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The Emerging Scenario of Alternative Energies in the IOR

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The energy transition from fossil fuels to renewable sources of energy is moving much faster than could be imagined a few years ago. Given this unanticipated acceleration, it is widely believed that renewable energy is attaining a momentum which is of great significance in the context of the global energy and climate situation. Whereas the 20th century was marked by the globalisation of the world energy economy as countries everywhere turned to oil, much of it coming from the Middle East, without doubt, this century will see the localisation of energy production as the world turns to wind, solar, tidal, geothermal and other forms of energy. This paper aims to expound the potential of the four main "renewable" energies i.e., wind, solar, ocean and geothermal, including potential assessment of their growth in the Indian Ocean Region (IOR) and the attendant challenges in their future intensification and acceptability. As any study on this topic would bring out, the plans and investment of China are staggering and will have profound implications for the emerging geopolitics.

Introduction

The 20th century was the ''oil'' century. World oil production, which was about 150 million barrels in 1900, jumped to 28 billion barrels in 2000 – a 185-fold jump.[1]

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This was the century in which "black gold" overtook coal to become the world's leading source of energy and reshaped for much of humanity, "life" – as they knew it. The rapidly expanding supply of cheap oil led to an explosive worldwide growth in food production, population, urbanisation, and human mobility. But today's petroleum based civilization is heavily dependent on a resource whose production will soon be falling. Since 1981, oil extraction has exceeded new discoveries by an ever-widening margin. In 2008, the world pumped nearly 31 billion barrels of oil but discovered only seven billion barrels.[2]

The fossil fuels, which include mainly crude oil and its refined products, coal, and natural gas, all have their origins in plants and animals existing upon the earth during the last 500 million years. When we consider that it has taken 500 million years of geological history to accumulate the present supplies of fossil fuels, it should be clear that, although the same geological processes are still operative, amount of new fossil fuels that is likely to be produced during the next few thousands of years will be inconsequential.

Therefore, we can assume with complete assurance that the industrial exploitation of the fossil fuels will consist in the progressive exhaustion of the initially fixed supply. In face of the peaking of global oil production – to be followed by peaks in natural gas and coal extraction – and of the need to reverse trajectory in carbon emissions, the world needs a long term cure to the myriad "ills" thrown up by indiscriminate of use of fossil fuels over the last century. Thus the promise of alternative energies.

Apart from the uncertainty underpinning the long term availability of oil, the alternative or renewable energies (the two words are used interchangeably) also owe their genesis to fluctuation in oil prices, concerns related to climate change and energy "insecurity" of nations dependent on imported fossil fuels to propel their economies. Most importantly, renewable energy development has the potential to create new industries and generate millions of new jobs. Globally, there are an estimated three million direct jobs in renewable energy industries, with additional indirect jobs well beyond this figure.[3]

Renewable Energy

The phrase "Fuels from Heaven, Fuels from Hell" was coined by Rochelle Lefkowitz to describe the differences between depletable fuels and renewable forms

of energy.[4] The so-called ''fuels from hell'', or fossil fuels, comprise coal, oil and natural gas, all of which come from underground, are exhaustible and emit carbon dioxide/pollutants that are leading to climate change and massive environmental pollution. In contrast, ''fuels from heaven'', also called renewable/alternative energy sources, comprise wind, hydroelectric, biomass, solar and tidal power. These all come from over the ground, are endlessly renewable and produce no harmful emissions.

This paper aims to expound the potential of the four main ''renewable'' energies i.e., wind, solar, ocean and geothermal, including potential assessment of their growth in the Indian Ocean Region (IOR) and the attendant challenges in their future intensification and acceptability. As any research on this topic would bring out, the plans and investment of China are staggering and will have profound implications for the emerging geopolitics.

