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Contents

The Asian Energy Institute (AEI) is a network of 18 energy institutes from Asian countries. These include Bangladesh, China, India, Indonesia, Iran, Japan, Jordan, Korea, Kuwait, Malaysia, the Philippines, Pakistan, Sri Lanka, and Thailand. Besides, there are 13 associate members, both within and outside Asia. The AEI was formally established in August 1989. Its aims and objectives are to promote greater information exchange; facilitate sharing and dissemination of knowledge; undertake research and training activities that are of common interest to its members; and analyse global energy developments and their implications. TERI hosts the secretariat of the AEI. The secretariat publishes a biannual newsletter that informs the readers about the diverse research activities undertaken by the member institutes. Currently, the AEI is hosting the regional secretariat for Renewable Energy and Energy Efficiency Partnership (REEEP) in South Asia.

Editors Deepti Mahajan and Swati Ganeshan

Editorial

*R K Pachauri**

The Asian scene is changing very rapidly in respect of energy consumption and supply. Both last year's World Energy Outlook 2010 produced by the International Energy Agency (IEA) and the recently released version for 2011 clearly show the enormous growth in energy demand projected for Asia, dominated of course by China and India but with major contributions from other Asian countries as well. There are many changes taking place in the global scenario for energy. While fossil fuels remain the dominant source of energy supply, we find in several countries a major expansion of RE (renewable energy) production and use.

The Intergovernmental Panel on Climate Change (IPCC) brought out earlier this year a Special Report on Renewable Energy Sources and Climate Change Mitigation, in which it found that globally RE accounted for 12.9% of the total 492 Exajoules of primary energy supply in 2008. The largest RE contributor was biomass (10.2%) with the majority (roughly 60%) being traditional biomass used in cooking and heating applications in developing countries, with rapidly increasing use of modern biomass as well. Hydropower represented 2.3% whereas other RE sources accounted for 0.4%. In 2008, RE contributed approximately 19% of global electricity supply with 16% coming from hydropower and the balance 3% from other RE sources. Biofuels contributed 2% of global road transport fuel supply. There are several Asian countries which are investing heavily in renewable energy development and dissemination. Prominent among these are the People's Republic of China, the Republic of Korea and India. However, with the growth in demand for fossil fuels, Asia would have to manage this segment of energy production and consumption in a manner that enhances efficiency substantially. Such a change can only be achieved with major changes in the energy consuming sectors such as transport and buildings which present choices of technology with significant scope for improving energy efficiency.

Asia has to carve out a unique path of development and some countries are already focusing on low carbon and green growth development. Prominent among these nations is the Republic of Korea which has set up a Global Green Growth Institute with sizeable commitment of funding.

One major driver of change in the energy sector would be considerations for reducing emissions of greenhouse gases (GHGs). As it happens, the reduction of GHGs is accompanied with several co-benefits including improved health as a result of lower pollution at the local level and higher levels of energy security resulting from greater levels of efficiency in the energy cycle as well as a shift towards renewable sources.

Against the backdrop of imperatives for change, there is a much greater need today for cooperation among research institutions and think tanks in the Asian region than has been the case in the past. Conventional solutions are not going to provide answers to the challenge that Asia faces on the energy, environment and sustainability front. There is a need for thinking out of the box and charting out new paths which can only be done with substantial intellectual effort. It is for this reason that the Asian Energy Institute network now acquires a renewed relevance and importance. Indeed, there is perhaps need for redefining the charter for the AEI which reflects the new realities both at the global level as well as in Asia. The Secretariat of the Institute is seized of this challenge and hopes to initiate some changes as a consequence.

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The new energy order and its impact on the energy policy of Asian countries

*Nandakumar Janardhanan**

The world is at a crossroads of a new energy order, which is characterized by many challenges. The following are a few of them: (1) the already existing global energy supply systems[1] are unable to meet the growing demand in many countries, (2) major economies are facing tremendous environmental pressures to minimize fossil fuel consumption and energy-related emissions, (3) clean energy sources are increasingly preferred, but have been lacking the required innovation and technological breakthrough that could democratize their access, and (4) many new nations had begun to build new nuclear reactors, signalling industry growth despite increasing concerns about the safety and security of the facilities. Apart from this supply-strained energy dynamic, two recent developments could potentially stress the global energy sector further. First, the ongoing turbulence in the global petroleum market due to the "Arab Uprising"[2] could jeopardize the energy security of petroleum-import-dependent countries; second, the unexpected shock to the resurgence of the global nuclear energy sector, consequent to the radiation issues at the tsunami-hit Fukushima nuclear facilities in Japan, has ignited serious questions about the efficacy of the safety and security systems of nuclear facilities. These two challenges have not only raised concerns in the countries, which are directly affected, but also among the economies that do not even have any geographical proximity to the affected regions. As a result, many foresee potential changes in the future energy policies of many countries, arising from the need to cope with the changing global energy dynamics.

The Arab Uprising and Fukushima incident represent two different types of challenges to two of the most important energy sources in the world today, namely petroleum and nuclear. These two sources enjoy significant importance in the global primary energy mix. Following the recent developments, one of the most important questions, which emerged is what are the short-term and long-term impacts of these events on global economies, particularly among Asian countries?

