement cost curve, carbon productivity and energy efficiency. Those research draws heavily from extensive client service on climate change topics, and contributes to better understanding of the issue and possible solutions in the broader society.

On the occasion of the Danish-Chinese conference on climate change, McKinsey is proud to be invited by the Danish Embassy and five leading Danish companies to explore the potential for technology cooperation to address carbon emissions in China. This effort, extending the current work on the China Climate Change Abatement Cost Curve, attempts to quantify the abatement potential of five Danish technologies in China and facilitate the cooperation.

Chapter 1: The opportunity for technology cooperation

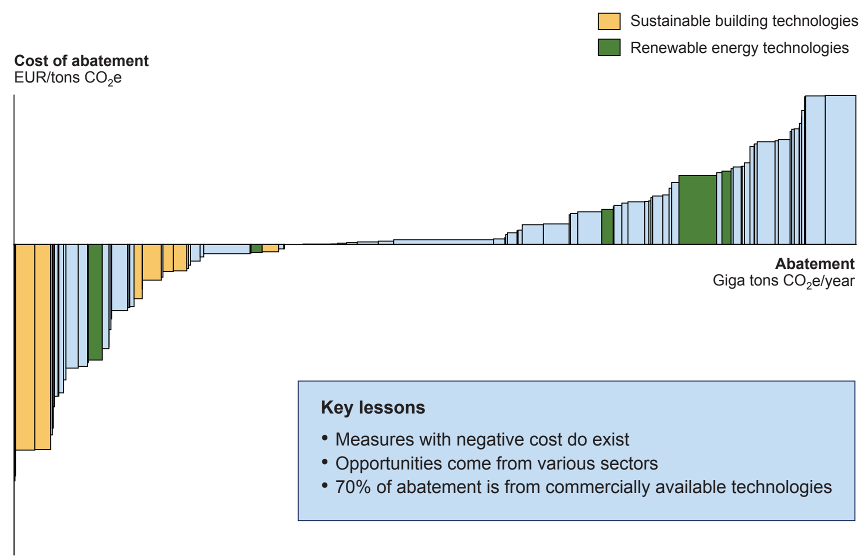
CHINA'S CARBON ABATEMENT LEVERS

Before considering the potential for a cooperation on carbon abatement, it is important to understand: What are the abatement potentials of different measures? How much will each of them cost? These are questions that the McKinsey cost-curve analysis aims to answer. By plotting the costs of carbon abatement against the amounts of emissions reduction available from the abatement measures, as illustrated in exhibit 1.1, cost-curve analysis provides a fact base for policy-makers to understand the significance and cost of each carbon-abatement measure.

Exhibit 1.1

CHINA GHG ABATEMENT COST CURVE*

ILLUSTRATIVE



* Preliminary curve for 2030; final result will come out by the end of 2008

Source: McKinsey

The preliminary result of China cost curve has already clarified several commonly held myths surrounding carbon abatement and is leading to a more accurate understanding of the realities. The first myth is that abatement opportunities are concentrated in the industrial and traditional power sectors. However, it is estimated that the industrial and power sectors represent less than 45 percent of the total 2030 abatement potential. Meanwhile, buildings and renewable energy also have sizable abatement potential. Next, we all too often hear that "abatement is costly". However, technologies with negative abatement cost from society perspective do exist. And developing countries may also hold a cost advantage in some areas. For instance, it's cheaper to apply green technologies in new builds rather than by retrofitting. The third common misconception is that we can only achieve the required abatement through new technologies. Reality is that 70 percent of the total 2030 abatement potential can be achieved from technologies that are commercially available. Many developed countries and leading companies have successful experiences in applying these technologies in achieving significant abatement potentials.

As exhibit 1.1 illustrates, significant opportunities exist for huge carbon abatement in the sectors of sustainable buildings and renewable energy. From a total life-cycle cost perspective, these two areas also demonstrate relatively low or even negative abatement cost.

- **Sustainable buildings**

  Buildings that are designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. They often incorporate many green technologies in heating and ventilation, passive designs, windows, appliances, stand-by losses, etc.

- **Renewable energy**

  Energy generated from resources that could be naturally replenished. In China, key opportunity technologies include wind, biofuels, hydropower, etc.

RELEVANT DANISH TECHNOLOGIES

In these two important opportunity areas, Denmark possesses some "state-of-the-art" technologies. Exhibit 1.2 provides more examples.

Exhibit 1.2

KEY DANISH TECHNOLOGIES IN BUILDINGS AND RENEWABLE ENERGY

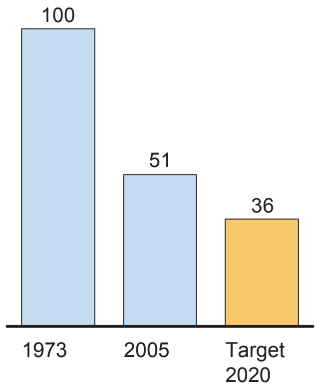
Sustainable buildings	Renewable energy
• District heating and metering	• Wind power
• Pumps	• Biomass/bioethanol
• Passive design	• Hydro and wave power
• Building materials	• Solar power
• Ventilation and air conditioning	• Geothermal power
• Micro combined heat & power	• Fuel cell
• …	• …

Source: Dansk Industri; McKinsey analysis

By applying these technologies, Denmark has achieved impressive success. Energy consumption per private household (excluding transport) has fallen by 30 percent since 1980. Space heating needs per unit area has dropped nearly 50 percent and is expected to continue downward, as illustrated in exhibit 1.3. The share of renewable energy has now reached 17 percent, mainly driven by wind power, and aims to reach 30 percent in 2020, as illustrated in exhibit 1.4; while biofuels' share of all transport fuel is also targeted to achieve 10 percent in the same timeframe.

Exhibit 1.3

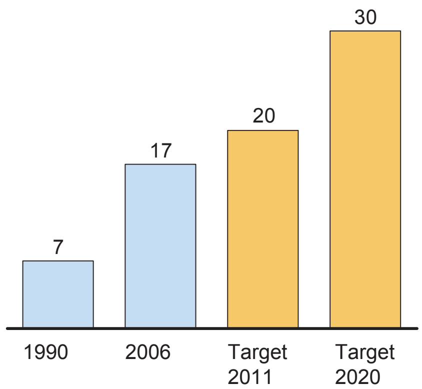
HEAT NEEDED PER UNIT AREA
Index



Source: VEKS; Danish Energy Agency; McKinsey analysis

Exhibit 1.4

RENEWABLE SHARE OF TOTAL ENERGY
Percent



Source: Danish Energy Agency; McKinsey analysis

In the following chapters, we will explore in close detail five Danish green technology examples in these two fields, with a focus on their abatement potential, adoption challenges and potential policy direction and business strategy to speed adoption.

— **Passive building design** that significantly lower energy demand of buildings

— **Energy-conserving temperature control systems** that efficiently regulate the temperature and heat flow throughout the whole system

— High-quality, high-efficiency **pump technology** used to transport water and other fluids in buildings and industrial applications in energy efficient manner

— **Enzymes technology** used in biofuel, textile and animal feed applications

— **Wind power technology**

Chapter 2: Building passive design

INTRODUCTION TO PASSIVE BUILDING DESIGN

Passive building design is a holistic approach to buildings that integrates specific architectural technologies and techniques to optimize the insulation, ventilation, orientation and shade of a building, bringing comfort to inhabitants at reduced energy consumption levels. Because it reduces energy consumption, passive design has the potential to reduce CO_2 emissions.

Energy consumption from buildings accounts for around 20 percent of total energy consumption in China. Share of carbon emission from buildings is also at 15 to 20 percent of total emissions in China. Passive building design could potentially abate 120 million CO_2e in 2020 at negative abatement cost. Therefore, it is one of the most important abatement technologies in the building sector.

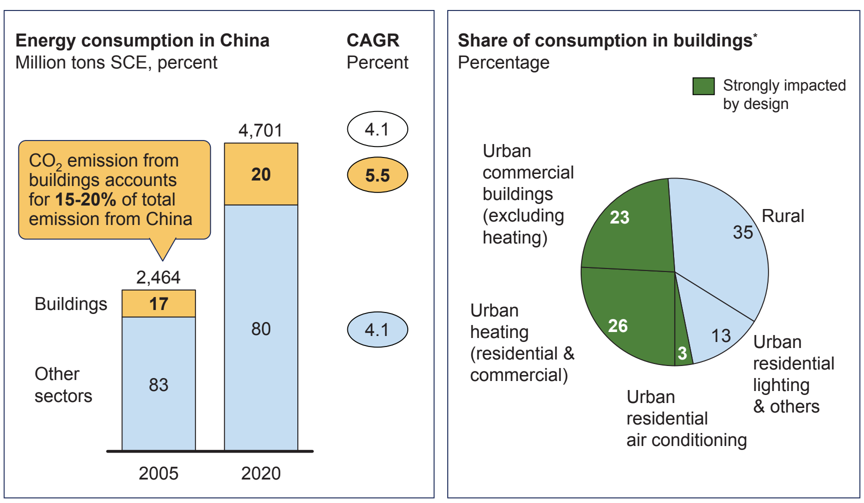
However, there are certain barriers that prevent large-scale adoptions of passive design. It would take significant additional efforts from the public and private sectors to expedite adoptions and capture the full potential.

CARBON ABATEMENT POTENTIAL AND COST

As illustrated by exhibit 2.1, a breakdown of energy consumption in China shows more than 50 percent of that is from heating and cooling, which has significant energy saving potentials from passive design.

Exhibit 2.1

ENERGY CONSUMPTION FROM BUILDING SECTOR



For example, in the northern region of China where winters are harsh, huge amount of energy is consumed each year to keep in-door temperatures at a comfortable level. Energy consumption from heating accounts for 25 percent of the total energy consumption in buildings. However, poor insulation and the escape of heat through ill-fitting windows and walls are causing significant waste of energy. It is estimated that passive building design could reduce energy consumption of heating by 50 percent on an individual-home basis.

Passive building design also holds important energy saving potential for the mighty commercial buildings that are being erected across China's cities. Cooling of these buildings significantly is another major energy consumer. The energy consumption of large commercial buildings (with floor space of more than 20,000 m^2) is 3 times that of "normal" buildings, with more than a third of that consumption coming from air-conditioning. The better shading and orientation afforded by passive building design could reduce the electricity consumption of air conditioning by 40 percent. Case 2.1 shows a recent study on energy saving potential by a Danish architectural design firm.

CASE 2.1: ENERGY SAVING POTENTIAL BY PASSIVE DESIGN

A recent study, conducted by a Danish architectural design firm, has illustrated significant energy-saving potential from passive building design and complementary technologies. The study is based on a "virtual" (simulated by computers) high-rise residential building in Beijing, with 5 towers and 157,000m^2 of floor space.

In the study, a mix of passive and active design measures were tested. These design measures will interact organically with the users of the building as well as the geographical, climate and cultural context. Specific design parameters include:

— Optimization of passive design qualities: building envelope, climate zoning through use of atrium and gardens, natural ventilation, use of daylight through correct use and positioning of windows, daylight reflection, and thermal mass.

— Application of additional active technological design qualities: applying adsorption machines and borehole storage to cover heating and cooling demand, either supplemented seasonally with traditional cooling on electricity, or based entirely on solar energy

The result of the study shows a 69 percent reduction by applying passive building design alone (from 165 to 52 kWh/m^2) and up to 86 percent reduction by applying additional active technology-based design parameters, assuming reasonable level of living comfort, improved indoor climate and local living habits. The pay back period of passive design is 5–9 years while that of active technological design 11–12 years, depending on the choice of specific design parameters.

A detailed list of design parameters used are provided below:

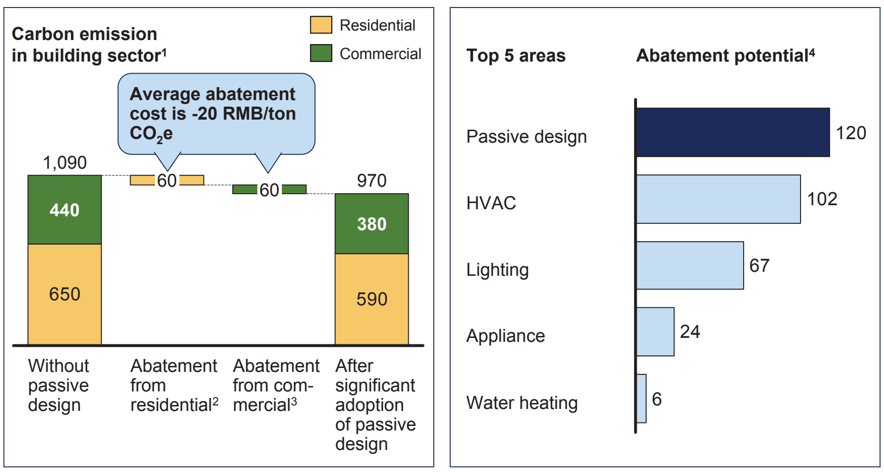
Design Parameter Set	Passive design	Additional applications
1. Prioritizing and optimizing daylight	X	-
2. Solar shading	X	-
3. Compact design	X	-
4. A green design	X	-
5. Strategic construction design	X	-
6. Easy to access and to install	X	-
7. A sound building technique	X	-
8. Using sound materials	X	-
9. Ventilation concept	X	-
10. Automatically controlled artificial lightning	X	-
11. Water installations	X	-
12. Use of rainwater	X	-
13. Measuring the use of energy and water for each unit	X	-
14. Displaying the energy use	-	X
15. Using geo thermal techniques	-	X
16. Producing hot water or air in solar collectors	-	X
17. Producing electricity in solar panels	-	X
18. Using low energy equipment – pumps, fans etc	-	X

In a "business as usual" scenario, a scenario where current trends are effectuated but where market conditions are unchanged in regard to technology development and regulations, carbon emissions from energy consumption due to heating and cooling of residential and commercial buildings in urban areas would reach 1,090 MT CO_2e by 2020. However, with significant adoptions of passive building design in new buildings, as illustrated in exhibit 2.2, an abatement potential of 120 MT CO_2e could be realized (60 from residential buildings and 60 from commercial buildings), with average abatement cost at -20 RMB/ton. This would account for nearly 10 percent of the total abatement potentials in the building sector.

