SUSTAINABILITY INSIGHTS:

AIR POLLUTION IN CHINA

COLLECTIVE RESPONSIBILITY

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Collective Responsibility
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1 CHINA'S AIR CRISIS

While the world debates the impact of carbon emissions and the need to create binding international agreements, China's battle with air pollution has grown tangible enough to effectively catalyze stakeholders into action.

With only six of China's cities meeting the second tier of the National Environmental Air Quality Standards (NEAQS) in 2015, air pollution has become one of the biggest challenges to sustainable economic growth. The 2015 average annual $PM_{2.5}$ – fine particles smaller than 2.5 micrometers – for Beijing averaged 80.4µg/m3, a figure 8 times what the World Health Organization (WHO) considers acceptable for human health. Additionally there is a significant financial implication to this phenomenon as premature deaths and health problems from air pollution cost China as much as USD 300 billion a year (Greenpeace, 2015).

Why this is an issue of concern over the next 15 years is that as Chinese incomes rise, people will demand new cars, more electricity, and better industrial products. All of these factors rely on increasing energy supply and will in turn cause more emissions if the business-as-usual development model is applied.

This has wide-ranging impacts on the environment, economy, and health of individuals, the latter of which is an area of great concern to the Chinese population and is driving change. The issue of air pollution is not isolated in cities alone; its impact is seen across the country and awareness and action throughout is on the rise. China now has the financial capabilities to tackle this issue head on.

Improvements in China's air quality will not only come through national government action, but also require the engagement and enforcement of regulations at both provincial and local levels of government. Recent pledges coming from the national level to reduce pollution, through the 13th Five-Year Plan and measureable improvements in local Air Quality Index (AQI) levels in 2015, show progressive steps towards visible improvements. However, these improvements are only the first steps in what will be a decade-long transformation before China's air quality will be considered "clean".

Many of these steps are going to open up vast numbers of opportunities for firms to bring their solutions to China, and actors must be well-placed to capitalize and fill gaps in services required by the society and market.

This report analyzes the composition and sources of air pollution in China, explains important trends in relevant industries, introduces recent regulatory measures, and provides predictions about policies and technologies that could help curb air pollution in the next decade.

2 SOURCES OF POLLUTION

King Coal: In 2013, coal accounted for 66% of China's overall energy consumption – 42% higher than the world average – making it the most coal-dependent country among the world's top energy consumers (EIA, 2015). Despite its large share in the energy mix, coal consumption growth in China has reduced in recent years. In 2014, the annual growth rate of coal consumption dropped to 0.06% (CNBS, 2016), a significant slowdown compared to the average 9% growth over the past decade.

Although these statistics represent progress, and the closure of factories and stalling of new capacity developments are gathering momentum, we still fully expect coal to remain a vital part of energy production for the foreseeable future. One result of this trend will be that high concentrations of pollutants within China's local atmosphere will persist .

Manufacturing: The manufacturing industry, so important to China's economic rise, has major direct and indirect impacts on the level of atmospheric pollution. Indirect emissions come through high levels of energy and electricity use required for processes such as aluminum smelting, many of which are satisfied through coal burning. Direct emissions from these industrial processes contribute significantly to the reduction in ambient air quality. The economic transition and the easing of manufacturing processes will reduce this contribution, but it is regardless an area that requires efficiency development and attention to address pollution in China's cities.

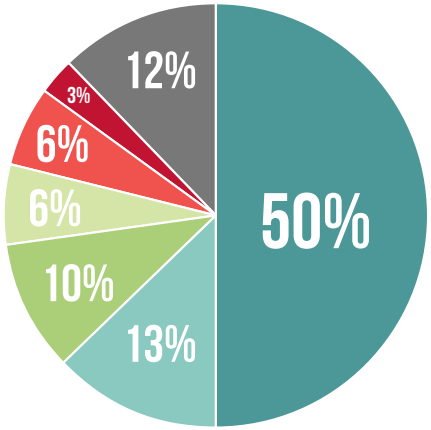
Urban Infrastructure: As China's populace has become more urbanized, overall energy demand has increased dramatically. As cities develop and the expected 300 million more people enter the cities, individual energy consumption will increase further. This will place greater pressure on energy systems to accommodate this growing population.