Petroleum amounted to almost 60% of the total commercially-traded primary energy in the world in 2009. This shows the extent to which oil and gas together play an undeniable role in global economic activity and how they cannot be replaced with any other energy sources available today. The Middle East and Africa together account for more than 66% of the global oil reserves and about 48% of the global natural gas reserves. In 2009, the regions together produced 42% of the world's daily oil supply and about 20% of the daily natural gas supply. This indicates that any significant interruption to the oil and gas supply could constitute a major challenge to the energy security of many countries. However, the ongoing Arab Uprising, in its current form, may not have a large-scale impact on the global petroleum market, especially because the problems are limited to certain petroleum producers. Though Libya is a major petroleum producer in the African region its percentage contribution to the supply to Asian countries remains well below 10%. There is also pressure from producing countries to ensure continued supply of oil to the market, as uninterrupted market access is critical in order to maintain their energy security.[3] From the consumer point of view, these regions, especially the Middle East, are seen as politically volatile since the 1973 Arab oil embargo. Importing countries have been adopting various strategies, such as diversifying supply regions, developing strategic petroleum reserves to meet emergency requirements, increasing domestic production, and diversifying supply sources. Though these measures would not offer any complete immunity to supply shocks, the impact of energy supply crunches would be mitigated to a certain extent. Hence, the future energy policies of major import-dependent countries in the world are highly unlikely to undergo any immediate restructuring to adjust to perceived energy security challenges. In most cases, existing energy policies would continue, while encouraging a higher share of domestic energy sources, including renewable energy. Another significant development could be that more investment will be expected in energy technology R&D in order to increase the supply of domestically available energy sources, as well as to boost energy saving and efficiency improvement.

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1 Various supply sources, such as petroleum, renewable, and nuclear energy.

2 Ongoing political volatility in the Middle East and North African region. The region's importance in the global energy map makes the political unrest a major concern to the petroleum-importing countries across the world.

3 While the energy security of an import-dependent country can be defined as "ensuring uninterrupted fuel supply at affordable cost", the energy security for a producer is defined as "ensuring a stable market for their energy produce at a cost profitable to them".

In the wake of recent developments, the global nuclear industry would face certain challenges to its planned expansion in the short term, mostly stemming from the anti-nuclear public sentiment. The four reactors at Fukushima Daiichi damaged in the 3/11 tsunami, accounted for about 2,700 MW of installed capacity, approximately 6% of the total nuclear installed capacity in Japan. More severe was the concern raised due to the radiation leak that occurred in the immediate aftermath of the incident. This has wider implications, in countries currently reviving their nuclear programmes and particularly in those planning to build their first reactors. The incident could have a significant impact on the energy policy of countries in Europe, the continent with the highest number of operating nuclear reactors. The decisions taken by the political leadership in some of the countries indicate that the new build[4] nuclear reactors may face a slowdown in the next few years. Many of the countries planning to begin construction of their first nuclear reactors are facing the heat of the anti-nuclear public sentiment. Asia, including India and China, has a significant number of reactors both under construction and in the planning and proposal stages. Though nuclear energy will continue to be a preferred option in India and China, domestic challenges could be a concern to the industry expansion plans.

As climate change is one of the most important public policy issues facing countries around the world, there are various policies being adopted by countries in order to address these concerns. Of these, limiting anthropogenic greenhouse gas emissions is a significant mitigation measure. Since the use of fossil fuel is one of the major sources of anthropogenic emissions, it is important to promote a climate-sensitive energy policy, which would help countries increase non-fossil fuel sources in their energy mix. Various non-conventional sources, in which nuclear and renewable sources play key roles, are being explored and developed by countries as part of their diversification efforts. The recent developments in the energy sector will have certain impacts on the climate policies of developing Asian countries, such as India and China. This is primarily due to the potential changes in energy targets necessary in order to meet environmental goals. There will be more pressure on countries to explore possible ways to stick to their low-carbon development plans if the nuclear industry expansion faces any significant hurdles. In addition, massive investment in the new and renewable energy sectors will be required in order to increase "non-fossil" energy usage. With respect to Japan, there are various views about the possible course energy policy might take over the coming decades. Japan is the second largest energy consumer in the Asian region and depends on overseas supply to meet more than 90% of its petroleum demand. The limited domestic petroleum resources and few renewable energy generation facilities pose a major challenge to the energy security of the country. However, nuclear energy plays a key role in the electricity supply in the country. With more than 50 operating reactors, Japan has been the largest producer of nuclear energy in the region. Hence, despite the fact that the recent Fukushima incident raises widespread concerns about the potential hazards of radiation among the general public as well as authorities, a substantial reframing[5] is highly unlikely in the short term. This is primarily due to fact that nuclear energy plays a critical role in the day-to-day economic activities of the country. In the long term, the country needs to increase the share of renewable energy in its energy mix.

Conclusion

Among Asian countries, it is unlikely that any drastic change or restructuring of energy policy or fuel choices will occur in the short term. This is primarily due to the fact that the demand for conventional fuel materials cannot be replaced immediately by any other domestic supply sources. Regarding nuclear power in the region, it is unlikely that countries will halt production in the short term, although there is a chance of potential delays to the building of new plants due to the possible demand for enhanced safety regulations. Public concerns on the nuclear sector would continue regarding (1) potential radiation impacts from nuclear as well as uranium facilities, (2) the efficacy of existing civil nuclear liability laws, and (3) safety regulations. With respect to petroleum sources, there may be greater stress from governments for energy conservation and improvement of fuel efficiency. In the long term, low-carbon-source development will continue to guide the economic development plans of these countries and there will be increased attention to alternative energy sources. More significant emphasis may be placed on increasing the investment in R&D, with the goal of improving energy efficiency and fostering innovation and technological breakthrough in the exploration of new energy sources in these countries.

[4] Newly built (New Build) is a usual industry term for reactors that are under construction or under planned stage.

[5] Such as a complete nuclear phase out or replacing the nuclear facilities with other energy facilities.

The energy and water nexus in Asia

*Deepti Chatti**

The importance of energy in improving the economic and social welfare of a country's population is widely acknowledged, as is the role of water in the same. Both resources are considered to be essential building blocks of a healthy, comfortable and productive society. Vulnerability of energy and water to various factors such as climate change is increasingly understood, although separately. Vulnerability of energy and water to each other, however, is yet to be fully understood and addressed. A significant amount of water is needed to produce energy, and a large amount of energy is expended in using water. Both resources are dependent on each other. Policies to improve energy security are unlikely to be successful unless bolstered by the recognition that energy issues are inextricably linked to water. Similarly, water security cannot be achieved unless energy issues are considered in parallel.

