



EXISTING AND  
**EMERGING SOLUTIONS**

**Businesses are delivering hundreds of existing and emerging greentech solutions to China markets, providing the potential for significant positive impact on the environment. While these solutions are often already attractive to adopters and represent tremendous market opportunities, some areas are closed to foreign and private entities.**

**CHINA'S TRANSFORMATION TO ENVIRONMENTAL SUSTAINABILITY** requires solutions that do not contribute to climate change, do not pollute the atmosphere or water and do not rely on finite resources such as coal and oil. It also requires technologies that enable the efficient delivery and use of energy. Water shortages and pollution, land degradation, and the proliferation of hazardous and other waste all require solutions as well. Fortunately, an extensive number of existing and emerging green technologies are being applied in China to address these challenges.

A key objective of the China Greentech Initiative was to understand which greentech solutions are likely to play key roles in the short to medium term as China addresses the sustainability of its growth, and the relative advantages and disadvantages of each.

**The analysis carried out by the Initiative suggests:**

- A great number of greentech solutions in China have the potential for significant positive impact on the environment
- While a number of solutions are still in development, many are already commercially available in China and are attractive to adopters
- China is generally an attractive market for the application of greentech solutions, given its large size and rapid growth; However, some markets are closed to private and foreign participants

This chapter presents the approach the Initiative has taken to identify and evaluate greentech solutions in China, defines prioritized solutions by sector and provides key findings from the assessment.

*Fig.1: PRIORITIZED GREENTECH SOLUTIONS EVALUATED BY THE CHINA GREENTECH INITIATIVE*

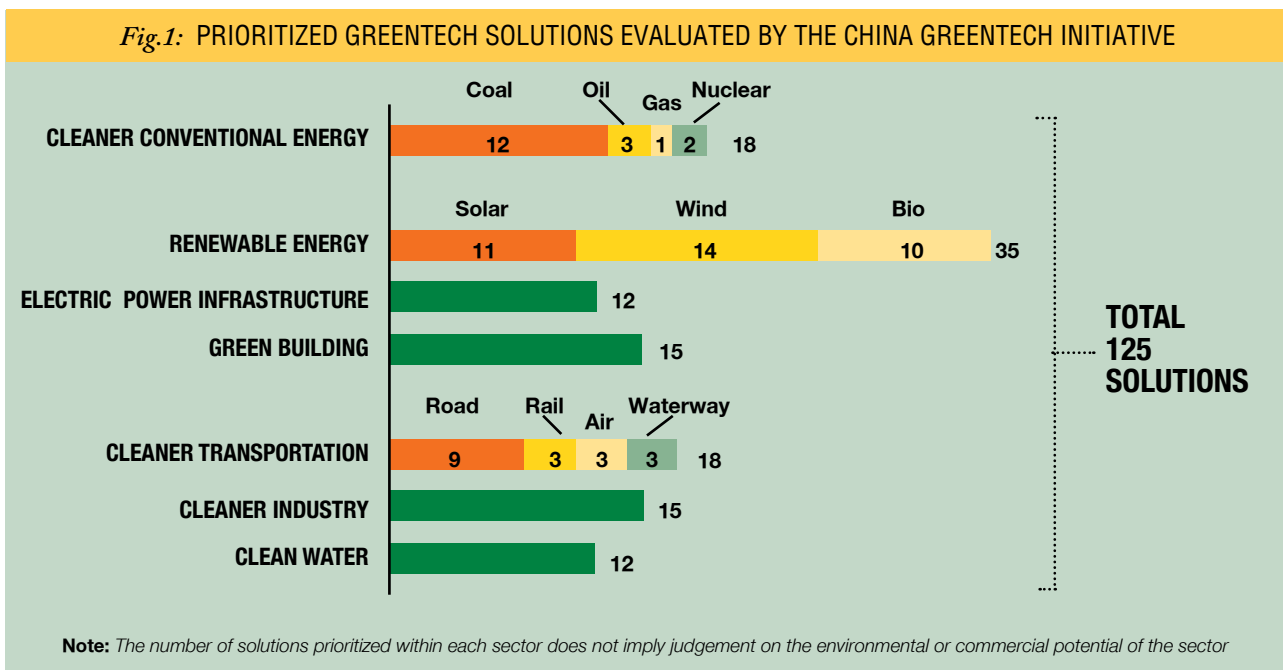


Fig.2 DEFINITION OF CRITERIA IN THE SOLUTION EVALUATION FRAMEWORK

UNIT ENVIRONMENTAL IMPACT POTENTIAL		SOLUTION ATTRACTIVENESS	
<ul style="list-style-type: none"> <li>Potential of the solution to <b>abate negative impact</b> on the <b>natural environment</b> while delivering benefits similar to or greater than the conventional solution</li> <li>Focuses on <b>one target metric</b> of negative impact (e.g. SO<sub>x</sub> emission, water use, electricity use) of the conventional solution abated to the largest degree</li> <li>Is <b>measured in percent on unit basis</b> – i.e. the potential to abate negative impact in delivery of one unit of benefit (e.g. miles driven, Kwh produced)</li> </ul>		<ul style="list-style-type: none"> <li><b>Economic attractiveness</b> of the solution to adopters – i.e. ability to deliver expected benefit at competitive cost is measured on life basis driven or influenced by:                             <ul style="list-style-type: none"> <li><b>Lifecycle unit cost</b> against the alternative</li> <li><b>Policies</b> encouraging the adoption</li> <li><b>Risk</b> of not becoming industry standard in China</li> </ul> </li> <li>All solutions <b>mandated by the regulation</b> are considered <i>advantaged</i>, regardless of actual penetration</li> </ul>	
VALUE	DEFINITION	VALUE	DEFINITION
	<b>Very high:</b> <ul style="list-style-type: none"> <li>Potential to decrease impact on the environment of the target metric by <b>over 40%</b></li> </ul>		<b>Advantaged:</b> <ul style="list-style-type: none"> <li>Lower cost than conventional alternatives Is the industry standard</li> <li>Is regarded as the industry standard</li> </ul>
	<b>High:</b> <ul style="list-style-type: none"> <li>Potential to decrease impact on the environment of the target metric by <b>30%-40%</b></li> </ul>		<b>Attractive:</b> <ul style="list-style-type: none"> <li>Cost on par with conventional alternatives</li> <li>On way to become industry standard in China</li> </ul>
	<b>Medium:</b> <ul style="list-style-type: none"> <li>Potential to decrease impact on the environment of the target metric by <b>20%-30%</b></li> </ul>		<b>Emerging:</b> <ul style="list-style-type: none"> <li>More expensive but cost declining</li> <li>Active competition from other technologies</li> </ul>
	<b>Incremental-medium:</b> <ul style="list-style-type: none"> <li>Potential to decrease impact on the environment of the target metric by <b>10%-20%</b></li> </ul>		<b>Disadvantaged:</b> <ul style="list-style-type: none"> <li>Significantly more expensive than alternative</li> <li>No indication of becoming major industry force</li> </ul>
	<b>Incremental:</b> <ul style="list-style-type: none"> <li>Potential to decrease impact on the environment of the target metric by under <b>10%</b></li> </ul>		<b>Unavailable:</b> <ul style="list-style-type: none"> <li>Still a concept or in early research phase</li> <li>High risk of pursuing the technology</li> </ul>
ADDRESSABLE MARKET SIZE		MARKET ACCESSIBILITY	
<ul style="list-style-type: none"> <li>Annual <b>sales of the solution</b> if it were purchased by 100% of potential adopters that year</li> <li><b>Adopters are organizations and individuals that purchase solutions</b> (either conventional or greentech solution under evaluation) to achieve certain benefits</li> <li>Is measured in US\$ billion (billion yuan) per year and mathematically is a product of:                             <ul style="list-style-type: none"> <li>Total <b>number of potential adopters</b> that year</li> <li><b>Price of current “standard”</b> substitute</li> </ul> </li> </ul>		<ul style="list-style-type: none"> <li><b>Degree</b> of market accessibility for private/foreign players</li> <li>Is driven or influenced by:                             <ul style="list-style-type: none"> <li>Degree of <b>direct state influence</b> over the sector</li> <li><b>Openness</b> to foreign capital and ownership</li> <li><b>Preferential treatment</b> of SOEs or local players</li> </ul> </li> <li>Where accessibility for private is different than for foreign players, the more restricted value is used</li> <li>In cases where 3-tier evaluation is used, terms applied are shown in parenthesis</li> </ul>	
VALUE	DEFINITION	VALUE	DEFINITION
	<b>Very large:</b> <ul style="list-style-type: none"> <li>Over US\$50 billion (350 billion yuan) per year</li> </ul>		<b>Fully open (Mostly open):</b> <ul style="list-style-type: none"> <li>Low to no state control of the sector</li> <li>Fully open to private/foreign capital/ownership</li> </ul>
	<b>Large:</b> <ul style="list-style-type: none"> <li>Between US\$10 and US\$50 billion (70 and 350 billion yuan) per year</li> </ul>		<b>Open with restrictions (Mostly open):</b> <ul style="list-style-type: none"> <li>Generally open, but restrictions on the degree of private/foreign ownership apply</li> </ul>
	<b>Medium:</b> <ul style="list-style-type: none"> <li>Between US\$3 and US\$10 billion (20 and 70 billion yuan) per year</li> </ul>		<b>Partially limited (Limited):</b> <ul style="list-style-type: none"> <li>Some parts of the sector are open while others are restricted to private/foreign ownership</li> </ul>
	<b>Limited-medium:</b> <ul style="list-style-type: none"> <li>Between US\$0.5 and US\$3 billion (3 and 20 billion yuan) USD per year</li> </ul>		<b>Limited (Limited):</b> <ul style="list-style-type: none"> <li>Generally strong state control of the sector</li> <li>In exceptions, private/foreign ownership allowed</li> </ul>
	<b>Limited:</b> <ul style="list-style-type: none"> <li>Under US\$0.5 billion (3 billion yuan) per year</li> </ul>		<b>Restricted (Restricted):</b> <ul style="list-style-type: none"> <li>Full state control of the sector</li> <li>Private or foreign ownership is not allowed</li> </ul>

## Evaluation Approach

The China Greentech Initiative developed an initial set of over 300 greentech solutions across seven sectors, which were then prioritized into a list of 125 solutions (see Figure 1) based on environmental impact and commercialization potential. Each prioritized solution was then evaluated, using the Solution Evaluation Framework developed by the Initiative.

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

The SEF evaluates solutions across four dimensions: *unit environmental impact potential, solution attractiveness, addressable market size and market accessibility*. The last three criteria collectively represent the overall commercial potential of the solution in China. As described in Figure 2, each dimension may take on one of five distinct values. Visually, a Harvey Ball is used to express the rating, with an empty ball representing the lowest and a full ball representing the highest value. Solutions were evaluated according to three time periods: Short (under one year), Medium (1-5 years) and Long (5-10 years). The analysis in this chapter focuses on the Medium term evaluations.

Due to the nature of the SEF, the Initiative partners and advisors sometimes had different views on how to evaluate given solutions. Significant attempts were made to validate and reconcile differing perspectives; however, ultimately the Initiative research team used its judgment to determine the value for each criterion. Given that the SEF is only a tool meant to facilitate the evaluation of greentech solutions, as with any framework, it has limitations and its results should be interpreted accordingly.

### UNIT ENVIRONMENTAL IMPACT POTENTIAL

Unit environmental impact potential (environmental impact) expresses the ability of one unit of technology (e.g. one solar panel, one flue gas desulphurization system or one water treatment system) to abate a particular pollutant (e.g. sulfur dioxide, ammonia or solid waste) or increase efficiency of a particular resource (e.g. energy, water or material feedstock) compared to the conventional solution used or no solution at all. The metric used is a percentage which reflects the proportion of pollution abated or efficiency gained by using a particular solution. This consistent metric makes it possible to compare greentech solutions based on their environmental impact within and across segments and sectors.

