Issues in Science, Technology and Resource Security in Asia

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Contemporary scientific and technological developments in Asia provide an important context with which to understand the ongoing intellectual and policy debates defining the global security environment and the institutional and structural future of global politics.[1]

One primary node of the discourse revolves around the modern state and its ability to provide security and prosperity for its citizens in a hyperconnected world burdened with growing transsovereign concerns. There is growing consensus in the literature that the state is undergoing transformation as it responds to challenges that are specifically global in scope. One such concern is resource scarcity. The combined pressures of globalization, economic growth, population increase, urbanization and climate change are driving the enormous demand for water, energy and food, but supplies of these resources are rapidly dwindling. Three conditions underpin resource scarcity as a national strategic priority. First, most of these resources are existential in nature – water, energy and food are essential to life and therefore directly impact human security. State provision of these resources to its citizenry is a core national interest. Second, resource scarcity is interwoven with environmental concerns derived from climate change, itself an emerging global security issue because of its potentially catastrophic impact on the planet. And third, existing solutions to resource scarcity (political, economic, environmental, technoscientific) do not preclude local and/or global conflicts from happening in the future.

Asia animates in full relief the landscape of scarcity. It is at the forefront of the ongoing transformations in international order of type, not degree – towards what India's former Foreign Secretary posits is a "more pluralistic, non-European, non-Western world" where its dynamic economies have "retaken control of vast resources, huge assets, big markets, are generating surplus capital, and are less dependent on imported innovation, capital inflows, development aid and technology."[2] The state is overwhelmed by the number of challenges it will need to manage. As the world's fastest growing region, demand for water for energy and industrial use is projected to rise the highest among the world's regions at 78% between 2000 and 2030.[3] The region is also the world's most populous and hyper-urbanizing, with a rapidly expanding affluent middle class that tripled in size between 1990 and 2005[4] and is still expected to grow in the decades to come: this means a shift in consumption patterns, diets and resource use of its population that will only increase food and energy requirements. Fulfilling these enormous demands will further aggravate pressures on the degrading ecosystem. Lastly, the region is heavy on geopolitics, rife with traditional security dilemmas and the location of the world's rising regional/global powers, India and China. The strategic picture of Asia will not be complete without taking full measure of the linkage between resources and the region's geopolitical giants.

As a core component of national security, science and technology (S&T) is an essential element of state responses to the growing challenge of resource scarcity. Among Asia's emerging and developed economies, these responses derive from two major strategies – extraction and adaptation – that Michael T. Klare discusses in his most recent book.[5] Klare maintains that the world economy is now entering into a period of what he calls the "tough" extraction for increasingly scarce natural resources, and that this scramble for what is left will be "one of the defining political and environmental realities of the 21st century.[6] He suggests that the "race to adapt" to develop efficient, environmentally industrial processes and transportation systems presents a better alternative[7] to resource scarcity management.

I build upon these two constructs in this paper and examine their technoscientific articulations in the Asian setting. The purpose is two-fold: first, to identify and examine the S&T dimensions of the current security environment in Asia; and second, to provide empirical substantiation to the assertion that the nature of global affairs is evolving. Yes, state sovereignty continues to structure international dynamics and great power politics still matter. But the growing list of transnational security problems, the emergence of non-state entities as key actors in tackling global problems and the transformative power of technologies are major variables changing the global landscape. Within this context, scientific and technological developments simultaneously shape, are shaped by, and co-produced with, the dynamics of interactions defining the global environment.

This paper is an exploratory effort to acquire a better understanding of the interface of S&T, security and the dynamics of global politics. The actions and decisions of the state in a changing operating environment articulate key parameters of the future, and knowledge and understanding of these variables is valuable towards identifying critical inputs that will shape global dynamics. This inquiry also allows for identifying conceptual trends in Asia. As the region's global position becomes more pronounced, so will the ideas that come out of it carry more strategic weight. These can provide us with contours of the where, why and how of conflict and cooperation in the future. From a theoretical standpoint, the objective of this paper is to substantiate the growing consensus among scholars of international relations and security theorists for the need to revisit existing conceptual approaches and sustain the ongoing dialogue that aims to draw out new constructs to analyze and understand the empirical realities of global politics.