Exhibit 2.2

ABATEMENT POTENTIAL FROM PASSIVE DESIGN

Million tons CO_2e



1 From energy consumption of heating and cooling in urban area only
2 Penetration of passive design assumed to be 20% in 2015 and 40% in 2020 for new residential buildings
3 Penetration of passive design assumed to be 25% in 2015 and 50% in 2020 for new commercial buildings
4 Abatement potential figures are preliminary and will be finalized in 2009

Source: McKinsey Cost Curve Analysis; expert interview; press search; McKinsey analysis

CHALLENGES TO ADOPTING PASSIVE BUILDING DESIGN IN CHINA

China has placed great emphasis on building energy efficiency and tackling climate change. In recent years, the Chinese government has taken the following initiatives to improve energy efficiency in the building sector:

- Aggressive target of reducing energy consumption per unit of GDP by 20 percent in the 11th 5-year plan, in which the building sector will account for 20 percent of the reduction
- A set of building codes specifically designed for energy saving and customized for different climate zones
- Large-scale energy audit work to further understand current energy consumption in public buildings (similar work for consumption in residential buildings will also be carried out soon)
- New regulation, taking effect from October 1st 2008, to ensure that building codes related to energy-efficiency are strictly enforced for both new buildings and retrofits
- Promotion of “Green Building Label” system, a voluntary standard to encourage the adoption of leading “green building” technologies, including those for energy efficiency

Despite these efforts, however, the adoption of passive design has been extremely slow. This is mainly due to issues around building standards, recognition of economic benefits, and capability.

- **Lack of influential standards**

  The newly launched “Green Building Label” system, a voluntary set of evaluation criteria for buildings, has not yet received recognition among real-estate developers. Meanwhile, similar voluntary standards are competing with it for market attention and confusing consumers.

  Implementation challenges also exist. While some criteria under the current system lack sufficient details customized for residential buildings, other criteria are too comprehensive to be effective. For example, water recycling is very difficult – very few households are motivated to seriously consider it as current water price is quite low in China.

- **Low recognition of economic benefits**
  Many developers do not see energy efficiency as a key selling point to consumers and are therefore not willing to incur the extra upfront cost of passive design. Furthermore, some consumers in the northern regions would not appreciate the benefits of energy saving as their heating expenses are largely government subsidized.

- **Capability gap**
  Most architects and designers in China do not have the requisite skills to create an integrated solution that could fully capture the energy-saving potential. Nor are there many best practices in the market for professionals to learn from. Furthermore, software and other tools are not sufficiently mature to facilitate such designs.

OPTIONS TO ADDRESS THE CHALLENGES

As the Chinese policy makers continue to build on their efforts to achieve greater energy efficiency within the building sector a number of options are available to enhance the efforts, especially in strengthening the current Green Building Label system, while the private sector also faces a few options to address the agency issue and develop the necessary capabilities.

Options for policy makers to improve the Green Building Label system

Experience from Denmark and the United States shows that to implement a successful green building labeling system, the originator needs to:

- **Engage leading players**
  Encourage internationally-leading architects to work with local developers to build China-specific best practices; incentivize leading developers to apply for and obtain certificates from now on. Exhibit 2.4 provides some details on similar experience in United States.

- **Improve evaluation criteria**
  Create a separate set of criteria for residential & commercial buildings; create subset labels for energy efficiency & other dimensions.

- **Enhance brand awareness**
  Distinguish the system from other voluntary standards and emphasize its role in promoting green buildings; also increase promotion of this standard through various public media.

CASE 2.2: LEED IN THE UNITED STATES

The experience of LEED in the U.S. illustrates the importance of incentivizing developers to adopt green buildings. The Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the U.S. Green Building Council (USGBC), provides a suite of standards for environmentally sustainable buildings. Such buildings, certified by LEED Steering Committee, are designed to use key resources more efficiently when compared to conventional buildings, which are simply built to code. Since its inception in 1998, LEED has grown to encompass more than 14,000 projects in 50 U.S. States and 30 countries covering 1.062 billion square feet (99 km^2) of development area.

One of the key reasons for such huge influence is that developers see the certification from LEED as an effective and economically sustainable approach to construct green buildings. With continuous promotion and education from the Green Building Council and leading developers, consumers appreciate the social and economic benefits of these green buildings. The certification system also makes them easy to recognize "truly green" buildings. As a result, some consumers are willing to pay a premium for buildings with such certificates. Meanwhile, as the evaluation criteria are public and transparent, it is relatively easy for architects and engineers to design buildings that comply with the standards. Combining these factors, the market mechanism has worked to expedite the adoption of green buildings in the U.S.

Despite the successes it would not be feasible for China to replicate the LEED mode directly. The evaluation criteria, for example, would not be suitable to China as it has quite a different climate and energy consumption compared to the U.S. China should continue to improve its "Green Building Label" system to the specific Chinese situation. However, more improvements are required to make the China market mechanism more effective. It is especially critical to incentivize developers, as well as other key stakeholders, to adopt green buildings in an economically sustainable manner.

Options for leading architectural design companies:

The private sector could play an important role in facilitating changes to help achieve greater energy efficiency in buildings. Specifically, closer collaboration, and more open channels for feedback and shared learning could be highly beneficial.

- **Build best practices**
  Work with leading developers to build pilot projects designed to follow "Green Building Label" guidelines. This would bring wider attention to the Green Building Label and ensure shared learning among local architects from best-practice cases.

- **Provide technical feedback**
  Provide early and rich fact-base feedbacks through building energy auditing to the government through such pilot projects in order to improve the current evaluation criteria based on implementation experience.

- **Transfer basic skills**
  Actively participate in training efforts organized by the government targeting to architects and engineers in order to gradually build basic skills in domestic players.

Chapter 3: Energy-conserving temperature control systems

As China continues to urbanize its population at an unprecedented scale, energy used for temperature control has also expanded to match previously unmet need.

However, the choice of making temperature control an energy efficient process remains exactly that—a choice. Technology solutions that can improve energy efficiency now exist, but it remains a collective choice on the part of government, society, and business whether these solutions will be implemented in China. Application of this technology has huge potential for energy savings across China's large existing infrastructure and more importantly, the tremendous amount that are being built.

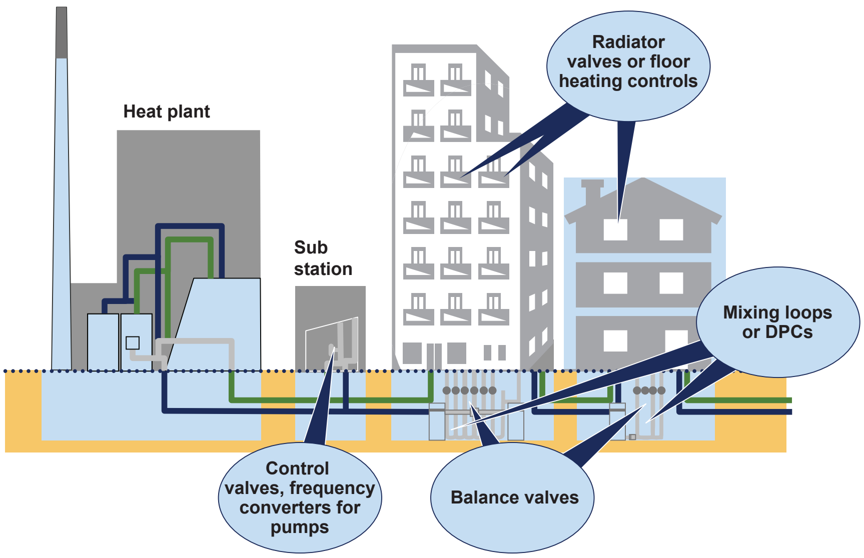
INTRODUCTION TO AUTOMATIC HEATING CONTROLS

In regions with regularly-occurring cold winters, it is often more efficient to centralize the process of heating buildings than to allow each building or household to burn fuel to provide heat for itself. This heat is produced at a heating supply plant, which typically burns coal to heat water that is then distributed through pipes to a routing point known as the substation. This is the primary heating network. The substation, in addition to maintaining water pressure, channels heated water to buildings. This is the secondary heating network. Finally, a system of pipes at the building entrance circulates heated water to individual rooms. This is the tertiary heating network, where end-users finally receive heat. Heating controls, which regulate the flow and volume of heat through the system, may be integrated at both the secondary heating network and at the end-user level. Exhibit 3.1 provides a graphical illustration of automatic heating controls in a district heating network.

Heating controls are comprised of a collection of valves, frequency converters, and other control products. While manual heating controls have recently gained increased acceptance in China's new residential buildings, the impact of these manual controls is strongly diminished by the current heat billing system that provides no financial incentive for building residents to reduce heat use. Even if end-users did manually reduce their heat use, heating plants may not be able to benefit by cutting back on fuel consumption due to the design of heating networks. Additional automatic controls must be installed at the secondary network level to reap the full extent of these savings. As a result, this section focuses primarily on automatic heating controls.

Exhibit 3.1

AUTOMATIC HEATING CONTROLS IN A DISTRICT HEATING NETWORK



Source: McKinsey analysis

If thoroughly implemented, automatic heating controls will reduce energy waste endemic in China's heating networks. With prevailing technology, heating supply plants must produce sufficient heat to provide adequate, legally required temperature levels to homes furthest away. Without automatic controls, heating plants are forced to overproduce heat by 25 percent on average. Automatic controls can solve this problem by channeling excess heat toward the furthest away homes simultaneously and therefore abate carbon emissions. Additional abatement potential exists by reforming the billing system to charge by heat use, causing end-users to voluntarily adjust their heat use when not needed.

CARBON ABATEMENT POTENTIAL AND COST

China has huge potential for reducing CO_2 emissions and could realize a substantial economic benefit by exploring the full potential of automatic heating controls for buildings in China.

Large carbon abatement potential

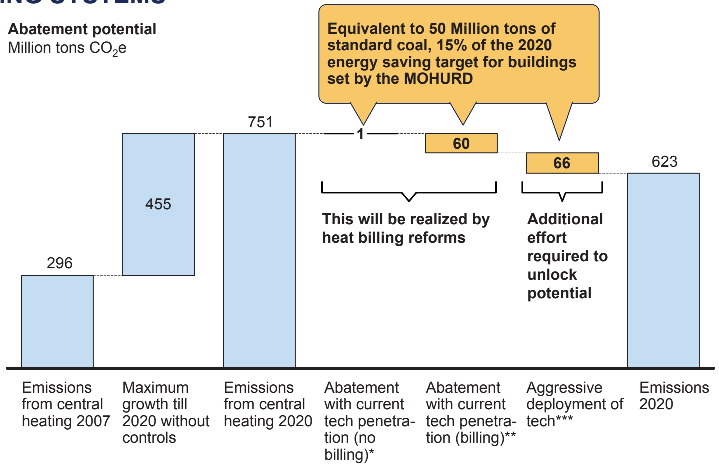
China's tireless urbanization effort is one unparalleled in human history. The McKinsey Global Institute estimates approximately 1 billion new square meters of urban residential space will be constructed in China, annually. If current trends hold, nearly 60 percent of this building space would be constructed in regions that endure winters cold enough to benefit from centralized heating. As a result, a significant amount of energy is expended on heating, currently accounting for 10 percent of China's total energy use, or 130 MT Standard Coal Equivalents (SCE). However, without additional control systems, this figure could grow to as much as 300 MT SCE in 2020.

Centralized heating provides a more energy efficient alternative to individual gas or coal boilers, the prevailing technology for China's winter residents. Even still, it is apparent that there is tremendous room for efficiency improvement even within centralized heating. China currently consumes 2 to 3 times the amount of energy per square meter compared with the EU. Part of this inefficiency can be attributed to the low penetration of heating controls in China at the end-user level (at just 1 percent) compared to virtually full coverage in advanced European countries such as Denmark.

Currently, 296 MT CO_2e is produced by China's centralized heating network. If central heating networks were fully applied in places where it makes economic sense, 455 MT more CO_2 could be produced in these networks in 2020. Without the implementation of any reforms, the current low penetration of automatic heating controls would remain low, leading to just abatement of just 1 MT CO_2e in 2020. Fortunately, China has begun a series of reforms that will ultimately change the way consumers pay for, and thus how they choose to use or misuse, heat coming from central heating networks. An additional potential of 60 MT CO_2e exists by changing relevant end-user behaviors. If automatic controls were fully installed, China could benefit from an additional 66 MT CO_2e abatement, bringing the total abatement potential to 127 MT CO_2e, as illustrated in exhibit 3.2.