Fig.3: DISTRIBUTION OF SECTORS BY ENVIRONMENTAL DIMENSIONS TARGETED BY PRIORITIZED SOLUTIONS

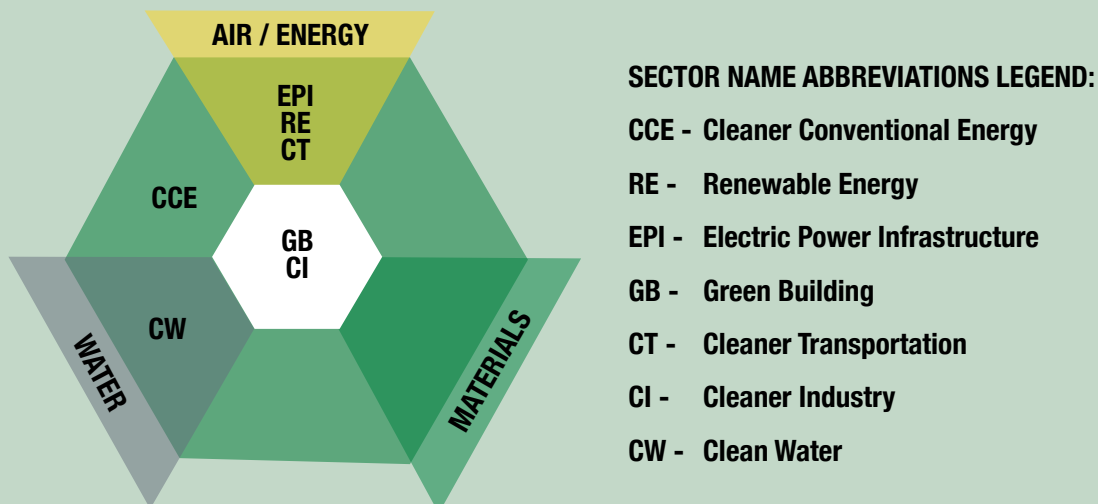


Figure 3 demonstrates the distribution of China's greentech sectors among three dimensions of environmental impact abatement: Air/Energy, Water and Materials. Air and energy are combined into one dimension because the majority of air pollution and CO<sub>2</sub> emissions in China comes from fossil fuels, which can be abated through improved energy efficiency and increased use of renewable energy sources. For each prioritized greentech solution, the dimension on which the greatest unit environment impact abatement could be delivered was chosen.

This graphic shows that the Renewable Energy, Electric Power Infrastructure and Cleaner Transportation sectors primarily impact the environment by reducing atmospheric emissions, including CO<sub>2</sub>, and improving energy efficiency. Clean Water solutions focus on addressing challenges associated with the shortage and pollution of water. Cleaner Conventional Energy solutions abate environmental impact on both air and water. Green Building and Cleaner Industry include solutions that address all three environmental dimensions.

Unit environmental impact potential, as defined by the Solution Evaluation Framework, does not represent the potential of a solution to abate a specific pollutant or increase resource use efficiency for a particular resource for China as a whole. The consideration of the scale of impact is included under the addressable market size dimension.

### SOLUTION ATTRACTIVENESS

Solution attractiveness aims to capture the value of adopting a greentech solution compared to alternatives, focusing on the ability of the solution to deliver benefits to adopters at costs equal to or lower than substitutes on a life cycle basis (e.g., energy savings from the use of a Combined Heat and Power (CHP) system or an Energy Efficient Motor).

Cost competitiveness generally is correlated with technological maturity. For instance, the cost of electricity generated using solar photovoltaic (PV) technology is currently much higher than that of electricity generated using thermal coal fired power plants. Due to these higher costs, the SEF does not qualify Solar PV for a rating of *attractive*, but rather *emerging*. This rating reflects the fact that solar PV technology is currently under rapid development and as technology matures, it will likely achieve cost parity with conventional energy sources like coal, at which time it would be rated *attractive*.

Solutions that are mandated in China, such as Flue Gas Desulphurization (De-SO<sub>x</sub>) and Flue Gas Denitration (De-NO<sub>x</sub>) systems are rated as *advantaged*. This assumes that non-compliance among solution adopters with China's regulation is a short-term phenomenon, and that in the long run it will be an exception.

### ADDRESSABLE MARKET SIZE

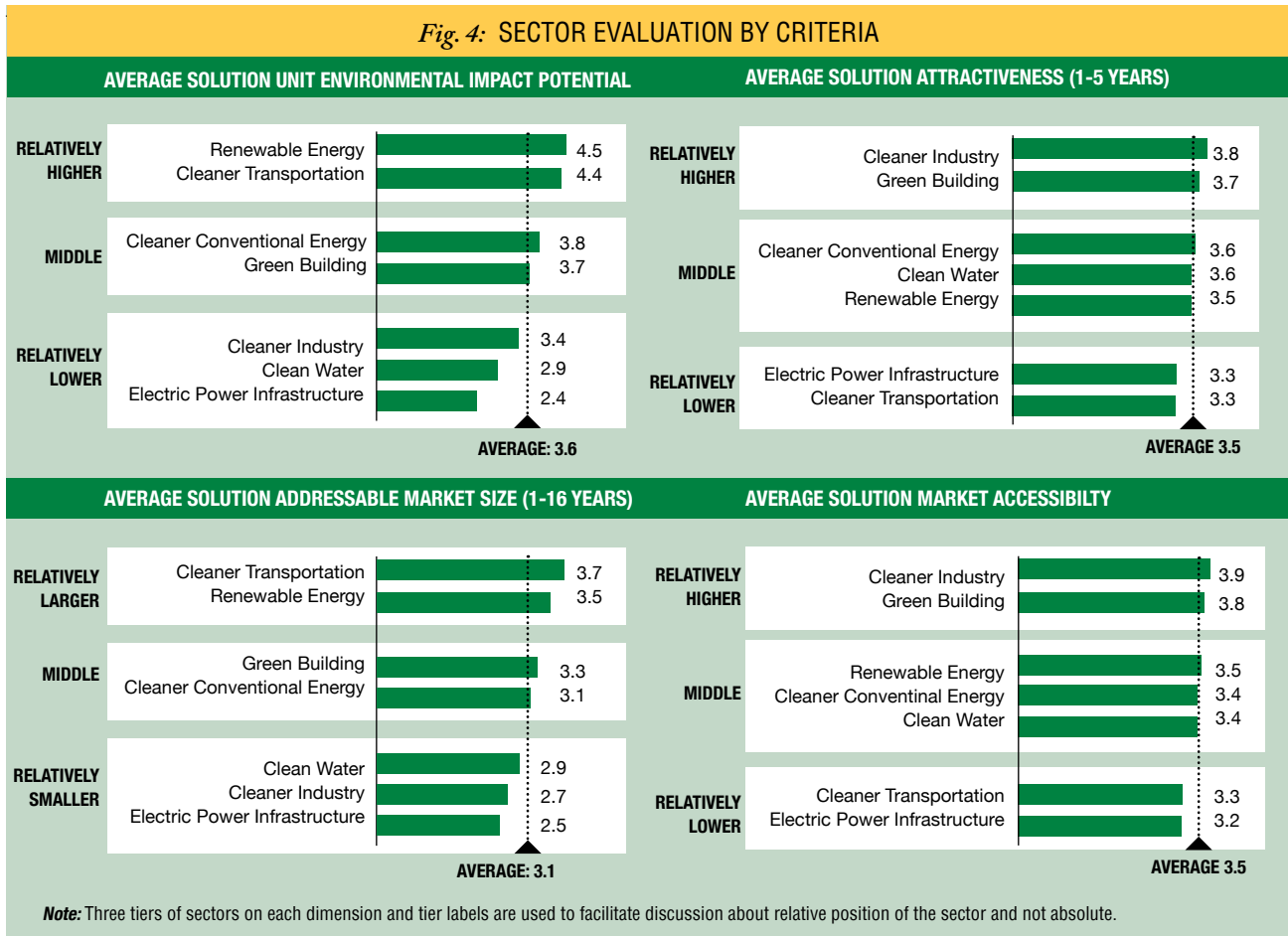
Addressable market size identifies the potential scale at which a particular solution could be applied in China. It is an estimate of the total revenues a particular solution (expressed in US\$ or yuan) could achieve if it were *advantaged* in terms of solution attractiveness today. This is a hypothetical number meant to differentiate technologies, rather than forecast market trends. In other words, addressable market size helps differentiate between power plants, turbines used in power plants and blades used in turbines, as the latter are components of the former and therefore have smaller addressable market size by definition.

Values were estimated by the China Greentech Initiative, relying on information gathered by the research team and feedback from partners and advisors.

### MARKET ACCESSIBILITY

The objective of the market accessibility criteria is to differentiate between markets to which foreign and private players have access and those that are restricted due to regulations or other barriers. *Mostly open* markets are not specifically restricted by the Chinese government. Examples of *mostly open* markets include home appliances, machinery equipment and components, and select technologies that China is interested in developing. *Limited* access markets are those that China controls and allows partial access to, such as construction design, wind power

Fig. 4: SECTOR EVALUATION BY CRITERIA



development and conventional power generation. *Restricted* markets are those that China normally does not allow foreign and/or private players to participate in, such as air traffic control and the construction and operation of electrical grid networks.

### Cross-Sector Findings

Figure 4 shows the average values given to solutions within each of the seven greentech sectors across the four evaluation dimensions introduced above. The sectors are ranked from highest to lowest solution average on each dimension and categorized into three tiers. The labels used to describe the tiers provide a relative assessment of sectors in comparison to the other sectors. For example, the *relatively higher* label applied to the Renewable Energy and Cleaner Transportation sectors on the “Average Solution Unit Environmental Impact Potential” dimension reflects that solutions in these two sectors, on average, have higher unit environmental impact than solutions in the other five.

#### UNIT ENVIRONMENTAL IMPACT POTENTIAL

As highlighted above, Renewable Energy and Cleaner Transportation solutions on average have *relatively higher* environmental impact compared to other sectors. This is because many of these solutions, such as solar photovoltaics, wind turbines and new energy vehicles, have the potential, on a per unit basis, to abate up to 100% of the emissions associated with fossil fuel burning.

Cleaner Industry, Clean Water and Electric Power Infrastructure solutions have, on average, *relatively lower* unit environmental impact compared to other sectors. This is mainly due to the incremental improvement in efficiency and abatement that many of these modular solutions offer.

The average of solutions in the Cleaner Conventional Energy and Green Building sectors falls in the *middle* tier. This is driven by a combination of solutions with *high* and *very high* environmental impact in each sector, such as Carbon Capture and Sequestration (CCS) and De-SO<sub>x</sub> in Cleaner Conventional Energy, with solutions that deliver *incremental* to *medium* environmental impact.

### SOLUTION ATTRACTIVENESS

Cleaner Industry and Green Building have *relatively higher* average solution attractiveness to adopters. Many solutions in these sectors focus on energy efficiency and are already economically feasible on a life cycle basis today. Cleaner Industry also includes solutions, such as De-SO<sub>x</sub> and De-NO<sub>x</sub>, which are mandated by regulation in certain industries.

Electric Power Infrastructure and Cleaner Transportation solutions are ranked *relatively lower*, due to the fact that many of these solutions are in the early stages of technological maturity (e.g. Composite Material Cables and Advanced Metering Infrastructure in the former and Battery Electric Vehicles and Cleaner Aircraft Fuels in the latter).

Cleaner Conventional Energy, Clean Water and Renewable Energy solutions place in the *middle* category, driven by a large number of solutions that technologically are relatively mature or rapidly emerging, but not yet economically competitive in China.

### ADDRESSABLE MARKET SIZE

Solutions in Cleaner Transportation and Renewable Energy on average received the highest evaluations. These sectors include many solutions with *large* to *very large* addressable market sizes, such as New Energy Vehicles and Advanced Aircraft in Cleaner Transportation and Solar Photovoltaic, Concentrating Solar and Biomass Combustion Solutions in Renewable Energy.