These high levels of air pollution come from a variety of sources including the direct emissions from truck traffic, dust particles from construction, and indirect emissions of factory and energy processes. Without significant developments in building practices, the externalities will continue to grow and negatively impact urban populations.

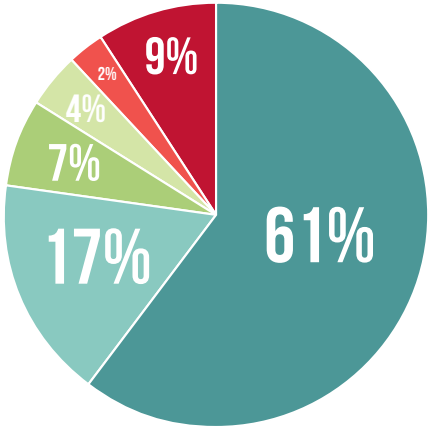
Transportation: China has become the world's largest new automobile market. This growing level of ownership has caused congestion in many of China's first- and second-tier cites and increased levels of localized pollution. To combat this, some cities are increasing the cost of license plates and have implemented policies that ban odd- and even-numbered plates by day in an attempt to reduce emissions.

Additionally, because trucks are also major emissions contributors, some cities now restrict trucks within predetermined city boundries by day. Ships and ports are another large contributor, particularly of SO_2, as they commonly use lower-cost, dirty "bunker" fuel. While legislation put in place tries to counter these sources within coastal regions, considerable work still needs to be done in this area.

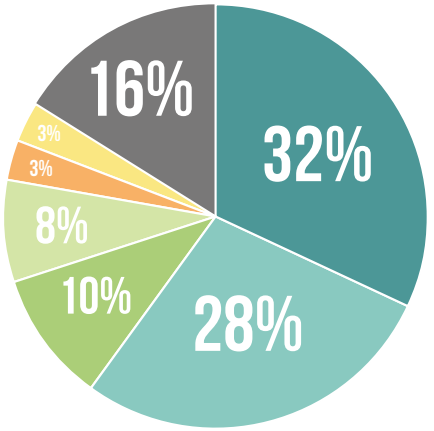
INDUSTRIAL SOURCES OF SO_2 EMISSION



INDUSTRIAL SOURCES OF NO_X EMISSION



INDUSTRIAL SOURCES OF SMOKE EMISSION



ELECTRIC & HEAT PRODUCTION
CEMENT PRODUCTION
STEEL SMELTING & PRESSING
RAW CHEMICALS MATERIALS & CHEMICAL PRODUCTS
PAPER & PAPER PRODUCTS
PROCESSING OF FOOD PRODUCTS
SMELTING & PRESSING OF NON-FERROUS METALS
REFINED OIL, COKING, NUCLEAR FUEL PROCESSING
OTHER

Source:Deutche Bank, 2013

China's air pollution is mainly composed of particulate matter, sulfur dioxide, nitrogen dioxide, ozone, and carbon monoxide. Each of these has a wide range of sources which only complicate efforts to find solutions. It is therefore vital to mitigation that the intricacies of each system are understood and that macro policies and innovations are taken to best reduce overall risk from all harmful pollutants.

Particulate matters (PM) are tiny particles of solid matter suspended in gas or liquid and can be composed of soot, acids, chemicals, metals, soil, and dust. Larger particles of pollution can be filtered out by mucous and cilia in the nose and throat, but smaller ones like $PM_{2.5}$ and PM_{10} can enter into areas between the lungs and the bloodstream where gas is exchanged, and thus affect other organs. When inhaled, PM can cause various breathing ailments, cancers, cardiovascular issues, birth defects, and premature death.