Exhibit 3.2

CARBON ABATEMENT POTENTIAL FOR CHINA'S DISTRICT HEATING SYSTEMS



* Maintains current penetration of ~1% automatic and ~99% manual controls on end-users, assumes no billing system reform

** Maintains current penetration of ~1% automatic and ~99% manual controls on end-users, assumes network-wide automatic controls for hydraulic balancing, and a reform in billing system to charge by consumption by 2020

*** Assumes 100% automatic controls penetration on end users, in addition to network-wide automatic controls and billing system reform

Source: Danfoss; Energy Efficiency Committee; McKinsey analysis

Attractive business case

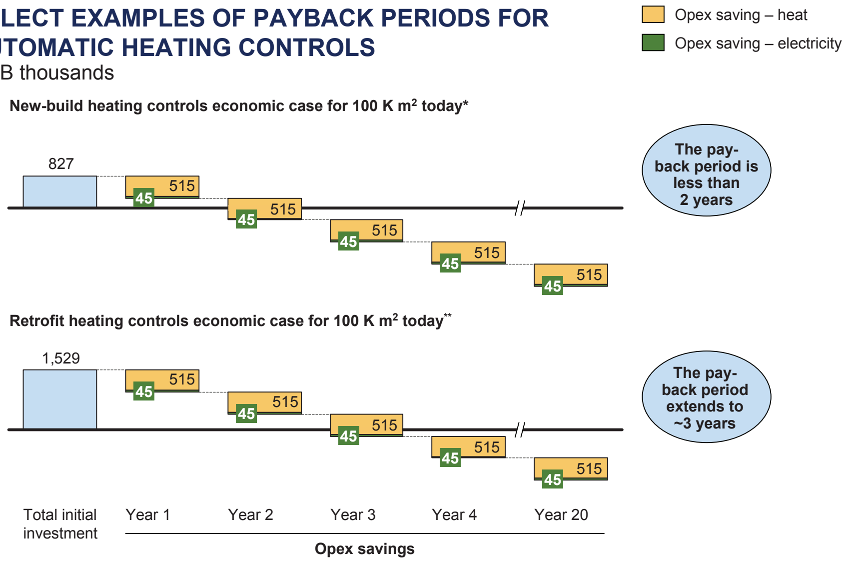
Given the tremendous growth of centralized heating in China, implementation of automatic heating controls could play a central role in helping China achieve its aspiration to reduce its CO_2 emissions and become more energy-independent.

Controls have an established track record from installation across developed heating markets in Europe. While payback periods vary depending on local conditions, in China, energy cost savings of automatic heating controls could easily compensate for the upfront investment. Due to the level of overheating in China's heating networks (25 percent of heat produced is wasted this way, according to the leading Chinese experts), automated heating controls could pay for themselves in just 1.5 to 3 years, a figure confirmed by European experience, as illustrated by exhibit 3.3.

Exhibit 3.3

SELECT EXAMPLES OF PAYBACK PERIODS FOR AUTOMATIC HEATING CONTROLS

RMB thousands



* Simulates a district in China's Extreme Northern region, adequately insulated and equipped with radiators and dual-piping

** Simulates a district in China's Extreme Northern region, adequately insulated and equipped with single-piping

Source: Danfoss; McKinsey analysis

This payback period presupposes one key component in the buildings – the buildings must be adequately insulated to recent building code standards. Without this level of insulation, the heating controls are not as effective in reducing heat use, since the room requires much more heat to maintain a comfortable temperature. Fortunately, these building codes have been in place since 1994 and have seen a rapid rise in adherence rates since 2003.

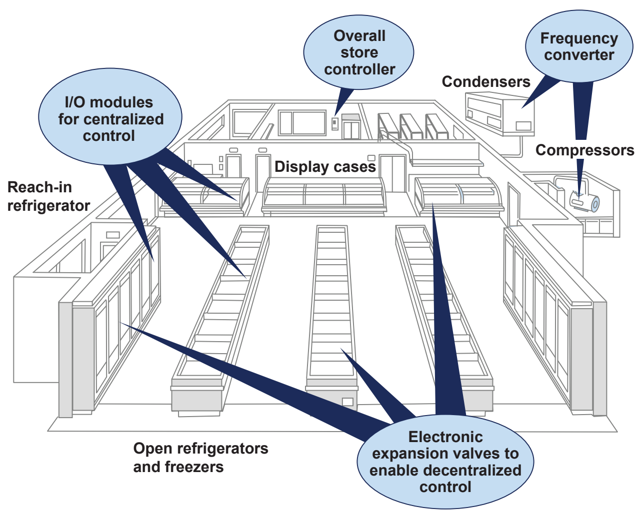
China faces a window of opportunity to install the automatic heating controls in new builds as opposed to developed countries where most of the opportunities have to come from retrofitting existing buildings. Due to the relative ease of installing automatic heating controls in a building still being built, the costs and therefore payback period to equip a typical residential district in a wintry province like Liaoning is very low, approximately a year and a half. Given that almost 600 million m^2 of residential buildings will be added in China's cold winter urban regions every year, the size of this opportunity is tremendous. For existing buildings, there are two options: to retrofit individual rooms with the controls at the end-user level, or to install a relatively costly heating control product at the network level known as a "mixing loop." The more financially attractive of these two solutions, the installation of mixing loops, has a payback period of nearly 3 years in a province like Liaoning. While these economics are still attractive, the most cost-effective solution remains in new buildings.

INTRODUCTION TO REFRIGERATION CONTROL MANAGEMENT SYSTEMS

To complete the journey from the farm to our plate, food must travel through an extensive distribution network. The very last link in this distribution network is the grocery store, where the final hand-off is made to the consumer. In the modern grocery store, a variety of refrigeration units are employed to increase product visibility and maintain maximum shelf life. Typically, refrigeration units in grocery stores are built simply with a traditional on-off switch and are typically run at a single fixed setting regardless of actual energy need. As a result, food is often inefficiently chilled, especially at night and during colder seasons. Refrigeration control management systems are a collection of controller valves and frequency converters that can capture this opportunity for energy savings by adjusting the intensity of the condenser fans and compressors in accordance with actual need. With these management systems, temperature can be kept at a precise level to keep food at the required level with minimal inefficiency. Exhibit 3.4 provides a graphical illustration of grocery store refrigeration system.

Exhibit 3.4

REFRIGERATION CONTROLS MANAGEMENT SYSTEMS IN A GROCERY STORE



There are two types of systems that can be applied to grocery stores

- Centralized control
  - I/O modules
  - Frequency converters for condensers and compressors

OR

- Decentralized control
  - Electronic expansion valves
  - Frequency converters for condensers and compressors

Source: Danfoss; McKinsey analysis

CARBON ABATEMENT POTENTIAL AND COST

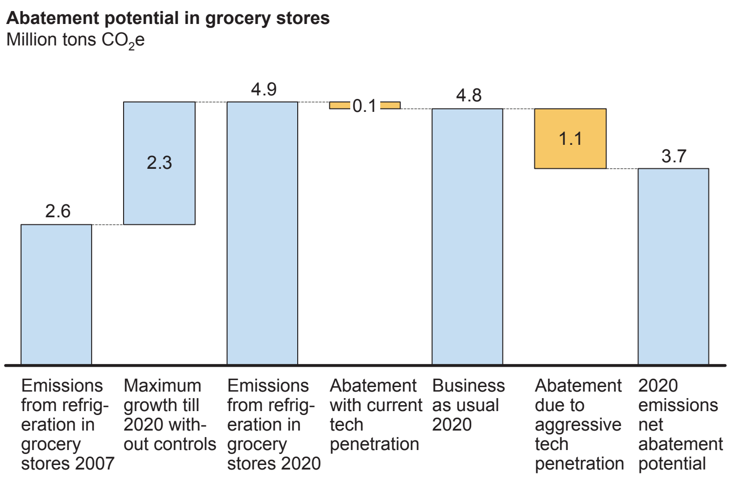
China has a significant opportunity to reduce CO_2 emissions stemming from the energy use from refrigeration in grocery stores. As China's cold chain continues to develop and expand, refrigeration control management systems could have a wider set of applications and thus also greater abatement potential.

Carbon abatement potential

Modern grocery store formats have taken off in China, with hundreds of new stores constructed in recent years and thousands of new stores yet to be built. Efficient control of refrigeration energy use by the grocery retailer industry in 2020 holds an abatement potential of 1 MT CO_2e per year, as illustrated in exhibit 3.5, mainly from the efficient reduction of refrigeration intensity and fan speed.

Exhibit 3.5

CARBON ABATEMENT POTENTIAL FOR REFRIGERATION IN CHINA'S GROCERY STORES



Source: Planet Retail; Danfoss; McKinsey analysis

Although noteworthy in itself, this abatement figure still represents just the tip of the iceberg in terms of potential. The grocery stores are just the last small step bridging producers with food consumers in a distribution network known as the cold chain. The cold chain refers to the entire temperature-regulated food distribution network, including refrigerated trucks, ships, railcars, cold rooms, and warehouses. Just as in grocery stores, each link in the chain employs energy-intensive refrigeration units to keep food preserved and could potentially conserve energy if management systems are installed. China's cold chain is in the process of rapid expansion, encompassing a larger and larger portion of food travelling from producer to consumer. Currently in China, the cold chain has a low coverage rate of just 15 percent of food that should be temperature-controlled. European and American cold chains have had a longer time to mature and now feature coverage levels of 85 percent. Thus, China's cold chain still has a tremendous room for expansion even within the existing food distribution network.

Not only will the cold chain expand as a fraction of the total food distribution network, the distribution network itself will also undergo rapid expansion through 2020. Food sales in China to the middle class, whose consumption will drive the growth in the cold chain, are projected to increase 5 times. Furthermore, it is estimated that just 20 billion RMB of food in China was distributed to the middle class via the cold chain in 2007. As noted in the previous paragraph, the cold chain penetration rate could rise by more than five times to match penetration rates observed in the US and Europe. As a result, the food travelling through the cold chain could eventually exceed 500 billion RMB by 2020, a tremendous 25-fold plus increase.

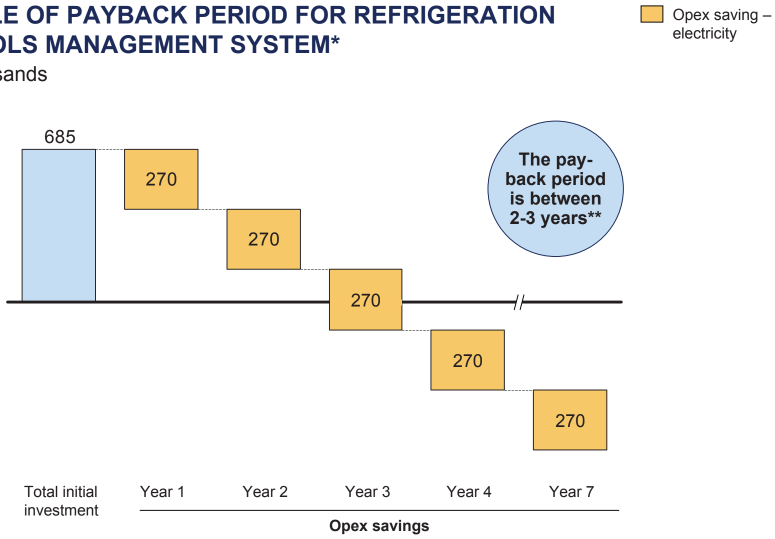
Attractive business case

Refrigeration control management systems have already been well-received in developed markets, particularly by the large hypermarket chains that have the most exposure to international energy management practices. These systems have been accepted in these markets because of their short payback periods and long term reductions in operating costs, a critical consideration in the cutthroat cost-sensitive industry of grocery retailing. While payback periods vary depending on local conditions, in China, these systems are financially attractive. Due to the high level of energy waste in refrigeration today, the energy savings can reach up to 30 percent with the implementation of the entire system that includes electronic valves and frequency converters. In a grocery store, where energy used for refrigeration accounts for approximately half of total energy use, this amounts to significant savings. A systems package can pay for itself in just 2.5 years and abate carbon at a very attractive negative cost of -770 RMB/ton of CO_2e. See exhibit 3.6 for details.

Exhibit 3.6

EXAMPLE OF PAYBACK PERIOD FOR REFRIGERATION CONTROLS MANAGEMENT SYSTEM*

RMB thousands



* Refers to a package of electronic valves and frequency converters installed in a new grocery store larger than 5,000

** Assumes 1,000,000 kWh/year refrigeration energy consumption, electricity prices frozen at RMB0.89/kWh. Savings from reduced food waste would reduce payback period further

Source: Planet Retail; Danfoss; McKinsey analysis

A combination of global and national factors is expected to cause electricity prices to rise in the future. On the global level, rapid growth in energy demand combined with the global call for a switch to cleaner (but often more expensive) fuel sources will spur electricity generation costs higher. On the national level, China is expected to continue the process of commercializing its electricity prices over time, as industry and residents become wealthier and gain the resilience to withstand this price increase. The future expected rise in electricity prices will only improve the business case for these systems. For instance, an increase of 0.25 RMB/KWh in addition to current commercial electricity prices of 0.89 RMB/kWh, will drop the payback period to 2 years.