An increasingly thirsty and water stressed world

There is no creation of "new water" in the world. There is a finite available amount of water that is repeatedly recycled through the hydrological cycle. Thus, with each passing year and increase in global population, the global per capita water availability constantly decreases making water an increasingly scarce resource. At the same time, global water demand has been increasing not only fuelled by the rapid growth in population but also by rising per capita water consumption rates. In fact, water use has been growing at more than twice the rate of population growth in the world in the last century[1].

Shown in Table 1 is the historic national per capita water availability for the member countries of the Asian Energy Institute (AEI), the average for Asia and the Pacific,

Table 1 Per capita water availability

	Per capita water availability* (cubic metre per year)				
Country	1992	1997	2002	2007	Percentage reduction in 15 years (1992–2007 period)
Bangladesh	10,233	9,205	8,353	7,761	24 %
China	2,391	2,274	2,184	2,130	11 %
Fiji	38,653	36,455	35,132	34,260	11 %
India	2,113	1,913	1,753	1,647	22 %
Indonesia	15,035	13,972	13,050	12,400	18 %
Iran	2,323	2,152	2,041	1,957	16 %
Japan	3,457	3,409	3,373	3,361	3%
Korea (North)	3,713	3,464	3,315	3,254	12 %
Korea (South)	1,594	1,522	1,474	1,451	9 %
Malaysia	30,387	26,768	23,909	22,211	27 %
Pakistan	1,892	1,676	1,501	1,400	26 %
Philippines	7,469	6,692	6,026	5,553	26 %
Sri Lanka	2,852	2,721	2,647	2,603	9 %
Thailand	7,374	6,968	6,647	6,462	12 %
Asia and the Pacific average*	6,252	5,819	5,470	5,224	16 %
World average	10,079	9,372	8,779	8,349	17 %

Notes: * Defined as the maximum theoretical amount of water available to the country, including internal renewable water resources and natural incoming flow originating outside the country; ** Includes non-AEI member countries also.

Source Adapted from Statistical Yearbook for Asia and the Pacific 2009

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[1] Food and Agriculture Organization (FAO) of the United Nations

and the world average. As can be seen from the table, in the fifteen-year period between 1992 and 2007, all AEI member countries experienced a drop in per capita water availability. Some countries saw a decrease in per capita availability of 27%, while others saw a more modest decrease of 3%. The per capita water availability in Asia and the Pacific in 2007 was the second lowest in the world at 5,224 cubic metres per year (m^3/year), significantly lower than the world average of 8,349 m^3/year[2]. This is primarily due to the high population density in Asia. However, this means that Asian countries need to be more cautious with their water resources and implement strategies for efficient resource utilization more aggressively than their Western world counterparts to achieve similar levels of water security.

It is estimated that by 2025, two out of every three people in the world will live in water stressed areas[3]. Additionally, climate change places an added stress on water resources, thereby exacerbating an already grave problem. Figure 1 shows the areas of water stress in the world.

Understanding the energy and water nexus

Several topics come under the gamut of the "energy-water nexus". These include water used to produce energy, energy used to provide water, impacts of energy policies on water, and lastly, impact of water policies on energy. This article will limit its focus to describing the physical dependence of each resource on the other by discussing water used to produce energy, and vice versa. Since that is a substantial topic by itself, this article will not discuss policy interdependence in great depth. However, it will conclude with some pointers for integrated planning and policy-making.

