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# Targeting the Future: Smarter, Cleaner Infrastructure Development Choices

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<http://dx.doi.org/10.5772/50972>

## 1. Introduction

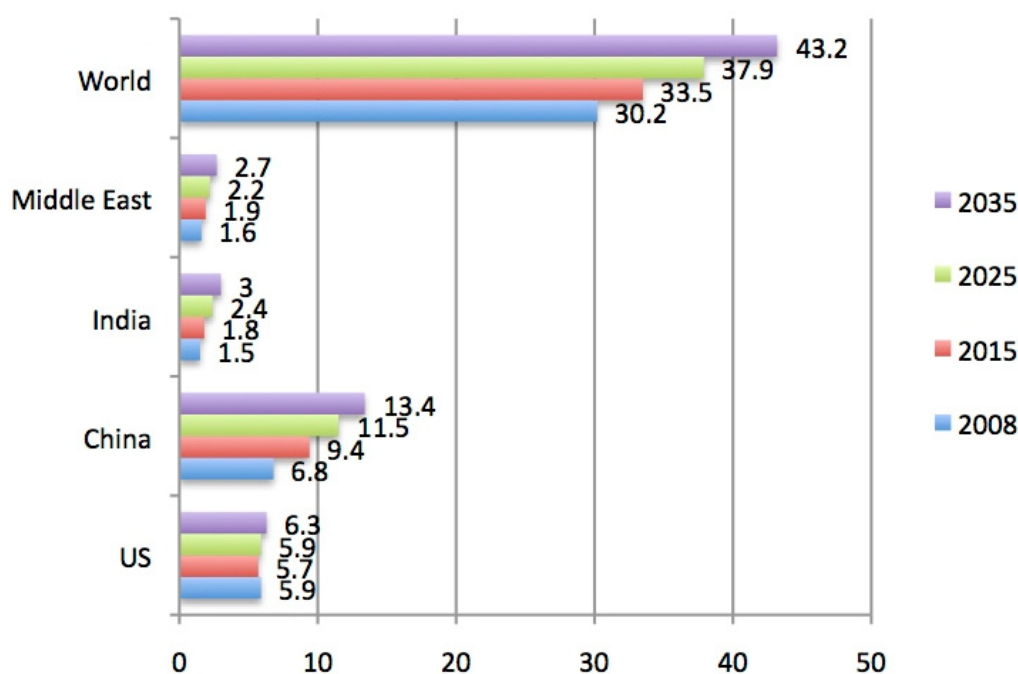
Asia's giants China and India are pivotal changelings for the world's ecosystem and economic system. These two countries, with high economic growth trajectories, offer the planet a significant opportunity to reduce carbon emissions provided they invest in climate-smart infrastructure. Choosing greener and more efficient energy infrastructure offers the chance for generations to reduce carbon emissions, a key contributor to climate change. Additionally, attention to more efficient use of water resources and infrastructure will be needed in tandem. Understanding the energy-water-climate nexus is critical to achieving sustainable development. The challenges of climate change and minimizing its negatives impacts will require bold choices by governments, private sector actors, consumers, and significant capital investments.

Climate change is a *force majeure* that afflicts developed and developing countries alike but some countries get hit harder than others. An Economics of Climate Adaptation Working group indicates that some regions could lose 1- 12% of GDP because of existing climate patterns [1]. In September 2006, the Chinese government calculated its economic growth within an environmental context. Economic losses to the economy from environmental impacts amounted to 3.05% of GDP; water pollution cost the economy \$37 billion, seconded by air pollution of \$28 billion.<sup>1</sup> In a May 2010 Economist survey report, water pollution and scarcity were cited as costing the Chinese economy 2.3% of GDP. In a 2009 economic survey, India's government reported that it was already spending over 2.6% to adapt to climate change in regard to agriculture, water resources, health and sanitation, forests, coastal-zone infrastructure and extreme weather events [2].

<sup>1</sup> Climactico, "China & Green GDP," Feb 3, 2010; chinadialogue, "China Issues First Green GDP Report," Sep 7, 2006.

These economic and cost equations interact and change with ever-evolving variables —how water is used in conjunction with energy; growth rates changes unforeseen; and even the climate change-related effects and real costs of pollution and health expenditures that conventional country economic-growth forecasts lack calculations for.

As more countries move along the development spectrum, the growth of energy demand is a key culprit for increasing CO<sub>2</sub> emissions. Global energy demand is expected to be 53% higher up to year 2035 according to the Energy Information Administration's 2011 International Energy Outlook [3]. China and India alone would account for over half of the demand. In these projections, carbon emissions rise 43% by 2035, from a 2008 baseline. The International Energy Agency projects China consuming 70% more energy than the U.S. in 2035.<sup>2</sup> By 2015, China accounts for 28% of total global emissions as Figure 1 shows. This trend of China's continues, even slightly upward to 2035. India replaces Russia as the third largest emitter by 2015, and even surpasses the entire Middle East in carbon emissions by 2025.



U.S. Energy Information Agency, 2012

**Figure 1.** CO<sub>2</sub> Emissions, gigatons

To finance the large-scale "greener" infrastructure needed for China and India's expected growth and emissions trajectories, new infrastructure funding approaches will be needed to bridge the gap between climate-friendly intentions and actions that benefit both economy and environment. China's pledges toward a lower-carbon economy could bring about 25% of the reductions needed to steer the globe toward the desired 2° C temperature increase limit, also known as the 450 Scenario.<sup>3</sup> India claims a low-carbon agenda as well. The challenges ahead are complex and expensive.

<sup>2</sup> International Energy Agency (IEA), "World Energy Outlook 2011 Factsheet."

<sup>3</sup> The 450 Scenario refers to greenhouse-gas concentrations being stabilized at 450 ppm (parts per million) to limit the most severe weather, sea-level rise, and temperature increases. From IEA's World Energy Outlook, 2009.

First some of the key challenges and drivers related to climate change and infrastructure will be explored. Growing energy demand parallels rising emissions and is therefore a major focal point for intervention. Water resource and infrastructure issues are an area of vulnerability for growing economies, especially in an increasingly climate-stressed world. Following that, Section II offers an overview of the infrastructure development environment and why past approaches are lacking. A new "market-finance" approach can help initiate and sustain the low-carbon and efficient infrastructure projects that will be needed. A discussion about the environment for implementation follows in Section III. Conclusions are drawn in the last section.

## 2. Challenges of climate change

Choices made now serve as an insurance policy against climate change effects both seen and unforeseen. A fundamental conclusion about climate change was declared by scientists world-wide in a May 2010 *Science* article: "The planet is warming due to increased concentrations of heat-trapping gases [such as carbon emissions] in our atmosphere." [4] This warming is occurring due to human activities, especially the burning of fossil fuels. With increased warming, the hydrologic cycle will be altered; oceans are acidifying; sea levels are rising. A ton of CO<sub>2</sub> emitted today is worse than a ton emitted a decade ago with the earth's lessened capacity to absorb the emissions, according to reporting by Union of Concerned Scientists.<sup>4</sup> Thus energy infrastructure choices today can impact global warming, and simultaneously, water challenges need to be addressed.