Clean Water, Cleaner Industry and Electric Power Infrastructure ranked lowest, due to the fact that solutions in these sectors are more specialized and are often individual components of larger systems.

Green Building and Cleaner Conventional Energy solutions are positioned in the *middle* of the ranking. In fact, a number of solutions in these sectors were evaluated to have large and *very large* addressable market size, but fewer than those in the top two sectors.

### MARKET ACCESSIBILITY

Market accessibility for solutions in Cleaner Industry and Green Building segments is on average *relatively higher* compared to solutions in other sectors. Many of these solutions are modular by nature with a large number of private business providers (both domestic and foreign) already operating in China.

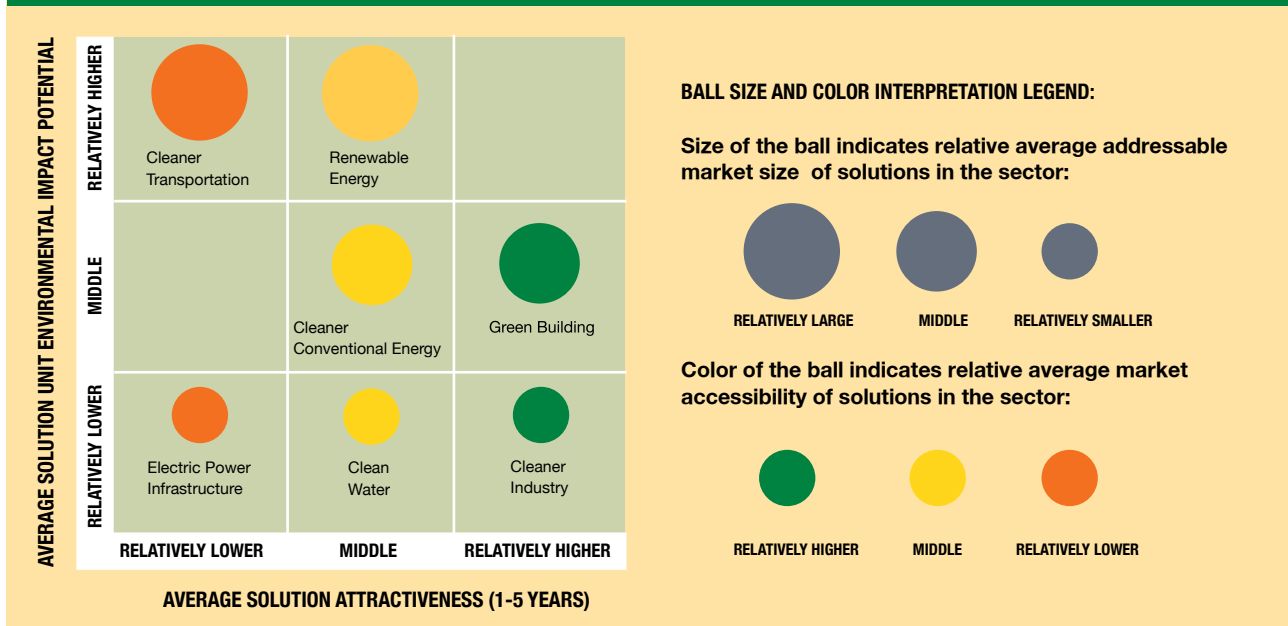
Cleaner Transportation and Electric Power Infrastructure are markets with *relatively lower* accessibility in China. Cleaner Transportation includes solutions in the railway and air transport segments, where access to many value chain elements is *restricted*. The Electric Power Infrastructure market is a regionalized monopoly controlled by the government. While exceptions exist, solution procurement generally favors local state-owned enterprises.

Renewable Energy, Cleaner Conventional Energy, and Clean Water solutions place in the *middle*. Although markets for a number of solutions in these sectors are *mostly open*, a large number of solutions are applicable to markets that have *limited* accessibility, and in some cases, markets that are *restricted*, which is the case with Underground Coal Gasification Combined Cycle in Cleaner Conventional Energy and Extraction Solutions in Clean Water.

### CROSS-SECTOR AVERAGE SOLUTION EVALUATION MATRIX

Figure 5 presents average sector findings in a matrix format, using two axes and the size and color of the ball to incorporate relative evaluation of sectors on all four criteria for the medium term time frame of 1-5 years. Based on this analysis, four groups of sectors emerge:

Fig.5: CROSS-SECTOR AVERAGE SOLUTION EVALUATION MATRIX



■ **Cleaner Transportation and Renewable Energy** - sectors in which solutions on average have *relatively higher* environmental impact, *relatively larger* addressable market size, while being in the *relatively lower* or in the *middle* category in terms of solution attractiveness to adopters and functioning in markets that rank *relatively lower* or in the *middle* on accessibility, compared to other sectors

■ **Green Building and Cleaner Industry** - solutions on average have *relatively higher* attractiveness to adopters, with *relatively higher* market accessibility, while offering environmental impact that ranks *relatively lower* or in the *middle* and addressable market size that ranks in the *middle* or in the *relatively smaller* category, compared to solutions in other sectors

■ **Cleaner Conventional Energy and Clean Water** - solutions rank in the *middle* in terms of relative attractiveness to adopters and market accessibility, present environmental impact that ranks in the *relatively lower* or the *middle* categories and addressable market size that ranks in the *middle* or the *relatively smaller* tiers, compared to other sectors

■ **Electric Power infrastructure** - solutions on average have *relatively lower* environmental impact, *relatively lower* attractiveness to adopters, and *relatively smaller* addressable market size with *relatively lower* accessibility, compared to other sectors

#### TWO DISTINCT INSIGHTS RESULT FROM THIS ANALYSIS:

■ **Correlation of solution attractiveness with market accessibility:** Sectors with more attractive solutions generally exist in markets that are more open (in the medium term 1-5 year timeframe). The two sectors with solutions that on average are found to have *relatively higher* attractiveness to adopters (Green Building and Cleaner Industry) appear to have markets with *relatively higher* accessibility than other sectors. On the other hand, the two sectors with solutions that on average have *relatively lower* attractiveness (Cleaner Transportation and Electric Power Infrastructure) tend to have markets that rank *relatively lower* on accessibility.

■ **Correlation of solution unit environmental impact potential with addressable market size:** Sectors which contain solutions with higher average environmental impact also have greater average addressable market size. For instance, the two sectors that fall into *relatively higher* tier on unit environmental impact potential (Clean Transportation and Renewable Energy) also have *relatively larger* addressable market size compared to other sectors. This is partially due to the concentrated nature of solutions in these sectors, such as vehicles, aircraft, locomotives and Solar Photovoltaics, rather than modular or component-oriented solutions, as is the case in other sectors.

**KEY FINDINGS FROM THE CLEANER CONVENTIONAL ENERGY SOLUTION EVALUATION ANALYSIS INCLUDE:**

■ **OVER HALF OF ALL SOLUTIONS HAVE VERY HIGH UNIT ENVIRONMENTAL IMPACT POTENTIAL.**

This includes all coal post-combustion solutions – Flue Gas Desulfurization (De-SOx), Flue Gas Denitration (De-NOx), Particulate Matter (PM) Removal and Carbon Capture and Sequestration (CCS) solutions. Each of these is able to capture and abate up to 90% of the targeted air pollutant. Additionally, cleaner oil and nuclear power solutions offer *very high* environmental impact. Nearly all other solutions offer lower, though significant, environmental impact. An exception is Coal Liquefaction, which does not present abatement potential due to the high energy intensity of the liquefaction process, but is considered for its strategic energy security benefits.

■ **A MAJORITY OF SOLUTIONS ARE CONSIDERED TO BE ATTRACTIVE OR ADVANTAGED TO ADOPTERS.**

These solutions are either mandated by regulation, such as De-SOx, De-NOx and PM Removal systems, or are economically feasible on a life cycle basis, mostly due to the energy efficiency gains they offer, such as Coal Blending, Combined Heat and Power (CHP), Ultra Supercritical Power Generation (USPG) and F-class Gas Turbine. Carbon Capture and Sequestration (CCS), Underground Coal Gasification Combine Cycle (UCGCC) and Fast Neutron Reactor are currently under development, and given the costs and risks involved, are yet *disadvantaged* in terms of attractiveness to adopters. Coal Liquefaction is *disadvantaged* due to its high operating costs.

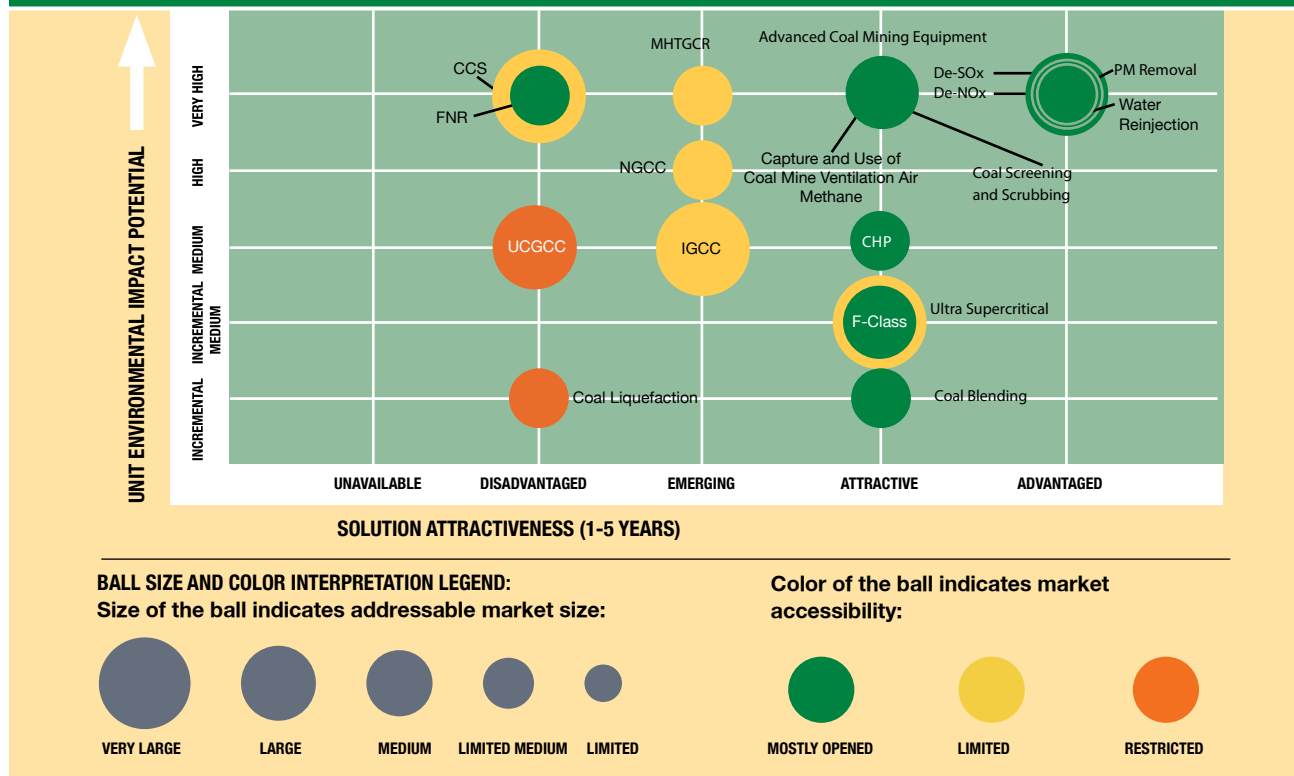
■ **WHILE MOST PRIORITIZED SOLUTIONS OFFER LIMITED-MEDIUM TO MEDIUM ADDRESSABLE MARKET SIZE, A NUMBER OF SOLUTIONS HAVE LARGE TO VERY LARGE ADDRESSABLE MARKETS.**

Three technologies have *very large* addressable markets – Integrated Gasification Combined Cycle (IGCC), USPG and CCS. This evaluation is driven by the current market size of China’s new coal thermal capacity, which is estimated at over US\$50 billion (350 billion yuan) annually. UCGCC, De-SOx and De-NOx solutions are viewed to have *large* addressable market size. Nearly all solutions in Cleaner Gas and Nuclear Power segments have smaller addressable market size, mainly due to the limited capacity of gas fired and nuclear power plants brought online every year, especially when compared to China’s coal capacity.