The energy transition from fossil fuels to renewable sources of energy is moving much faster than could be imagined a few years ago. Given this unanticipated acceleration, it is widely believed that renewable energy is attaining a momentum that is of great significance in the context of the global energy and climate situation. The speed of this so called second energy revolution – the shift from an economy powered by oil, coal, and natural gas to one powered by wind, solar, and tidal energy – is manifested in the following statistics. In Europe, new electrical generating capacity from wind, solar, and other renewables now exceeds that from fossil fuels by a wide margin. In the United States, new wind-generating capacity of 8,400 megawatts in 2008 dwarfed the 1,400 megawatts from coal. Nuclear power is fading, too. Worldwide, nuclear power generation actually declined in 2008 while wind electric generating capacity increased by 27,000 megawatts, enough to supply 8 million American homes, known for their high power consumption levels.[5] Thus, the world is changing fast.

Wind

Wind Energy has been harnessed by man since time immemorial. The first invention that used wind to create energy were the sails which enabled transportation on water. Since then, the methodologies to harness wind have come a long way. In a fundamental essence, wind is a form of solar energy and is caused by the uneven

heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth.

In the present era, this wind flow, or motion energy, when harvested by modern wind turbines, is being increasingly used to generate electricity. A worldwide survey of wind energy by the Stanford University team of Cristina Archer and Mark Jacobson concluded that harnessing one fifth of the earth's available wind energy would provide seven times as much electricity as the world currently uses. World wind electric generation is growing at a frenetic pace. From 2000 to 2008, generating capacity increased from 17,000 megawatts to an estimated 121,000 megawatts.[6] The world leader in total capacity is now the United States, followed by Germany (the leader until recently), Spain, China, and India. But with China's wind generation doubling each year, the US lead may indeed be short-lived.

With vast wind-swept plains in the North and West, countless mountain ridges, and a long coastline, all rich with wind, China has enough readily harnessable wind energy to easily double its electrical generating capacity, year after year. China has some 12,000 megawatts of wind generating capacity, mostly in the 50–100 megawatt wind farm category, with many more medium size wind farms coming up. Beyond this, its Wind Base program is creating six mega-complexes of wind farms of at least 10 gigawatts each. These are located in Gansu Province (15 gigawatts), Western Inner Mongolia (20 gigawatts), Eastern Inner Mongolia (30 gigawatts), Hebei Province (10 gigawatts), Xinjiang Hami (20 gigawatts), and along the coast north of Shanghai in Jiangsu Province (10 gigawatts).[7] When completed, these complexes will have a generating capacity of 105 gigawatts – as much wind power as the entire world had in early 2008.

Though wind energy has been harnessed on land for several centuries, however, offshore wind farms are a comparatively recent phenomena which entails situating wind turbines offshore, where the wind blows harder and larger turbines can be installed. Many offshore wind farms are being proposed and developed today in densely populated Europe, where there is limited space on land and relatively large offshore areas with shallow water. Such investments have been largely absent in Asia. However, winds of "change" were visible in 2009. China installed a 21 Megawatt offshore wind farm near Shanghai, the first major step outside of Europe.[8]

Cost challenges will determine the future of offshore wind energy, as turbine foundation costs increase rapidly with increasing water depth and wave height. The

cost of connecting with utility power lines also increases rapidly as the distance from shore increases. Many hope that the technical challenges will be overcome and that in the future offshore wind farms will be built much further offshore, perhaps even on floating platforms at sea. Developers intentionally site wind turbines outside of established shipping lanes, thereby avoiding conflicts with routine traffic. The wind industry also is working actively with the fishing industry to ensure, as the oil and gas industry has done before it, that the fishing industry is not disadvantaged by the growth of offshore wind farms.

Solar

Solar energy around the world is fast catching up as a preferred energy source. Sunlight can be converted directly into electricity using photovoltaics (PV), or indirectly with concentrating solar power (CSP). The PV cell is a device which generates electricity directly from visible light by means of the photovoltaic effect. In order to generate useful power, it is necessary to connect a number of cells together to form a solar panel, also known as a photovoltaic module. Photovoltaics are being used for a wide variety of applications, from the calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array. The second method to harness solar energy on a massive scale is simply to use reflectors to concentrate sunlight on a closed vessel containing water or some other liquid, heating the liquid to produce steam that drives a turbine. This solar thermal technology, often referred to as CSP, first came on the scene with the construction of a 350-megawatt solar thermal power plant complex in California, US.