The costs of climate change are high in a resource and infrastructure context. Delaying action and investment on climate change becomes more expensive in the future. A climate change opportunity exists to develop and fund the new "green" energy and water infrastructure needed to meet developing countries continuing economic growth and development. Overall estimates vary greatly about the costs of climate change globally: the United Nations Framework Convention on Climate Change (UNFCCC) says its \$49 - \$171 billion annually, while an Imperial College London report says it's two to three times those amounts.<sup>5</sup> They cite that extreme weather damage alone costs more than \$50 billion annually. In India's Maharashtra state, drought could cost their agricultural productivity up to \$570 million annually by 2030. Emerging markets with reliance on hydropower that are susceptible to drought put 50% of their energy budget at risk to the detriment of their economy [1].

### 2.1. Energy variables

The challenge of meeting energy demand in the future requires large-scale investments. The International Energy Agency estimates that \$38 trillion will be needed to meet future energy

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<sup>4</sup> Union of Concerned Scientists, Climate Science Update, Feb 2009. Also at [http://www.ucsusa.org/global\\_warming/science\\_and\\_impacts/science/global-warming-faq.html](http://www.ucsusa.org/global_warming/science_and_impacts/science/global-warming-faq.html)

<sup>5</sup> "Costing Catastrophe," The Economist.com. Dec. 8, 2009.

supply to 2035, two-thirds of which goes to developing countries.<sup>6</sup> To deploy clean energy and reduce emissions, a McKinsey 2011 resources report projects another \$315 billion on average will be needed to meet the 450 Scenario, or \$7.88 trillion to 2035 [1].

A large contributor to emissions growth world-wide, China's demand for electricity escalates to 2030. By 2015, the demand for electricity consumption of China exceeds that of the U.S., and forecasts even two years earlier had China not doing so until 2030 (see Table1). With China's continued heavy reliance on coal-burning power plants<sup>7</sup> into the future and ever-increasing demand for electricity, energy source choices and power demand combine for unfavorable emissions calculations. India's coal consumption also increases dramatically, doubling use by 2035 and displacing the U.S. as the second-largest coal consumer by 2035 [5].

	2007	2015	2030	2007-2030
<b>U.S.</b>	3826	3986	4679	0.9%
<b>China</b>	2717	4723	7513	4.5%
<b>India</b>	544	892	1966	5.7%
<b>Middle East</b>	575	790	1382	3.9%
<b>Asia</b>	4108	6777	11696	4.7%
<b>OECD</b>	9245	9792	11596	1.0%

Source: World Energy Outlook, 2009

**Table 1.** Electricity Demand (TWh)

Increased demand for electricity serves as a proxy for development. Developing rapidly, the new investment needed for China to 2030 to meet electricity demand is estimated at \$3.12 trillion. Of total world demand for power generation, China consumes 30% of the world's total energy budget over the period 2008-2030, also revised upward since earlier calculations. India's demand exceeds that of the Middle East region. The sole country of China takes in more investment than the entire developed country region of Europe and the U.S. as Table 2 illustrates.

	Capacity Additions (Gigawatts)	2008-2015	Capacity Additions (Gigawatts)	2016-2030
<b>U.S.</b>	148	\$554	420	\$1515
<b>Europe</b>	220	762	492	1672
<b>China</b>	530	1209	795	1912
<b>India</b>	117	332	338	1016

Source: World Energy Outlook, 2009

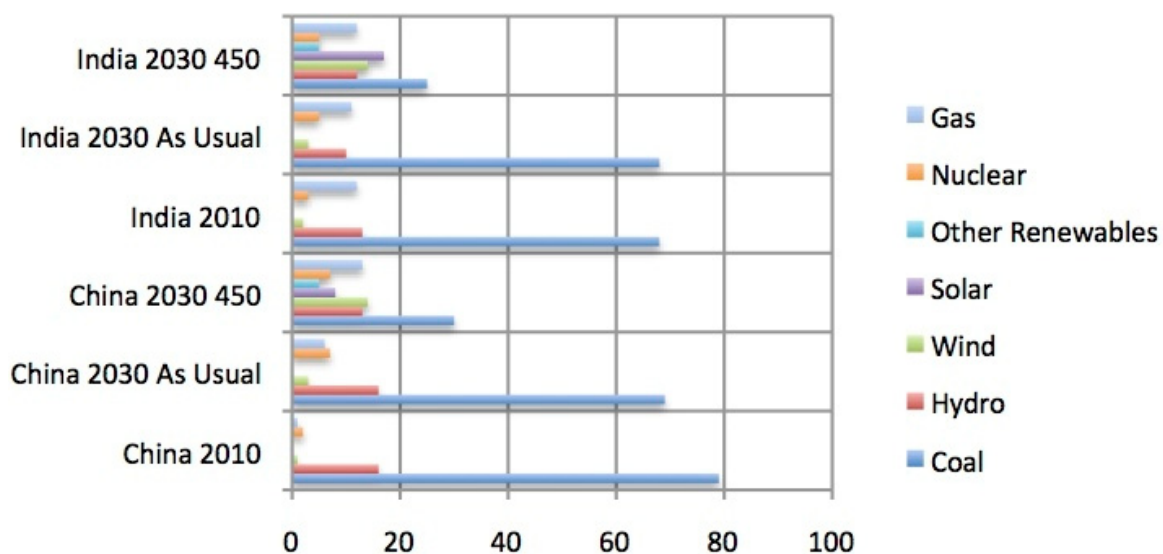
\*Includes power generation, transmission, and distribution

**Table 2.** Power Generation Infrastructure Investment 2005-2030 (in billion \$)

<sup>6</sup> IEA 2011 World Energy Outlook Factsheet.

<sup>7</sup> China accounts for nearly 75% of the global increase in coal generation (EIA 2011, Global Econ Outlook article, aol.com).

How the energy mix changes for these growing economies can create a different and more positive outcome for generations to come. The choices of China and India, such as including more renewables (wind, solar, and hydropower), zero-carbon nuclear and movement away from the heaviest polluting fossil fuels are key to outcomes. If China decides to fully embrace a glide path toward a 450 scenario, in 2030 coal generation would be 30% over 69% in a business as usual case according to McKinsey study scenarios (Figure 2). Hydropower use remains virtually the same for China at 13% of its energy mix. But solar and nuclear power grow considerably from a currently low base. India following a 450 scenario would need to make significant solar power contributions, reduce coal-based power, add wind (14%) and other renewable forms. The IEA expects investment of \$15.2 trillion by both supply-side and consumers to meet the 450 Scenario by 2035.<sup>8</sup> Both countries need to use more natural gas with its lower carbon content for power generation and potentially transportation. While pivotal countries address energy demand, energy mix, and investment issues, another critical resource warrants analysis.