■ **WHILE SOME MARKETS ARE RESTRICTED, OVER HALF OF THE ANALYZED SOLUTIONS HAVE MARKETS THAT ARE MOSTLY OPEN.**

Coal Liquefaction and UCGCC markets are *restricted* to foreign and private investors and predominantly driven by SOEs. Markets for some key solutions, such as CCS, IGCC, NGCC and USPG are seen as *limited* due to the generally high degree of control exercised by the government. However, markets for many other solutions are *mostly open*, in part driven by China’s interest in international collaboration on developing them. These include Fast Neutron Reactor, F-class Gas Turbine and Capture and Use of Coal Mine Ventilation Air Methane.

**Fig. 6: CLEANER CONVENTIONAL ENERGY SECTOR SOLUTION EVALUATION MATRIX (1-5 Years)**



## Cleaner Conventional Energy Solutions

**THE CHINA GREENTECH INITIATIVE PRIORITIZED 18 CLEANER CONVENTIONAL ENERGY SOLUTIONS** for detailed evaluation from 30 that were originally identified as a result of research and partner feedback. Solutions were chosen from across four segments: Cleaner Coal, Cleaner Gas, Cleaner Oil and Nuclear Power.

The primary focus was on cleaner coal solutions due to China's heavy reliance on coal as a primary energy source. 12 cleaner coal solutions were organized into three categories: Pre-Combustion, Conversion and Combustion, Post-Combustion solutions.

### CLEANER COAL - PRE-COMBUSTION

- **Advanced Coal Mining Equipment** – Coal mining equipment that is more energy efficient and enables higher extraction rates than conventional equipment
- **Coal Blending** – Process of combining various types of pulverized coal to take advantage of their different combustion and emission properties
- **Coal Screening and Scrubbing** – Processes that reduce impurities, such as ash and sulfur, contained in coal prior to burning, normally carried out at or close to the coal mine

### CLEANER COAL - CONVERSION AND COMBUSTION

- **Coal Liquefaction** – Process that converts coal into liquid fuels
- **F-Class Gas Turbine** – Advanced technology gas turbine, which is a rotary engine that extracts energy from a flow of combustion gas at thermal power plants
- **Integrated Gasification Combined Cycle (IGCC)** – System that turns coal into synthesis gas which is then combusted in gas turbines to generate electricity; the waste heat is captured and passed to a steam turbine system for energy recovery
- **Ultra Supercritical Power Generation (USPG)** – Coal-fired power plant that operates at very high temperatures and uses advanced steam cycles that result in higher heat efficiencies and less emissions than conventional coal power plants
- **Underground Coal Gasification Combined Cycle (UCGCC)** – Process by which coal is converted into a product gas underground and then combusted aboveground to generate electricity in combustion systems that capture and utilize waste heat

### CLEANER COAL - POST- COMBUSTION

- **Carbon Capture and Sequestration (CCS)** – System that captures carbon dioxide from fossil fuel, either prior to or after combustion, and sequesters it for long term storage underground
- **Flue Gas Denitration (De-NOx)** – System that removes nitrogen oxides from flue gas
- **Flue Gas Desulfurization (De-SOx)** – System that removes sulfur oxides from flue gas
- **Particulate Matter (PM) Removal** – System that removes particulate matter – harmful fine particles – from flue gas

### CLEANER GAS

- **Capture and Use of Coal Mine Ventilation Air Methane** – Capture and use of methane contained in the exhaust air from underground coal mines
- **Combined Heat and Power (CHP)** – System that simultaneously generates electricity and usable heat by capturing heat that would normally be lost
- **Natural Gas Combined Cycle (NGCC)** – System that generates electricity using gas turbines, and then captures waste heat to generate steam and additional electricity using a steam turbine

### CLEANER OIL

- **Water Reinjection** – Reinjection of water recovered at Gas Oil Separation Plants (GOSPs) back into oil reservoirs as a method of Enhanced Oil Recovery (EOR)

### NUCLEAR POWER

- **Fast Neutron Reactor (FNR)** – Type of nuclear reactor that can utilize nuclear waste from conventional nuclear reactors as feedstock and operate at higher efficiencies
- **Modular High-Temperature Gas-Cooled Reactor (MHTGCR)** – Type of nuclear reactor that is safer and has higher efficiency compared to conventional nuclear reactors

## Renewable Energy Solutions

**THE CHINA GREENTECH INITIATIVE EVALUATED 35 RENEWABLE ENERGY SOLUTIONS.** These solutions are split nearly equally across three segments: Solar, Wind and Bioenergy. While the Renewable Energy sector is defined to include hydroelectricity, wave and geothermal segments, these solutions are not covered in this report.

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

Unlike other sectors discussed in this chapter, the values shown on the Renewable Energy evaluation matrix represent the average values for the solution areas defined above, not individual solutions. This is due to the number of solutions analyzed.

### KEY FINDINGS FROM THE RENEWABLE SOLUTIONS EVALUATION ANALYSIS INCLUDE:

■ **NEARLY ALL AREAS HAVE VERY HIGH AVERAGE SOLUTION UNIT ENVIRONMENTAL IMPACT POTENTIAL.** This is based mainly on the ability of renewable energy sources, particularly Solar and Wind, to completely abate CO<sub>2</sub> and other air emissions associated with fossil fuel combustion in generating electricity. The two exceptions are within the wind segment and include Wind-Development and Wind-Maintenance areas, which have *incremental-medium* to *medium* potential. These two areas focus on discrete parts of the wind value chain and offer efficiency gain improvements rather than direct emissions abatement. Bioenergy-Electricity has high environmental impact, or more than 40% abatement. This is significant because this area includes Biomass Co-Firing solution that normally abates less than 40% of CO<sub>2</sub> emissions due to the fact that biomass is normally Co-Fired with coal.

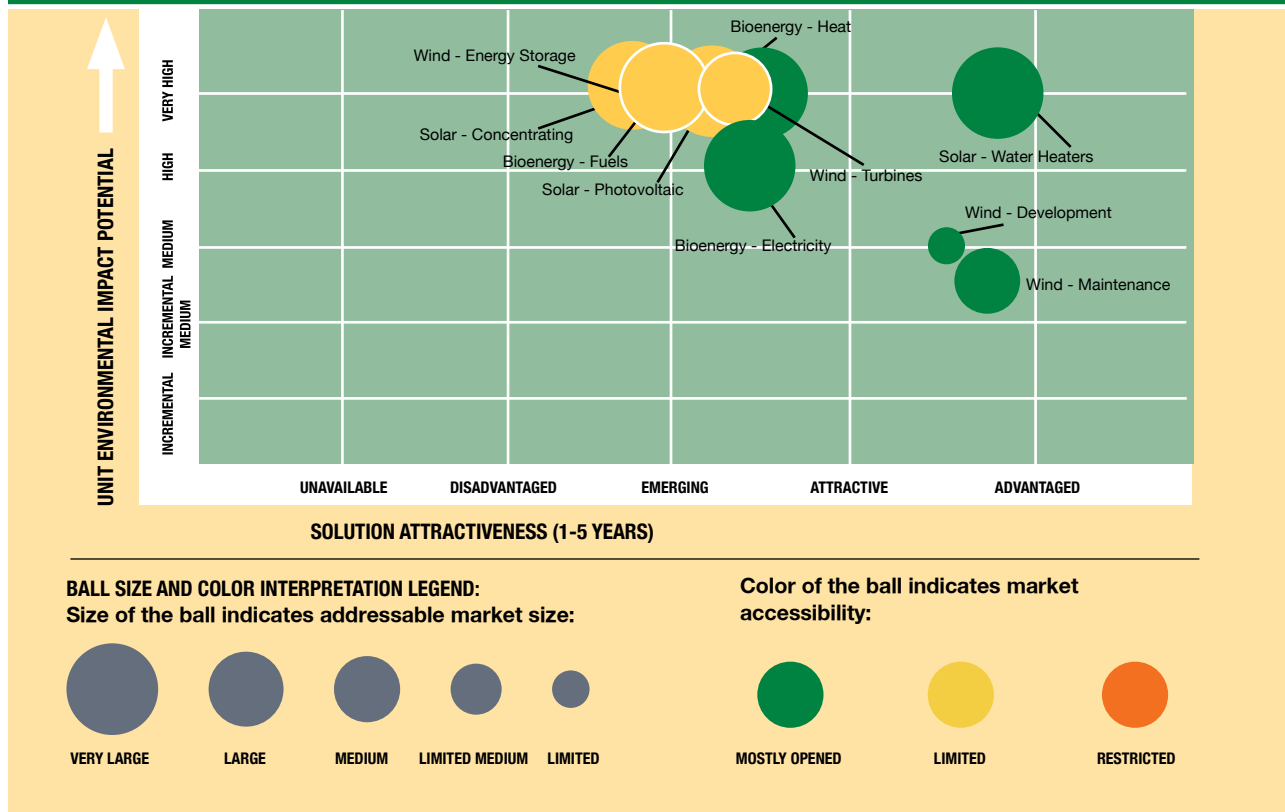
■ **WHILE SOLAR-WATER HEATERS ALREADY ARE ADVANTAGED FROM THE ADOPTER PERSPECTIVE, SOLUTIONS IN MOST AREAS ON AVERAGE ARE BETWEEN EMERGING AND ATTRACTIVE.** Wind-Development and Wind-Maintenance areas include solutions that are either *attractive* or *advantaged* which determined their position between the two evaluations. Bioenergy-Electricity and Bioenergy-Heat both rely on biomass combustion and are found to be between *emerging* and *attractive*. The analysis suggests that among Solar, Wind Power and Biofuels solutions, most attractive are Wind-Turbines solutions, followed by Solar-Photovoltaic, and then by Bioenergy-Fuels solutions. This ranking parallels the technological maturity of solutions within these segments. Wind Power is approaching cost parity with electricity generated using conventional sources, such as coal and natural gas, while generating power using Solar-Photovoltaic solutions is still considerably more expensive. Although a number of Bioenergy-Fuels solutions are technologically mature, the unreliability of feedstock supply significantly decreases their attractiveness to adopters.

■ **THE ADDRESSABLE MARKET SIZE IS ESTIMATED TO BE LARGEST FOR SOLUTIONS IN SOLAR-PHOTOVOLTAIC AND SOLAR-CONCENTRATING AREAS.** This is a reflection of the ability of solutions in these areas to compete for a share of China's forecasted increase in power generation capacity against conventional power sources, especially coal-fired capacity, assuming they reach technological maturity and cost-parity over the medium term timeframe. A number of other solution areas have *large* addressable market sizes, such as Wind-Energy Storage, Solar-Water Heater and all three Bioenergy areas. Apart from two off-grid solutions included in the Wind-Turbines area, solutions there also have *large* addressable market sizes. Solutions in Wind-Maintenance and Wind-Development areas on average offer relatively smaller market sizes, mainly due to how specialized these solutions are.

■ **ON MARKET ACCESSIBILITY, SOLUTION AREAS ARE SPLIT HALFWAY BETWEEN MOSTLY OPEN AND LIMITED.** Notably, the five solution areas that rank lower on solution attractiveness are seen as *limited* in terms of market accessibility due to both formal and informal restrictions. These areas include Wind-Turbines, Solar-Photovoltaic, Bioenergy-Fuels, Wind-Energy Storage and Solar-Concentrating. A number of areas, however, contain solutions that on average have markets that are *mostly open*, such as Solar-Water Heaters, Wind-Maintenance, Wind-Development, Bioenergy-Electricity, and Bioenergy-Heat.