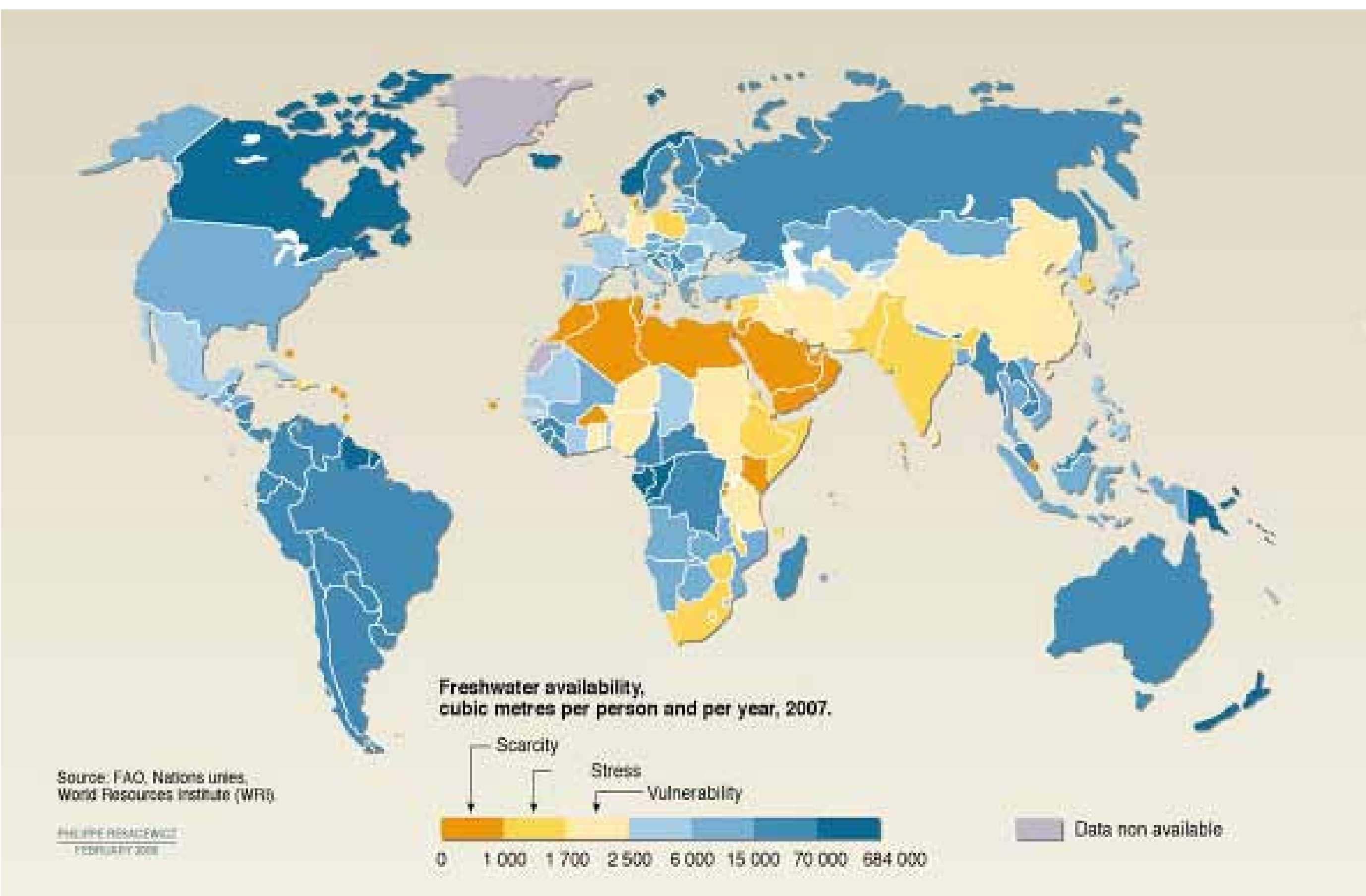

Figure 1 Global water stress and scarcity in 2008
Source *Global Water Stress and Scarcity,* United Nations Environment Programme, http://www.unep.org/dewa/vitalwater/article69.html

[2] Statistical Yearbook for Asia and the Pacific 2009
[3] Vital Water Graphics, United Nations Environment Programme (UNEP)

Water plays a vital role in the production of energy, right from the production of energy raw materials, to the transformation of raw materials into a usable form like natural gas, liquid fuels, or electricity. Energy uses account for approximately 8% of all freshwater withdrawn worldwide, and in some developed countries the percentage is as high as 40%.[4] As countries develop, the generally observed trend is that an increasing percentage of annual water demand is used by energy needs. For example, in 2000, India used 2 billion cubic metres (BCM) of water in the energy sector, which constituted only 0.32 % of the total annual water use. However, in 2010, India used 5 BCM of water in the energy sector, which was 0.62 % of that year's national water use. By 2050, it is projected that the water demand of the Indian energy sector will rise to 130 BCM, and will constitute approximately 9% of the total annual water demand of the country[5]. At the same time, irrigation water demands are expected to rise from 541 BCM in 2000 to 1,072 BCM in 2050, and industry water demands are expected to increase from 8 BCM to 63 BCM. However, the sharpest increase is expected in the energy sector, as shown in Figure 2.

Water use in the energy sector

The energy industry performs three main activities—production of energy raw materials, transformation of the raw materials into a usable form, and delivery of the product to the customers. Water is used in all the three steps, although a majority of the use occurs in the production of energy raw materials, and transformation into usable forms. The amount of water "used" describes the water that is consumed in the activity, although much greater amounts are typically withdrawn from the water source and subsequently returned. This difference is not insignificant; for instance, in the United States, the amount of water withdrawn is 25 times the water consumed[6]. It is important to note that the water withdrawn is a vital number for power plants since that water is required to be available for their functioning. An additional issue of importance is that the water that is returned to the source may be impaired in quality as compared to when extracted.

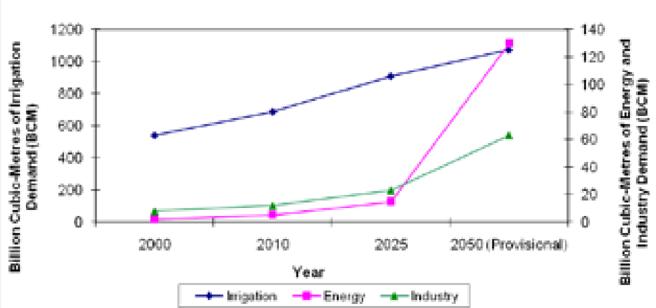

Figure 2 Annual water demands in India
Source Data sourced from Water and Related Statistics, March 2002, Central Water Commission, Ministry of Water Resources, Government of India

In the natural gas and liquid fuels value chain, water is primarily used in the raw materials process. Traditional oil extraction uses the least amount of water, 3–7 litres per gigajoule of energy (L/GJ), whereas enhanced oil recovery (EOR) techniques, or extraction from oil sands use significantly higher amounts, 50–9,000 L/GJ, and 70–1,800 L/GJ, respectively. Regardless of the oil extraction process used, approximately 25–82 litres are needed for refining, and consequently, the production of gasoline[7]. As the world's oil resources become increasingly difficult to extract, greater amounts of water will be needed to obtain raw materials for liquid gasoline. Similarly for unconventional sources of natural gas, which consist of gas trapped in tight formations of shale or sandstone underground, a large amount of water is required to fracture the underground formation and push the gas out to the well. For biofuels, the water footprint (or the volume of water used per unit of fuel produced) depends largely on the species grown - whether the crop is irrigated or rain-fed, and the fuel produced.