**Figure 2.** Changes to Energy Mix Scenarios China and India, 2010-2030 (% TW hours)

## 2.2. Water resources

The United Nations reported that by 2030 nearly half of the globe will be water stressed [6]. Water resource security has become a top global policy issue, and can be more problematic than energy issues. Private companies, governments and civil society institutions realize that inadequate water resources can impede the best-laid plans for economic and business development. The high risk that water scarcity poses for economic growth and stability makes this policy area a priority.

A number of drivers impact the future of water for China and India, though these two countries are not alone. Economic growth, urbanization, industrialization and increasing affluence will shift demand for water and sanitation purposes even higher. For example,

<sup>8</sup> IEA, 2011, FactSheet.



China's middle class is expected to grow from 4% of the population in 2005 to 56% by 2030.<sup>9</sup> Population growth makes declining water supplies spread among more people, agriculture, industry and businesses challenging, even posing competitive threats to one another.

Climate change is expected to worsen water problems by increasing the frequency and severity of floods and droughts. According to climate change projections, the changes in snow and glacier melt of the Himalayas could affect hundreds of millions of India's and China's population [7]. Several of India's river systems rely upon Himalayan glacier melt. In the immediate term, snowmelt increases their flows; in the long run, the impact is expected to be a decrease of 30-50% [8]. Projections indicate that the freshwater availability in India will drop from 1820 cubic meters to less than 1000 m by 2025.<sup>10</sup>

The policy areas of energy, health, food security and environment intersect water demand and supply issues. In Kashmir and the borders between Assam and Bangladesh, national security risks arise because of conflict over resources and the environmental refugees that flood into neighboring countries. Owing to the effects of drought, hydropower generation in India declined 10% in 2009 over the year before.<sup>11</sup> The World Preservation Foundation stated that aquifers under Beijing and Delhi are drying up.

China also has the potential for security conflicts both outside and within its own borders, owing to water resource conflicts. Water refugees within China are driven from their homes. Ten provinces in China, accounting for 45% of GDP, are considered water poor by the World Bank.<sup>12</sup> The Mekong River runs through the Yunnan province, Myanmar, Laos, Thailand, Cambodia and Vietnam. Fifty years of drought and the Chinese government's building of dams have caused insecurities, even unrest in cases, for the 60 million who depend on the river. Worsening water resource challenges lie ahead for China, India, and other countries, with both developed and developing countries facing different sides of climate change-related water challenges.

The case of China warrants a brief focus as its water challenges reveal a slow-moving crisis. For its fast-growing economy, water challenges are intertwined in meeting its energy demand. Rapid urbanization and industrial growth are main drivers for its water-energy demand challenges. Agriculture makes up 50% of water demand, and industrial demand comprises the other 32%, which is largely driven by thermal power generation [8]. Water shortages cost China about 1.3% of its annual economic output, with a further 1% lost to water pollution, says the World Bank.<sup>13</sup> Significant industrial and domestic wastewater pollution makes the quality gap larger than the quantity gap, according to the Water Resources Group. Urban sewage, refuse, and industrial waste have polluted over 90% of groundwater.<sup>14</sup>

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<sup>9</sup> Water Resources Group report, p.56

<sup>10</sup> IPCC Report 2007, Ch 7.

<sup>11</sup> "India Braces For Drought..." Reuters, Aug 18, 2009.

<sup>12</sup> Economy, Elizabeth, "China's Global Quest for Resources and the Implications for the United States, " Testimony before the U.S. Congress, Jan26, 2012.

<sup>13</sup> *Economist* survey report, May 2010. Also note 25.

<sup>14</sup> Ibid. "China's Global Quest for Resources and the Implications for the United States, " Testimony before the U.S. Congress, Jan26, 2012.

Industrial users dominate overall water demand growth in China. With industrial and urban water users being the fastest growing segment, water-efficient infrastructure programs and a focus on conservation could result in net annual savings of \$22 billion even after capital costs are considered [8]. Productivity gains could also accrue by implementing greater industrial efficiency measures in water usage. China knows how to squeeze out energy efficiencies in power production to reduce carbon emissions as it did across two earlier decades. Water is a key industrial input for China and India's power base, since coal is a heavy user of water. With its recent policy shift to more renewable power generation, water efficiencies in solar power should be a priority as well. India has a similar dynamic with increasing coal usage in the future.

Sector	2005	2015	2030	Cumulative annual growth rate
Municipal/ Domestic	68	88	133	2.7%
Industry	129	194	265	2.9%
Agriculture	358	385	420	0.6%
Totals	555	667	818	1.6%

Source: Water Resources Group, 2009

**Table 3.** China Water Demand by Sector, Withdrawals, billion m<sup>3</sup>

In 2009, India was especially hard hit with blistering droughts afflicting 177 districts, owing to poor monsoons in the year.<sup>15</sup> Agricultural production, a significant part of the Indian economy that impacts 2/3 of Indian livelihoods, was curtailed; India's economic growth rate had also taken a tumble when all was accounted for.<sup>16</sup> India with water needs of 1.5 trillion m<sup>3</sup>, is projected to face a water supply deficit of 50% or 754 billion m<sup>3</sup> (cubic meters) by 2030, according to a study on global water resources.<sup>17</sup> Current supply is 740 billion m<sup>3</sup>. Increases in demand for water in agriculture, alongside a limited supply infrastructure will contribute to this gap. India's water demand from agriculture is expected to double from 2005 levels, and comprise 80% of total water demand. Demand from water users in India, besides agriculture, is also expected to growth rapidly. Municipal and domestic water demand doubles by 2030, and industrial users demand four times the amount as 2005 levels.

As *Figure 3* indicates, a supply deficit of 201 billion m<sup>3</sup> is estimated up to 2030 in China given water demand. Certain regions will suffer more severe shortages than others. The Yangtze Basin is expected to face the largest size water gap of 70 billion m<sup>3</sup> or a 25% gap.

<sup>15</sup> Prime Minister and Agriculture Minister declaration from August 17, 2009 news story on FEER.