*A more detailed analysis of each individual solution can be found in the Renewable Energy chapter in the full version of The China Greentech Report*

Fig.7: RENEWABLE ENERGY SECTOR SOLUTION AREAS EVALUATION MATRIX (1-5 Years)



**SOLAR - PHOTOVOLTAIC**

- **Amorphous Silicon Thin Film Photovoltaic Cell (a-Si PV)** – Type of thin film solar cell based on amorphous silicon chemical compound
- **Building Integrated Photovoltaic (BIPV)** – Application of solar photovoltaic materials, whether crystalline or thin film, into actual building structures, normally replacing conventional building materials in parts of the building envelope such as the roof, skylights or facades
- **Cadmium Telluride Thin Film Photovoltaic Cell (CdTe PV)** – Type of thin film solar cell based on cadmium telluride chemical compound
- **CIGS Thin Film Photovoltaic Cell (CIGS PV)** – Type of thin film solar cell based on copper iridium gallium selenide chemical compound
- **Crystalline Silicon Photovoltaic Cell (cSi PV)** – Type of solar cell made from a single crystal or a polycrystalline slice of silicon that was the first type to be widely commercialized

**SOLAR - CONCENTRATING**

- **Concentrating Photovoltaic (CPV)** - Device that concentrates sunlight onto photovoltaic surfaces to produce electricity
- **Fresnel Mirror** – Solar thermal energy collector that consists of a series of long, narrow, slightly curved mirrors that focus the light onto linear receivers positioned above the mirrors to be eventually converted into electricity
- **Parabolic Dish Stirling Engine** – Device that concentrates sunlight at a single focal point via a parabolic dish to produce electricity and that can track the sun along two axes by automatically adjusting the direction of the dish
- **Parabolic Trough** – Solar thermal energy collector that consists of a long parabolic mirror and a Dewar tube running its length at the focal point that absorbs energy from the sunlight which is converted into electricity
- **Power Towers** – Type of solar power plant that uses a tower and a high heat capacity component to receive the sunlight focused by an array of flat movable mirrors and convert it into electricity

**SOLAR - WATER HEATERS**

- **Solar Water Heater (SWH)** – System that heats water by absorbing energy from sunlight, normally consisting of solar thermal collectors, fluid systems to transport the heat and a water tank where water is heated and stored

**WIND - TURBINES**

- **Offgrid / <1 MW / Horizontal** – Horizontal wind turbine with under 1 MW capacity that generates electricity to be used locally and does not require connection to the power grid

**WIND -TURBINES**

- **Offgrid / <1 MW / Vertical** – Vertical wind turbine with under 1 MW capacity that generates electricity to be used locally and does not require connection to the power grid
- **Ongrid / 1-3 MW / Onshore** – Horizontal wind turbine with capacity between 1 and 3 MW that is located onshore and feeds the generated electricity onto the power grid
- **Ongrid / >3 MW / Onshore** – Horizontal wind turbine with capacity over 3 MW that is located onshore and feeds the generated electricity onto the power grid
- **Ongrid / >3 MW / Offshore** – Horizontal wind turbine with capacity over 3 MW that is located offshore and feeds the generated electricity onto the power grid

**WIND DEVELOPMENT**

- **Micrositing** – Consideration of an array of factors related to wind flow, terrain, local power demand, environmental and land-use issues carried out during site selection for wind turbines to maximize wind farm's operational efficiency and economics
- **Wind Assessment** – Process of assessing the quality of wind at a particular location for the purpose of estimating future potential energy production of a wind farm if it were to be installed at that location

**WIND MAINTENANCE**

- **Control System** – System that monitors and controls the behavior of other devices or systems to ensure optimal operation of the wind turbine
- **Conversion Technology** – Device that converts electricity received from a set of wind turbines to the standard required by the power grid before feeding the electricity onto the grid
- **Maintenance** – Set of inspections, repairs or modifications of individual wind turbines or wind farms to ensure optimal operation
- **Standard Operating Procedures (SOPs)** – Set of prescriptions for employees, often mandated, on how to execute specific tasks or to react to circumstances in the most efficient and effective ways

**WIND ENERGY STORAGE**

- **Battery Storage** – Electrochemical cells that can be used to store energy and be charged using electricity and discharged to produce electricity
- **Compressed Air Energy Storage (CAES)** – System that can store energy by compressing air in a compartment, such as airtight underground cavern, and then generate electricity by releasing the air from storage through a combustion turbine
- **Pumped Hydro Storage** – Method under which energy can be stored by pumping the water to a high reservoir and then released back into a lower reservoir to generate electricity when passing through power generating turbines

**BIOENERGY - ELECTRICITY**

- **Biomass Co-Firing** – Combining biomass with coal to be burned to generate electricity at a power plant
- **Biomass Combustion** – Burning of biomass to generate electricity at a power plant

**BIOENERGY - HEAT**

- **Civil Heat** – Burning of biomass to generate heat to be used for civil purposes
- **Industrial Heat** – Burning of biomass to generate heat to be used for industrial purposes

**BIOENERGY - FUELS**

- **Cassava Bioethanol** – Bioethanol produced from cassava crop
- **Cellulosic Bioethanol** – Bioethanol produced from wood, grasses or other plants
- **Jatropha Diesel** – Biodiesel produced from jatropha crop
- **Mircoalgae Diesel** – Diesel produced from microalgae, which are photosynthetic organisms that can be farmed in water
- **Sweet Sorghum Bioethanol** – Bioethanol produced from sweet sorghum crop
- **Waste Vegetable Oil Biodiesel** – Biodiesel produced from waste vegetable oil

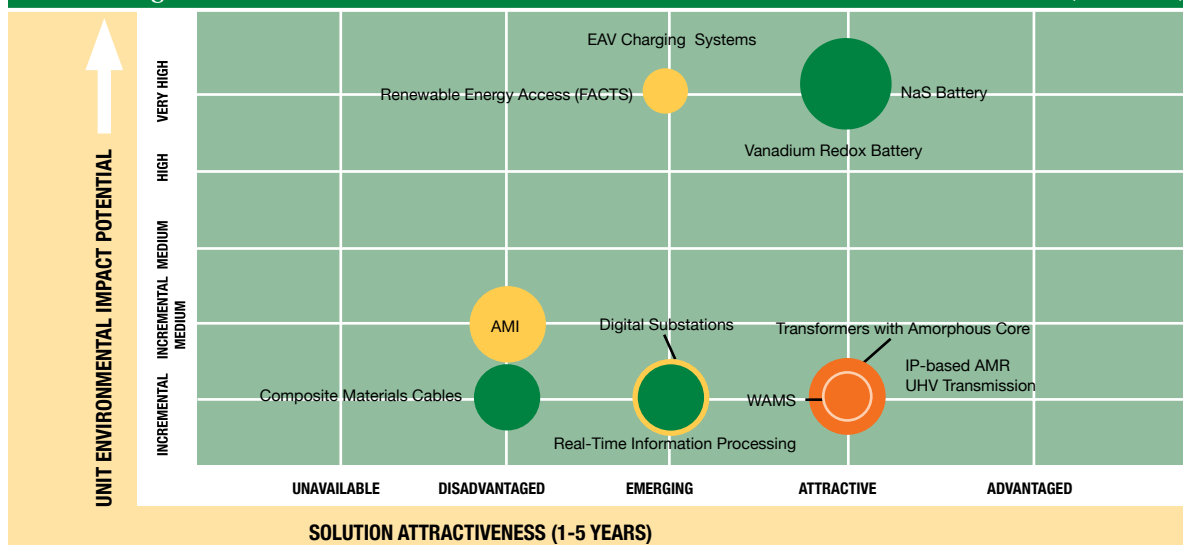
## Electric Power Infrastructure Solutions

**THE CHINA GREENTECH INITIATIVE PRIORITIZED 12 ELECTRIC POWER INFRASTRUCTURE SOLUTIONS** for detailed evaluation from an original set of 20. These solutions are organized in four areas: Loss Reduction, Smart Grid, Energy Storage and Grid Access solutions.

### KEY FINDINGS FROM THE ELECTRIC POWER INFRASTRUCTURE SOLUTIONS EVALUATION ANALYSIS INCLUDE:

- TWO-THIRDS OF ANALYZED SOLUTIONS OFFER INCREMENTAL UNIT ENVIRONMENTAL IMPACT POTENTIAL.** This is due to the focus of these solutions, such as Digital Substations, Composite Materials Cables and Wide Area Management System (WAMS), on transmission and distribution loss reduction, which represents less than 10% of today's overall electricity generation in China. The benefit these solutions deliver in improving the reliability of the network is not captured in this evaluation. However, the two energy storage and two grid access solutions represent *very high* environmental impact. This means they are able to abate over 40% of negative environmental impact, which in this case are CO<sub>2</sub> emissions from power generation utilizing China's current fuel mix. Rather than delivering direct impact, these solutions enable the collective system, which is comprised of power generation, storage, transmission, distribution and application, to achieve 40% abatement.
- HALF OF THE SOLUTIONS ARE STILL DISADVANTAGED OR EMERGING, WHILE HALF ARE ALREADY ATTRACTIVE.** From the adopter perspective, many solutions are still *disadvantaged* or *emerging*, such as Composite Materials Cables, Advanced Metering Infrastructure (AMI) and Electric Auto Vehicle (EAV) Charging System. Although all of these technologies hold great promise, currently, they are in relatively early stages of technological maturity. In comparison, Ultra High Voltage (UHV) Transmission and the two energy storage solutions were evaluated as *attractive*. Particularly in the area of UHV Transmission China has invested heavily in building strong domestic expertise and today possesses world class technology.
- ALL SOLUTIONS, WITH THE EXCEPTION OF ENERGY STORAGE, HAVE LIMITED TO MEDIUM ADDRESSABLE MARKET SIZE.** This is driven, in part, by the nature of solutions that were prioritized, which represent individual grid components, rather than comprehensive systems. Especially in cases such as Digital Substation and WAMS, these solutions have very narrow application and once installed have long lifespans, not requiring replacements. This constrains the yearly addressable market size of these technologies. The two energy storage solutions, however, NaS Battery and Vanadium Redox Battery, have *large* addressable market size, as they could be deployed to store electricity generated during non-peak times, in place of incremental peak power generating capacity, and used to mitigate power supply and demand fluctuation. UHV Transmission is estimated to have medium addressable market size, driven by China's ongoing investment in the sector.
- THE MAJORITY OF MARKETS HAVE EITHER LIMITED OR RESTRICTED ACCESS.** In the case of UHV Transmission and WAMS, China has made significant investment in these solutions and the government is focusing on deploying them independently. For other technologies – such as AMI, IP-Based Automatic Meter Reading (AMR) and EAV Charging System – markets are viewed to be relatively more open, albeit still *limited*, due to the government-owned regionalized monopoly responsible for the construction and management of China's electric grid.