In the production of electricity, most of the water use occurs in the transformation stage, mainly for cooling of thermoelectric generation plants. A megawatt hour (MWh) of electricity from coal uses 20–270 litres of water at the coal mining stage and an additional 1,200–2,000 litres to convert into electricity, needing a total of 1,220–2,270 litres of water per MWh. Nuclear energy uses 170–570 litres of water per MWh during the mining of uranium and production of the reactor fuel, and 2,700 litres per MWh as the energy from nuclear fission is converted into electricity, for a total of 2,870 to 3,270 litres per MWh[8]. The type of cooling system used determines the amount of water needed.

[4] World Economic Forum. 2011. *Water Security: The Water-Food-Energy-Climate Nexus* . Island Press.
[5] Water and Related Statistics, Central Water Commission, March 2002
[6] World Economic Forum. 2011. *Water Security: the water-food-energy-climate nexus*. Island Press: Washington DC.
[7] World Economic Forum, and Cambridge Energy Research Associates. 2009. *Thirsty Energy: Water and Energy in the 21st Century*, p. 19. Available at http://www3.weforum.org/docs/WEF_WaterAndEnergy21stCentury_Report.pdf.
[8] World Economic Forum, and Cambridge Energy Research Associates. 2009. *Thirsty Energy: Water and Energy in the 21st Century*, p. 21. Available at http://www3.weforum.org/docs/WEF_WaterAndEnergy21stCentury_Report.pdf.

It is more complicated to estimate the water footprint of hydroelectric power, as consumption in the form of evaporative losses from reservoirs varies greatly depending on climate and surface area of the reservoir. It is estimated that on average the evaporative losses of water are 17,000 litre/MWh[9].

The energy cycle is extremely dependent on water for its functioning. Several times the amount of water "consumed" is needed for cooling, and sometimes this amount is far greater than is readily available. Energy production is increasingly constrained by the availability of water. About 2,340 MW of installed thermal power plant capacity in India shut down in April 2010 due to water scarcity[10]. A quarter of France's nuclear plants were shut down in 2003 due to water shortages caused by a severe heat wave[11]. The vulnerability of power plants to water availability is an increasingly recognized fact, and power utilities that plan for maintaining sustainable water resources are more likely to see uninterrupted power production.

Energy use in water sector

Just as water is integral to the energy value chain, energy is vital to the water value chain. Even before water reaches its users, significant amounts of energy are spent in extracting it from a source, treating it to a desired quality, and then transporting it to the location of use. After that, energy is sometimes expended in heating it as needed, and treating it at the point of use, and then finally, treating the wastewater that is generated by the user. All these steps along the water chain require significant energy. For instance, in the US, it is estimated that up to 13% of the country's electricity is spent in water-related activities[12]. A more illustrative example is provided by the Unites States Environmental Protection Agency (USEPA) which estimates that letting a tap run for five minutes is equivalent to running a 60-watt light bulb for 14 hours[13]. Table 2 below summarizes the range of energy footprints of the various processes in the water value chain.

The energy intensity of various water treatment processes varies depending on the source of supply. Treating high quality surface water takes hardly any energy at all, while desalination of seawater consumes a lot. Described in Table 3 is the energy intensity of various sources of water supply.

Table 2 Energy intensity of processes in the water value chain

	Range of energy intensity (kWh per million gallon)	
Process	Low	High
Water supply and conveyance	0	14,000
Water treatment	100	16,000
Water distribution	250	1,200
Wastewater collection and treatment	700	4,600
Wastewater discharge	0	400

Source Griffiths-Sattenspiel B and Wilson W. 2009. *The Carbon Footprint of Water*. River Network

Table 3 Energy intensity of water supply types

Source type	Energy intensity (kWh per million gallon)
Surface water (gravity fed)	0
Groundwater	2,000
Brackish groundwater	3,200
Desalinated seawater	13,800
Recycled water	1,100

Source Griffiths-Sattenspiel B and Wilson W. 2009. *The Carbon Footprint of Water*. River Network

As competition for water resources increases, water will be transported greater distances to meet the needs of a growing population, and governments will increasingly need to rely on additional sources of water such as desalinated seawater, which are more energy intensive than other water sources. This will raise the energy and monetary cost of water in an increasingly thirsty world. This trend is already observed in many water stressed regions of the world including hot desert climate regions and urban areas in Asia.

Conclusion

As more water is needed for food production, industry, domestic supply, and energy production, governments

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[8] World Economic Forum and Cambridge Energy Research Associates. 2009. *Thirsty Energy: Water and Energy in the 21st Century*, p. 21. Available at http://www3.weforum.org/docs/WEF_WaterAndEnergy21stCentury_Report.pdf.

[9] World Economic Forum. 2011. *Water Security: the water-food-energy-climate nexus*. Island Press: Wasington DC. p. 52.

[10] Hardikar J and Mehta R. 2010. *Maharashtra's Largest Power Plant to close all units by May 15,* April 7. Details available at http://www.dnaindia.com/mumbai/report_maharashtra-s-largest-thermal-power-plant-to-close-all-units-by-may-15_1368282

[11] Morrison J, Morikawa M, Murphy M, Schulte P. 2009. *Water Scarcity and Climate Change,* Ceres and Pacific Institute. Available at http://www.pacinst.org/reports/business_water_climate/full_report.pdf.

[12] Griffiths-Sattenspiel B and Wilson W. 2009. The Carbon Footprint of Water. River Network.

[13] Water Sense. USEPA. Details available at http://www.epa.gov/watersense/water_efficiency/benefits_of_water_efficiency.html, last accessed on 11 August 2011

will need to spend greater amounts of resources for obtaining supplies. More water needs more energy in the form of liquid fuels for transporting water in tankers, electricity for pumping water in long distance pipelines, or energy for desalting seawater. Further, this growing energy demand for water processes will need increasing amounts of water to produce it, thus forming a cyclical water-energy nexus.