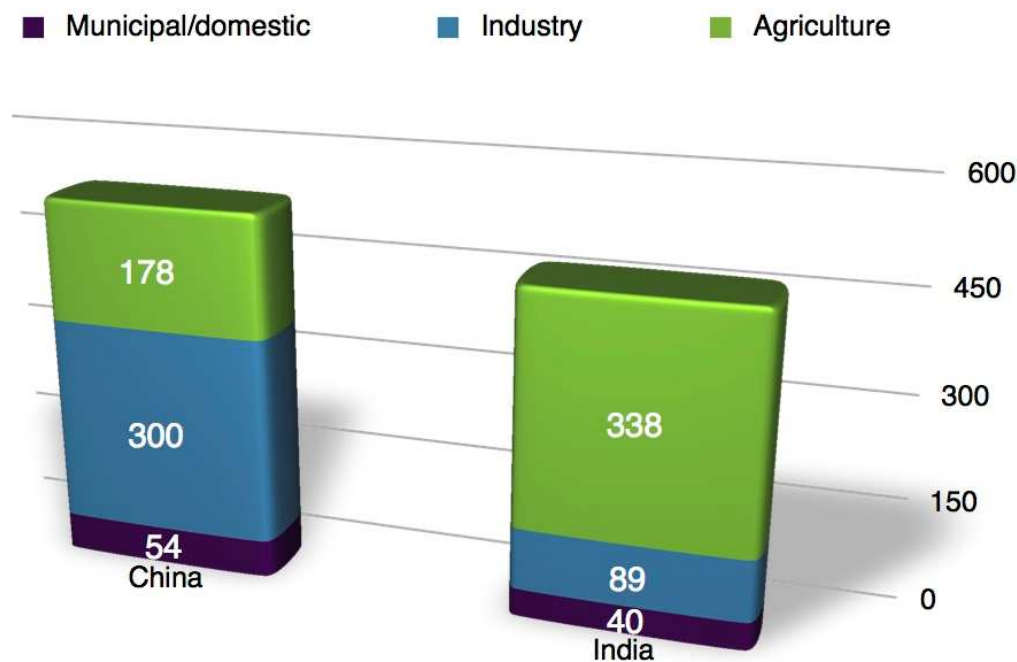
<sup>16</sup> "India Braces For Drought..." Reuters, Aug 18, 2009.

<sup>17</sup> Water Resources Group, "Charting Our Water Future," 2009.



China has water storage capacity per capita of 2,220m<sup>3</sup> — less than half that of the U.S. and 100 times that of India's. However, China's water *availability* per capita is approximately one-quarter of the global average.<sup>18</sup>

In developing countries, municipal and domestic water demand will grow significantly. Figure 3 illustrates how China and India's sectors grow, and where the efficiency gains could be targeted. China's industrial water demand accounts for 40% of the *additional* growth of global water demand for industrial users, largely as a result of power generation. China's increased water demand from 2005 to 2030 is 61% versus India's increase of 58%. China and India could be considered benchmark cases, as they represent developing countries having common urbanization and water-energy challenges, which could impact development.



Source: Water Resources Group, 2009

**Figure 3.** Comparison of China and India's water demand, 2005-2030 (billion m<sup>3</sup>)

### 2.3. Managing water

Water managers may not be fully aware of climate change impacts related to the infrastructure they manage, or they have other priorities. Climate change needs to be factored in relative to an area's particular challenges like flooding, drought, or low-lying area problems such as salt-water intrusion. The UNFCC estimates that additional investments for climate change adaptation will be \$28 billion-\$67 billion (even up to \$100 billion) per year several decades from now.<sup>19</sup> Water infrastructure, usage patterns and institutions have developed in the context of past and present conditions, according to the

<sup>18</sup> Congress Report of Second China Water Congress 2008, Beijing, *International Journal of Water*.

<sup>19</sup> U.N. World Water Development Report 3 (Factsheet on Water), 2009.

Intergovernmental Panel on Climate Change [9]. Water managers in numerous countries – the Netherlands, US, UK, Germany, Bangladesh, Australia and others—have begun to address climate change in their planning. While China faces water shortage issues, India's challenge partly surrounds managing its supply better. In fact, India can learn from the mistakes of China in upstream and downstream management practices.

China and India can learn from the lessons of advanced economies and their outcomes. A recent study by the Pacific Institute found that one way to manage scarce supply of water is simply by curbing waste. The state of California illustrates developed-country water challenges and how to begin managing them among stakeholders. The authors suggest that some combination of irrigation technologies and management practices can save 17% of all the water used by California farmers and more than twice the total of the state's millions of city dwellers. They add that spending on capital-intensive projects like de-salination plants and solar power plants make less sense when you can gain efficiencies in this manner.<sup>20</sup> With most of India's water budget spent by agriculture, efficiencies in this sector should be one, among other priorities.

By making appropriate investments in infrastructure and changes in land use and management structures, the impacts of floods and droughts could be abated. For example, India's Konkan Railway suffers approximately \$1 million annually in damages because of landslides during the rainy season [9]. Twelve percent of India's land is prone to flooding and 80% could be abated by providing reasonable protections.<sup>21</sup> China's Yunnan Province officials studied the temperature over the last 30 years in an attempt to understand the droughts of the last half a century. Temperature increases between 1950 to 2003 caused losses to agriculture costing the economy 10 billion yuan (approximately \$1.5 billion). Its Water Resources Department recently outlined a number of drought-related infrastructure undertakings (though it had focused on floods earlier and missed the drought abatement opportunities that are now critical). Pushing for more private investment will exacerbate demand. A senior engineer at a research institute in Kunming, China said by 2020, urbanization and industrialization will take its toll on water supply, with an annual shortfall that amounts to the city's current water demand.<sup>22</sup>

While India has a substantial water resource base, current infrastructure to buffer its variability is low. India has only 200 m<sup>3</sup> of water storage capacity per capita compared to China's 2,220 and the U.S.'s 6000m<sup>3</sup>. The Water Resource Group's (WRG) assessment says India's "accessible, reliable supply of water amounts to 744 billion m<sup>3</sup>, or 29% of its total water resource."<sup>23</sup> Water quality is a major issue for India and a lack of wastewater treatment plants in the middle and lower parts of most Indian rivers causes surface water quality degradation.

<sup>20</sup> "Waste Not: A Demand-side Solution for California's Water Troubles," Wall Street Journal, July 24, 2009.

<sup>21</sup> Food & Agriculture Organization of the United Nations (FAO), Aquastat country profile (India). <http://www.fao.org/nr/water/aquastat/countries/india/index.stm>

<sup>22</sup> Hujun, Li. "No Easy Fix After Decades of Droughts In Yunnan," Caing.com (English), Mar 11, 2010. <http://english.caixin.com/2010-03-11/100125559.html>

<sup>23</sup> Water Resources Group, 2009. p 56.

More than half of China's 660 cities suffer from water shortages, says the Institute of Public and Environmental Affairs. To accommodate continued urbanization, both agriculture and industrial users will have to reduce consumption. The government has plans for more wastewater treatment facilities to deal with water pollution. In anticipation of water shortages, one of China's most technically challenging infrastructure projects, the South-North transfer, will divert water from the Tibetan Plateau to western regions through a 300-mile network of tunnels. At one point, siphoning water from the Brahmaputra River, vitally important to India, was considered but the Chinese backed down after controversy ensued. The project's costs are an estimated \$62 billion, surpassing that of the Three Gorges Dam project of over \$20 billion.<sup>24</sup> Additionally, the project's intent to re-supply the dry north may not be keeping up with nature's changing courses. China will have to re-think future water diversion projects.