Sulphur dioxide (SO_2) is a major pollutant that can enter into the human respiratory system and cause diseases such as bronchitis. Its main sources are coal and gasoline. SO_2 can lower infant birth weight and increase the rate of birth mortality. Environmentally, when mixed with water, it forms acid rain, which is a major cause of deforestation and loss of biodiversity.

Nitrogen dioxide (NO_2) is often produced by power plants, heating furnaces, and ships and vehicles. It passes through the respiratory bronchi and alveoli and may disrupt the respiratory function and cause pulmonary emphysema.

Ozone (O_3) is beneficial when high up in the atmosphere but can be extremely harmful when close to Earth's surface. It is a main component of smog and can cause various respiratory diseases like asthma.

Carbon monoxide (CO) can be highly toxic in high concentrations. It is often produced by the combustion of fuels like coal, natural gas, oil and propane. CO can result in headaches, nausea, vomiting, dizziness, and fatigue.

There is no one-fix solution to the impacts of myriad chemical byproducts of energy production, industrial processes, and consumption. Prevention measures should be both reactionary, to prevent current harm through the use of masks and air filters, but also proactive in addressing the sources of emissions and investing in cleaner technologies throughout the emissions chain. Combining these approaches will reduce atmospheric pollutant levels and best mitigate negative impacts on health and the environment.

3 TANGIBLE EXTERNALITIES

The growing tangibility of the issues faced in China are catalyzing change. While other, less noticeable issues are lower on the public and political agenda, air pollution is a issue that neither China's government nor its citizens can ignore. This section outlines the major areas of air pollution's negative impact on China's urban environment and society.

Economic: While it is accepted that there is a trade-off between economic development and the environmental, social and economic burden, China has reached a point where the air crisis is significantly impacting on its economic development. Economic implications of air pollution are estimated to reduce gross national income by 2% - 10%, and in 2010, the Ministry of Environmental Protection estimated that 1.5 trillion RMB, or around 3.5% of China's GDP, was lost due to the phenomenon.

This is clearly a major concern for stakeholders going forward as they look to continue the exponential growth of the past two decades. They strive to reduce externalities and develop preventative measures on both the production and consumption sides to aid this. As China naturally begins to transition away from the heavy industries towards a more consumption-based economy, air pollution will continue to be a prominent issue going forward. Therefore, its economic impact should be carefully monitored and reduced in as many ways as possible.

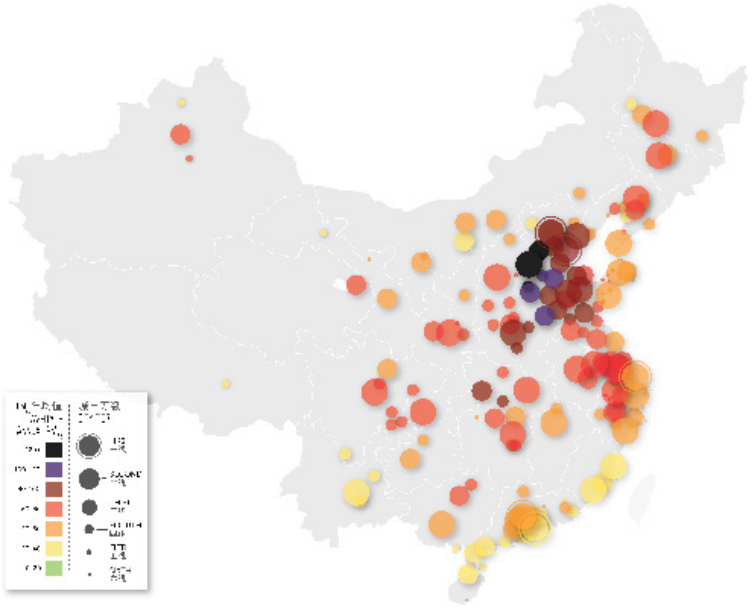
Environmental: Environmental impacts of energy emissions exist on both a macro and micro level. The impact of CO_2 on the global environment is well-documented, and heavy international pressure has been placed on China due to its large contribution to global concentrations.