This interdependence is seen played out in policy matters, which are not addressed in this article because they form a substantial topic in themselves. Examples include the unintended impacts of energy policies on water such as the well-intentioned provision of free electricity to farmers in some states in India causing a sharp drop in ground water table levels. The short-term benefit causes a long-term negative impact to the same farmers, placing their water resources in great jeopardy. Similarly, there may be trade-offs in decisions on renewable energy. An alternative that may be a good solution because it has a low carbon impact could have a high water footprint, such as some forms of biofuels.

This interdependence is yet to be effectively addressed by policy-makers across the world. Energy and water issues continue to be regarded individually, although there is growing evidence to suggest that policies that recognize the inter-dependence of the two resources are more likely to achieve their desired objective of efficient resource utilization.

Climate Change Economics: Linking trade and environment negotiations

*Anomitro Chatterjee**

"*We're in a giant car heading toward a brick wall and everyone's arguing over where they're going to sit!*"
David Suzuki

Background

Climate change mitigation through international negotiation is an objective which is both pressing and notoriously difficult to achieve. Since climate change is inherently a trans-boundary environmental externality, it is becoming increasingly clear that dealing with the problem through conventional negotiations may not present a feasible solution, no matter how many participants sit at the table.

The externality of environmental damage (including climate change) can be internalized most efficiently if it is possible to apply the "polluter pays" principle, where countries impose Pigouvian taxes on polluting industries or consumers in order to bring about a convergence between private and social costs (for industries) or benefits (for consumers). However, the very fact that climate change transcends international boundaries makes it impossible to apply the same principle to address this problem in particular. For instance, sulfur dioxide emissions from China are often taken to be the cause for acid rain in Japan. Without an appropriate incentive mechanism and/or an enforcing environmental authority, however, Japan cannot hope to get China to cut down its emissions since these are not adversely affecting the latter.

This sort of a problem, therefore, warrants a "second-best" solution, which would involve addressing the trans-boundary pollution issue through trade negotiations. In the absence of an international enforcing agency for environmental actions alone, it is impossible to push the mitigation agenda on another country without impinging upon national sovereignty. With global temperatures increasing each year, it is imperative to seek alternatives to isolated environmental negotiations.

Juxtaposed against the sluggish progress of action on mitigation, global trade volume has burgeoned over the last few decades to reach a staggering figure of $12.18 trillion last year[1]. The rules that govern trade flows are a massive force for economic, environmental and social change. International trade is becoming an increasingly important driver of economic development, as it has been expanding at almost twice the pace of total global economic activity for the past 15 years. A growing number of developing countries look to trade and investment as a central part of their strategies for development, and trade considerations are increasingly important in shaping economic policy in all countries, developed as well as developing. The World Trade Organization (WTO), with 153 member countries (accounting for 97% of the world's trade volume), deals with global rules of international trade and has mechanisms for enforcing multilateral agreements upon member nations.

Trade-environment linkages

Trade and environment are linked in a complex and inextricable manner. Increased global economic activity has undoubtedly precipitated environmental damage, especially trans-national pollution. However, it should be kept in mind that trade liberalization by itself is neither necessarily good nor bad for the environment. Its effects on the environment, in fact, depend upon the extent to which environment and trade goals can be made complementary and mutually supportive. A positive outcome requires appropriate supporting economic and environmental policies at the national and international levels. The international community has already recognized the need for linking these two spheres of activity, with the Doha round of WTO negotiations incorporating a number of environmental aspects in multilateral talks.

Participants in these negotiations usually have one of three objectives in mind – trade liberalization, climate change mitigation or economic development. With such vastly different and conflicting priorities, it is not surprising that convergence is difficult to arrive at, more so if the climate change angle features more prominently in the mix.

However, it is widely recognized that the inseparability of environment, social and economic objectives is the central tenet of the concept of sustainable

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[1] Source: International Trade Statistics 2010; World Trade Organisation

development. The climate change issue warrants looking at solutions with a broader scope than just the environmental angle.

Theoretical analyses

Scholarly work in the area of linking environment negotiations to trade dialogue has progressed steadily over the last few decades with a large number of models having been developed to demonstrate how such linkages can help the cause of multilateral climate change mitigation. This section reviews some of these analyses to throw some light on how the impasse can be addressed and a sustainable solution arrived at.

Treatment of the trans-national pollution problem through models of strategic behavior began in earnest since the 1990s. Hauer and Runge (1999) and Abrego et al (2001) are prominent papers which have dealt with the issue and have tried to look towards a possible solution.

In modeling strategic interactions between countries, Hauer and Runge (1999) present a game theoretic framework where two agents interact on two aspects. The first of these is a one-shot environmental game which is typically represented in the form of a prisoner's dilemma, while the second is a one-shot trade game which is represented as an assurance problem. A prisoner's dilemma is a situation where strategic interaction between two players always results in the achievement of a sub-optimal outcome, since it is in each player's best interest to not cooperate no matter what the other player does. An assurance problem, on the other hand, is a situation where the possibility of cooperation exists since it is better for a player to cooperate if the other player's cooperation is assured, although the first player would be better off not cooperating if the other player does not cooperate.

In the isolated environment game, a country will always choose not to undertake abatement expenses. This is because if the other country chooses to undertake such expenses, it would be in the first country's interest to "free ride" and forego such expenditure. If the other country does not spend on abatement, the first country would still be better off by not undertaking such expenses, since trans-boundary pollution would remain unless both countries undertake abatement. Therefore, the environment game has a Nash equilibrium outcome wherein both countries choose not to spend on pollution control. The figure below represents the payoff structure for this game. Benefits of undertaking abatement expenses are denoted by B^i_{jk} where i = 1, 2 represents the country, 'j' represents the strategy of the first country (c = spend on abatement; d = don't spend) and 'k' represents the strategy of the second country (c = spend; d = don't spend).