China will have to simultaneously consider reducing the carbon and water footprints of their new infrastructure additions in the years ahead. Water and energy cost savings can accrue by focusing on water efficiencies in thermal power processes and energy choices. To close China's 201 billion m<sup>3</sup> water supply gap, investment capital of \$7.8 billion is needed annually to fill the deficit to 2030, or \$156 billion in total. However, when for operational expenditures are considered, net annual savings of \$21.7 billion could accrue according the WRG. These savings get distributed among thermal power, wastewater reuse, pulp and paper, textile, and steel industries. The water efficiency measures required to create these savings will divert resources to water efficiency that may slow growth in the short-term but create sustainable business practices and technical innovation over the long haul. Limited water supply and environmental pressures in numerous basins indicate that wastewater treatment and wastewater reuse are critical challenges ahead for China.

Greater private sector participation is being encouraged in China, according to an official at a recent water congress in Beijing. However the Chinese government is believed to lack the capacity to implement the many intended reforms of the water sector.[11] Raising water tariffs are expected to bring more private sector participation. Shenzhen planned to increase water prices 30% for households and 60% for businesses; cities in China that have already raised tariffs or plan to include Beijing, Shanghai, Tianjin, Shenyang, Guangzhou, Nanjing, and Chongqing.<sup>25</sup> Of World Bank infrastructure private-public partnerships (PPPs), China accounted for more than 70% of projects established in developing countries; 60% are for sewage treatment plants, reflecting a government priority of dealing with urban wastewater.<sup>26</sup> Though India will come to the same conclusions as China, India has a rougher road ahead with its policy reversals being greater in water infrastructure development than in China.

Water savings can accrue to India, and other developing countries, by managing water leakage better. In India's municipalities, a 26% savings is possible. The World Bank found

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<sup>24</sup> [http://www.water-technology.net/projects/south\\_north/](http://www.water-technology.net/projects/south_north/)

<sup>25</sup> "China Cities Raise Water Price in Bid to Conserve," *Wall Street Journal*, July 31, 2009. And [http://news.xinhuanet.com/english/2009-12/27/content\\_12711285.htm](http://news.xinhuanet.com/english/2009-12/27/content_12711285.htm)

<sup>26</sup> World Bank PPI database, June 2009

inefficiencies in Indian cities of more than 40%, partly because of water leakages and a lack of invoicing customers.<sup>27</sup> In Brazil's Sao Paulo an effort toward reducing waste has resulted in losses falling from 32% of revenue to 24%, with a goal of 13%; Brazilian losses average 40%.<sup>28</sup>

Water is a complex, multi-faceted infrastructure and resource challenge for countries developed and developing alike. Resource challenges however have also been managed from a national policy standpoint — Germany's current zero-nuclear movement to 2022 and China's energy efficiency and conservation efforts in the period 1980-2000. Australia implemented water sector reform, resulting in agricultural productivity gains of 36% between 2000-05 and a financial water market worth \$1.7 billion in 2007-08, the Water Resources Group notes. Across the globe, water-oriented institutions are informing the dialogue on the need for better management of water resources. A key challenge remains: How will the green and efficient infrastructure for sustainable growth and development be funded?

### 3. Infrastructure needs and funding

Developing world economic growth is a driver of needed infrastructure. As the growth paths of China, India, Africa and South America will contribute to increased carbon emissions, countries will need a new set of tools to finance the much needed climate-sensitive infrastructure. Over the next twenty years, to deliver renewables at scale, \$500 billion could be needed annually, according to an expert in a World Economic Forum symposium.<sup>29</sup> Research shows that the ways in which infrastructure has been financed in the past has wasted resources. Given resource constraints in both developed and developing countries, new approaches are needed that are more conducive to modern economic and political realities.

Demand for urban infrastructure will continue to increase dramatically. Research from the McKinsey Group projects 136 new cities entering the top 600, all in developing countries with 100 new cities in China alone. With trends in urbanization, the opportunity for economies of scale exists in infrastructure. Cities generally have denser infrastructure and policies directed toward low-carbon and water resource efficiency offer a unique opportunity to counter the energy-water-climate nexus. Also what happens in one city bleeds into the comprehensive carbon emissions count, ie., the pollution of Shanghai reaches the atmosphere of Japan, even the West Coast of the U.S.

Economies of scale in infrastructure exist in the growing urban centers of China, India and other developing countries. "The doubling of a population of any city requires an 85% increase in infrastructure," according to research on scaling laws. There are similar savings

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<sup>27</sup> McKinsey "Resource Revolution" p.95. Citing Pronita Chakrabarti Agrawal, "Designing an effective leakage reduction and management program," World Bank, April 2008.

<sup>28</sup> Ibid, p.138.

<sup>29</sup> Kerr, Thomas. "Renewable energy: developing solutions to deliver low-carbon investment," World Economic Forum presentation, 2011 July 6.

in carbon footprints. Most large, developed country cities are greener in terms of per capita emissions though they are centers of concentrations of emissions as well [12]. Rapidly developing cities in China and India have inconclusive results to date, though researchers are pursuing the data trail.

However, creating and operating the same infrastructure in higher densities is more efficient, economic and can lead to better innovations. Because of denser settlement, the per capita space required shrinks resulting in a more intense use of infrastructure. The notably accelerated pace of life in cities with their universal features leads to higher productivity, which is also characteristic of a more efficient and economic use of infrastructure. Finally, owing to the nature and commonalities of cities, the intertwining of more diverse economic and social activities heightens economic specialization and expression of social networks. Innovation is a byproduct of the wealth and creativity effects of urbanization and agglomeration that does not typically happen in smaller places. Infrastructure is a natural beneficiary of urban scaling laws and cities as complex adaptive systems. To make better use of finite resources and growing, wealthier populations, innovation, economy and efficiency are imperatives to deal with the energy-water-climate nexus.

With the region of Asia needing around \$8 trillion over the next ten years in infrastructure investment, new approaches to leverage capital are needed. In a recent high-profile Asian water summit, the director of the Asian Development Bank called for extensive use of new technologies, large-scale reuse of wastewater, and plugging in the gaps with small-scale efforts. India's power sector requires \$600 billion by 2017 to meet demand, according to a 2011 report by McKinsey. Private-public partnerships are expected to fill in the infrastructure gaps the public sector cannot fund or manage.

In the traditional water sector for 'downstream' water supply such as sanitation and industrial use, spending across this sector was \$485 billion in 2005. It is expected to grow to \$770 billion by 2016, mainly in the water and sanitation areas. Utilities account for 70% of the total spending. In comparison, utilities in other sectors spend \$770 billion in natural gas sectors and in electricity some \$1.5 trillion.<sup>30</sup> Upstream water supply, often government-funded, is expected to become more expensive in time as cheaper supply is superceded by demand. In developing countries, spending on water infrastructure is a small part of total global spending as mentioned above. Given their respective states of development, expected growth, and resource dynamics, China and India will be spending vast sums in the future.