MANAGING RESOURCE SCARCITY

Extracting in a world of resource scarcity

Countries and multinational resource companies – jointly or independently – are leading the way to extract water, energy, minerals and buying up or leasing land for agricultural projects – "global land grabs," as Klare puts it.[8] No place on earth is left unexplored, from the deep oceans, the Arctic, war zones such as Afghanistan, to the 'last frontiers' of Asia and Africa. In Asia – China, India and the smaller, developed economies of South Korea and Japan are leading the region in global extraction activities, particularly in the acquisition of energy resources (oil and gas). Oil and gas extraction is underpinned by national energy security strategies containing the following features: the expansion of oil and gas pipeline diplomacy, increasing competition for potential offshore supplies, governmental support for foreign investments by their own national oil companies (NOCs) and concern over the security of sea lanes.[9] For China and India, energy security is a strategic requirement inherent in their growing geopolitical status, and oil and gas pipeline diplomacy is a critical strategy to enhance their positions vis-à-vis their power rivals, neighbors and the rest of the region. The strategic point of departure is that, as Malik points out, "every international order is based on an energy resource," making great power rivalries as "essentially struggles for resources."[10] China's plans to create a hub-and-spokes economic system linking itself via a network of pipelines, railroads and highway transportation systems to Central, Southwest and Southeast Asia is a strategy designed to bring in raw materials and energy resources to China and as a conduit to export Chinese manufactured goods to those regions and beyond.[11] In May 2012, perhaps lesser in scope but carrying the same intention, the national oil companies (NOCs) of India, Pakistan, Afghanistan and Turkmenistan signed the historic gas sale purchase agreement (GSPA) through the so-called "peace pipeline" – the $7.6-billion Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline that regional observers say will not only reshape regional energy cooperation but will transform regional political dynamics as well. The over-all effect of these Chinese and Indian regional energy engagements can only enhance their status as power center of the region.

The scientific and technological dimension of resource extraction bears out the interplay of geopolitics, resource competition, the role of the NOCs, and sea lane security in two ways: as critical tools in energy resource extraction and appropriation, and as component of the country's capabilities to protect the resources themselves. Innovations in extraction technologies, such as those used in deriving oil from tar sands and deep-water explorations, are emerging as major requirements for securing energy sources. For instance, China intends to further develop deep-water exploration capabilities within the context of its territorial claims in the South China Sea (SCS).[12] As relative newcomers in deep-water exploration, China's powerful quasi-governmental NOCs are taking the lead to improve Chinese capabilities in this area. Thus far, only the Chinese National Offshore Oil Corporation (CNOOC) possesses deep-sea drilling technology capacity, but this monopoly is expected to be short-lived. Because foreign private companies are the primary source of global expertise on deep-sea drilling, the NOCs have taken to either buying out or partnering with these foreign firms to acquire and build technological capabilities. CNOOC has provided a great precedent – it produced what is considered as a significant advancement in China's deep-water exploration capabilities – the "981" drilling platform that it completed in 2011. Insiders have sighted technological barriers as one of the reasons why China has not fully engaged in the SCS, so one can posit that as its NOCs develop their exploration and extraction technology base, it is highly likely that Chinese presence in the SCS will become more pronounced. China's development of its technology base via foreign acquisition speaks to a trend that will become more pronounced in other countries as competition for resources intensify. For instance, India's Oil & Gas National Corp. (ONGC) partnered with ConocoPhillips this year for deep-water and shale gas exploration off of India's coast. ONGC will provide the local knowledge about the basins, while ConocoPhillips will share its knowledge to "unlock that potential and bring it to production," according to ConocoPhillips' global geosciences chief.[13]

The ongoing SCS disputes bring to the fore how a country's military can be involved in resource extraction activities: protecting resources by providing the necessary assets for a safe and secure operating environment. Having moved to the top of Asia's security agenda, scholars of the region argue that tensions in the disputed territories are likely to escalate as competition for oil and gas intensifies.[20] This dispute is seen as one of the drivers of the technological development and acquisitions of the claimants and their allies as the "militarization of the dispute continues apace."[21] Indeed, the ASEAN nations' ramp-up of military modernization activities of late has partly been attributed to the combination of competing territorial/EEZ claims and China's increasing presence in the SCS.[22]