Additional societal benefits of management systems

- **Food safety**

  McKinsey's 2008 Chinese consumer survey showed that 90 percent of Chinese consumers worry about food and beverage safety. More specifically, the presence of hazardous bacteria is the number one health concern when buying fresh food. Precise temperature control with accurate temperature meters can help to prevent this issue.

- **Food waste**

  Food security is becoming an increasingly important issue in China. An easy way to boost this security is to make full use of food that is already produced in China by minimizing waste.

CHALLENGES TO ADOPTING AUTOMATIC HEATING CONTROLS IN CHINA

While both refrigeration control management systems and automatic heating controls both hold immense potential for carbon abatement, the latter face more challenges. Thus, the following sections will focus on identifying the challenges and potential policy directions for adopting automatic heating controls.

Despite the tremendous societal benefits offered by heating controls and development directions set by central government, the opportunity remains largely untapped in China, with approximately 1 percent penetration at the end-user level, even including areas where it makes economic sense to do so.

Four challenges are largely responsible for the situation:

- **Lack of awareness**

  Compared with developed heating markets in Europe, automatic heating controls remain a relatively new concept for local government officials, building designers and developers, and residents in China.

- **Lack of incentives**

  Under the current incentive structure each key stakeholders have reasons to maintain their current behaviors. Energy efficiency in the building sector has not been fully integrated into the evaluation systems of local government officials. Heating companies are facing fiscal constraints that limit upfront investment and financial uncertainties that would result from adoption of controls and billing-by-consumption. Without a clear timeline of reforms leading to consumption-based billing, building developers fear that their investment costs will not be recouped by higher building prices.

- **Lack of governmental support**

  Multiple government agencies at the central and local level are involved, but limited coordination has slowed the heating reform. The structure of the local reporting matrix is another complicating factor. In general, implementers, such as the construction commission, receive tasks from the upper ministry, such as MOHURD, though they need support from local governments in allocating resources. While such a system has its merits, it can create lost momentum when local officials have to consider other priorities from command lines.

- **Insufficient industry standards and poor compliance**

  There are insufficient product standards and relevant, executable details in current building codes. All of these result in uncertainty for building developers and therefore are reflected in the low rate of automatic heating control installation and wide variance in product quality. Compounding the issue are low building auditing and inspection capabilities.

OPTIONS TO ADDRESS THE CHALLENGES

As the Chinese government continues to build on its efforts to achieve greater energy efficiency within the building sector, there are a number of options available to the government, such as clear goal setting and realigned incentives, which could bring significant improvements. Along with private sector efforts to improve the quality of policy and build domestic capabilities, these moves could encourage more widespread adoptions of automatic heating controls.

Options for policy makers

- **Set actionable goals**

  Setting prioritized and actionable goals at the national level would go a long way to accomplishing energy efficiency targets, e.g. the retrofit of automatic heating controls in all public buildings in urban areas, and clear goals for local governments to enforce heating control application in new-build residential buildings, the building segment with the most attractive payback on investment.

- **Better align incentives for key stakeholders: heating utility, developers and residents**

  Alignment of incentives requires that the cost and benefits of efficiency investments are reasonably shared between relevant players. At the government level, this would require making energy efficiency a more prominent KPI for local governments. For heating supply companies, incentives could be aligned by providing a financing window for energy efficiency investments. Consumption-based billing turns automatic heating controls into a tool to manage residents' payment behaviors, encouraging them to pay on-time or risk heat shutoff. Consumption-based billing, including placing a monetary consequence for wasting heat, would be critical in aligning incentives among real estate developers and end-users.

CASE 3.1: TIANJIN EXAMPLE

China is fortunate to have several local governments that have conducted extensive experiments in heating reform.

Among them, the city government of Tianjin has been particularly successful in aligning the incentives for stakeholders. The city requires that new building permits be issued with approval from the heating supply company, causing developers to align their construction plans with applicable heating regulations. Tianjin awards monetary and non-monetary prizes for heating companies that have made rapid reform progress, incentivizing companies to quicken the pace of improvement. Tianjin was also the first to pilot reforms which billed users by heat consumption, providing building residents an incentive to reduce their heat use.

- **Enforce codes and standards**

  Currently under the national building code the installation of automatic heating controls is a voluntary option. While this has produced successful results in cities such as Tianjin and Chengde, many more cities are proceeding with heating reforms at a much slower pace. Progress could be expedited with actionable guidelines from the central government. The local level would benefit from more detailed industry standards supplemented by an enforceable building auditing and inspection system.

- **Gradually adjust heating prices to reflect market realities**

  Currently, heat prices are based on political criteria with marginal consideration for total costs, and no differentiation between justified and unjustified costs. Experiences from countries such as Poland shows that in order to make heat prices more market-driven it would be necessary to define and identify what costs should be considered justifiable (e.g., efficiency improvements or energy price hikes) and what should not (e.g., wasteful practices). Meanwhile, it would also be important to ensure that the market-priced heat remains accessible to low-income population through targeted subsidies.

CASE 3.2: POLAND EXAMPLE

Faced with heating inefficiency several times worse than Western European averages, Poland initiated an ambitious plan to modernize Poland's heating infrastructure and practices. Central to this effort was an increase in heat prices to incentivize better efficiency and reduce the government's budgetary burden. Heat prices in the decade starting from 1995 rose more than 50 percent.

To ease this transition, Poland has 3 intermediary institutions that take a proactive role in safeguarding residents' access to heat. First, the Social assistance centers provide financial assistance to needy families that apply for help. Secondly, the Energy Regulatory Authority provides official mediation when heating companies wish to terminate contracts for non-paying residents. Thirdly, building societies, which are voluntary organizations that manage homes, collect dues and make building improvements, collectively represent individual interests to the heating companies.

These institutions have enabled Poland to implement aggressive reforms that reduced total heating energy use by 25 to 30 percent in a decade's time.

Options for leading companies

- **Understand and engage with the government agenda**

  Government will continue to take the lead role in guiding the direction of the heating sector. However, leading companies can apply their knowledge and play an advisory role in this process by engaging with the regulatory process. This process must begin by clearly understanding the division of responsibilities between NDRC, MOHURD, and MEP. Communication with these agencies should be tailored to their responsibilities and priorities.

- **Achieve breakthroughs at the local level**

  While several cities have already made significant strides in heating policy with the help of leading companies, more can be done. To achieve quicker breakthroughs, leading companies could consider first approaching local governments that have stronger drive to change, such as cities with large-scale renovation plans or those in process of designing their heating networks.

- **Help nurture local capability**

  Developing local capabilities is an important consideration in China, given that energy efficient central heating remains a relatively new concept. Leading companies can help to boost local capabilities on both the technical aspect and standards enforcement aspect of automatic heating controls. On the technical side, they can transfer district heating system design and maintenance skills. On standards enforcement side, they can introduce successful industry standards and best practices for building inspection mechanisms.

- **Create innovative financing plans**

  A shortage of funds hinders the adoption of automatic heating controls. As the organizations with rich experiences in credibly quantifying these savings, leading companies should actively help to address the financial constraints by introducing innovative financial plans, such as underwriting loans to heating supply companies in exchange for a share of energy cost savings.

Chapter 4: Pump technology

INTRODUCTION TO PUMP TECHNOLOGY

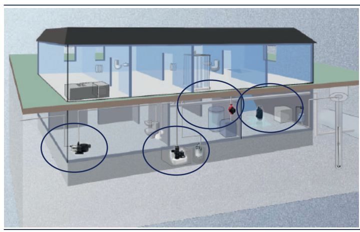
Pumps are widely used in applications transporting water and other fluids. They play a critical role in the operation of most industrial processes, as they are present in most commercial and residential buildings in heating, cooling (AC), water supply, waste water and firefighting applications.

As illustrated in exhibit 4.1, pumps are far from a unified entity. Based on different application areas and uses, a wide range of different pump types exists. In calculating CO_2 abatement potential, a segmentation of pumps is therefore useful, i.e., individual home pumps (for heating, cooling (AC) and water supply; often smaller in size and less efficient), building pumps (same type of pumps as for homes but larger in size and with higher efficiency) and industrial pumps which cover building-support pumps (similar to building pumps), process-support pumps and process pumps which are each a huge and fragmented segment in and of themselves.

Exhibit 4.1

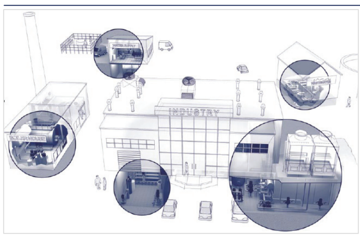
PUMP TECHNOLOGY OVERVIEW

Pumps in buildings



Pump types
- Heating
- Cooling (AC)
- Water supply
- Waste water
- Firefighter

Industrial pumps



Pump types
- Building support (heating, cooling (AC), water supply, firefighter, waste water)
- Process support
- Process pumps

Source: Expert interview; McKinsey analysis

The CO_2 abatement potential stems from replacing low-efficiency pumps with high-efficiency variable-speed pumps within each pump segment where technically and practically possible and where not currently applied. As the same type of pump with the same application area can have different efficiencies, the first step in abating CO_2 is to replace all low-efficiency pumps with high-efficiency ones. Also, as utilization of pumps varies during the day and over the year (depending on the type of pump installation), considerable CO_2 abatement potential exists if energy saving opportunities resulting from fluctuations in pump demand are captured by installing variable-speed pumps (pumps that run only when needed). Finally, additional abatement potential exists by ensuring the right size and design of the pumps installed i.e. re-build and optimize the pump system. In this report, analysis on abatement potential focuses on the first two pump abatement levers only, i.e., the potential of high-efficiency variable-speed pumps (waste water pumps and firefighting pumps are excluded). The last part of the chapter, on barriers to adoption and potential directions to overcome the challenges, focus mainly on high-efficiency pumps.

CARBON ABATEMENT POTENTIAL AND COST

China has huge potential for reducing CO_2 emissions and could achieve a substantial economic upside by exploring the full potential of energy-efficient variable-speed pumps in buildings and for industrial uses.

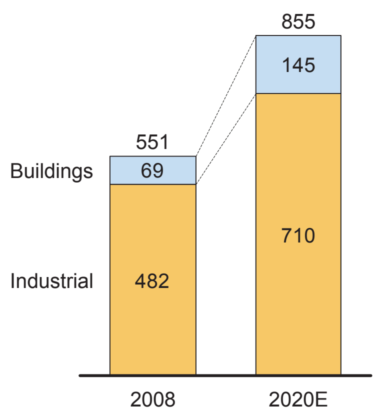
Large carbon abatement potential

Pumps consume 10 to 20 percent of electricity in the rapidly growing building and manufacturing industrial sector. Today, total pump electricity consumption is 550 billion KWh/year. Going forward, as illustrated in exhibit 4.2, electricity consumption by pumps is expected to grow to 855 billion KWh/year by 2020 due to strong growth in both the building and the industrial sectors.

Based on pumps with similar specifications (pump size of $600m^3/h$, pressure of 35m, hours run per year 2,520), the energy consumption of low-efficiency pumps (efficiency factor of 70 percent) is 14 percent higher than that of high-efficiency pumps (efficiency factor of 80 percent). By further installing variable-speed pumps, an additional 25 to 35 percent of electricity saving could be achieved, as illustrated in exhibit 4.3. High-efficiency pumps could technically and practically reach full penetration by 2020, i.e., 100 percent penetration

Exhibit 4.2

ELECTRICITY CONSUMED BY PUMPS
Billion KWh/year

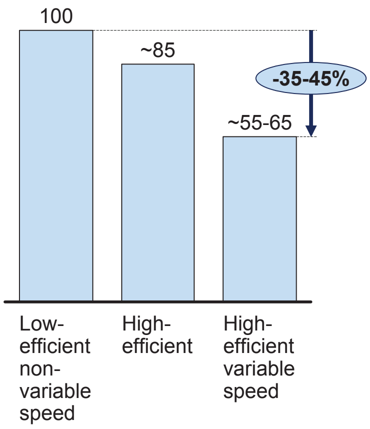


Source: McKinsey analysis

while variable-speed pumps would be applicable in most building pump solutions (heating, cooling (AC) and water supply) but only partly applicable in industrial installations as these often run at constant flow and therefore may not have electricity savings potential from installing a frequency converter. In China today only 2 to 4 percent of pumps are of high-efficiency. Under a business as usual scenario, this number is not expected to increase above 8 percent in either buildings or the industrial segment by 2020. Though in the industrial segment there will be a stronger tendency to upgrade the lowest-efficiency pumps to medium/high-efficiency pumps compared to the building segment. Consequently, in 2020 only 25 percent of pumps in the industrial segment are expected to be of low-efficiency vs. 40 percent in the building segment. Furthermore, variable-speed pumps would be unlikely to reach penetration of above 5 percent by 2020 in either of the segments.