To fill the large gap in funding infrastructure development, private capital will need to be mobilized. Many governments around the globe acknowledge the limits of their ability to fund projects. With greater integration of capital markets, globalized markets offer opportunities that benefit both developed country investment searching for returns and diversification, and developing countries seeking funds. Financing infrastructure projects by way of global capital markets' invisible hand can infuse economic development alongside the policy imperatives of lower-carbon energy and water security.

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<sup>30</sup> Datamonitor, "Electricity: Global Industry Guide," 2009.



### 3.1. Some pitfalls of existing approaches

In the past two decades, the primary approaches of Build-Operate-Transfer (BOT) and Private-Public Partnerships (PPP) have been widely applied for hundreds of large-scale infrastructure projects worldwide. Both BOT and PPP approaches can be considered “contract finance” approaches. These approaches were encouraged to counter the shortcomings in the older build-own-operate approach and create a pathway for private participation. Throughout numerous cities in China—Pudong BOT project (Shanghai), Chengdu, Tianjin, Lanzhou, and many more—the government is privatizing its water and wastewater infrastructure to add capacity and modernize operations. But these existing approaches of BOT and PPP reveal shortcomings as well, and have led to substantial amounts of wasted resources across countries and sectors.

Infrastructure project financing is structured in a way, which creates the problem of “plums” in contrast to Akerlof’s illustrious ‘lemons’ problem [13]. The plums problem arises when the buyer (bidder or firm providing capital) knows more about the quality and economic value of the project than the seller (government agencies). Under the existing approaches of BOT and PPP, project companies have incentives to play political games which gives rise to corruption and waste. Project sponsors and investors may then be deterred from future projects in the host country or even the region [14].

Under existing approaches, infrastructure project financing is structured in a way which creates flaws: inefficiencies and added costs, greater political (policy) risk, and a lack of diverse ownership needed for transparent incentives. India’s failed \$2.9 billion Enron-Dabhol project highlights some of the issues surrounding infrastructure projects. In this case, there was a lack of competitive bidding, unfair contracts, and limited knowledge by the seller (the government) in terms of project scale, technologies and complexity [15]. Unfair competition for contracts will not yield the longer-term goals of sustainable growth and development and better governance records. Consequently, investors may then be deterred from future projects as happened in India post-Enron for many years.

Both BOT and PPP projects in China have a checkered history. In 1988, China’s first BOT project with private participation was the Shaijiao power plant in Shenzhen. Early PPPs revealed signs of the plums problem by foreign investors, and at a later time, state-owned enterprises displayed operational and management inefficiencies. In Ke’s study of sixteen Chinese PPP projects [16], the classic shortcomings of the “contract finance” approach were observed: a) inefficient bidding processes, b) imperfect project contracts, and c) lack of diversification and liquidity in project finance. The sixteen projects studied either failed to bring reasonable returns to investors; were suspended or purchased by the government during the concession period; or were forced to re-negotiate with the government. These projects were predominantly water and energy infrastructure PPPs for which policy risk ran high across the spectrum of projects.

Political or policy risk is a significant concern for investors considering developing country projects. In a study of the political risks associated with BOT projects in China, several



obstacles were found as China embarked on its campaign to encourage private participation. The top five critical risks faced by foreign investors in order of threat were: changes in legal risk (law and regulatory changes by government), corruption risk, delay in approval risk, expropriation risk, and Chinese entities reliability risk [17]. This story repeats itself in India as well. Research by Wilkinson revealed that corruption in infrastructure projects in India often has political roots.<sup>31</sup>

In China, most wastewater treatment plants with private investment are BOT, and foreign investors have grown wary. The government controls the water prices, thus creating return on investment or market risk for the private firm. Other foreign firms have complained that local governments give preference to domestic firms, though their technology is in fact superior. The government is acting as provider, regulator and customer, with the conflicts of interest implied—political and policy risk for the foreign firm/investor.<sup>32</sup> Inconsistent laws and regulations and their irregular application to foreign firms are classic BOT shortcomings that plague other developing countries besides China and India.

### 3.2. Market approach for progress

Governments around the globe are seeking the experience and capabilities of the private sector to both fund and provide necessary services to their citizens. Given the emergent lower-carbon and water-related infrastructure needs in China and India, a progressive approach is needed that levels the playing field, deters political and policy risk, and develops more efficient, transparent market mechanisms. Rather than initiating a government-controlled infrastructure project, which may then be privatized, the market-based approach can allocate capital and resources more efficiently from the project's onset. A government can choose to be the majority shareholder under this approach, but the risks and incentives will be transparent when shareholder-stakeholders are responsible for the project's sustainability. This is a truer form of private-public partnership.

A “market finance” approach, which creates immediate private ownership of public investment projects among diverse groups of investors, may lead to more efficient and successful infrastructure development. In a study of seven provinces in northern China facing water scarcity, groundwater markets through the privatisation of tubewells re-organized water usage and management for farmers. Water was managed more efficiently and cropping patterns became more productive and profitable, without a lack of access for poorer farmers. India's large agriculture withdrawals and waste are the result of a lack of market pricing mechanisms.

Project securitizations or initial public offerings of project securities can be designed with financial innovations for any new large-scale infrastructure project, or projects linked by theme, sector or region. These could effectively be “green zones.” A group of green projects— a large biomass plant, a solar plant, and a water-efficient utility—could be

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<sup>31</sup> Chen and Warren (Kubik), 2007.

<sup>32</sup> *China Economic Review*, “Drinking Buddies,” Dec 2009.

funding targets for capital markets. This approach would complement the low-carbon centers that China and India's governments intend, but do so in a more financially-sustainable manner.

Securitizations would create diversification, liquidity, and mitigate many of the problems that accompany existing approaches in financing infrastructure. Managerial incentives could be more aligned with productivity, thus reducing the widespread problems of cost overruns and inefficiency in traditional BOT and PPP. It could also unravel the perverse incentives pervading infrastructure spending in China, India and other developing countries.

Financial innovations in the securities offering can serve as both a deterrent and an incentive. For example, including event-risk provisions in project bonds can deter politicians' attempts to make undesirable policy changes. This can ultimately foster a more investment-friendly environment that developing countries need to attract. Sound decisions and proper management will bring its own reward through enhanced project value and the value it brings to the community and economy at large. The invisible hand may prove more capable in setting infrastructure project agendas spanning varied political tenures and agendas.

Governments—central, provincial, and local—could be allocated project securities to achieve true public-private ownership. In market-based PPPs, governments can play a role as needed according to their capacity. Market-based PPPs can address investors' reluctance due to political risk and profitability concerns, bring projects online more quickly, and attract longer-term institutional players. Conventional PPP projects and deals line the news media pages, but another approach will be needed to marshal the financial resources for the challenges ahead.