There is also an emerging race in deep-sea mining for rare earth elements (REEs), which are key ingredients used in high technology manufacturing, e.g., hybrid cars, lasers, aviation, smart phones, clean-energy technologies and defense technologies. China controls about 95% of the world's output of these minerals, and in 2009 and 2010 made a series of policy decisions that tightened its exports of these elements, citing protection of its natural resources, environmental concerns, excessive exploitation and illegal mining as reasons for their REE strategy.[14] Seriously concerned about this development, the U.S., Japan and the European Union (EU) filed a complaint to the World Trade Organization (WTO) in March alleging that China was using the exports restrictions on REEs as an economic and political weapon, i.e., to protect domestic manufacturing and as a retaliatory measure against Japan for the latter's detention of a Chinese fishing boat captain when his boat collided with two Japanese Coast Guard vessels near the contested Diaoyu/Senkaku Islands in 2010.

China's REE strategy served as a wake-up call for other countries whose response was multi-pronged: Japan, India and the U.S. established R&D programs on deep-sea prospecting, initiated searches for alternative deep-sea deposits in the region and started programs that developed technologies to improve prospects for mining undersea metals. In June 2012, Japan announced its discovery of a large deposit of REEs in its Pacific seabed, estimated at 6.8 million tons, enough to supply Japan's high-tech industries for at least 200 years.[15] Concerned about having China suspend their REE supplies yet again in light of the ongoing island disputes, Japanese companies are resorting to innovation to lessen their dependence on China: according to the *Asahi Shimbun,* Japan's largest newspaper, Honda Motor Corp. is planning to "start extracting rare earths from nickel-metal hydride (NiMH) batteries used in hybrid vehicles," i.e., to recycle rare earths from its existing products.[16] The establishment of mining companies in several countries has also facilitated technology transfer and diffusion. For instance, when Colorado-based Molycorp acquired China-based Neo Materials, the purchase included the company's technology needed to provide the more purely refined rare earth oxides used in computer, defense and telecommunications equipment.

Given the level of deep-sea mining technology right now, commercialization of any recently-discovered deposits will take years. Innovations will be critical: the minerals are found deep beneath the seabed (5,600 m) and difficult to find in profitable concentrations.[17] Petroleum extraction technologies are currently used, but they are not optimal. Leading-edge advantage will accrue to countries or firms who are able to develop technological innovations that can accelerate deep-sea mineral extraction while doing this safely and cheaply. This is one node of the REE technology race in the next decades. Already, India's recent decision to enter into the REE race in the deep sea includes a plan to bring together marine science experts and engineers in nuclear energy, space research and defense to help expedite the innovation process for REE extraction. Its marine science programs are leading the study of the seabed as well as test mining that has already reached depths of 6,000 m. Another node of the technology race will be the capacity to master, integrate and innovate upon large technological systems that will allow a country to maintain or enhance its relative power position in the international system. To illustrate: China's state-owned venture Ship Scientific Research Centre unveiled what could be an initial foray into large-scale underwater mining with the development of a deep-sea station. Earlier this year it announced plans for a nuclear powered mobile deep-sea station; its *Jiaolong* manned submersible already reached depths of 7,000 m.[18] The creation of a deep-sea station embodies advanced technological capabilities in numerous fields, e.g., maritime, space, nuclear, materials, extraction, defense.[19] On a strategic level, this plan, if realized, is not only a material manifestation of S&T leadership; it also adds another dimension for geopolitical engagement in the maritime domain.