	Country 2		
	–	Don't spend on abatement	Spend on abatement
Country 1	Don't spend on abatement	0,0	B^1_{dc} , B^2_{dc}
	Spend on abatement	B^1_{cd} , B^2_{cd}	B^1_{cc} , B^2_{cc}

Figure 1 Isolated Environment Game

The payoffs are valued such that $B^1_{dc} > B^1_{cc} > B^1_{dd} = 0 > B^1_{cd}$ and $B^2_{cd} > B^2_{cc} > B^2_{dd} = 0 > B^2_{dc}$.

In the trade game, each country garners benefits from free trade if the other country chooses to cooperate. However, it is better to go for restricted trade if the other country chooses the same strategy. There are two pure strategy Nash equilibria here, one where both countries have open trade and the other where both have restricted trade. Hence, there is an opportunity for cooperation and free trade between the two countries. The payoff structure is given below, with benefits denoted as U^i_{jk} where 'i' = 1, 2 represents the country, 'j' represents the strategy of the first country (c = cooperate and free trade; d = non-cooperation and restricted trade) and 'k' represents the strategy of the second country (c = cooperate and free trade; d = non-cooperation and restricted trade).

	Country 2		
Country 1	–	Restricted Trade	Open Trade
	Restricted Trade	0,0	0, U^2_{dc}
	Open Trade	U^1_{cd} , 0	U^1_{cc} , U^2_{cc}

Figure 2 Isolated Trade Game

The payoffs are valued such that $U^1_{cc} > U^1_{dc} = 0 = U^1_{dd} > U^1_{cd}$ and $U^2_{cc} > U^2_{cd} = 0 = U^2_{dd} > U^2_{dc}$.

Now, if the countries agree to link the two issues together, such that cooperation involves spending on abatement and freeing up trade while defection involves not spending on abatement and restricting trade, then the "restricted trade-spend on abatement" and "open trade-no abatement" strategies need not be considered. Therefore, the linked game will look like the figure below, with the payoffs from the two games being additive.

Depending on the valuation of the payoffs, the linked game can either be an assurance problem or a prisoner's dilemma. More specifically, if the gains from trade are large enough to offset the benefits from not undertaking abatement, it is worthwhile to link the two issues. Therefore, if $U^1_{cc} + B^1_{cc} > B^1_{dc}$ and $U^2_{cc} + B^2_{cc} > B^2_{cd}$ then the

	Country 2		
Country 1	–	Restricted Trade - Don't spend on abatement	Open Trade - Spend on abatement
	Restricted Trade - Don't spend on abatement	0,0	B^1_{dc}, $B^2_{dc} + U^2_{dc}$
	Open Trade - Spend on abatement	$B^1_{cd} + U^1_{cd}$, B^2_{cd}	$U^1_{cc} + B^1_{cc}$, $U^2_{cc} + B^2_{cc}$

Figure 3 Linked Game

linked game becomes an assurance problem which can have a cooperative solution.

There is, however, a caveat to this story. Even if the linked game forms an assurance problem, the possibility of achieving a cooperative outcome is lower than that for the isolated trade game. Hauer and Runge prove this result mathematically by showing that the probability of one country's cooperation (under mixed strategies) required for the other country to cooperate in the linked game is higher than that required in the trade game alone.

It should be kept in mind that although the model developed by Hauer and Runge is substantial, it is only a simplistic representation which does not take into account repeated interactions between the two players. Moreover, the model does not explicitly consider differences between the players' valuations of the gains from trade as well as the benefits of foregoing abatement expenses. Trade between developed and developing countries, also referred to as "North-South" trade is especially relevant in this context. Developing countries usually argue for separation of trade and environment issues, instead demanding direct compensation for undertaking mitigation expenditure. Developed countries are the ones who are usually more amenable to the two issues. The fact that developing countries control a relatively larger number of environmental assets (such as forests) than the developed world only serves to exacerbate the problem. The developing countries often feel that linking trade and environment dialogue would make it even more likely for developed countries to restrict exports from the "South" to the "North".

Looking at this aspect of the problem, Lisandro et al (2001) argues that developing countries can actually use environmental negotiations to leverage their case at multilateral organizations such as the WTO. Their general equilibrium model incorporates two countries (North and South) and two commodities (one traded and one non-traded). The South is assumed to be the sole owner of environmental assets which along with one other input (value added) is used to produce an environment-using input. This input, in turn, is combined with value added to produce both the traded and the non-traded commodities. The North uses only value added to produce these commodities. The model takes into account trade negotiations through a tariff imposed on the traded commodity which both countries can use to interact strategically. The environmental aspect is taken into consideration using a pollution tax imposed on each unit of emissions generated by the environment-using input.

Lisandro et al (2001) runs numerical simulations on the constrained general equilibrium model to arrive at the equilibrium outcomes for the trade game and the linked trade-environment game. The simulations are done with statistics taken from the IMF and the World Bank and a number of rationalizable conjectures are made, the details of which can be found in the paper.

The main results of the simulation are shown in the figure below.

	Non-cooperative equilibrium	Bargaining over trade alone	Bargaining over trade and environment
Tariff rates (%)			
North	500[2]	253.63	0
South	101.3	0	47.68
Environmental internalization rate (%) [3]			
North	0	0	0
South	0.41	0.41	54.10
Hicksian equivalent variation (% of GDP)			
With respect to non-cooperative equilibrium			
North	0	0.57	6.53
South	0	2.54	6.87

Figure 4 Numerical Simulation Results

These results indicate that it is in the interest of the South (the developing countries) to link environmental negotiations to trade dialogue. In relation to the non-cooperative outcome, the South gains 6.87% of GDP in the linked bargaining process while the gains are at only 2.54% when bargaining occurs over tariff policies alone. Tariff rates in the North are driven down to zero in this case from the high rate of 253.63% in the trade bargaining outcome. The South is able to retain some

[2] Upper bound for tariff assumed to be 500%
[3] Ratio of emission tax to marginal emission damage

tariff protection, maybe as a "concession" by the North for the higher internalization rate of environmental damage (54.10%) in the South.