Water resource issues and price increases often lead to public backlash. Under this new approach, citizens can participate as shareholders and stakeholders, and therefore participate in governance and oversight issues. The bankruptcy of U.S.-government backed solar firm Solyndra might have had a different outcome for solar power development in the U.S. were an alternate approach taken. In Asia, the Asian Development Bank can play an important role as project guarantor in water infrastructure PPPs as well. Additionally, utilizing capital markets offers the potential to scale up projects that might otherwise receive funding on a smaller scale. This is important with economies of scale needed to deal with the significant carbon emissions reductions required of China and India and with respect to the scope of wastewater and efficient water systems.

Much of the world's infrastructure revolves around cities —highways, ports, power plants, and water systems — with fossil fuels at their epicenter of operations. Owing to age and a preference of cleaner energy, a massive capital stock turnover is coming across the next few decades. China's wind power and hydropower generation comprise 25% of their total capacity.<sup>33</sup> China plans wind power to grow a staggering 14.2% annually to 2035. While China has shown strides as major green player, in order to grow and power their economy, more attention to infrastructure choices and sustainable financing will be required.

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<sup>33</sup> *China Economic Review*, "89.7 Million kW of Power in 2009," 11 Jan 2010.

India plans to double its hydropower capacity by 2030, but environmental concerns have already led to rejections of several projects. India will need to manage its water resources more stringently with hydropower and agriculture demands, coupled with expected changes owing to climate. India's National Solar Mission plans to expand solar power from 20 GW to 200 GW by 2050,<sup>34</sup> but again government may not be capable of financing their clean energy ambitions.

The time for action is now as delaying investments mean less chance to reach a 450 Scenario. According to the IEA, if coordinated international action is not taken by 2017, all permissible emissions would come from the then existing infrastructure and therefore all new infrastructure (includes power plants, factories, and buildings) from 2017 to 2035 would need to be zero carbon unless older emitting infrastructure is retired early. Much of the power sector infrastructure stock in existence today accounts for half of the emissions locked-in to 2035. The IEA calculates for every \$1 of investment avoided before 2020 in the power sector, an additional \$4.3 would need to be spent after 2020 to compensate for the higher emissions [5]. The stakes are high— and developing countries, particularly high current and future emitters such as China and India— are a targeted response to prevention.

#### 4. Practical and policy implications

Numerous opportunities exist to address the energy-water-climate nexus through cleaner energy infrastructure and by utilizing efficiencies in water in developing countries. However energy and water resources are often subsidized by governments, distorting pricing signals. In fact, according to the McKinsey resource study, between 70-85% of opportunities to boost resources productivity are in developing countries. And importantly, in order to engage the private sectors, reducing subsidies in energy and water make more projects attractive for private sector engagement through higher rates of return. If carbon were priced and subsidies reduced, water projects with rates of return of 10% or greater increase from 76% to 90%.<sup>35</sup> In general, resource competition from developing country growth will require new approaches and interventions to provide power, water and modern lifestyles.

A Chinese official recently stated that they would be pursuing and competing for natural resources globally alongside other major economies. Coal, for example, is one resource that China will heavily influence in the future, as it adds 550 gigawatts (GW) of coal capacity between 2010 - 2030, from 50 GW in 2005-2010.<sup>36</sup> China and India can further leverage their domestic agricultural resources through biomass power plants. Power from biomass is more reliable than wind and solar and has the ability to provide base-load capacity when old coal plants are de-commissioned. But the challenges in project financing are proving to be an obstacle for biomass expansion. Market prices for the agricultural waste are not set like coal inputs or natural gas. This type of 'greenfield' project would be ideal for the market-based approach. It could help determine a market price, and therefore further biomass's expansion, which supports China and India's green agendas.

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<sup>34</sup> U.S. EIA, 2011, p. 97-8.

<sup>35</sup> McKinsey Global Institute, 2011, p.17.

<sup>36</sup> Ibid. p 108.

In emerging markets, many of the new greenfield opportunities are “sustainable” and green types of infrastructure. A fund managed by PIMCO, one of the largest bond investors in the world, will purchase fixed income securities in infrastructure sectors of importance to emerging market governments such as energy, transport, telecoms, water and treatment. They are targeting both retail and institutional investors; this is effectively an outsourcing of infrastructure investing owing to demand for the asset class and the knowledge it takes to manage these types of assets. These opportunities are not being ignored in progressive developed countries. A U.K. start-up firm is scaling up waste-to-energy power plants. A key reason for underdevelopment in this novel area has been financing, even in an advanced economy.

In India, the past five years has seen considerable growth in infrastructure investment, which is a stated government goal. Over the next five years, infrastructure investment is expected to reach a new high relative to GDP. The private sector is expected to make \$1 trillion in investment. According to a recent Economist article, the infrastructure firms developing roads, power stations and airports are heavily indebted however. The top 70 Indian stock exchange-listed (BSE) firms were roughly \$12 billion cash flow negative. The time for more equity, and shareholders (over oligarchs), is ripe in India to sustain its economy's growth, which 'slowed' to 7%.<sup>37</sup> This market-based approach could jettison greener infrastructure development in India.

Institutional investors like infrastructure investing because these investments often mirror the long-term nature of their portfolio needs— and they are “real” assets, which are more attractive post-financial crisis. Specific to climate-change infrastructure, power generation and their grids, energy storage, and water infrastructure rank high on the list as climate change-targeted infrastructure opportunities. Upgrades to power plant infrastructure — from subcritical technology to ultra-supercritical coal— is one area where resource and carbon emissions savings can accrue. China's coal plants are 80% subcritical, with about one-third of conversions taking place toward greater efficiency.<sup>38</sup> More efficient gas-fired plants using combined-cycle gas turbines can also offer savings, especially with the projected switching to more natural gas from coal in the future. Greatly increased supply has come online from unconventional resources, such as shale gas, tight gas and coal-bed methane sources.

Within this space of infrastructure investing, climate change adaptation and mitigation efforts also apply to the areas of corporate governance and social responsibility. Many large institutional investors—banks, insurance companies, or pension funds—are integrating sustainable business practices into their lending and/or investment criteria. For example, India's YES Bank has a dedicated Sustainable Investment Group, specializing in alternative energy and other environmentally-focused sectors.<sup>39</sup> Players in global supply chains are becoming better environmental stewards. A number of coalitions, such as Ceres, the World Economic Forum, NGO groups and supra-national organizations, have been formed that

<sup>37</sup> "Infrastruggles," The Economist, Dec 31, 2011.

<sup>38</sup> McKinsey Global Institute, 2011.

<sup>39</sup> Ceres and RiskMetrics Group, "Addressing Climate Risks: Financial Institutions in Emerging Markets," Sept 2009.

produce meaningful research and new forms of assessment tools. In essence, business, government and varied organizations are raising the bar of infrastructure development, in which “greener,” smarter, and more efficient forms of infrastructure are emerging.