Adapting to Resource Scarcity: Clean-energy on the Rise

Alongside the increasing urgency to extract and appropriate scarce resources, countries are also pursuing the adoption of "new materials, methods, and devices" that would "free the world from its dependence on finite resource supplies."[23] One major policy initiative among countries is the prioritization of green or clean-energy innovation[24] as a strategic component of national economic, environmental, and science and technology (S&T) development plans. Worldwide, clean-energy has come into its own only in the last decade or so and continues to experience growth in the face of daunting challenges[25] in the form of high costs and inadequate global investment. Nevertheless, Asian countries are beginning to institutionalize their commitments to clean-energy, with China leading the effort in terms of total investment and technological development. Southeast Asia nations such as Indonesia, Vietnam, Thailand and Malaysia have started to put green policies in place.[26] In India, the government's annual Economic Survey 2011-2012 included, for the first time, a chapter on sustainable development and climate change that contains a proposal for lower-carbon sustainable growth as a central element of India's 12th five-year-plan.[27] Its investment in green industries is expected to increase to $70B in 2015 from a projected $45B in 2012.[28]

In 2008, South Korea's government declared green growth as a national development model and is focusing on synergizing the country's economic development and environmental protection by striving for a low-carbon green economy that promotes investments in resource savings and other environmental growth sectors. Japan's New Growth Strategy, first approved in December 2009 and revised in June 2010, is the government's guiding policy underpinning its current economic recovery plan that puts increased focus on fast-growth sectors, including renewable energy, green vehicles, farming and healthcare. The Fukushima triple catastrophe also paved the way for the Noda cabinet to endorse the 2012 white book on the environment that specifically calls for power generation in the Tohoku region through renewable energy sources using wind and solar power.

China spent $54B in low carbon energy technology in 2011, making it the world's largest investor, surpassing the $34B investment of the U.S.[29] Of its seven strategic emerging industries identified in its "12th Five-Year Development Plan for National Strategic Emerging Industries (2011-2015), three – alternative energy automotive, energy-saving/environmental protection and new energy – are in the green energy sector.[30] Its increasing investments in clean technology in recent years have started to pay off: China is now either more advanced than, or provides serious competition to, American technologies in its low-emission coal energy plants, third and fourth generation nuclear reactors, high-voltage transmission lines, alternative-energy vehicles, solar and wind energy devices.[31]

Adopting green or clean-energy innovation draws out a distinct S&T profile. First, in contrast to non-renewable, finite energy resources (oil and gas) that are concentrated in specific geographic areas and thus found only in a limited number of countries, renewable sources and significant potentials for energy efficiency exist virtually everywhere, so a country's renewable source and capacity are significantly determined by its natural resource endowments.[32] Reduced energy intensity and the geographical and technological diversification of renewable, sustainable energy sources[33] thus offer great opportunities for enhancing national energy security, government capacity to support local business endeavors and the delivery of public services to local communities. For instance, South Asia's high insolation and dense populations make solar power an ideal renewable energy option and allow government companies such as India's National Solar Mission to support large-scale deployments of solar power[34]. This natural solar power advantage and falling solar panel/LED costs also make it profitable for local companies to build and operate low-cost solar-powered microgrids that provide clean light and charge phones to rural villagers[35]. The use of indigenous renewable resources in concert with grassroots technopreneurship that deliver accessible and low-cost solutions to the base-of-the-pyramid population articulate an emergent paradigm of innovation in Asia, the site of significant green growth as global leadership in renewable markets shifts towards the region's developing economies. In contrast to the dominant model of innovation that uses indicators such as numbers of scientists and engineers, amount of R&D investment and numbers of scientific publications and patents produced to measure the innovation capability of countries, the emerging "grassroots" paradigm offers alternative indices of innovation capability. This include the production of indigenous solutions to serve the needs of the majority lower-income populations, the extent of outside-the-lab innovations, and the presence of institutional and organization innovations that enable co-creation and cooperation to create reach, reduce costs and deliver products and services to the majority of the people.[36] The focus is on simplicity and frugality in the process of innovation as opposed to the expensive innovation in the conventional paradigm that features, among others, large resource and facility investments and highly qualified and educated personnel.[37] Recognizing the growing importance of the green growth-innovation nexus, the annual Global Innovation Index (2012) included, for the first time, "ecological sustainability" as a key pillar of innovation input.[38] This indicator will be a defining feature of evolving S&T systems in the future, effectively housing notions of grass-roots innovation and renewable energy adoption.