Exhibit 4.3

ELECTRICITY SAVING POTENTIAL BY HIGH-EFFICIENCY VARIABLE-SPEED PUMPS
Index, KWh/year



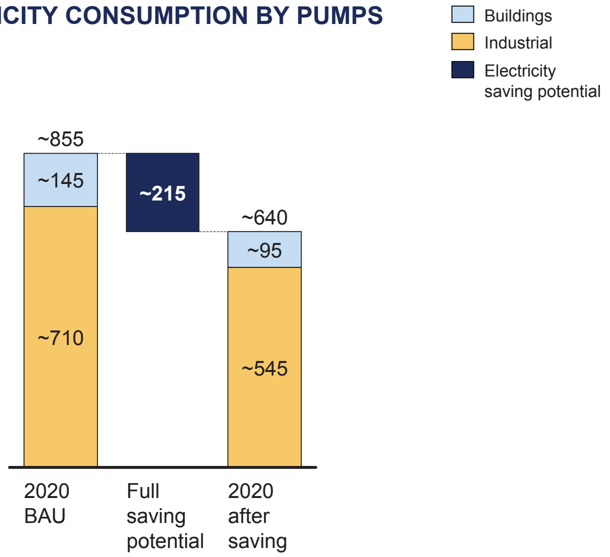
Source: Expert interviews; McKinsey analysis

In 2020, if all low-efficiency pumps in the market were replaced with high-efficiency variable-speed pumps, 135 MT CO_2e could be abated, of which 25 percent is from the building segment, as illustrated in exhibit 4.4. 46 percent of this would be the effect of installing high-efficiency pumps whereas 54 percent of variable speed. From an electricity-saving perspective the savings potential in 2020 would be 215 billion KWh, as illustrated in exhibit 4.5, or the equivalent of 400 100MW coal-fired power plants saved per year by 2020 or 26 MT SCE. In total the electricity savings potential would equal an electricity savings of 3.5 percent of total consumption in buildings and 4.5 percent of total consumption in the industrial segment. The corresponding yearly cost-saving potential on the electricity bill would be 147 billion RMB in 2020.

Exhibit 4.4

ANALYSIS OF ELECTRICITY CONSUMPTION BY PUMPS

Billion KWh

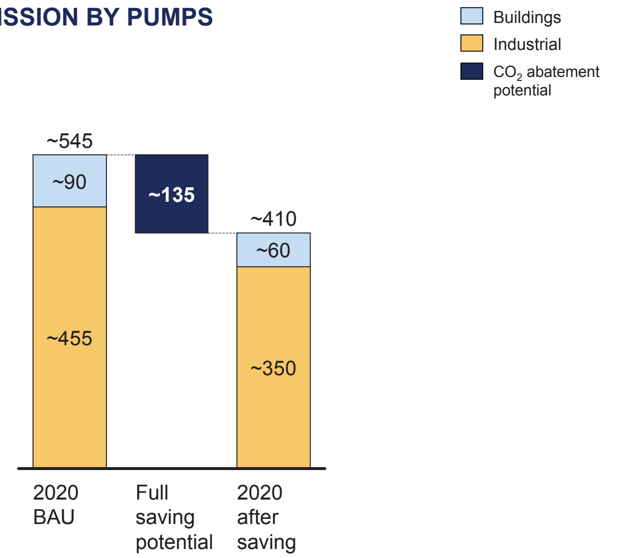


Source: McKinsey analysis

Exhibit 4.5

ANALYSIS OF CO_2 EMISSION BY PUMPS

Million tons CO_2e



Source: McKinsey analysis

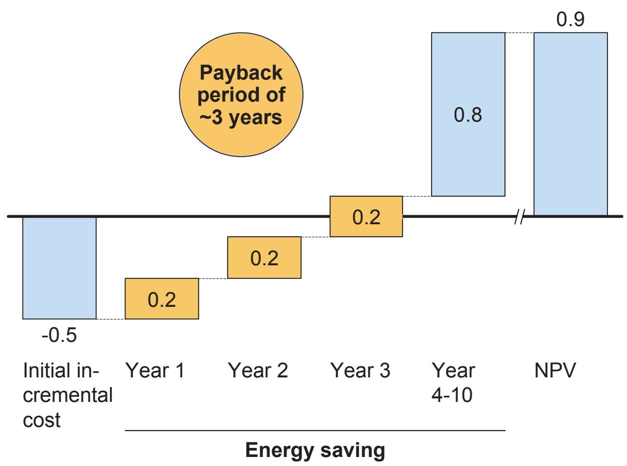
Attractive business case

The business case for installing high-efficiency variable-speed pumps is attractive as illustrated in exhibit 4.6. In a typical example of an AC pump installation in a 220,000 m² new-build office building, the lifetime cost comparison shows a payback period of 3 years from installing high-efficiency variable-speed pumps. In other words, the savings in electricity will offset, in only 3 years, the higher CAPEX associated with high-efficiency variable-speed pumps vs. low-efficiency pumps.

Exhibit 4.6

EXAMPLE OF COST SAVING POTENTIAL FROM INSTALLING HIGH-EFFICIENCY VARIABLE-SPEED PUMPS*

RMB millions



* Typical example of AC pump in a 220,000 M2 office building (new build). Assuming electricity price at RMB0.75/KWh, cooling hours of 2880/year, 10% cost of capital

Source: Expert interviews; McKinsey analysis

Additional electricity-saving and abatement potential exists by looking further into re-design of pump solutions, i.e., installing the right size pump and placing pumps to utilize them to an optimal level. A case example in exhibit 4.7 shows that from a 10 year NPV perspective, on average 1.1 million RMB could be saved by re-designing an AC system.

Exhibit 4.7

EXAMPLE FROM AC SYSTEM RE-DESIGN IN OFFICE BUILDING

ZhongZi Building, Beijing

Old AC system

4+4 cooling/chilling units
- 200 m^3/h
- 32 m
- 30 Kw

New AC system

- **220 m^3/h**
- **19 m**
- **18.5 Kw**

Gains from AC re-design
- **52%** increased efficiency
- Only 2-year pay back period
- **RMB1.1 million** saved in a 10-year running period

Source: Grundfos

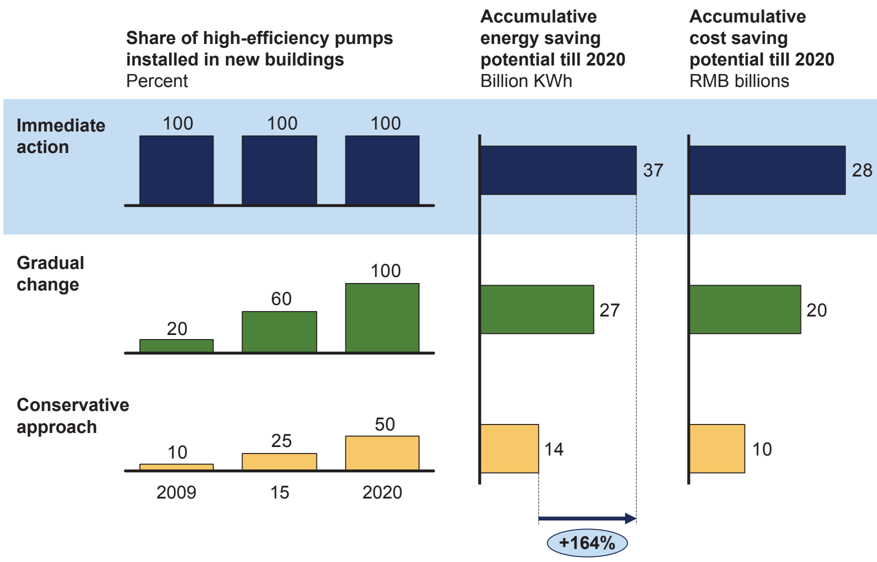
From both abatement potential and economic value angles, high-efficiency variable-speed pumps are one of the most important abatement technologies in the building sector.

A WINDOW OF OPPORTUNITY

Given the building boom China is facing in the next 10 years, early action in installing energy-saving pumps could potentially lead to significantly more electricity savings. As illustrated in exhibit 4.8, the accumulated savings would be 160 percent more in an aggressive scenario, where high-efficiency pumps were installed in all new builds till 2020, than that in a more conservative scenario, where the penetration of high-efficiency pumps in new installation started with 10 percent in 2009 and ended at 60 percent in 2020. This would also be equivalent to 18 billion RMB of additional saving on electricity bill.

Exhibit 4.8

SCENARIO ANALYSIS OF ENERGY AND COST-SAVING POTENTIAL BY TAKING IMMEDIATE ACTION



Source: McKinsey analysis

CHALLENGES TO ADOPTING HIGH-EFFICIENCY PUMPS IN CHINA

Although China has already placed great emphasis on building energy efficiency and tackling climate change, the adoption of high-efficiency pumps remains slow. Two main challenges are preventing high-efficiency pumps from realizing their vast energy-saving potential within China's buildings: lack of mandatory standards and misaligned incentives.

- **Lack of mandatory standards**

  The first voluntary technical standard (GB19762) governing the energy efficiency of pumps came to market in 2005. So far products from very few manufacturers, albeit most of them are local, have been approved via the China Quality Certification Center. Meanwhile, this standard is not included in current version of building codes and therefore voluntary for real estate developers as well. In addition, waste of energy due to over-capacity of pump systems is also common, as designers have different criteria in designing pump systems and therefore over-weight the risk factor against energy efficiency.

- **Misaligned incentives**

  Currently, the incentives to adopt energy-efficient pumps are misaligned between key decision makers. Specifically, the people who make and influence the choices of energy-efficient pumps, including developers, general contractors, designers and consumers, despite their good intentions, receive no incentive, reward or direct economic benefit from choosing and using energy-saving pumps. Those who would receive the economic benefits, mostly property managers, have little influence over the choice of pumps during the design/construction phase.

  Furthermore, property managers are not in a position financially to undertake the large-scale replacement of equipment such as pumps. Compounding the issue is a lack of trust between energy-service companies (ESCO) and property managers due to the low level of information transparency on energy consumption. All of these reasons make replacement of low-efficiency pumps with high-efficiency ones difficult even when it make economic sense to do so.

OPTIONS TO ADDRESS THE CHALLENGES

As the Chinese government continues to build on its efforts to achieve greater energy efficiency in the building sector, there are a number of options available, such as making energy efficient pumps requisite in new buildings, which could bring significant improvements. Along with efforts from the private sector to improve the market situation these moves could be critical to help capture the full carbon abatement potential of high-efficiency pumps.

Options for policy makers

Taking lessons from other countries, policy makers could consider the following:

— As evidenced in insulation materials, the adoption of energy efficient pumps will take off if they are required in the building codes. Actually that is the case in Denmark and many other developed countries. China could consider implementing similar building codes, at least to start with tier-1 & tier-2 cities.

— Experience from other countries such as Japan also proves the benefit of gradually raise the requirement of energy efficiency in newer product standards.

— It is also a proven solution to encourage commercial banks or other financial institutions to provide finance to ESCOs or property managers to expedite replacements

— Other effective measures taken in developed countries include:

- Conduct building energy audit work and make energy consumption information more transparent
- Make energy efficient pump part of the "Green Building Label" system so that developers can justify a premium price for high energy efficiency

— Encourage social and NGO funds to enter the area to provide extra incentives for using energy-efficient pumps

Options for leading pump manufacturers

- — Collaborate more closely with designers (mainly HVAC engineers) to make design of energy-saving pump systems less complex and time-consuming
- — Develop educational program's where designers and engineers achieve education in pump efficiency inclusive the effect of variable speed and saving potential in design optimization
- — Publish tools, handbooks, decision trees, pump installations guidelines and make these available for key stakeholders
- — Explore collaboration with ESCOs to further expedite energy-saving pumps in retrofit market
- — Education on cost and approach of retrofit to make the process less complex and highlight the cost savings achievable
- — Integrate with complementary technology providers, such as motor manufacturers, to realize the full energy-saving and abatement potential
- — Promote holistic green projects with other energy-efficient building technologies such as chillers, insulation, windows, heat exchange, etc.
- — Continue to invest in R&D to and introduce more attractive high-efficiency pumps to the market

Chapter 5: Enzymes technology

Many chemical transformation processes used in various industries have inherent drawbacks from a commercial and environmental perspective. High chemical and energy consumption, and harmful by-products have a negative impact on the environment. Enzyme, as a bio-catalyst, can help to eliminate all these drawbacks.

INTRODUCTION TO ENZYMES AND CARBON ABATEMENT POTENTIAL

Enzymes are widely applied in people's daily life. One of the most common enzyme applications is a functional ingredient in household detergents for cleaning (for example, laundry and dishes). Enzymes are also used to produce textiles and leathers as well as foodstuffs and components of animal feeds. The new breakthrough applications of enzymes even include the ligno-cellulosic ethanol used for the renewable energy industry.

Enzymes could abate CO_2 through three major mechanisms: 1) they help replace petroleum-based fuels, which have direct CO_2 impact; 2) they reduce energy consumption by lowering the activation energy, thus increasing the rate of reaction; and 3) they replace chemicals in many processes, hence having an indirect impact on CO_2 emissions.

Beyond CO_2 abatement, enzymes have additional benefits in spurring process efficiency, improving product performance and achieving cost savings.