Coal mining and power plant construction, particularly when poorly managed, have direct environmental impacts on the surrounding area. Leaching of chemicals can pollute local water sources, and the use of water itself within the processes can disrupt the local environmental equilibrium. The chemicals present within emissions can react with molecules in the atmosphere to create harmful secondary organic aerosols. These can then be precipitated as acid rain, which contributes to the weathering of buildings and disrupts soil pH, plant growth, and agricultural practice.

Health: The impact of air pollution on human health is also well-documented, and the effects are directly or indirectly a product of particle inhalation. Throughout its development, coal use has contributed heavily to the high levels of $PM_{2.5}$ and SO_2 in China. Short-term exposure can lead to respiratory emergencies, particularly for sensitive groups, while long-term exposure leads to more chronic issues, such as reduction in cardiovascular function.

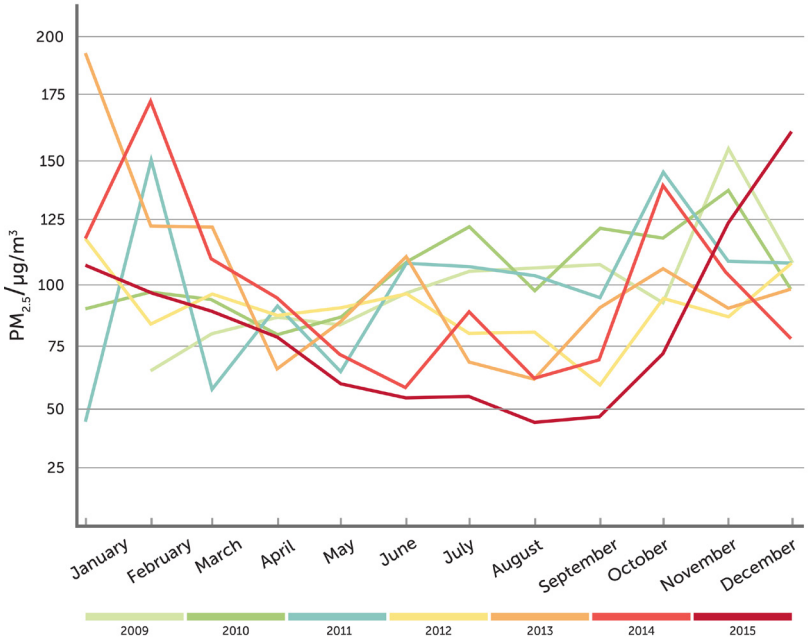
Congestion has increased with city development and increased car ownership. Car emissions produce significant levels of NO_2, a harmful gas that can cause lung inflammation in higher concentrations, which is the case for much of China's urban population. These gases all contribute towards the high rates of premature death that are increasing throughout China.