Second, clean-energy is increasingly socialized and politicized as a critical component of climate change, food and water security. The borderless and existential nature of these issues has stepped up transnational commitments, marked by the growing presence of non-state stakeholders in the 'green' discourse. The interactions of state and non-state actors are giving rise to a complex network of institutions facilitating S&T transfer and diffusion that are helping to spur innovations in clean-energy. While these interfaces and the security issues mentioned above are not new features of international engagement, using the water-energy-food-climate change "nexus approach"[39] to frame sustainability is a relatively new approach, especially in terms of developing 'nexus S&T' solutions that harmonize innovation efforts across the security issues. In this respect, clean-energy innovation will most likely be a part of integrated technological solutions to address resource scarcity and sustainability.

Finally, states do matter. In Asia, the state is the main driver for clean-energy development. It is crucial in promoting international S&T cooperation and sustaining the momentum for innovation particularly the central role it plays in the protection of intellectual property rights (IPR). Among Asia's emerging economies, IPR is still a maturing regime. Even China, poised to become a global leader in various S&T areas including clean-energy, is challenged by a weak culture of IP protection. Asia's expected lead role in global green growth and innovation will need to be matched by the parallel development of a more effective IPR regime, and the state will be pivotal towards this end.

In the Skyline

This paper set out to examine the scientific and technological dimensions of state responses to the growing challenge of resource scarcity as a way to derive currents filling up the regional and global landscape. The preceding analysis that focused on extraction and adaptation strategies as major ways of enhancing national resource security among Asia's emerging and developed economies bears out the analytic point of this paper that the emergence of transnational security problems, non-state actors and S&T developments are key drivers of change in global affairs. From their dynamic linkage we derive several propositions:

- Interstate competition for scarce resources will continue to create tensions between countries and will be a long-standing feature of the region's security landscape. The converging triad of ever-increasing domestic energy demand, the NOCs' improved extraction technology capabilities and geopolitical/sovereignty considerations will heighten maritime tensions in the region;
- The quasi-governmental NOCs will likely play a greater, more independent role not only in territorial disputes but in shaping national energy policy;
- A strategic alliance coalescing around scarce resources is distinct from a strategic alliance based on S&T capabilities. In the long run, and within the context of climate change, power and wealth will accrue not from control over dwindling resource supplies, but from the mastery of new S&T areas embedded in effective S&T alliances;
- Global S&T leadership will critically depend not just on success with individual technologies or particular scientific fields, Deep-sea mining and clean-energy innovations

highlight the trend for technological systems integration – this converges with the growth of S&T interdisciplinary fields underpinned by the continuous development of IT.

- With their strategic focus on advancing green capabilities, the emerging economies of Asia will become major sources of indigenous, clean-technology innovations, among others; in this context, the region will be a major source of game-changing developments, disruptive innovations and technological surprises;
- The 'vulnerability and risk' construct of a green economy is yet to be fully examined; green technologies for one will most likely generate dual-use concerns;
- National core interest management is increasingly dependent on the cumulative activities of multiple non-state actors, so public-private partnerships will continue to flourish. It is possible that this relationship will provide the nucleus for new forms of governance structures. While the state's power and authority are bounded by territory, the power and authority of transnational entities who operate beyond the state's control lie in their networked capacity to move people, ideas, beliefs, money, technology and other resources in and out of the state's territory;
- The nexus of energy-environment-economic security suggest that a systemic approach to transnational security issues will provide more comprehensive and optimal solutions.

Globalization is a permissive environment, engendering the creation and re-invention of actors, institutions, processes and issues. The dynamics around resource security and the role of science and technology in managing resource scarcity illustrate tight and explicit linkages between geopolitics, S&T and economics that produce new settings and conditions with significant implications for global affairs. While it is clear that the state and the international system are undergoing transformations, there is no consensus on what the shape of the future global landscape will look like, but the issue of resource scarcity does sketch out some important variables and developments that will matter in the decades ahead.