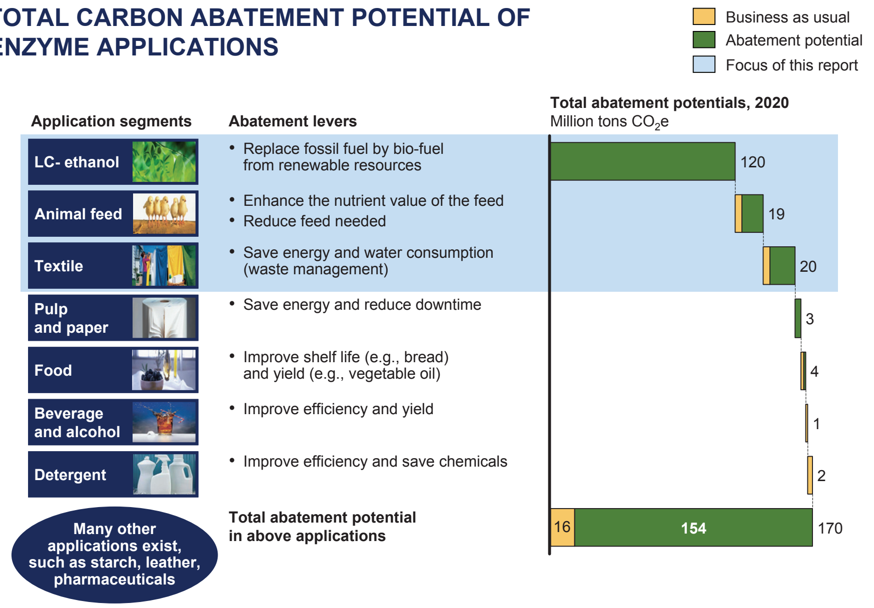
Large carbon abatement potential with negative cost

Harnessing the power of enzymes can create attractive opportunities for carbon abatement across an array of industries. We have studied the potential of enzyme applications in just seven sectors, where they have a total carbon abatement potential of 170 MT CO_2e per year in China by 2020 at negligible cost. See exhibit 5.1 for details.

Of these seven sectors, three hold tremendous promise for carbon abatement: biofuels, textiles and animal feeds, which together account for more than 90 percent of the total CO_2 abatement and at negative cost. Enzymes in these sectors also bring numerous benefits to society including energy security, sustainable industry development, and value creation for farmers

Exhibit 5.1

TOTAL CARBON ABATEMENT POTENTIAL OF ENZYME APPLICATIONS



Source: McKinsey analysis

THE APPLICATION OF ENZYMES IN THE BIOFUEL INDUSTRY

Clean-burning biofuel is becoming an increasingly popular alternative to gasoline in many markets. It's cheaper than oil, emits less CO_2 than petroleum-based fuels, and is produced from renewable sources. While there are legitimate concerns about the sustainability of current biofuels produced from sugar and starch-based crops such as corn, a lower-cost and more sustainable alternative has emerged. This technology, namely second-generation biofuels, or cellulosic ethanol (lignocellulosic ethanol), are produced from lignocellulose, a fibrous material found in nearly every plant. In this process, enzymes play an important role in converting biomass to ethanol. The following section will focus on second-generation biofuels.

Introduction to enzymes in lignocellulosic ethanol

Lignocellulosic biomass is composed of cellulose, hemicellulose and lignin (among other things), mainly from agricultural residue, energy plants, bagasse, wood, and forestry residues—all abundantly available.

The production process comprises four main steps:

— **Pretreatment:** Initial chemical or physical pre-treatment is applied to open up the fibrous material and make the cellulose accessible for further treatment and production of a slurry that can be easily pumped out.

— **Hydrolysis:** Liquefaction of a highly viscous polysaccharide matrix to a liquid stream of sugar oligomers. This step can be performed in an acid/base and/or heat catalysed reaction with the aid of enzymes.

— **Fermentation:** Fermentation of both glucose (C6) and xylose (C5) to ethanol.

— **Distillation:** Distillation for separating and upgrading ethanol from the fermentation broth to crude ethanol.

Before this process can be fully integrated and optimized some technology improvements are necessary. These are described in more detail in the section "Challenges to adopting lignocellulosic ethanol in China".

Carbon abatement potential and cost

With its cheap production costs, abundant feedstock, and tremendous capacity to reduce carbon emissions compared to first-generation biofuels, lignocellulosic ethanol could help China achieve its aspiration to improve its CO_2 intensity. Its advantages are:

- **Low production costs:**

  Once the technology is fully optimized, cellulosic ethanol will be cheaper than sugar/starch-based ethanol in all geographies. The long-term production costs of lignocellulosic ethanol from agricultural residues are estimated to reach 8 RMB/gallon by 2020. Enzyme costs are heavily dependent on the entire integration process (feedstock selection, pretreatment, organism, etc.) and could become even lower as the technology is further refined. Both incremental improvements to enzyme production costs and enzyme efficiency could lower costs and there is potential for breakthroughs (e.g., an integrated one-step process for hydrolysis/sacharification/fermentation).

- **Abundance of available feedstock**

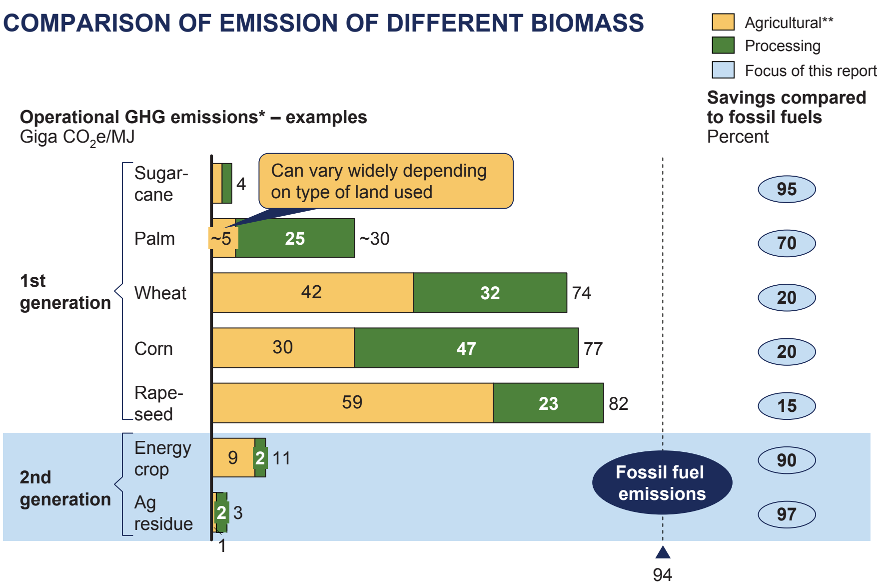
  The land availability of sugar/starch crops will limit biofuel penetration to around 10 percent but abundantly available lignocellulosic biomass could theoretically push this to approximately 50 percent penetration.

- **Huge capacity to reduce CO_2 emissions**

  Corn-based and wheat-based ethanol show limited CO_2 savings vs. gasoline (around 10 percent), while lignocellulosic ethanol is expected to lead to savings of around 90 percent CO_2 vs. gasoline. Lignocellulosic ethanol from agricultural residue and energy crops holds the greatest CO_2 abatement potential. See exhibit 5.2 for details.

Exhibit 5.2

COMPARISON OF EMISSION OF DIFFERENT BIOMASS



* Cane: Brazil; palm: Indonesia; wheat; France; corn: US; rapeseed: France; energy crop: US; CO_2 emissions from land use change not included

** Includes agricultural emissions due to fertilizer usage, etc.; excludes effect of land use change

Source: EBAMM; SRI Report; HGCA Calculator; McKinsey analysis

Lignocellulosic ethanol boasts very high CO_2 abatement potential at a considerably low cost. Even under the most conservative scenario it could reduce CO_2 emissions in China by 120 MT CO_2e per year by 2020 at negligible cost.

It also brings other benefits to society, such as a reduction in gasoline demand in China and additional revenue for local farmers.

The abatement potential of lignocellulosic ethanol is described under three different scenarios below, as illustrated in exhibit 5.3 as well:

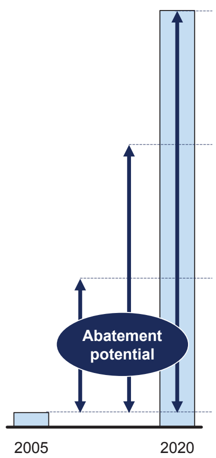
1. Limited by availability of biomass: Lignocellulosic ethanol can achieve a total abatement potential of 120 MT CO_2e by 2020 at an abatement cost of -50 RMB/ton of CO_2. In this scenario supply would be limited by the available amount of biomass and only 35 percent of agricultural residues that can be obtained sustainably would be collected for industrial applications, whereas the other 65 percent would be used in replenishing the soil, animal feeds and so on. In this scenario, we assume that 100 percent of the collected agricultural residues would be used for lignocellulosic ethanol production as the full potential scenario. This would translate into 52 MT lignocellulosic ethanol in 2020, which is around 20 percent of gasoline consumption in terms of heat value in China.
2. Dependent on growth of the industry: Lignocellulosic ethanol could achieve a total abatement potential of 77 MT CO_2e by 2020. In this scenario, demand would be limited by growth of the industry. The Chinese lignocellulosic ethanol industry would grow from 2011 at the same rate that the Department of Energy assumes for lignocellulosic ethanol in the US. Annually, approximately 1 billion gallons or 10 plants of 100 million gallons capacity would be added.
3. Defined by government targets: Lignocellulosic ethanol could achieve a total abatement of 19 MT CO_2e by 2020. Demand defined by government targets assumes the intention to achieve 10 MT bioethanol by 2020. It would be largely met by lignocellulosic ethanol, not sugarcane ethanol and corn ethanol production would remain constant.

It is important to note that for all the scenarios above, abatement cost is based on the current price of crude oil (US$ 70/barrel), and the price of biomass at 350 RMB/ton. Even with price fluctuations, abatement cost would remain negative, as illustrated by exhibit 5.4.

Exhibit 5.3

CO_2 ABATEMENT POTENTIAL BY DIFFERENT SCENARIOS, 2020

Million tons CO_2e



	LC-ethanol, 2020 (Billion gallons)	Abatement potential (Mt CO_2e)	Key assumptions
(1) Biomass availability scenario	17	120 (Theoretical maximum)	• ~200 Million tons of ag residues (~35% of total residues) that can be obtained sustainably for industrial use • Other 65% is mainly used in return to soil, animal feeds etc., which is strategic important to agricultural industry
(2) Max. growth scenario	10	77 (Practical maximum)	• Chinese LC-ethanol industry will grow from 2011 with the same rate that the US DOE assumes for LC-ethanol • Yearly addition of ~1 billion gallons or 10 plants of 100 million gallons capacity
(3) Government target scenario	2.7	19	• Announced target of 10 Million tons of bio-ethanol by 2020 • ~80% can be taken by LC-ethanol and production of 1st generation biofuel existing will remain
(0) No LC-ethanol (BAU)	0	0	

Source: McKinsey analysis

Exhibit 5.4

CO_2 ABATEMENT COST BY DIFFERENT SCENARIO, 2020

RMB/tons CO_2e

Crude price USD/bbl* \ Biomass cost RMB/ton	150	350	500
40	70	410	660
70	-380	-50	200
100	-830	-500	-250

Most likely price/cost ranges (crude price 70–100 USD/bbl, biomass cost 150–350 RMB/ton)

* Based on exchange rate of 7 (RMB/USD)

Source: McKinsey analysis

Challenges to adopting lignocellulosic ethanol in China

China has made a solid commitment to renewable energy by implementing regulations for the development of the renewable energy industry, adopting a framework for biomass power generation, and setting targets E10 of 10 MT bioethanol by 2020. However, there are a number of challenges to the widespread adoption of lignocellulosic ethanol. These include:

- **Lack of a comprehensive regulatory framework for biomass development**

  Currently there is no framework in place to guide the development of biofuels. Success in Brazil and India suggests that such a framework would be essential to regulate the overall bioenergy direction, coordinate between multiple stakeholders, issue mandates, set targets, grant farm subsidies, and coordinate among all types of biomass applications.

- **Status of technology**

  Further development of the conversion technology for lignocellulosic ethanol is required in three areas:

  — Lignocellulosic biomass needs to be pretreated to make it accessible to the enzymes that break down the cellulose. A number of technologies are being developed though the winning technology is yet to be determined.

  — The cost and performance of cellulases, the enzymes that break down the (hemi) cellulose in C5 and C6 sugars, has to improve in order to reach commercial viability.

  — The efficiency of fermentation organisms needs to improve. Current fermentation organisms can only ferment C6 sugars efficiently. Approximately 30 percent of the total sugar in biomass is C5 sugars which would be lost. Microorganisms with greater fermentation ability are being developed.

  In addition, international technology companies are concerned about intellectual property risk. There is also competition for investment from non-biofuel technologies (e.g., natural gas, LPG).

- **Availability/supply of biomass**

  Problems along the supply chain include insufficient biomass availability. Roughly 200 MT agricultural waste will be available for biofuels, which is only 20 percent of the total needed for fuel by 2020 in terms of heat value. Furthermore, biomass collection incurs high logistics costs due to the fragmented industry structure.

  There is also competition for biomass from alternative applications (e.g., power generation, cement) though from an abatement cost perspective it is less economical to use biomass in power generation and cement in terms of abatement cost.

Options to address these challenges

While the government has already taken steps to commit to renewable energy, further options are available to help make biofuels a truly viable alternative. These include technological improvements and the establishment of adequate regulatory frameworks that can support the build-up of the full value chain from biomass production/collection to biofuel logistics. In addition, the interests of IP-holding companies and the strategic interest of China to localize energy-related industries/know-how need to be aligned. Available options include:

- **Establish a regulatory framework for biomass/bioenergy development**

  A stringent and integrated regulatory approach to govern the overall bioenergy strategy would be an important step. It could encompass the issuing of mandates, the setting of targets and the granting of subsidies via a transparent mechanism. The Pro-Alcohol programme in Brazil exemplifies such an approach. Brazil has succeeded in demonstrating the technical feasibility of large-scale ethanol production from sugarcane and its use to fuel cars.