Fig.8: ELECTRIC POWER INFRASTRUCTURE SECTOR SOLUTION EVALUATION MATRIX (1-5 Years)



**BALL SIZE AND COLOR INTERPRETATION LEGEND:**

Size of the ball indicates addressable market size:



Color of the ball indicates market accessibility:



**LOSS REDUCTION**

- **Composite Materials Cables** – Transmission and distribution line cables made from composite materials that are specifically engineered to reduce losses
- **Transformers with Amorphous Core** – Alternative transformers that are more energy-efficient and environmentally-friendly than conventional
- **Ultra High Voltage (UHV) Transmission** – Power transmission lines with voltages of 1,000 kV or higher for alternating current or 800 kV or higher for direct current that allow power to be transmitted at greater distances with lower losses than lower voltage transmission lines

**SMART GRID**

- **Advanced Metering Infrastructure (AMI)** – Integrated system that measures, collects, stores and analyzes utility usage, such as electricity, gas or water usage; is a broader concept than AMR-IP based solution
- **Digital Substation** – Automated and computerized substation that provides greater transparency, higher reliability and efficiency of operations
- **IP-Based Automatic Meter Reading (AMR)** – Solutions that automatically gather data from energy metering devices and transmit to a central processing facility where billing is handled and consumption patterns are analyzed
- **Real-Time Information Processing** – Solutions that enable real time communication between core nodes in the electric network, including customer premise, and allow better management of demand, improved reliability and flexibility of the network
- **Wide Area Management System (WAMS)** – Integrated system that monitors and controls elements of the electrical power grid to ensure availability and improve reliability and efficiency of the network

**ENERGY STORAGE**

- **NaS Battery** – Sodium-sulphur battery with high energy density and high efficiency of charge/discharge that requires high operating temperatures
- **Vanadium Redox Battery** – Flow battery with deep cycling life that can be mechanically refueled and has low negative environmental impact

**GRID ACCESS**

- **Electric Auto Vehicle (EAV) Charging System** – System that allows for plug-in electric vehicles to be charged using power from the grid
- **Renewable Energy Access - Flexible Alternating Current Transmission System (FACTS)** – System comprised of static equipment used for the alternating current transmission that is meant to enhance controllability and increase power transfer capability of the network

## Green Building Solutions

**THE CHINA GREENTECH INITIATIVE PRIORITIZED 15 GREEN BUILDING SOLUTIONS** for detailed evaluation from an original list of nearly 30. Prioritized solutions fall into four categories: Energy Efficiency, Water Efficiency, Optimized Materials and Cross-Area solutions.

### KEY FINDINGS FROM THE GREEN BUILDING SOLUTIONS EVALUATION ANALYSIS INCLUDE:

**■ HALF OF ALL SOLUTIONS HAVE HIGH TO VERY HIGH UNIT ENVIRONMENTAL IMPACT POTENTIAL.**

Solutions that offer *very high* environmental impact include Advanced Envelope, Building-Integrated Heat and Power, Passive Design, Integrated Design and Sustainable Urban Planning. Each, when applied separately, has the potential to improve a building's energy efficiency by 40% or more. The three planning and design solutions have the potential to ensure a building's sustainability early in the development process, when it is still possible to apply a wide range of optimization techniques, including building location, construction materials used and systems intergrated. Solutions with *high* environmental impact include Greywater Systems, Low-Impact Materials and Recycled Materials. All other solutions are estimated to have a *incremental-medium* to *medium* environmental impact.

**■ THE MAJORITY OF GREEN BUILDING SOLUTIONS ARE ATTRACTIVE TO ADOPTERS.**

Low-Flow Fixtures are considered to be *advantaged* as they deliver operational savings while their initial cost is comparable to conventional alternatives. Advanced Envelope, Building-Integrated Heat and Power, Commissioning and Efficient Operations, Resource Service Companies and the three design and planning solutions are considered to be *attractive*, as the technologies are mature and the savings delivered during the operation part of the building life cycle outweigh additional upfront costs. However, because of the necessary additional investment and lack of alignment of interest in the value chain between developers and users of buildings, these solutions are not yet widely applied in China.

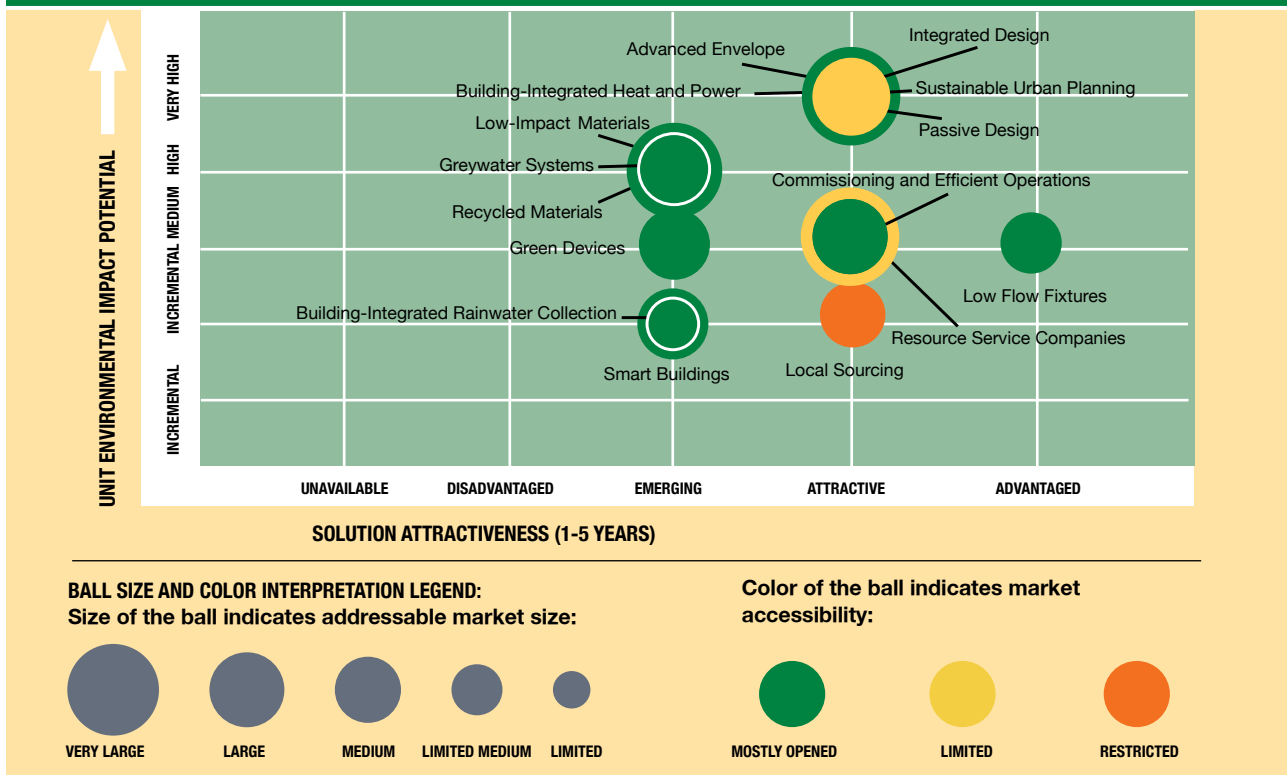
■ **SOLUTIONS VARY BY ADDRESSABLE MARKET SIZE AND ONE THIRD OF ALL SOLUTIONS HAVE LARGE TO VERY LARGE MARKETS.**

Advanced Envelope, Low-Impact Materials and Recycled Materials were all evaluated to have *very large* addressable markets, driven by the large amount of new building construction that takes place in China every year. At the same time, Building-Integrated Heat and Power and Resource Service Companies solutions were estimated to have *large* addressable market size, which is driven by the rapidly growing floorspace in China and the low existing penetration of these solutions. Most other solutions were evaluated to have medium addressable market size.

■ **EXCEPT FOR PLANNING AND DESIGN SOLUTIONS, NEARLY ALL GREEN BUILDING SOLUTIONS MARKETS ARE VIEWED AS MOSTLY OPEN.**

China currently limits the scope of operations of foreign building design firms by requiring the involvement of local architecture, design and planning bureaus in design approval, and does not permit foreign construction firms. This said, except for Local Sourcing and Resource Service Companies, markets for all other solutions are viewed as *mostly open* for foreign and private participants. In particular, Green Devices and Smart Buildings, among others, are considered to be areas with the highest market accessibility.

Fig.9: GREEN BUILDING SECTOR SOLUTION EVALUATION MATRIX (1-5 Years)



**ENERGY EFFICIENCY SOLUTIONS**

- **Advanced Envelope** – Includes insulation, windows, roofing and other passive solutions either installed more accurately than China’s market convention or combined with active systems such as moisture or temperature sensors to enable reduced heat gain or loss
- **Building-Integrated Heat and Power** – Combination of heating and power generation solutions that could be integrated into a building, such as solar photovoltaic cells, wind turbines and solar water heaters
- **Green Devices** – Electronic devices used inside buildings, including lighting solutions, appliances and consumer electronics that are more energy efficient than conventional alternatives
- **Smart Buildings** – Buildings that rely on integrated IT-based resource use measurement and monitoring, intelligent analysis of the internal environmental and performance data, and automation of connected building systems

**WATER EFFICIENCY SOLUTIONS**

- **Building-Integrated Rainwater Collection** – System that collects and

- stores rainwater from the rooftop of a building to be used locally
- **Greywater Systems** – Systems for the reuse of water generated from domestic processes such as dish washing, laundry and bathing for either indoor use or in irrigation
- **Low-Flow Fixtures** – Faucets and other water use systems that use less water than conventional systems but deliver the same or greater benefit to the user

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## OPTIMIZED MATERIALS SOLUTIONS

- **Local Sourcing** – Procurement and sourcing of building materials within the geographical proximity of their intended use
- **Low-Impact Materials** – Building materials produced using less resources and that generate less pollution compared to conventional building materials over their life cycle
- **Recycled Materials** – Building materials manufactured from materials that have been recycled

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## CROSS-AREAS SOLUTIONS

- **Commissioning and Efficient Operations** – Assuring that all systems in a building are installed, tested, operated and maintained as originally intended
  - **Integrated Design** – Approach that brings together all the stakeholders in the building process at an early stage to maximize building comfort and usability while minimizing resource use
  - **Passive Design** – Building design that takes advantage of the local climate to provide some or all of the heating, cooling, lighting and ventilation needs of the occupants
  - **Resource Service Companies** – Professional service companies, including Energy Service Companies (ESCOs), that provide project management, consulting, engineering, financing, operation and maintenance services that reduce energy and water use in buildings
  - **Sustainable Urban Planning** – Urban planning that optimizes the use of the built environment, transportation system, energy, water and land, while aiming to minimize the negative impact of the community on the natural environment
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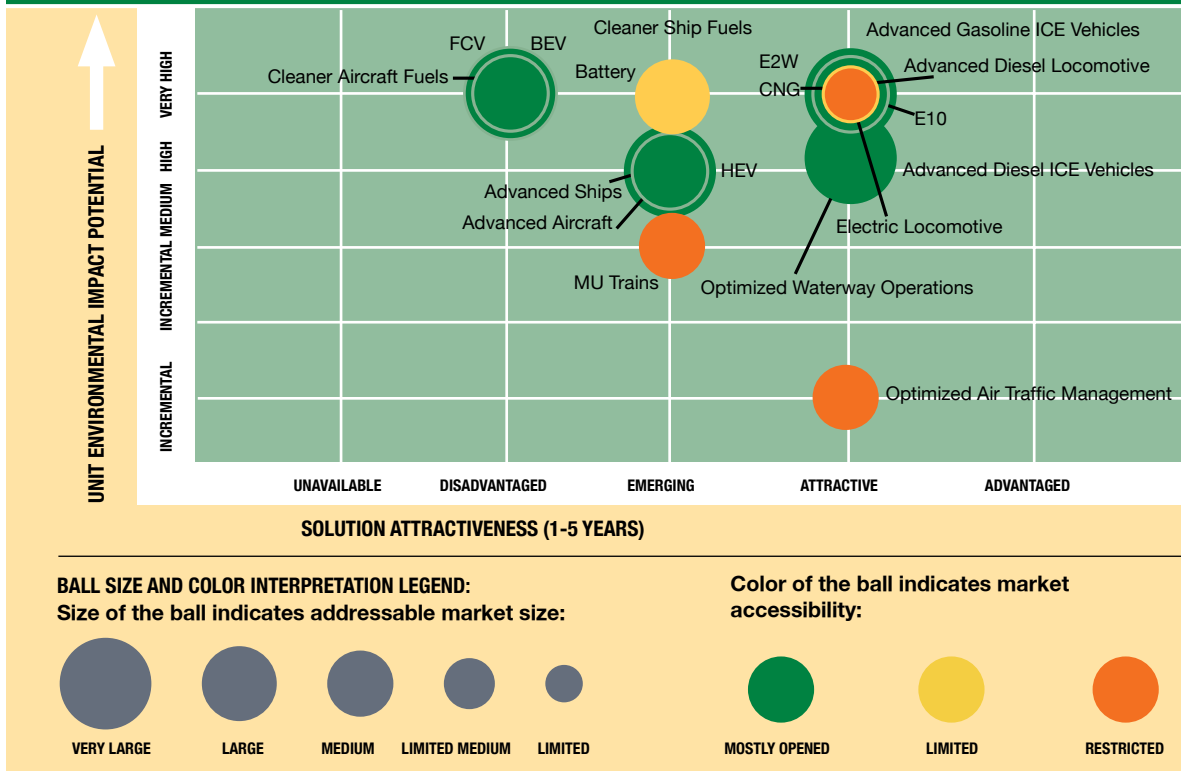
## Cleaner Transportation Solutions

**THE CHINA GREENTECH INITIATIVE SELECTED 18 CLEANER TRANSPORTATION SOLUTIONS** for detailed evaluation. Solutions were identified across four segments: Cleaner Road Transportation, Cleaner Rail Transportation, Cleaner Air Transportation and Cleaner Waterway Transportation.