The intensity of the sun's radiation changes with the hour of the day, time of the year, and weather conditions. To obtain electricity, solar panels are directed south in the northern hemisphere and north in the southern hemisphere, at an angle dictated by the geographic location and latitude of where they are installed. Until recently PV production was concentrated in Japan, Germany, and the United States. But several energetic new players, mainly from Asia, have entered the field, with companies in China, Taiwan, Philippines, South Korea, and the United Arab Emirates. China overtook the United States in PV production in 2006. Taiwan did so in 2007.[9] In early 2009, China Technology Development Group Corporation and Qinghai New

Energy Group announced they were joining forces to build a 30-megawatt solar PV power facility in remote Qinghai Province. This is the first stage in what is eventually expected to become a 1,000-megawatt generating facility.[10] For a country that ended 2008 with only 145 megawatts of installed solar cell capacity, this is a huge leap into the future.

The pace of solar energy development is accelerating as solar water heater technology is at the ''take off'' stage. China, for example, is now home to 27 million rooftop solar water heaters. With nearly 4,000 Chinese companies manufacturing these devices, this relatively simple low-cost technology has leapfrogged in villages which do not yet have electricity. This technology is sweeping China like wildfire, already approaching market saturation in some communities. Beijing plans to boost the current 114 million square meters of rooftop solar collectors for heating water to 300 square meters million by 2020. Among other nations, sun drenched Spain, an established solar superpower, has 50 or so plants, each close to 50 megawatts in size, in various phases of development. There are a plethora of proposed CSP plants in other countries, including Israel, Australia, South Africa, the United Arab Emirates, and Egypt. At least a dozen other sun-drenched countries now recognise the potential of this inexhaustible, low-cost source of electricity and are mobilising to tap it. One of the countries for which CSP plants are ideally suited is India. The Great Indian Desert in the northwest offers a huge opportunity for building solar thermal power plants. Hundreds of plants in the desert could satisfy most of India's electricity needs. This potential is being recognised by India's dynamic entrepreneurs. Reliance Power, an Anil Dhirubhai Ambani Group company, is setting up the world's largest solar power plants with an investment of Rs 9,000 crore and has already identified sites in Rajasthan and Maharashtra.[11]

Ocean Energy

Energy naturally present in water bodies or in their movement can be used for generation of electricity. This energy, termed ocean energy, is the least established of the renewable energy options, as of 2011, but interest is growing in a wide range of possible technologies. Ocean energy technologies for generating electricity include tidal, wave, and ocean thermal energy conversion (OTEC) systems. Tidal energy

implies using the ''head'' (height difference) between low and high tides to create a fall similar to that in a conventional hydropower project. Wave energy entails using the kinetic (dynamic) energy of the waves to rotate an underwater power turbine and generate electricity thereon. In a basic sense, it is an underwater wind farm.

The third category, OTEC, refers to using the heat energy of oceans to generate electricity. This is similar to geothermal power generation where heat trapped in the earth surface is converted into electrical energy. No commercial OTEC plants are currently in operation. Even wave energy projects are in their infancy as on date. Comparatively, tidal energy is more promising. Tides are caused through a combination of forces created by the gravitational pull of the sun and the moon, and the rotation of the earth. When a tide comes onto the shore, it is trapped in reservoirs constructed behind barrages (dams). When the tide drops, this collected water is released and is then used like in a regular hydropower project. For the tidal energy method to work effectively, the tidal difference (difference in the height of the high and low tides) should be at least 4m (around 13 ft). Since tidal differences are peculiar to certain geographies, tidal energy projects are extremely site specific.