- **Strengthen coordination among regulatory bodies on biofuel development**

  It would be important to coordinate technology priorities and allocate resources, provide funding for the development of necessary technology, grant financial support for pilot-scale plants, and provide a framework for collaboration between international and local players in the sensitive intellectual property area.

CASE 5.1: "ALCOHOL PROGRAM" IN BRAZIL DURING 1970S

In the mid-1970s, before any other country had considered the idea, Brazil embarked on mass-producing biofuel for use in vehicles by producing ethanol, or alcohol as it is locally known, from its plentiful supplies of sugarcane. Today, Brazil is a world-leader in biofuels. The country-wide Pro-Alcohol programme was the key success factor to ethanol penetration.

Under the programme, the government invested US$ 5 billion in the agricultural and industrial sectors from 1975 to 1989. Specific initiatives included: 1) granting soft loans to sugarcane growers who built ethanol distilleries; a state trading enterprise purchased ethanol at favorable prices, with gasoline prices set to give ethanol a competitive advantage (a World Bank loan helped cover the costs of the programme); 2) offering ethanol (E10) through designated gas stations run by the state-owned oil company, Petrobras, which made investments for the distribution of ethanol; 3) encouraging the population to purchase pure ethanol (E100) cars by lowering taxes on E100 to encourage the population to purchase flex-fuel vehicles.

The programme has seen direct and indirect benefits, including better soil cultivation techniques, improved productivity of sugar cane, efficiency gains in industrialization (the conversion rate increased from 55 to 82 litres refined ethanol per ton of sugar cane); infrastructure build-out (34,000 gas stations are equipped with ethanol tanks and are integrated in the alcohol distribution network), and development of injection nozzles for flex-fuel engines in 2003 that can run with any given volume mix of ethanol and gasoline. As a result, 90 percent of all cars sold in Brazil are flex-fuel (able to run on both ethanol and gasoline), all gasoline is blended with 25 percent of ethanol, and more than 50 percent of transportation fuel is pure ethanol.

India's Ministry of New and Renewable Energy (MNRE) established in 2006 offers one such example. MNRE is the nodal agency of the government for all matters relating to renewable energy. It undertakes policy making, planning, promotion and co-ordination functions relating to all aspects of renewable energy, including fiscal and financial incentives, creation of industrial capacity, promotion of demonstration and commercial programmes, R&D and technology development, intellectual property protection, human resource development and international relations.

- **Technology collaboration**

  Further collaboration, leveraging both international and domestic resources and capabilities, could be an important step to commercializing the value chain. There is already progress in this area as some leading Chinese and Danish companies along the value chain have reached a cooperation agreement. The cooperation emphasizes an integrated value-chain concept, with local support, leveraging both international and domestic partners with clear responsibilities supporting infrastructure and transparent information sharing.

- **Grow the supply chain market for biomass/lignocellulosic ethanol**

  Specifically, support some pilot projects to encourage private sectors to enter and grow this market.

ENZYME APPLICATIONS IN THE TEXTILE INDUSTRY

Much of today's clothing is manufactured through harsh bleaching, washing and finishing processes, which are water and energy intensive. Biotech companies claim that enzymes can enhance these processes, negating the need for chemicals and saving on water and energy. Applied in China, enzymes could play a role in transforming the industry to become more sustainable.

Introduction to enzymes in the textile industry

Enzyme-assisted processes in the textile industry include bio-polishing, denim abrasion and de-sizing etc., where enzymes replace chemicals such as bleach, and enhance traditional washing processes to save water and energy.

Abatement potential and cost

By 2020, enzyme use in the textile industry holds an abatement potential of 20 MT CO_2e per year at negligible abatement cost, mainly from two processes – bio-scouring (a process to remove impurities from cotton) and de-sizing (a process to remove starch-based size from threads).

Challenges to adopting enzyme in textiles in China

The Chinese government has recently initiated steps to tackle environmental issues by placing greater emphasis on linking China's environmental standards to global standards. Some indicators in China are now even stricter than in Europe. For example, COD (chemical Oxygen Demand) in China is 100 vs. 125 in Europe, while BOD (Biochemical Oxygen Demand) in China is the same standard as in Europe. While these measures will certainly go some way to improving the environment, they will not be sufficient to significantly transform the textile industry into a cleaner, more sustainable sector. Enzyme applications, however, could play an important role in helping the sector to become more energy and resource efficient. This is due to their ability to negate chemicals used in traditional processes and reduce energy and water usage. Before the full potential of enzymes can be unlocked within the textile industry a number of challenges exist, including low awareness and lack of regulatory enforcement. Some of the particular challenges are:

- **Low awareness**

  There is very little awareness at both government and industry level of enzymes' green impact on the environment and in terms of energy savings.

- **Low enforcement of environmental standards**

  A loose regulatory environment and low enforcement have long been at the root of China's pollution issues. Low energy costs (e.g., waste water management) and little enforcement by local governments for noncompliance have seen high-polluting industries proliferate. This is changing, with the recent mandate of compulsory discharge standards, and linking COD to KPIs at the provincial level. However, more work will be needed in this area, including the development of guidance, an actionable plan and targets to monitor the process.

- **Insufficient motivation and capabilities of local players**

  Due to the fragmented nature of the textile industry, which is dominated by small-to-medium enterprises, there is no long-term vision on sustainable development and little will to adopt green technologies. This is coupled with the lack of capability in enzyme-assisted processes, which requires lean operations.

- **Application technology barrier/competition from other innovations**

  Application technology breakthrough is needed in certain processes (e.g., bio-scouring, bio-polish) to make it more convenient. Furthermore, competition exists from other process innovations such as CO_2 non-water dyeing.

Options to address the challenges

As the Government continues to build on its efforts to improve environmental standards, further options are available to help upgrade the textile industry through the use of enzyme technology. The options include:

- **Provide a targeted and integrated approach to improve awareness**

  Such an approach would include joint efforts with textile companies, associations and government to create seminars and forums on technology introduction, demonstration programmes with leading textile players and a customer-driven approach for awareness building. Wal-Mart, for example has taken the lead on developing eco-standards for suppliers, leading to significant industry upgrades.

CASE 5.2: WAL-MART'S ECO-STANDARD FOR SUPPLIERS

In 2007 Wal-Mart released its "packing scorecard," providing information about its plan to reduce packaging by 5 percent by 2013. The scorecard is a measurement tool that allows suppliers to evaluate the sustainability of their packaging. Wal-Mart has outlined the following metrics for the scorecard. Each is a percentage of the supplier's total score, for example:

— 15 percent based on carbon dioxide per ton of production

— 10 percent based on recovery value

— 5 percent based on renewable energy

— 5 percent based on innovation

— …

Wal-Mart's suppliers have access to the online scorecard, which allows them to input information about their packaging and measure their performance against competitors. Wal-Mart's suppliers will have a one-year trial period before Wal-Mart begins evaluating their performance.

- **Continue environmental-standards enforcement**

  Continued efforts to raise environmental standards and upgrade the industry will be important. Specific measures include setting environmental standards; implementation via KPIs linked to COD, and more importantly developing a mechanism, actionable guidance and targets for the industry's improvement (e.g., recommended product list in REACH); and differentiated pricing mechanisms.

- **Build capabilities**

  Capability building for enzyme applications and lean operations should be focused along four dimensions: Quarterly forums to build the relevant skills to lead business and enhance personal effectiveness within the industry; monthly follow-up sessions or refresher courses; on-the-job coaching; and frequent development dialogue or structured feedback sessions.

- **Support technology customization**

  Adopt a joint programme with local government, industry associations and leading companies to enable application technology improvement, e.g., through tax subsidies and preferred suppliers.

ENZYME APPLICATIONS IN ANIMAL FEED

Introduction to enzyme applications in animal feed

Phytase is already in wide use in China's animal farming. The expansion into Xylanase and Energex enzymes offers further opportunities for China to reduce its greenhouse gas footprint.

Phytase can be used as an alternative to inorganic phosphate supplementation to the feed and thereby reduce the excretion of phosphorus with manure. The application of phytase brings major benefits to farmers (including reduction of feed phosphate needed), and the environment, such as reduced phosphorus emissions to the aquatic environment, hence reducing algae bloom in rivers and lakes. Furthermore, considerable energy and phosphate rock savings are achieved.

Xylanase and Energex enzymes improve digestibility by enhancing the absorption of, for example, energy and protein, and thereby reduce the volume of feed needed.

Reduced contribution to acidification and nutrient enrichment is partly driven by reduced feed consumption and partly reduced N-emissions with manure, resulting from the reduced protein content of the feed.

Carbon abatement potential and cost

Enzymes in animal feed can play an important role in CO_2e abatement (19 MT CO_2e per year of abatement cost with negligible cost, mainly from Xylanase and Energex).

Challenges to adopting enzymes in animal feeds in China

China is taking steps to create a more healthy agricultural environment. Many favorable policies have been implemented, including favorable loans to large-scale breeding players, and subsidies to pig breeders. However, several challenges exist before enzyme technology in animal feed can reach its full potential, especially in the areas of economics, capability building and incentives to encourage the widespread adoption within the fragmented agricultural industry. These are:

- **Uncertain economics**

  The economics of enzyme technology for use in animal feed are uncertain for some enzymes (e.g., Xylanase, Energex) in the areas of technology and breeding capability:

  — *Technology:* limited cost improvement in corn-based feed structure (i.e., works less efficiently in corn-based than wheat-based feed). The economic benefit of 2 to 3 percent of feed reduction is not significant enough and is difficult to measure especially for small farmer holders.

  — *Breeding capability (tools and know-how):* There is a big variance in breeding capability (over 5 percent) due to the lack of proper measures/ evaluation kits and limited connection to market and knowledge.

- **Insufficient motivation of local players**

  The highly fragmented structure of the agricultural sector (e.g., in animal feed manufacturing Top 20 groups account for 30 percent of capacity), combined with a low capability in adopting and managing new technology among the small-to-medium enterprises, and a general reluctance by farmers to take risks in technology.

- **Lack of incentive system**

  There is no direct incentive system in place to help farmers (farming groups) or companies (breeding) to improve productivity and build capability via technology adoption.

- **Lack of enabling environment**

  The lack of stringent environmental standards (e.g., permissions in China are less strict compared to in Europe) and a proper framework to push industry consolidation or favorable policies, such as micro-financing for large-scale breeding make it difficult for enzyme technology to realize its full potential.

Options to address the challenges

As the government continues to build on its efforts to create a healthy agricultural environment, further options are available, including technology development, capability building, incentive systems, and market interventions.

- **Technology development**

  Further technology improvement is needed, especially for corn-based feed structure.

CASE 5.3: CP'S VARIOUS COOPERATION WITH TECHNOLOGY COMPANIES TO ENSURE HIGH QUALITY OUTPUT

CP in Thailand's joint venture with a leading technology player on capacity building for both farmers and contract breeders. Under the venture, CP had JVs with firms like Cargill to ensure high-quality seeds for production of feed grains. CP entered contracts with maize producers to buy their produce if they used the high-quality seeds. In breeding, they partnered with leading US firm Arbor Acres to perfect stock breeding.

Key success factors to the programme are importing and adopting latest technologies in poultry breeding from developed countries, and an end-to-end solution from ensuring quality for chicken feed through contract farming to developing quality stock through partnering with the best firms.

- **Capability-building programme**

  As has been successfully trialed elsewhere, the government could consider a pilot demonstration project involving leading breeding companies, technology companies and local government on overall breeding improvement afforded by new technology adoption. For example, CP in Thailand's joint venture with a leading technology player on capacity building for both farmers and contract breeders to ensure high quality output.

Another option is to set up tools and tracking systems to improve the stability of breeding in a scientific way. Thus, a joint effort between leading breeding companies, technology companies and local governments to develop a breeding handbook and distribute to players along the value chain is needed.

- **Incentive system**

  Consider adopting policies to encourage farmer groups or companies (breeding) to take up the green technology (e.g., subsidies, tax reduction, soft loans)

- **Identify market interventions**

  Create an enabling environment to help farmers benefit from investment with better access to input and output markets, an improved negotiation position and superior farming techniques. Successful market interventions in other countries have included market linkages, strengthening farmer groups, awareness /education, and enabling environment and infrastructure building. These interventions need the full cooperation of different types of players, such as governments, private sector or MNCs, local entrepreneurs, farmer groups, NGOs, and agricultural research institutions.