### KEY FINDINGS FROM THE CLEANER TRANSPORTATION SOLUTIONS EVALUATION ANALYSIS INCLUDE:

- **A LARGE MAJORITY OF SOLUTIONS HAVE VERY HIGH UNIT ENVIRONMENTAL IMPACT POTENTIAL AND SEVEN OF THESE ARE SIMULTANEOUSLY ATTRACTIVE TO ADOPTERS.** Advanced Gasoline and Diesel ICE Vehicles, Compressed Natural Gas (CNG) and Bioethanol (E10) alternative fuels, Electric Two Wheelers (E2W) and Advanced Diesel and Electric Locomotives all have the potential to abate CO<sub>2</sub> and other air polluting emissions related to the combustion of fossil fuels by over 40% on a per unit basis. They are attractive to adopters as costs are either comparable to, or less than, conventional alternatives (CNG, for example), or the fuel savings delivered through efficiency gain justifies the higher upfront cost.
- **ALTHOUGH HALF OF ALL SOLUTIONS ARE ATTRACTIVE TO ADOPTERS, MANY ARE STILL EMERGING OR DISADVANTAGED.** In addition to solutions described above, Optimized Air Traffic Management and Optimized Waterway Operations are *attractive*. For these solutions, cost savings from fuel efficiency gains delivered by the improved management normally outweigh the investment required for its optimization. At the same time, Advanced Aircraft, Advanced Ships, and Advanced Ship Fuels are considered to be *emerging*. A number of promising solutions, such as Fuel Cell Vehicles (FCV), Battery Electric Vehicles (BEV) and Cleaner Aircraft Fuels, are still *disadvantaged*. This is primarily due to the early technological maturity and still relatively high cost of these solutions.
- **THE ADVANCED GASOLINE ICE VEHICLES AND THE THREE NEW ENERGY VEHICLE SOLUTIONS (BEV, FCV, HEV) HAVE VERY LARGE ADDRESSABLE MARKET SIZE.** This implies addressable market size of over US\$50 billion (350 billion yuan) per year, and is determined by China’s motor vehicles market, which is one of the largest in the world by the number of units sold and is growing rapidly. A number of solutions were estimated to have *medium* addressable market size in China, as with Advanced Aircraft, Advanced Ships and cleaner fuels solutions for air and waterway transport.
- **WHILE MARKETS FOR NEARLY ALL ROAD SOLUTIONS ARE MOSTLY OPEN, IN THE CASE OF RAIL, AIR, AND WATERWAY TRANSPORTATION THE MAJORITY OF SOLUTIONS FACE LIMITED TO RESTRICTED MARKET ACCESSIBILITY.** The majority of markets for railway equipment are open to foreign participation through joint ventures, while in case of Electric Locomotives and Multiple Unit Trains, China is pursuing the development of indigenous technologies and exercises a greater influence. The Bioethanol (E10) market is concentrated under several State Owned Enterprises (SOEs) and the government maintains strong control. This is partially due to concerns over the disruption of the food supply chain if the market for Bioethanol feedstock is not managed.

Fig.10: CLEANER TRANSPORTATION SECTOR SOLUTION EVALUATION MATRIX (1-5 Years)



### CLEANER ROAD TRANSPORTATION - ADVANCED ICES

- **Advanced Diesel Internal Combustion Engine (ICE) Vehicle** – Vehicle with diesel ICE that is more fuel efficient and produces less emissions than conventional models used in China
- **Advanced Gasoline Internal Combustion Engine (ICE) Vehicle** – Vehicle with gasoline ICE that is more fuel efficient and produces less emissions than conventional models used in China

### CLEANER ROAD TRANSPORTATION - ALTERNATIVE FUELS

- **Bioethanol (E10)** – A mixture of gasoline with ethyl alcohol, a petroleum substitute produced from certain agricultural crops through a microbial sugar fermentation process, in a combination where 90% is gasoline and 10% is ethyl alcohol
- **Compressed Natural Gas (CNG)** – Fossil fuel substitute for gasoline, diesel or propane made by compressing natural gas which is then stored in special compressed gas cylinders

### CLEANER ROAD TRANSPORTATION - NEW ENERGY VEHICLE SOLUTIONS

- **Battery** – Combination of electrochemical cells that store electric energy
- **Battery Electric Vehicle (BEV)** – Vehicle that completely relies on electricity storage batteries as a power source and is driven by an electric motor
- **Electric Two Wheelers (E2W)** – Bikes and scooters equipped with a rechargeable battery and an electric motor used for propulsion
- **Fuel Cell Vehicle (FCV)** – Vehicle propelled by an electric motor using electricity generated through a chemical process within a fuel cell, which requires hydrogen fuel and oxygen from the air as feedstock
- **Hybrid Electric Vehicle (HEV)** – Vehicle that combines an internal combustion engine with an electric motor to drive the vehicle and relies on gasoline or diesel and electricity storage batteries as power sources

### CLEANER RAIL TRANSPORTATION SOLUTIONS

- **Advanced Diesel Locomotive** – Diesel locomotive that is more fuel efficient and produces less emissions than conventional models used in China
- **Electric Locomotive** – Locomotive powered by an electric engine which uses an electricity source, such as an overhead line, third rail or an on-board electricity storage device, rather than fossil fuel to meet its energy requirements
- **Multiple Unit (MU) Train** – Train that relies not on a locomotive but a series of self-propelling carriages controlled from one cabin for its propulsion

### CLEANER AIR TRANSPORTATION SOLUTIONS

- **Advanced Aircraft** – Aircraft that are more fuel efficient and produce less emissions than conventional models used in China
- **Cleaner Aircraft Fuels** – Aircraft fuels that produce considerably less air emissions than conventional aircraft fuels while delivering equal or better performance
- **Optimized Air Traffic Management** – Set of processes to achieve the highest possible productivity of the air fleet and ground facilities by optimizing flight planning, logistics and air traffic management, while ensuring safety and convenience and minimizing the negative impact on the environment

### CLEANER WATERWAY TRANSPORTATION SOLUTIONS

- **Advanced Ships** – Ships that are more fuel efficient and produce less emissions than conventional models used in China
- **Cleaner Ship Fuels** – Ship fuels that produce less air emissions than conventional ship fuels while delivering equal or better performance
- **Optimized Waterway Operations** – Set of processes to achieve the highest possible productivity of ships and related facilities, such as ports, by optimizing water traffic planning, logistics and traffic management, while ensuring safety and convenience and minimizing the negative impact on the environment.

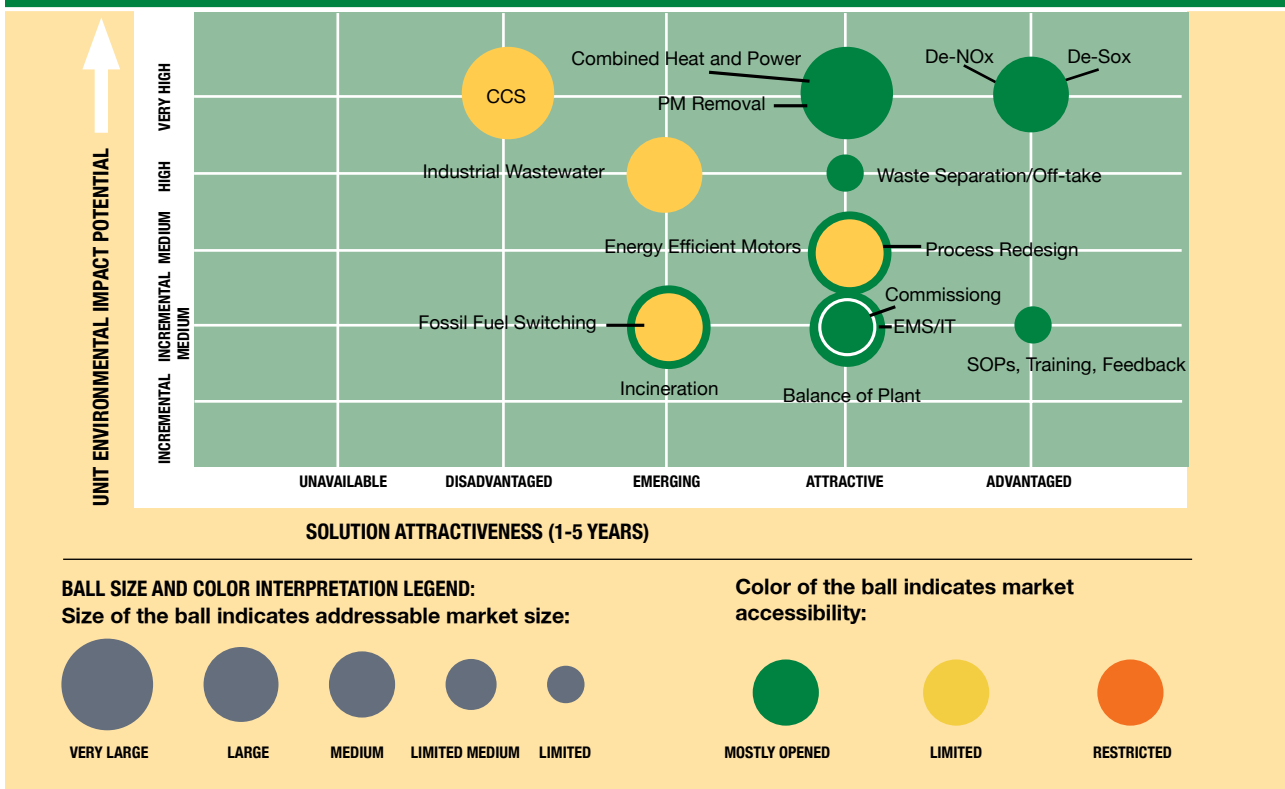
## Cleaner Industry Solutions

**FROM THE 75 CLEANER INDUSTRY SOLUTIONS ORIGINALLY IDENTIFIED**, the China Greentech Initiative prioritized 15 for detailed evaluation. The prioritized solutions apply to multiple industries, including heavy and light industries, and can be categorized into four areas: Energy Efficiency, Air & Water Pollution Mitigation, Solid Waste Management and Cross-Area solutions.