The first large tidal generating facility – La Rance barrage, with a maximum generating capacity of 240 megawatts – was built 40 years ago in France and is still operating today. The only cost that needs to be incurred is the huge initial infrastructural investment required for building the tidal energy plant and thereafter the plant runs with almost negligible maintenance costs and the plant life is usually 35 years. Within the last few years, interest in tidal power has spread rapidly. Presently, South Korea is building a 254-megawatt project on its west coast.[12] This facility will provide enough electricity for the half-million people living in the nearby city of Ansan. China is planning a 300-megawatt tidal facility at the mouth of the Yalu River near North Korea.[13] Asset finance in ocean energy rose from virtually nil in 2008 to 0.2 billion dollars in 2009,[14] a small but significant indicator.

India has a potential of producing more than 7000MW of energy using this technology alone as per a survey conducted by NHPC Ltd. The potential for India to harness this technology exists in three locations, i.e., the Gulf of Kutch, Gulf of Khambhat and Gulf of Mannar; authorities are considering building a 39-mile barrage across the Gulf of Khambhat on the country's west coast.

Geothermal Energy

Geothermal energy refers to the heat energy emitted from within the earth, usually in the form of hot water or steam, which can be used to produce electricity or direct heat for buildings, industry, and agriculture. Geothermal power is cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable geothermal resources, especially for applications such as home heating, opening a potential for widespread exploitation. The International Geothermal Association (IGA) has reported that 10,715 megawatts (MW) of geothermal power in 24 countries is online, which is expected to generate 67,246 GWh of electricity in 2010.[15] This represents a 20 per cent increase in online capacity since 2005. IGA projects growth to 18,500 MW by 2015, due to the projects presently under consideration, often in areas previously assumed to have little exploitable resource.[16]

The Earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, but only a very small fraction may be profitably exploited, owing to attendant challenges. Most of the easily located geothermal systems, those with hot springs, fumaroles, and geysers at the surface, are already known and many have been developed. In order to locate and characterise hidden geothermal systems that do not reach the surface, new approaches to exploration are needed. Drilling and exploration for deep resources is very expensive. Forecasts for the future of geothermal power depend on assumptions about technology, energy prices and exploratory costs.

Steam and hot water reservoirs are just a small part of the geothermal resource. The Earth's magma and hot dry rock will provide cheap, clean, and almost unlimited energy once technology can tap into them. One future promising new geothermal technology known as Hot Dry Rock (HDR) is designed to tap into much deeper geothermal resources than current technologies permit, thus allowing geothermal energy to be used for low cost, renewable electricity generation anywhere in the world. However, the technology to drill deep enough boreholes (approximately 4 to 10 miles into the earth's surface) does not yet exist at a low enough cost, and is a subject of intense research. Notwithstanding such challenges, with every passing year, countries endowed with suitable ''tectonics'' are moving to exploit this largely untapped source of renewable energy.

Rare Earth Minerals – Bedrock of Renewables

Rare earth minerals are the basic building materials for most of the renewable energy infrastructure. Fuel cells, for example, required platinum, palladium, and other rare earth elements. Solar photovoltaic technology requires gallium, and in some forms, indium. Advanced storage batteries rely on lithium. Wind turbines require neodymium and thin film solar panels rely on tellurium. Even technology designed to save energy, such as light-emitting diode (LED) or Organic led (OLED) lighting requires rare earth minerals such as indium and gallium. Therefore, expressing the costs of alternative energy only in monetary terms obscures the potential limits arising from the future paucity of the ingredient elements.

While rare earth ore deposits are geographically diverse, China is the most richly endowed nation. Further, current capabilities to process rare earth metals into finished materials are limited mostly to Chinese sources. The United States previously performed all stages of the rare earth material supply chain, but now most rare earth materials processing are performed in China, giving it a dominant position that could affect worldwide supply and prices. In 2009, China announced restriction on the export of rare earths,[17] ostensibly to encourage investments within China of industries using these metals. Whether for the rare earths themselves or final products made from them, import dependency in the face of Chinese measures would do little to alleviate ''energy security'' concerns, which is one of the underlying rationales for the adoption of renewable energies.