ANNUAL $PM_{2.5}$ LEVELS FOR CHINA'S MAJOR CITIES, 2015

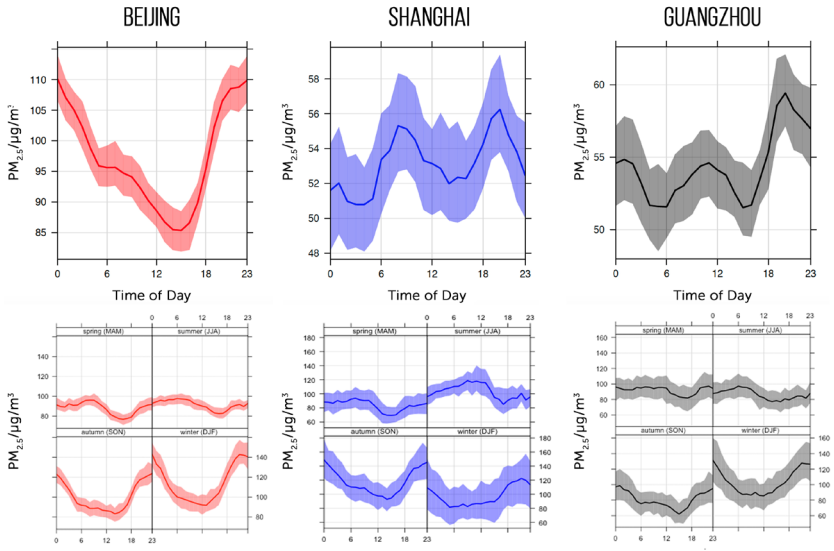


Source: Greenpeace, 2016

AVERAGE MONTHLY $PM_{2.5}$ CONCENTRATIONS IN BEIJING (2009-2015)

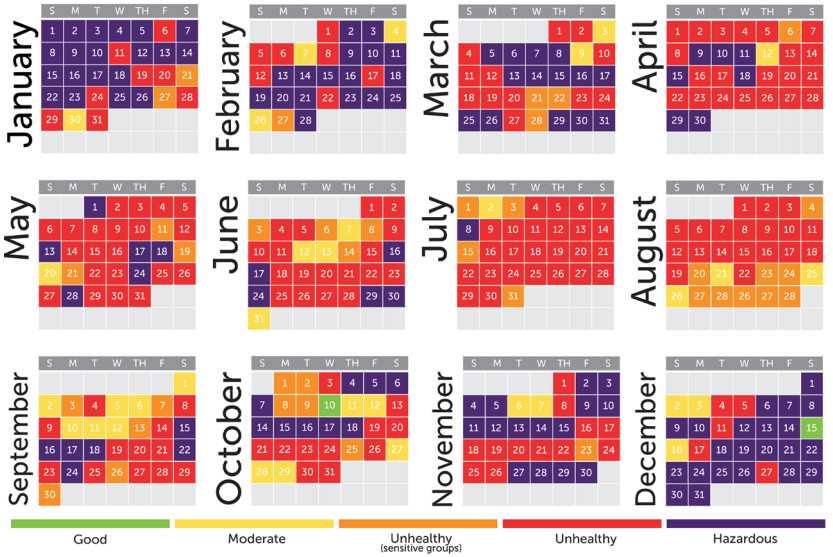


DAILY AND SEASONAL $PM_{2.5}$ CYCLES IN SELECTED CITIES



Source: United States Embassy & Consulate Data, All Available Years.

CALENDAR PLOT OF DAILY $PM_{2.5}$ CONCENTRATIONS IN BEIJING, 2015



Source: United States Embassy & Consulate Data. N.B. Source for both of the above graphs.

4 STAKEHOLDER ANALYSIS

While expatriates and foreign journalists have embraced the issue of air pollution for years, for the local Chinese population, this is a conversation that has only been thrown into the public eye in recent years. The topic that has grown in tangibility and urgency, particularly starting with the proliferation of APPs that provide detailed air quality information and catalyze localized discussion and action toward change.

The government is also becoming more proactive, taking measures to close factories, shut down construction sites, and issue "code red" alerts when safety thresholds have been breached, all actions aligned to the wider conversations of transforming the economy.

Government: Within the government, there are a host of important stakeholders on both sides of the issue. State-owned energy and manufacturing firms are often seen as the core protagonists, while bodies like the State Council, National Development and Reformation Commission, and Ministry of Environmental Protection are seen as the groups with the most influence to change and enforce energy policy and environmental standards.

Energy Producers: State energy producers are a key player in the management of countrywide air pollution. With heat and electricity production contributing to the majority of air pollution, the actions taken by these stakeholders can be key to the mitigation of future pollution. As a result, the government and energy producers' decisions to diversify to alternative sources, such as natural gas or non-carbon alternatives, will majorly impact the future of pollution in China.