Notes

1. Some recent works include Deborah D. Avant et al., eds. *Who Governs the Globe?* (Cambridge: Cambridge University Press, 2010); Sai Felicia Kirshna-Hensel, *Order and Disorder in the International System* (England: Ashgate Publishing Limited, 2010); David A. Lake, "Rightful Rules: Authority, Order, and the Foundations of Global Governance," *International Studies Quarterly* 54, No. 3 (September 2010): 287-613; James P. Muldoon Jr., et al., eds. *The New Dynamics of Multilateralism: Diplomacy, International Organizations, and Global Governance* (Boulder CO: Westview Press, 2011); Joseph S. Nye, Jr., The Future of Power (New York, NY: Public Affairs, 2011); Jennifer Shkabatur, *The Changing Role of International Organizations in the Information Age*, *http://works.bepress.com/jennifer _shkabatur/1*; and Beth Simmons, "International Studies in the Global Information Age," *International Studies Quarterly* 55, No. 3 (September 2011): 589-885.

2. Krishnan Srinivasan, "Languishing Europe and emerging Asia," *The Statesman,* Feb 10, 2012.
3. World Economic Forum Water Initiative, "*The Bubble Is Close to Bursting"* (2009).

4. Economist. "The ever-expanding middle-class in developing countries," (September 1, 2011).

5. Michael T. Klare, *The Race for What's Left: The Global Scramble for the World's Last Resources* (New York, NY: Metropolitan Books, Henry Holt and Company, LLC, 2012). Klare's book focuses primarily on extraction.

6. Ibid. See also a transcript of a Klare interview: Diane Toomey, "Global Scarcity: Scramble for Dwindling Natural Resources," May 23, 2012, *http://e360.yale.edu/feature/global_scarcity_scramble_for_dwindling_natural_resources/2531/*. Another reference on resource scarcity is Fred Pearce, *The Land Grabbers: The New Fight over Who Owns the Earth* (Boston, MA: Beacon Press, 2012).

7. Klare, 227.

8. Ibid., 183.

9. Philip Andrews-Speed et al., "Oil and Gas for Asia: Geopolitical Implications of Asia's Rising Demand," *NBR Special Report* #41 (September 2012): 3.

10. Mohan Malik, "Technopolitics: How Technology Shapes Relations Among Nations," *Science, Technology and Security: Areas of Concern Now and Ahead, Workshop Proceedings* (Honolulu, HI: APCSS, 2010), 23.

11. Ibid., 23-24.

12. Discussion of China's deep-water exploration in this paragraph is referenced from: International Crisis Group, "Stirring up the South China Sea (I)," *Asia Report* 223 (April 23, 2012): 25-26 (See also Footnote 281 of this report).

13. "ONGC, ConocoPhillips ink MOU on India deepwater exploration, shale gas," April 1, 2012, *http://www.plats.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/7434366*.

14. Biman Mukherji and Tom Wright, "India bets on rare-earth minerals," *Wall Street Journal*, August 13, 2012, *http://online.wsj.com/article/SB10000872396390443437504577546772533972202.html*. China blocked off Japan's supply of these minerals for two months in 2010 as a result of their skirmishes in the East China Sea.

15. Agence France-Presse, "Japan finds 6.8 million tonnes of rare minerals used in electric cars, iPods and lasers," June 29, 2012, *http://www.rawstory.com/rs/2012/06/29/japan-finds-6-8-million-tonnes-of-rare-minerals-used-in-electric-cars-ipods-and-lasers/*.

16. Stephen Robert Morse, "China's Monopoly on Rare Earth Mining and Exports Erodes," Sept. 27, 2012, *http://www.theatlantic.com/sponsored/bank-of-america/archive/2012/09/chinas-monopoly-on-rare-earth-mining-and-exports-erodes/262938*.

17. The minerals are found in a concentration of about 0.1 percent or 1kg per ton. See Michael Rundle, "Japan Discovers Massive Rare Earth Mineral Deposits Under Pacific Ocean," June 29, 2012, *http://www.huffingtonpost.co.uk/2012/06/29/japan-discovers-massive-rare-earth-min_n_1637140.html*.

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19. One can argue that India's plan to expedite REE extraction is following a similar trajectory.