COMMON APPROACHES ACROSS ENZYME APPLICATIONS

As described above, a number of common challenges have been seen across various applications sectors, including insufficient government support, low awareness, insufficient local capabilities, etc. Based on the experiences and lessons from other countries, the following options could be considered to capture the full abatement potential and other benefits of enzymes:

— Undertake a targeted and integrated approach to raise awareness within application sectors

— Encourage international technology collaboration to:

  - Commercialize the whole value chain of new industries such as ligno-cellulosic ethanol
  - Introduce technology customization for the local feed structure

— Enhance the government support, especially in key application sectors

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

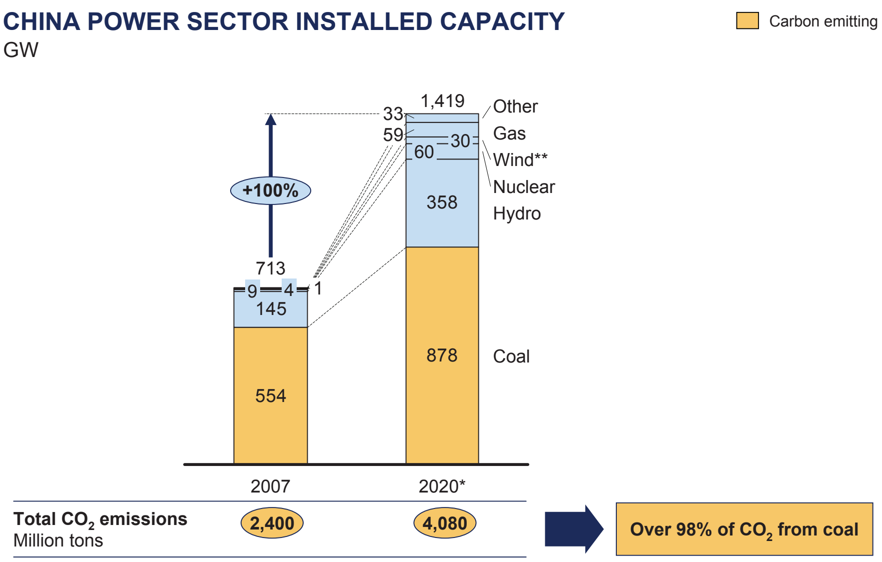
China has huge potential for reducing CO_2e emissions by installing and generating greater and greater amounts of wind energy. Capturing this carbon abatement opportunity makes sense for China, as wind is increasingly cost competitive and provides a number of additional benefits for China.

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



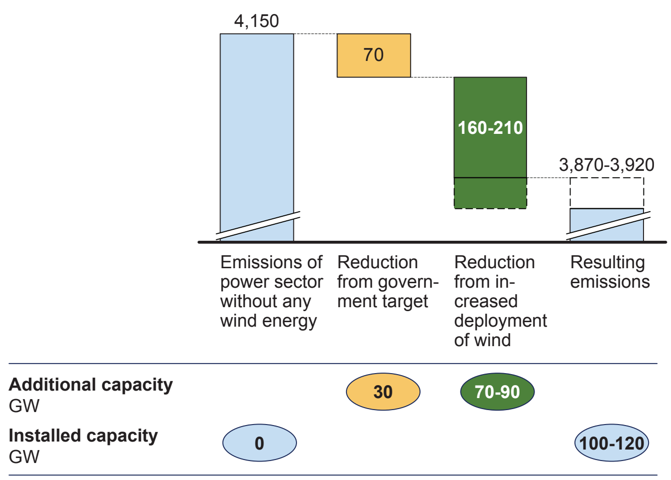
* Forecast based on NDRC targets for renewable sources and electricity growth coupled with McKinsey analysis on energy efficiency gains
** Of the total 6 GW installed, only 4 GW were connected to the grid
Source: China Electricity Council; NDRC; McKinsey analysis

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

Government target
Increased deployment



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.

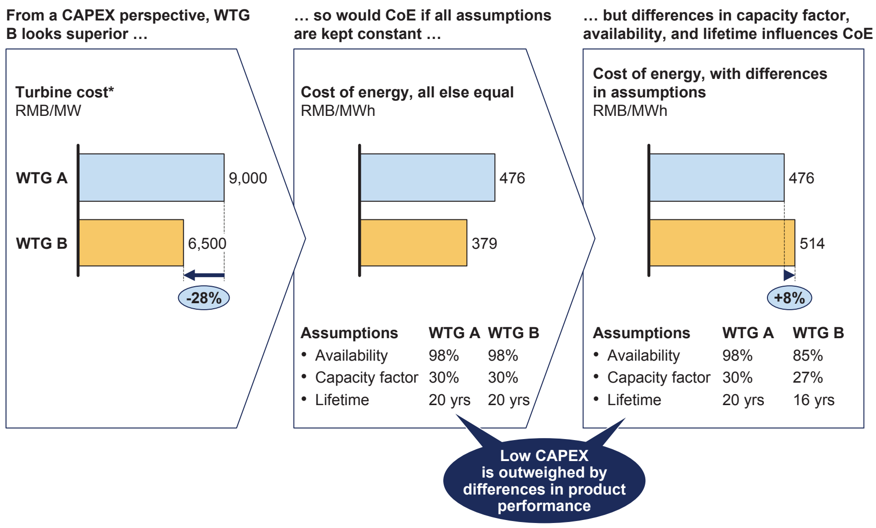
The cost of energy from different power plants varies in practice based on performance, fuel prices and uncertain capital costs. Based on this energy cost metric, a new wind farm is cost competitive with all other energy sources with the exception of coal today, as illustrated in exhibit 6.4.

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



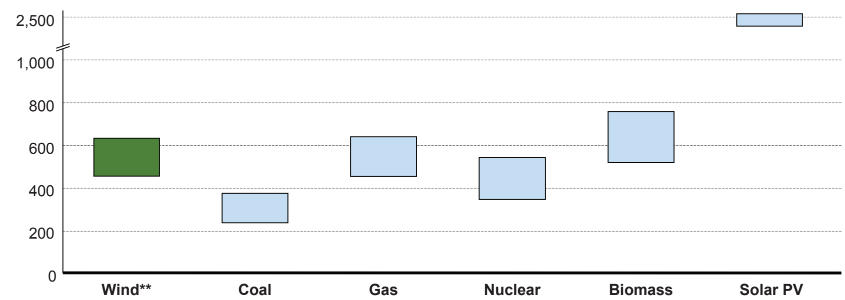
* Only represents the turbine cost, full CAPEX cost is often 25-30% higher; assuming park size of 50 MW; WTG size of 1.5 MW; WACC of 8%; does not include subsidies, taxes or VAT

Source: Expert interviews; McKinsey analysis

Exhibit 6.4

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

RMB/MWh



Wind**	Coal	Gas	Nuclear	Biomass	Solar PV
• RMB11,000/kW • 22-30% net capacity factor • Opex: RMB50/MWh • 20-year lifetime	• RMB4,000/kW • 80% cap factor • Fuel: RMB0.15-0.3/KWh • Opex: RMB35/MWh • 35-year lifetime	• RMB3,000/kW • 80% cap factor • Fuel: RMB0.4-0.6/KWh • Opex: RMB31/MWh • 30-year lifetime	• RMB11,000 - 24,000/kW • 88% cap factor • Decomis: RMB28 MM • Opex: RMB150/MWh • 50-year lifetime	• RMB10,000/kW • 80% cap factor • Fuel: RMB0.25-0.55/KWh • Opex: RMB70/MWh • 20-year lifetime	• RMB32,000/kW • 14-17% net capacity factor • Opex: RMB25/MWh • 25-year lifetime

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

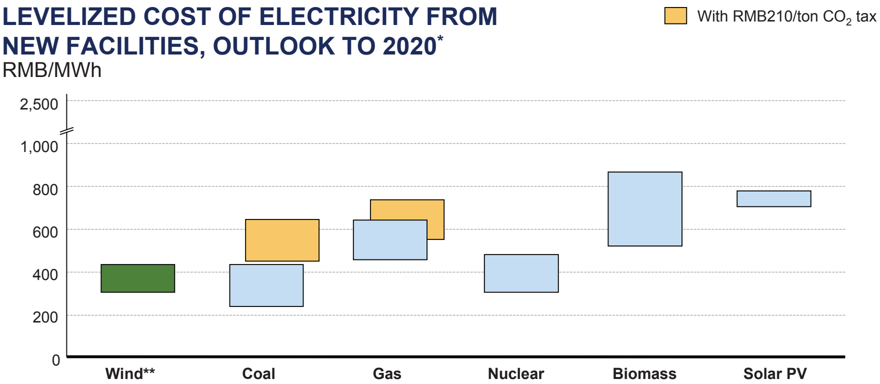
** Integration costs not included; McKinsey analysis suggests such costs would be less than RMB14/MWh with penetration <6%

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



Wind**	Coal	Gas	Nuclear	Biomass	Solar PV
• RMB8,000/kW • 25-32% net capacity factor • Opex: RMB50/MWh • 20-year lifetime	• RMB4,000/kW • 80% cap factor • Fuel: RMB0.15-0.4/KWh • Opex: RMB35/MWh • 35-year lifetime	• RMB3,000/kW • 80% cap factor • Fuel: RMB0.4-0.6/KWh • Opex: RMB31/MWh • 30-year lifetime	• RMB11,000 - 20,000/kW • 88% cap factor • Decomis: RMB28 MM • Opex: RMB150/MWh • 50-year lifetime	• RMB10,000/kW • 80% cap factor • Fuel: RMB0.25-0.65/KWh • Opex: RMB70/MWh • 20-year lifetime	• RMB10,500/kW • 16-18% net capacity factor • Opex: RMB25/MWh • 25-year lifetime

* 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

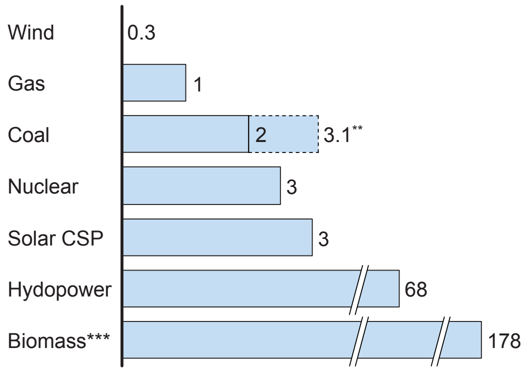
Wind power is strategically important to China as it provides China with increased energy security. Energy security is of outmost importance to China as it seeks to keep its economy booming and its population content. Many experts predict that China will become a growing net importer of coal in the coming 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

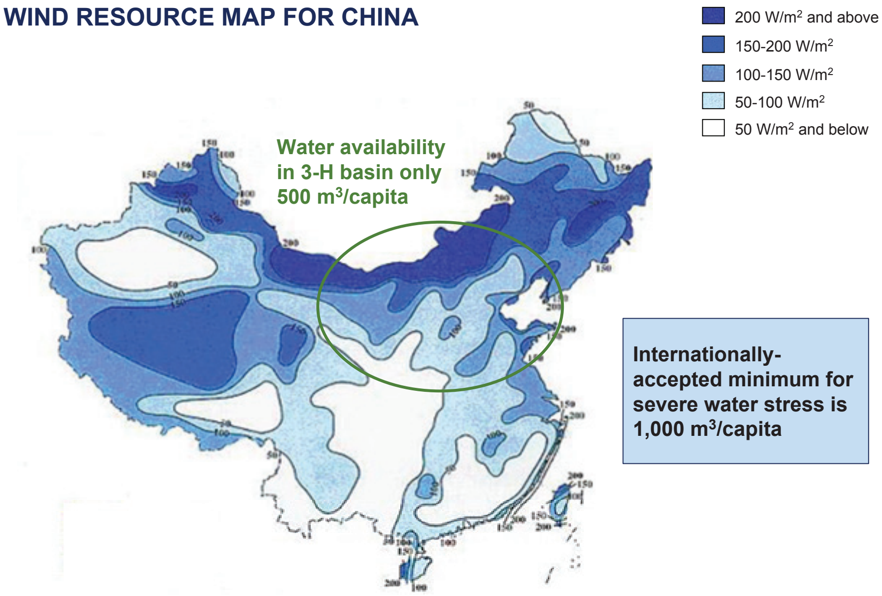
Source: Department of Energy; DHI; EIA; China Infobank; China Urban Construction Statistical Yearbook; China Regional Statistic Yearbook; World Bank

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

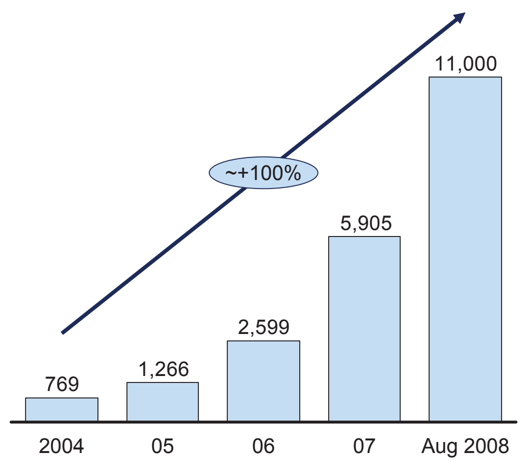
China is well aware of the many benefits of wind energy and has already done well to spur explosive growth in the sector. From less than 1 GW in 2004, China's installed wind capacity grew to 11 GW in August of this year – a yearly growth rate of nearly 100 percent, as illustrated in exhibit 6.8. In addition, 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.

During the project, we received great support from the Danish Embassy in China and close collaboration from many leading Denmark-based companies. Our project has also benefited from many interactions with various organizations across government, business, and academia, including the China Animal Feed Information Center, China Electric Power Research Institute, CNTAC, Lawrence Berkeley Labs, Tsinghua University, MOHURD, NDRC, and related bureaus within the Tianjin, Chengde, and Shenyang local governments, to name a few.

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