Alternative Energies: Present Shortcomings

No debate on the issue would be complete without considering the downsides of alternative energies, as they exist in 2011, though with passage of time these challenges are likely be overcome by a combination of technology, ingenuity, increased awareness and economies of scale.

Intermittency of supply is an essential concern. Modern societies are used to the concept that electrons will flow when a switch is flipped or that gas will flow when a knob is turned or the liquid fuels will pump when the handle is squeezed.[18] However, alternative energies such as a solar and wind power in contrast produce only intermittently, as the wind blows or the sun shines. Integration of these energy forms

into our current system creates challenges of balancing availability and demand. The key to overcoming the impact of their intermittency is storage of energy generated during periods of goods wind and sun for use at other times. This mandates continuous research and innovation in the future.

An oft-cited merit of renewables is the long-term cost benefit. Underlying this computation, however, is an assumption that the input costs to renewable energy production would remain static as oil prices rise, thereby providing the economic spur to development. This hypothesis however is incomplete, particularly for those alternatives for which energy itself is a key input. Rising oil prices have a tendency to push up the price of natural gas as well as coal; therefore, for the alternative energy infrastructure dependent on these fuels, higher oil prices also entail higher production costs.

As alternative energy today constitutes only a fraction of total energy production the volume of resources and energy demands for its production has so far been easily accommodated. This will not necessarily be the case with large-scale expansion. Can greatly increased demand for the resources be accommodated? As highlighted above, there are geopolitical underpinnings to the supply and demand of rare earth metals beyond the level of world production existing today. For example, in case of gallium demand from emerging technologies would be expected to reach six times today's total global production by 2030 and for indium, more than three times today's production.[19]

Can such challenges be overcome? The emerging trends augur well for the future. Notwithstanding the downsides, even in 2009, when, up against sturdy headwinds caused by the economic downturn, low oil prices, and the lack of an international climate accord, renewables managed to hold their own. And in early 2010, more than 100 countries had some type of policy target and/or promotion policy related to renewable energy; this compares with just 55 countries in early 2005.[20] More than $150 billion was invested in new renewable energy capacity and manufacturing plants – up from just $30 billion in 2004.[21] For the second year in a row, on a global level, more money was invested in new renewable energy capacity than in new fossil fuel capacity. Given such statistics highlighting the inevitability of the renewable in the emerging landscape, this paper now seeks to explore the scenario in the IOR region.

The Emerging Geography of Renewables

The adoption of renewable energy technologies is no longer confined to the industrialised world – more than half of the existing renewable power capacity is now in developing countries. This transition reflects a growing recognition that the developing ''oil and gas short'' countries, especially in Asia, have much to gain from the development of renewable energy in economic, environmental, and security terms. For the world as a whole, this is a momentous development, since Asian nations now lead the growth in carbon emissions. Given Asia's dominance of low-cost global manufacturing, the region's commitment to renewable energy will almost certainly drive down the price of many renewable energy devices in the coming years.

China now leads in several indicators of market growth. India is fifth worldwide in total existing wind power capacity and is rapidly expanding many forms of rural renewables such as biogas and solar PV. Many renewables markets are growing at rapid rates in IOR countries such as, Egypt, Indonesia, Kenya, Tanzania, Thailand, to name a few. The geography of renewable energy is changing in ways that suggest a new era for this energy source.

For example, wind power existed in just a handful of countries in the 1990s but now exists in over 82 countries. Manufacturing leadership is shifting from Europe to Asia as countries like China, India, and South Korea continue to increase their commitments to renewable energy. In 2009, China produced 40 per cent of the world's solar PV supply, 30 per cent of the world's wind turbines (up from 10 percent in 2007), and 77 per cent of the world's solar hot water collectors.[22] The increasing geographic diversity is boosting confidence that renewable are less vulnerable to policy or market dislocations in any specific country.