Energy-Intense Industries: Be it the construction industry, an automotive facility, or fims with high energy demand, many cities have begun active campaigns to discourage such energy-intense firms from investing or maintaining operations in their regions. For those whose investments were made years ago feel significant pressure to invest into emission abatements, pay fines, or move as mayors look for easy targets for energy and emission reductions.

Citizens: From the middle-class office worker wearing a mask to work, to the family raising a young child, to the elderly citizen, the role of the civilian as the core stakeholder has grown to the point at which it cannot be ignored. Through the urbanization of another 300 million citizens by 2030, the signficance of the civilian stakeholder as a driver for change will only increase.

NGOs & Media: While once perceived as antagonists to each other, NGOs and the media have collaborated effectively to bring forward awareness and discussion. This is true of both domestic and international NGOs and media bodies, and both stakeholders have released research and engaged in "name and shame" campaigns against heavy polluting firms, while finding ways to work with the government to demand stronger actions.

5 AREAS OF ACTION

While investment in cleaner energy provide for a measure of improvement, the big gains will come from energy efficiency. Efficiency in buildings will improve through better regulation and pricing of energy, and more widely, through China's economic transition from energy-intensive, high-emission industries to service-based industries. The transformation will begin along China's coast, where cities have greater economic stability, and will continue across China's interior as provincial capitals develop and populations grow more affluent.

In general, this transition should be accompanied by a shift away from carbonized energy and lead to a reduction in the harmful outputs of energy production. One way to do this is through the investment in alternative energies, but innovation and structural changes can also be developed to aid this transition.

Through this process, the areas of action and change that will lead to the highest order of returns fit into three categories: **movement away from coal, urban infrastructure, and transport.**