However, the paper does acknowledge that although it would be preferable for developing countries to link the two issues together, that would only be a second best solution. The claim is that the highest gains in GDP for the South occur in a situation where there are no taxes or tariffs and the North compensates the South for restricting its use of the environment-using input through cash payments. In the free trade case without taxes, the South loses 2.02% of GDP without side payments while it gains 5.11% if it can negotiate for cash transfers from the North.

It is clear that papers such as Hauer and Runge (1999) and Lisandro et al (2001) do provide sufficient grounds for a careful consideration of the possible benefits of linking environmental issues to trade negotiations. A lot more work surely needs to be done on the matter, especially on the empirical aspects of such linkages.

The view from the South

While recognizing that linking climate negotiations and trade talks may engender the possibility of a consensus on the climate front, it needs to be acknowledged that developing countries may not prefer such an approach, especially if it undermines their preeminent goals of energy security and sustainable development. As is well known, major developing countries argue that while their total emission levels may be higher than that in many advanced nations, their per capita emissions are far lower, making climate change mitigation much more costly and difficult to achieve for them. In the year 2007, while India and China had per capita emission levels of 1.47 and 5.26 metric tonnes of CO_2 respectively, the United States and United Kingdom had far higher per capita emission levels of 17.52 and 8.54 metric tonnes of CO_2 respectively[4]. It is also argued that over the course of time, industrialized nations have contributed much higher volumes of greenhouse gases to the atmosphere than the developing world. Therefore, if historical responsibility is to be accounted for, the more advanced economies should bear the lion's share of the cost of mitigation expenses. Another issue that developing countries are concerned about is that climate negotiations do not always pay enough attention to the costs of adaptation to climate change. This concern is especially significant for countries which are vulnerable to the impacts of climate change but do not have adequate resources to deal with the problem.

Central to India's own stand on the climate change issue is the idea of "common but differentiated responsibility" which was negotiated upon and finally accepted in the Rio Summit (1992) of the UNFCCC. India is already subject to a high degree of climate variability resulting in droughts, floods and other extreme weather events which compels India to spend over 2% of its GDP on adaptation, with the figure expected to go up significantly. Therefore, the country pushes hard for global action on adaptation in addition to action on GHG abatement and reduction. India has a comprehensive National Action Plan on Climate Change (NAPCC) that incorporates the objective of sustainable development and an outline of the measures that are required to achieve it. The country seeks financing and technology transfer from the developed world to aid mitigation and adaptation in the country. However, such financing should not be viewed as conventional aid, i.e Overseas Development Assistance (ODA), but as entitlements which are due to developing nations under an equitable climate regime.

Putnam's approach to modeling international negotiations

Although the theoretic analyses presented earlier argues for linking of trade and environment negotiations as the answer to the climate change problem, it is clear that ratification of such issue linkages would be considerably difficult to achieve. As such, moves in this direction may be construed as being detrimental to the interests and objectives of developing countries which argue for compensation for undertaking mitigation expenses on the grounds of historic responsibility and equity.

As in the models presented earlier, most of the theory on climate negotiations revolves around the assumption of players' objectives being restricted to the maximization of economic benefits alone. It is imperative to acknowledge that, on the contrary, international negotiations are carried out by political agents and diplomats whose objective function, as part of a particular government, must necessarily incorporate the desire to get re-elected to office in the next term. Often, an agenda that may generate long-term benefits but entails short-term losses is not palatable for the citizenship of the negotiators' respective countries and constituencies. Diplomats would ideally seek to avoid lending their support to such motions so as not to jeopardize their prospects of holding on to their offices. Therefore, the modeling of

[4] **Source** United Nations Millennium Development Goals Indicators; URL: http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=751&crid=

possible gains from strategic trade-environment inter-linkages should incorporate this behavior on the part of the players. In 1988, political scientist Robert D Putnam came up with a two-stage strategic model explaining the interplay between negotiators themselves (Level I of the game) and between the negotiators and their domestic electorate (Level II) (Putnam 1988). The model describes how international motions that a negotiator can feasibly pursue are constrained by what is considered acceptable by the domestic electorate.

Putnam theorizes the situation using "win-sets" for each stage of the two-level game. Each set contains all agenda which will be accepted at that stage of strategic interaction. An agreement can be possible only if the two win-sets overlap, and the larger each win-set, the more likely they are to overlap. On the other hand, the smaller the win-sets, the greater the chances of negotiations breaking down. Interestingly, Putnam goes on to show that if a negotiator has a small win-set on the domestic front, he will be better placed to push through his agenda without having to make compromises. This is because he can make a perfectly credible threat saying that any deviation from his agenda will result in the motion getting rejected at the domestic level and earning the displeasure of the electorate. Thus, a perceptibly weaker government may have firmer grounds to stick to their stated agenda than a stable, firm government which can make adjustments without necessarily getting removed from office in the next term.

Conclusion

Climate change is one of the most apparent and pressing problems on the planet that all countries must seek to address in tandem. However, with vast economic and demographic differences between them, coordination of their efforts and a harmonized agenda are incredibly difficult to arrive at. A possible solution to the impasse could be the linkage of climate negotiations to trade talks. This avenue needs to be explored very carefully, keeping in mind the aims and abilities of developing countries as well. Moreover, the methodology used to model strategic interactions should also take due cognizance of the fact that international motions will be tenable only if they are acceptable to the citizenry of each participating country.

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