### KEY FINDINGS FROM THE CLEANER INDUSTRY SOLUTIONS EVALUATION ANALYSIS INCLUDE:

- UNIT ENVIRONMENTAL IMPACT POTENTIAL VARIES GREATLY ACROSS SOLUTIONS.** Combined Heat and Power (CHP), Flue Gas Desulfurization (De-SOx), Flue Gas Denitration (De-NOx), Particulate Matter (PM) Removal and Carbon Capture and Sequestration (CCS) solutions were identified to have the highest environmental impact. CHP may provide a gain in energy efficiency of over 40%, and the remaining solutions have the potential to abate over 40% of the pollutants they target. On the other hand, solutions such as Balance of Plant, Fuel Switching and Commissioning received an *incremental-medium* evaluation due to lower, although still considerable, environmental impact improvements they offer.
- MOST SOLUTIONS ARE ATTRACTIVE TO ADOPTERS.** De-SOx and De-NOx systems are mandated through regulation in heavy industries and therefore were assigned the evaluation of *advantaged*. Management techniques, such as Standard Operating Procedures (SOPs), Training and Feedback are standard practice, although not yet applied universally in China, and were also evaluated as *advantaged*. Energy efficiency solutions, such as CHP, Energy Efficient Motors and Balance of Plant are technologically mature and economically feasible on life cycle basis, despite higher upfront costs compared to conventional alternatives, and are considered *attractive*.
- CCS AND CHP SYSTEMS ARE ESTIMATED TO HAVE THE LARGEST ADDRESSABLE MARKET SIZE.** This is driven by the large amount of new industrial construction that is projected to take place in China as well as the potential to retrofit existing facilities. These two solutions are followed by, most notably, De-SOx, De-NOx and PM Removal systems, which have *medium* addressable market size. This is determined by the many industrial sites that are required to install these solutions and their current, relatively low market penetration. A number of solutions were evaluated to have limited to limited-medium addressable market size.
- MARKETS FOR NEARLY ALL SOLUTIONS ARE CONSIDERED TO BE MOSTLY OPEN TO PRIVATE AND FOREIGN PLAYERS.** The four markets perceived to have *limited* accessibility, due to greater government control, are Process Redesign, Fossil Fuel Switching, Industrial Wastewater and CCS. It is noteworthy that due to early maturity of CCS, there are few official policies on whether international cooperation will be encouraged or restricted. However, given the importance and safety concerns associated with CCS, the technology will likely remain under close government supervision in China.

Fig.11: CLEANER INDUSTRY SECTOR SOLUTION EVALUATION MATRIX (1-5 Years)



**EFFICIENT ENERGY SOLUTIONS**

- **Balance of Plant** -Optimization of a plant's equipment aimed at maximizing energy and water efficiency and minimizing pollution and waste
- **Combined Heat and Power (CHP)** -System that simultaneously generates electricity and usable heat by capturing heat that would normally be lost
- **Energy Efficient Motors** -Electric motors that are more energy efficient than conventional models currently used in China

**AIR AND WATER POLLUTION MITIGATION SOLUTIONS**

- **Carbon Capture and Sequestration (CCS)** -System that captures carbon dioxide from fossil fuel, either prior to or after combustion, and sequesters it for long term storage underground
- **Flue Gas Denitration (De-NOx)** -System that removes nitrogen oxides from flue gas
- **Flue Gas Desulfurization (De-SOx)** -System that removes sulfur oxides from flue gas
- **Fuel Switching** -Ability to make use of alternative fuels either by using multiple fuels simultaneously or by switching between fuels
- **Industrial Wastewater System** -Systems used at industrial sites to treat water after use prior to either reuse or release into the natural environment
- **Particulate Matter (PM) Removal System** -A System that removes particulate matter – harmful fine particles – from flue gas

**SOLID WASTE MANAGEMENT SOLUTIONS**

- **Incineration Energy Recovery** -Waste to energy solution that generates power from the combustion of solid waste
- **Waste Separation and Off-take** -Sorting of solid waste at the industrial facility to assist its exchange, recycling, incineration or disposal

**CROSS-AREA SOLUTIONS**

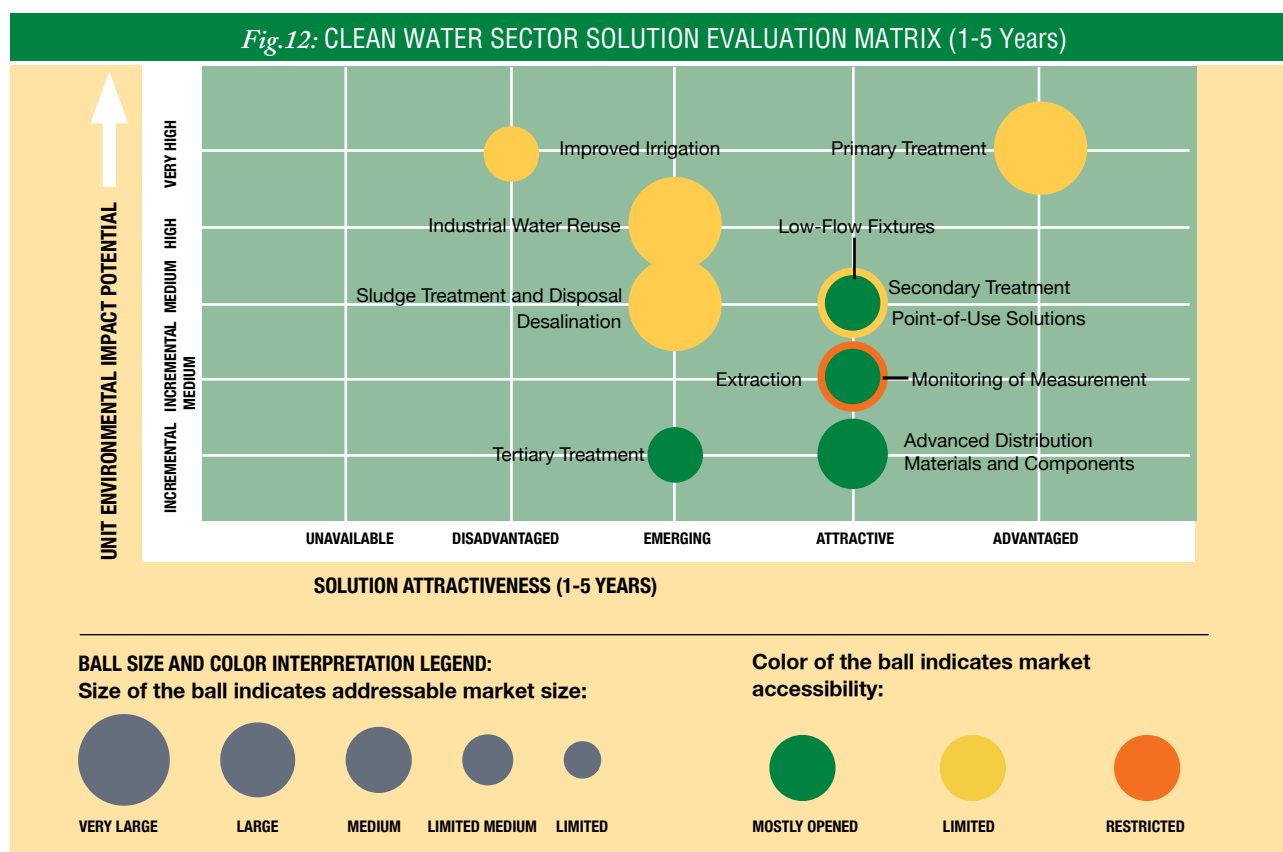
- **Commissioning** -Process of assuring that all systems at the industrial object are installed, tested, operated and maintained as originally intended
- **Environmental Management System (EMS) and IT Systems** -Comprehensive, systematic, documented management of an organization's environmental programs that rely on IT solutions for effective operation
- **Process-Redesign** -Redesign of the operation with the purpose of increasing resource use efficiency and minimizing pollution
- **Standard Operating Procedures (SOPs), Training, Feedback** - Collection of management tools designed to improve the efficiency of employees as well as the effectiveness of the management at an industrial site.

## Clean Water Solutions

**THE CHINA GREENTECH INITIATIVE PRIORITIZED 12 SOLUTIONS FOR DETAILED EVALUATION FROM AN ORIGINAL LIST OF 75.** Prioritized solutions fall into four broad categories: Water Supply, Water Pollution Treatment, Water-Use Efficiency and Multi-Use solutions.

### KEY FINDINGS FROM THE CLEAN WATER SOLUTIONS EVALUATION ANALYSIS INCLUDE:

- **SOLUTIONS COVER A WIDE RANGE OF UNIT ENVIRONMENTAL IMPACT POTENTIAL.** Primary Treatment and Improved Irrigation solutions have the highest environmental impact. This is due to their role in removing the highest percentage of pollution from the water in the treatment process, to their ability to significantly conserve water in irrigation, which presents an area of great improvement potential in China. In comparison, Tertiary Treatment Technologies and Advanced Distribution Materials and Components solutions have comparatively lower environmental impact due to their relatively incremental, but nevertheless still important, role in mitigating negative impact on the environment.
- **HALF OF THE ANALYZED SOLUTIONS ARE ATTRACTIVE TO ADOPTERS.** Extraction Solutions, Secondary Treatment, Low-Flow Fixtures, Point-of-Use Solutions, Monitoring and Measurement, Advanced Distribution Materials and Components and Industrial Water Reuse are all considered *attractive*. All of these solutions either conserve sufficient amount of water over the life cycle to justify the upfront investment, or deliver benefits at reasonable costs for adopters to actively seek them out. Primary Treatment is considered to be *advantaged* due to its standard use in the industry in China.
- **ONE THIRD OF THE SOLUTIONS HAVE LARGE ADDRESSABLE MARKET SIZE.** Desalination, Primary Treatment, Sludge Treatment and Disposal and Industrial Water Reuse solutions are estimated to have *large* addressable markets. The addressable market size is driven by the need for reliable sources of water in the case of Desalination, and by China's current strategy to deploy water treatment facilities throughout the country in the case of the other three solutions. On the other hand, Tertiary Treatment Technologies are estimated to have a *limited* addressable market size due to the fact that few facilities require such treatment.
- **COMPONENT SOLUTIONS FACE MOSTLY OPEN AND SYSTEMS SOLUTIONS FACE LIMITED ACCESSIBILITY MARKETS.** Component solutions, such as Low-Flow Fixtures, Monitoring and Measurement Solutions, and Advanced Distribution Materials and Components, face markets that are considered *mostly open* to private and foreign players. Most of the other solutions are systems solutions, such as Desalination, Primary Treatment, and Sludge Treatment and Disposal, for which markets are considered to have *limited* accessibility due to significant government control and strong presence of SOEs in the sector. The Extraction Solutions market is considered to be *restricted*, as the government closely regulates it, in part due to the risk of mismanaging underground water reservoirs.



**SUPPLY SOLUTIONS**

- **Extraction Solutions** - Solutions that help locate, access and extract water from underground sources
- **Desalination** - Process that removes salt and other minerals from saline water, such as sea water, in order to make it suitable for human consumption or irrigation

**POLLUTION TREATMENT SOLUTIONS**

- **Secondary Treatment Solutions** - Solutions that substantially remove the biological content of sewage, including derivatives of human waste, food waste, soaps and detergent
- **Sludge Treatment and Disposal** - Solutions including dewatering, landfill storage and fertilizer conversion that treat sludge generated from wastewater treatment to remove usable substances and properly dispose of residual wastes
- **Tertiary Treatment Solutions** - Solutions that provide a final treatment to raise the effluent quality of the water before it is discharged into the receiving environment

**WATER-USE EFFICIENCY SOLUTIONS**

- **Improved Irrigation** - Irrigation solutions such as sprinkler or drip irrigation that use water more efficiently than China’s conventional irrigation methods with equal or greater benefit to the user
- **Low-Flow Fixtures** - Faucets and other water use systems that use less water than conventional systems but deliver the same or greater benefit to the user

**MULTI-USE SOLUTIONS**

- **Advanced Distribution Materials and Components** - Pipes, valves and nozzles that are used to transport water, primarily between treatment plants and usage points that are higher quality and/or are more sophisticated and represent lower risk of leakage than conventional models
- **Industrial Water Reuse** - Process whereby certain pollutants are removed from industrial wastewater so that the water can be recycled for further uses at the same site
- **Monitoring and Measurement Solutions** - Solutions that track the composition or volumes of water flows in natural water sources, water distribution systems, water treatment plants or user premises, which are often integrated with IT and or GPS technologies
- **Point-of-Use Solutions** - Water monitoring or treatment solutions that are installed at the point where water is actually used, such as apartments, commercial and industrial facilities
- **Primary Treatment Solutions** - Solutions used primarily at the sedimentation stage, where the solids are separated from the wastewater stream