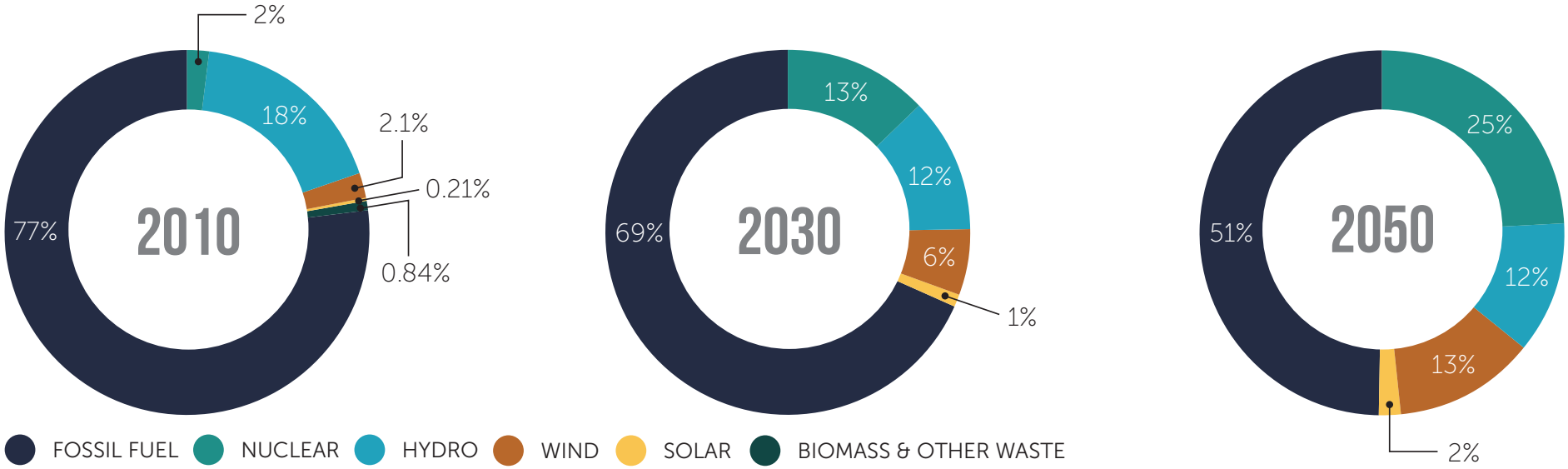
Directed Policy for Coal Reduction

Thermal power is one of the main contributors to all emission types, prompting a number of policy developments in September 2013, China's State Council released the Airborne Pollution Prevention and Control Action Plan, mandating reductions in coal consumption to prevent further air pollution. For the first time, it introduces province-specific coal consumption caps, with 12 of China's 34 provinces pledging to implement coal control measures. Collectively, these measures are estimated to reduce annual coal consumption by approximately 350 million tons by 2017 and 655 million tons by 2020.

Another major policy that targeted efficiency in the coal sector was the Small Plant Closure Program. Established in the 11th Five-Year Plan (2006-2010), the program required each province in the country to identify small power plants, iron and steel smelters, cement kilns, and other energy-intensive factories to be replaced with larger plants. A state-of-the-art, coal-fired power plant capable of reaching higher temperatures and pressures can increase efficiency by up to 50%. The 12th Five-Year Plan had strict policies to drive energy intensity down, and the 13th Plan built upon these policies, for the first time including quantified guidance for energy consumption – stating that it should not surpass 5 billion tonnes of standard coal equivalent (SCE).

The power of the Chinese government to administer policies supporting a cleaner future is greater in China than in any other nation. It is vital that companies pay close attention to these drivers and innovate and develop accordingly.

RENEWABLE CONTRIBUTION TO ELECTRICITY GENERATION



Source: Adapted from Lawrence Berkeley National Laboratory, 2011

Cleaner Coal: While the closing of factories and halting of new coal capacity developments have picked up speed at the start of 2016, coal will still remain an important part of China's energy mix as it provides services and infrastructure to a growing urban and expectant population. In order to best mitigate the negative externalities plaguing the country in recent years, investments into cleaner coal practices should be levied.

While sequestration is one route towards pollution reductions, it is the less infrastructurally-challenging investments that can provide the best short-term impact. This includes the installation of scrubbers onto coal towers and development of efficient coal cleaning to remove inpurites. A key area of expansion has been the installation of super critical coal plants, which increase energy production efficiency and thereby reduce externalities. These developments will provide vital emissions reductions while advancing the overall energy transition.

Alternative Energies: The Chinese government has been rapidly developing its nuclear, renewable, and hydro-power resources. By 2020, China aims to install 200 gigawatts (GW) of wind, 100 GW of solar, 30 GW of biomass, and 360 GW of hydro (The Climate Group, 2015; CEC, 2015). Meanwhile, nuclear capacity is expected to increase to 58 GW (World Nuclear Association, 2015).

Additionally, China is investing in increasing its natural gas supply. Government statistics have shown that China's natural gas consumption grew by 9.9% in 2014, or from 220 million to 242 million tonnes of SCE, representing a movement away from coal and a reduction in carbon intensity (CNBS, 2016). This is expected to continue over the next 10 years as extraction of China's domestic proven reserves becomes more difficult.

Smart investing into all of the above areas will be key to the sucessful transition away from coal and the cleaning of the country's skies. However, along with investment in technology, China must continue to focus its effort on grid infrastructure, a previously underdeveloped area that has left idle much of the country's wind and solar capacity. This is vital to the sucessful implementation of the capacity targets for renewable solutions.

Energy Efficiency: At present, China's national efficiencies are inferior to those of the world's leading nations. For coal power plant efficiency, China lags behind by ~8%. The contrast is even more stark for the other fossil fuels, where the world's leading countries are 14% more efficient in gas production and 12% more efficient in oil production than China (Ecofys, 2014).

Efforts should be made to encourage providers to increase these efficiency levels via effective policy aimed at production techniques. Additionally, consumption-side increases in energy pricing should be leveraged as a mechanism to drive conservation and investment into energy-efficient equipment and operating practices.