In mid-2008, Indonesia, a country with 128 active volcanoes and therefore rich in geothermal energy, announced that it would develop 6,900 megawatts of geothermal generating capacity.[23] Indonesia's oil production has been declining for the last decade, and in each of the last four years the country has been an oil importer. As Pertamina, the state owned oil company, shifts resources from oil into the development of geothermal energy, it could become the first oil company – state-owned or independent – to make the transition from oil to renewable energy. Additional geo thermal projects are being planned or are under way, in the

Philippines and notably in East Africa's Rift Valley in Kenya, as well as in Eritrea, Ethiopia, Tanzania, and Uganda. The Geothermal Energy Association notes that 11 African countries are now working to produce geothermal power.[24]

China's Visionary Steps

Concerns about the health effects of coal burning may help explain why China is making a massive push for wind and solar energy, planning to soon be the world leader in both. This is understandable. In China, cancer is now the leading source of death and coal pollution a mounting concern. A Ministry of Health survey of 30 cities and 78 counties that was released in 2007 reveals a rising tide of cancer.[25] Populations of some ''cancer villages'' are being decimated by the disease. The new reality is that each year as China grows richer and sicker, the Chinese leadership is becoming increasingly concerned not only with the cancer epidemic but also with the sharp rise in birth defects.[26] However, China's concerted push into alternative energies also has a lot to do with its vulnerability arising out of huge dependence on imported oil, most of which flows through the choke point of the Strait of Malacca, aptly termed as China's ''Malacca Dilemma''. Further, primary dependence for its future energy needs on a politically unstable Middle East is also not a reassuring thought amongst China's strategic thinkers.

As a result, investments in the Chinese renewable energy market are driven by various renewable energy policies and incentives provided by the government. Total investments in renewable energy industry in China have increased from $163 million in 2002 to around $11.48 billion by 2009 at a compound annual growth rate (CAGR) of 84 per cent. Government support in the form of supportive policies is expected to further drive the future investments in renewable energy sector in China. It is expected that the investments will grow to around $42.25 billion by 2015. By contrast, investments in renewable energy industry in India have increased from $94.58 million in 2001 to around $7.17 billion by 2009 at a CAGR of 72 per cent. The investment in renewable energy sector in India is expected to grow from $7.17 billion in 2009 to around $26.74 billion in 2015, at a forecasted CAGR of 24.54 per cent.[27]

The Future of Energy

As elucidated in the introduction to this paper, the geological handwriting on the wall is clearly visible. Discoveries of conventional oil total roughly two trillion barrels, of which one trillion have been extracted so far. By themselves, however, these numbers miss a central point. As security analyst Michael Klare notes, the first trillion barrels was easy oil: ''oil that's found on shore or near to shore; oil close to the surface and concentrated in large reservoirs; oil produced in friendly, safe, and welcoming places''. The other half, Klare notes, is tough oil: ''oil that's buried far offshore or deep underground; oil scattered in small, hard-to-find reservoirs; oil that must be obtained from unfriendly, politically dangerous, or hazardous places''.[28]

Whereas the twentieth century was marked by the globalisation of the world energy economy as countries everywhere turned to oil, much of it coming from the Middle East, without doubt, this century will see the localisation of energy production as the world turns to wind, solar, tidal, geothermal and other forms of energy. Renewables, by 2009, comprised fully one quarter of global power capacity from all sources and delivered 18 per cent of global electricity supply.