20. Ian Storey, "Asean Is a House Divided," *The Wall Street Journal*, June 14, 2012, *http://online.wsj.com/article/SB10001424052702303734204577465861459787498.html*. See also Richard A. Bitzinger, "A New Arms Race?: Explaining Recent Southeast Asian Military Acquisition," *Contemporary Southeast Asia: A Journal of International and Strategic Affairs* 52, No. 1 (April 2010): 50-69.

21. Storey, "Asean is a house divided."

22. R. Bitzinger, "A New Arms Race."; see also Renato Cruz de Castro and Walter Lohman, "Getting the Philippines Air Force Flying Again: The Role of the U.S.-Philippines Alliance," *The Heritage Foundation Backgrounder* #2733, September 24, 2012, *http://www.heritage.org/research/reports/2012/09/getting-the-philippines-air-force-flying-again-the-role-of-the-us-philippines-alliance*.

23. Klare, 227-234.

24. I will use these terms interchangeably in this paper.

25. International Energy Agency, "Clean Energy Progress Report," (Paris, France: OECD/IEA, June 2011): 11.

26. Martin Abbugao, "S.E. Asia urged to exploit abundant clean energy," February 22, 2011, *http://www.google.com/hostednews/afp/article/ALeqM5gMEPexBrKKotpyJIlXI3lFTnFGNw?docId=CNG.a9752ab9a9ad29f39dac145a6ef0e9bf.301*. See also Alexander Lenz, "Southeast Asia embraces solar power," August 17, 2011, *http://siew.sg/energy-perspectives/alternative-energies/southeast-asia-embraces-solar-power*. The exception in Southeast Asia is Singapore whose "Green Plan" has been in place since 1992 – see "The Singapore Green Plan 2012," *http://www.mewr.gov.sg/sgp2012/about.htm*.

27. Jamie Yap, "India's green IT, sustainability spend [sic] to hit $45B in 2012," October 3, 2012, *http://www.zdnet.com/in/indias-green-it-sustainability-spend-to-hit-45b-in-2012-7000005150/*.

28. Ibid.

29. "China Beats United States in Green Technology Innovation," December 11, 2011, *http://usgreentechnology.com/us-green-stories/china-beats-united-states-in-green-technology-innovation/*.

30. "China adopts new plan, highlights emerging industries as drivers of economic growth," June 12, 2012, *http://thecleanrevolution.org/news-and-events/news/china-adopts-new-plan-highlights-emerging-industries-as-drivers-of-economic-growth*.

31. Micah Springut, Stephen Schlaikjer and David Chen, *China's Program for Science and Technology Modernization: Implications for American Competitiveness* (Arlington, VA: Centra Technology, Inc., 2011): 129.

32. International Energy Agency, "Energy Technology Perspectives 2012: Pathways to a Clean Energy System, Executive Summary," (Paris, France: OECD/IEA, June 2012): 1.

33. Ibid.

34. Deployment will begin in 2022. See Michael Levi et al., "Globalizing the Energy Revolution," *Foreign Affairs* 86, No. 6 (November/December 2010): 113.

35. Seema Singh, "Solar Microgrids," *Technology Review* June 2012 (Cambridge, MA: MIT Press): 39. In this issue of Technology Review, Mera Gao Power, a local Indian company, is featured to showcase solar microgrids as one of the top 10 emerging technologies.

36. Arun Maira, personal communication with Yandaswami Sundara Rajan, cited in Soumitra Doutta, ed. The Global Innovation Index 2012 (France: INSEAD and WPO, Fontainebleau, 2012).

37. Ibid. The two innovation paradigms are of course not mutually exclusive, as developing economies employ both models to improve national innovation capabilities.

38. S. Doutta, ed., The Global Innovation Index 2012, 44.

39. Derived from three recent works: H. Hoff, Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus (Stockholm: Stockholm Environment Institute, 2011); The 2011/2012 European Report on Development, Confronting Scarcity: Managing Water, Energy and Land for Inclusive and Sustainable Growth (European Union, 2012); and Dominic Waughray, ed. Water Security: the Water-Food-Energy-Climate Nexus - the World Economic Forum Water Initiative (Washington, D.C.: Island Press, 2011).