Carbon Trading: A new wave of carbon trading is set to help reduce China's future carbon intensity. Ambitious targets have been set to roll out a nation-wide trading scheme by 2017. The scheme, already being piloted in 7 provinces, is just one among a number of policies that will develop the renewable and clean energy sector. The plan also sets a strong platform for investment within these areas, providing more opportunities within the energy sector for actors to develop progressive and innovative low-carbon solutions.

Curb Inefficient Infrastructure Development

Buildings will be one of the key areas for investments in efficiency, be they residential, commercial, or retail. Up until now, China's "growth at all cost" attitude has resulted in highly inefficient design and operation. As a result, developments will be integral to the reduction of China's energy footprint.

Investment into efficiency, promoted through national, provincial, and local incentives that drive energy efficient processes and building improvements, will aid development in this area. Similar to what western cities such as San Francisco, London, and Vancouver have created through their alignment to LEED certifications, requiring all newly-constructed buildings to align with better urban efficiency standards will lead to dramatic improvements.

Transportation

Given its large population, if China was to reach the per capita levels of car ownership of many of its economic counterparts, it would place stress on the country's transportation infrastructure, resulting in widespread system failures and higher levels of localized air pollution.

In light of these issues, the government should address the following areas to develop a more secure future:

- Increase investment in all means of public transportation to help urban centers efficiently and affordably move people.

- Increase fuel efficiency and emission standards for cars, trucks, and ships to reign in the growing amount of transport-related emissions.

- Work with state-owned energy firms to upgrade fuel processing and quality standards, remove heavy pollutants like sulfur and lead, and make investments in charging stations to support the growing demand for electronic cars.

- Develop tighter regulations on port emissions, particularly to reduce sulfur, where container ships are top contributors. In early 2016, the Ships Emission Control Area Implementation Plan was enacted, placing fuel-type controls in costal areas around Shanghai, Beijing, and Guangzhou. This shows positive action from the government, but when compared to European and US standards, there are still significant improvements to be made.

6 CONCLUSIONS

With China's urban population expected to increase by another 250 million people over the next 10 years, the energy demand of its cities will continue to grow. While some have already described 2016 as the year of China's energy peak, others believe that China may need to significantly increase its current supply to meet 2025 demand.

As production from primary energy sources will increase to meet the growing demand of urban lifestyles, car ownership is expected to grow rapidly over the next 10 years as well. Without significant changes in emission control, fuel quality, or policies, considerable rises in emissions could result.

In addition to the emotional and tangible implications of pollution, another catalyst for change is the government's own research showing that the environmental harms of pollution have a real economic cost. These costs are simply unsustainable and are inspiring a mindset shift around the need to address the externalities.

To prevent this, China needs to rethink how its cities are designed, built, and operated as it moves away from its current economic development model to one that is not reliant on the building of infrastructure or manufacturing. It must focus its attention on the second- and third-tier cities that have not yet reached the degree of economic transformation of the eastern first-tier cities. A cleaner China will only come through the development of supply- and demand-side efficiencies, with focus on new technologies and stringent policies.

The release of 13th Five-Year Plan sets a strong precident going forward, where regulations to limit the environmental and health impacts of pollution are the most progressive to date. But the impacts of these policies remain to be seen over the coming five years.

Regulations aside, in a best-case scenario, China's emissions will peak between 2025 and 2030, but in a worst-case scenario, the peak will not come until closer to 2050 when China's urban population itself peaks.

Reaching peak emissions and reducing their health implications will not only benefit markets that service the macro economy through cleaner energy production and emission-reducing equipment, but will also encourage localized demand for air-monitoring equipment, improved building materials, and products that reduce individuals' exposure to pollutants. These infrastructural and economic processes will begin in the more affluent first- and second-tier cities, but over time, will need to filter through the remaining cities if country-wide improvement is to be achieved.

Along with the solutions, regulations, and enforcement of laws outlined, solution-providers will continue to find great opportunity in one of China's fastest-growing areas: the movement away from coal and the diversification of the clean energy market.

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