In addition to larger infrastructure projects, small-scale water infrastructure opportunities have emerged such as the World Bank and ADB-backed Aakash Ganga project, which originated in India. This private-public partnership outperforms typical public works projects. The economic impact and quality of life has substantially improved the selected rural sites’ because it is a community-driven initiative. Water conservation is at the heart of the process. A large-scale study of China’s rural areas reveals a preference of villagers for infrastructure projects that raise standard of living and/or improve the environment, even beyond employment opportunities. These have included projects in irrigation, water supply, and environmental protection of forests. With China’s decentralized approach in rural development, progressive local-level leaders can attract private investment for their green growth goals as well.

Developed countries will need approaches to maintain and upgrade their infrastructure. The most developed PPP markets of the UK and Australia are attempting to motivate new investment through the private sector to share the burden of funding. Governments are finding the investment capital needed to keep their infrastructure modernized do not exist in public coffers. In the UK, the government plans to attract pension funds (institutional investors), sovereign wealth funds, and investors in Latin America and China to invest in modernizing its infrastructure. They also have a Green Investment Bank, targeting low-carbon investments, with L18 billion available by 2014-15.<sup>40</sup> The UK government sees this strategy of modernization critical for adding growth prospects into a slowing-moving economy.

## 5. Conclusions

The climate change story has energy and water as its primary protagonists and antagonists. By enhancing the ability of market-based PPPs to operate within China and India's borders, new cleaner infrastructure can be developed based on a sustainable model. Financial institutions and other stakeholder groups have been leading the way in lower carbon footprints in energy projects, but the water footprint is becoming a more pressing issue as well. Attention to sustainable development and finance will matter even more to India and China as their economy's grow and develop. A flexible, market approach which runs in tandem with the varieties of ways in which infrastructure investment exists, offers a new source of capital at a time when government resources are under pressure and other priorities exist.

Citizens, numerous governments, financiers and investors are favoring “green” infrastructure as it mitigates many types of risks seen and unforeseen. If China or India are losing 3% of GDP to environmental impacts, it is a *de facto* halving of 6% growth rate. This is likened to

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<sup>40</sup> Institutional Investor, Sept 17, 2011



inflation or a debt, which will erode true growth and real wealth and health over time. With climate change these debts will be paid by someone. Isn't it time to literally engineer this better? Entrepreneurs however want and need consistent policies from government to facilitate exchange. Barriers, policies, and practices that blunt clean energy and water security ambitions should be analyzed within the context of sustainability. Rather than the extreme step of diverting water resources as a first choice, aggressive national conservation measures can be policy instruments that complement what the private sector is incentivized to do.

The governments of China and India can implement progressive policies to become cleaner, greener and more efficient [18]. No objectives can be realistically met unless policy incentives are aligned; capital markets are more developed; a level playing field exists for investors; and steady governance exists. Germany has new energy policies underway to eliminate nuclear power, scale up renewables, and advance their low-carbon and energy efficiency export markets. Incentives are in place, and they will adjust subsidies accordingly as they did with their solar power push. But governments also lose credibility as in the case of Spain's solar and wind policy reversals and subsidy rollbacks. Governments need to make realistic promises to win the trust of investors. India had a long period of *mea culpa* with investors post-Enron.

Water and energy challenges are hard to disentangle. Water security problems could have a domino effect on energy development, and subsequently economic growth prospects. Global awareness about these issues is needed, and best practices in need of being shared. Investing in environmentally-sensitive forms of infrastructure is no longer an outlier. It is a mainstream trend—given the limits of the earth's resources and its ability to integrate particular types of man-made pollution into its cycles. Smarter and more sustainable ways to finance the development of Asia's giants complement the ideal of a cleaner, more efficiently managed use of the planet's resources.

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## 6. References

- [1] McKinsey Global Institute (2011). "Resource Revolution: Meeting the world's energy, materials, food, and water needs," November.
- [2] IANS (2009), "Climate change costs India over 2.6% of GDP: Economic Survey," Thaindian News, July 2. Available: <http://www.thaindian.com/newsportal/enviornment/climate->

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- change-costs-india-over-26-percent-of-gdp-economic-survey\_100212459.html. Accessed 2012 Feb 5.
- [3] Shifra, Mincer (2011). "Global Energy Outlook Puts China and India at the Fore," AOL Energy, Sep 20. Available: [http://www.thaindian.com/newsportal/enviornment/climate-change-costs-india-over-26-percent-of-gdp-economic-survey\\_100212459.html](http://www.thaindian.com/newsportal/enviornment/climate-change-costs-india-over-26-percent-of-gdp-economic-survey_100212459.html). Accessed 2012 Feb 5.
- [4] National Academy of Sciences Letter (2010). "Climate Change and the Integrity of Science." *Science*, May 2010.
- [5] International Energy Agency (2011), "World Energy Outlook 2011 Factsheet."
- [6] "Water Shortage," World Preservation Foundation. Available: <http://www.worldpreservationfoundation.org/topic.php?cat=water#.T1F3dGDnvEV>. Accessed 2012 Mar 2.
- [7] Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Doll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sçen and I.A. Shiklomanov, 2007: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.
- [8] 2030 Water Resources Group (2009). "Charting Our Water Future."
- [9] United Nations (2007). United Nations Framework Convention on Climate Change. "Investment and Financial Flows to Address Climate Change," October.
- [10] Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds. (2008) "Climate Change and Water," Technical Paper VI: Intergovernmental Panel of Climate Change, June.
- [11] Varis, Olli (2008). "Congress Report: 2nd China Water Congress, 2008, Beijing, China, 14-16 May 2008, International Journal of Water, Mar 2009: p. 175-77.
- [12] Bettencourt, Luis and Geoffrey West. *Nature*, Oct 27 2010, p 912, vol 467.
- [13] Akerlof, G. (1970). "The Model for 'Lemons': Quality Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, Vol. 89, 1970, 488-500.
- [14] Chen, Andrew (2009). "Rethinking Infrastructure Project Finance," working paper, November.
- [15] Chen, Andrew and Jennifer Warren (Kubik) (2007), "Complementing Economic Advances in India: A New Approach to Financing Infrastructure," *Journal of Structured Finance*, July/Aug.
- [16] Ke, et al (2009) "Public-Private Partnerships in China's Infrastructure Development: Lessons Learned," *Proceedings of International Conference on Changing Roles: New Roles and New Challenges*, Netherlands, October.
- [17] Wang, S. Q, et al (2000). "Evaluation and Management of Political Risks in China's BOT Projects," *Journal of Construction Engineering and Management*, May/June.
- [18] Warren, Jennifer (2008). "China's Green Future," *Far Eastern Economic Review*, December, Vol 171, No.10.