The moot question is: *Can the world scale up renewable energy use fast enough*? Necessity and technology are the determining factors. Recent trends in the adoption of mobile phones and personal computers give a sense of how quickly new technologies can spread. Once cumulative mobile phone sales reached one million units in 1986, the stage was set for explosive growth, and the number of cell phone subscribers doubled in each of the next three years. Over the next 12 years the number doubled every two years. By 2001 there were 961 million cell phones – nearly a 1,000-fold increase in just 15 years. And now there are more than four billion cell phone subscribers worldwide.[29] Sales of personal computers followed a similar trajectory. In 1980 roughly a million were sold, but by 2008 the figure was an estimated 270 million – a 270-fold jump in 28 years.[30] We are now seeing similar growth figures for renewable energy technologies. Installations of solar cells are doubling every two years, and the annual growth in wind generating capacity is not far behind. Just as the communications and information economies have changed beyond recognition over the past two decades, so too will the energy economy over the coming decades.

The potential of these technologies to create jobs is also a major contributory factor. In the United States, President Obama has made "green jobs" a centerpiece of his economic policy, and many state governors have done the same. In financial markets, renewable energy now appears prominently on the computer screens of investors across the globe – symbolised by Bloomberg LP's decision in December 2009 to purchase New Energy Finance, the world's leading renewable energy analysis firm.[31]

Before he was elected as the US President, Barack Obama wrote to Prime Minister Manmohan Singh on 23 September 2008:

> *"We also should be working hand-in-hand to tap into the creativity and dynamism of our entrepreneurs, engineers and scientists to promote development of alternative sources of clean energy. Imagine our two democracies in action: Indian laboratories and industry collaborating with American laboratories and industry to discover innovative solutions to today's energy problems. That is the kind of new partnership I would like to build with India as President".*[32]

Indian policy-makers must grab this moment to recreate the conditions analogous to those that engendered India's software exports in the mid 1990s. Placing India to be a player either through research or as the research back office, will lead to leveraging the next technology boom, which is both inevitable and imminent. If managed successfully, this partnership with US can result in substantial economic and financial gain for India.

Conclusion

Buoyed by hundreds of new government energy policies, accelerating private investment, and myriad technology advances, renewable energy is breaking into the mainstream of energy markets. Continued progress, even in the face of a steep global recession that has reduced annual world energy use for the first time in three decades, suggests that renewable energy now has tremendous forward momentum that is likely to yield continued progress and many surprises in the years immediately ahead. The arrival of such alternative energy options will have serious geopolitical consequences, as much as the discoveries of hydrocarbons which commenced in 1910 in the Saudi

peninsula and the Middle East. The US, being the traditional centre of most advanced research, is expected to harness the renewable energy boom, in order to maintain its technological lead and the resultant employment potential is likely to pull it out of the recession which it has been trying to battle since 2008. India must harness this US policy to its advantage.

Though it is assumed that in this scenario that the geopolitical weight will shift back to the US, it is clear that it is China that is emerging as the front runner. Its planning and execution, insofar as the future gains from renewable are concerned, are awe-inspiring. In 2009, China doubled the investment the US made in clean energy, spending more than $34.6 billion to the US investments of $18.6 billion.[33] It is clear that China is focused to assume the role of leader in renewable energy capacity and investments that will enable it to diversify its energy sources and have attendant environmental and health benefits. If such measures enable China to diminish its oil ''insecurity'' and the attendant Malacca dilemma, it would serve to accelerate its creeping assertiveness towards India and other SE Asian nations. Further, with rare earth minerals absolutely crucial to the development renewable energy economy, the potential advantage for China is quite promising, as it is the most richly endowed country. This issue also has a positive long-term impact on China's burgeoning military power, since rare earth metals are also widely used for military applications, like tank navigation systems, radar, and missiles.

In the second half of 2010, when the world news was dominated by the substantially damaging oil spill in the Gulf of Mexico, coal mine accidents in Chile, unprecedented forest fire generated smog in Moscow, and oscillating fuel prices, renewable energy was a rare good news story. The trends elucidated in this paper point to the unfolding story of this game changing technology, which is hitting a tipping point, with far-reaching implications for the global economy, environment and geopolitics, especially in India's extended neighborhood. There is a need to keep a close watch on these developments.

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