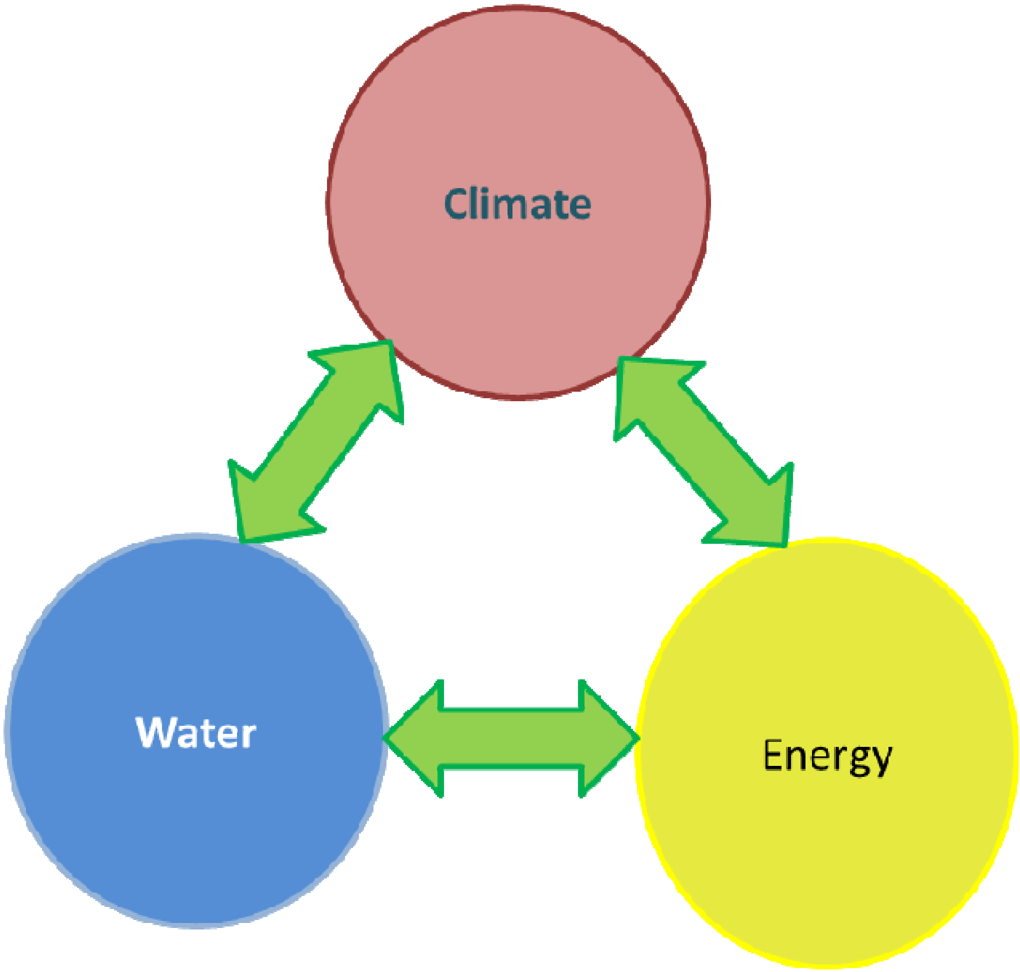
Dynamics of Water, Energy and Climate Interactions: Integrated Solutions for Sustainable Resources Development

Shresth Tayal and Ritu Mathur



NORWEGIAN EMBASSY

www.teriin.org

The Energy and Resources Institute

Acknowledgement

This paper was written as part of the project 'Water, Energy, and Climate Interactions: Identifying Issues and Assessing Response Capacity at the State level' under the Program of Activities, Framework Agreement between the Norwegian Ministry of Foreign Affairs (MFA) and The Energy and Resources Institute (TERI), briefly referred to as the Norwegian Framework Agreement (NFA). We would like to thank the Norwegian MFA for their support.

Dynamics of Water, Energy and Climate Interactions: Integrated Solutions for Sustainable Resources Development

Shresth Tayal and Ritu Mathur
The Energy & Resources Institute, New Delhi

INTRODUCTION – CLIMATE CHANGE, WATER, ENERGY NEXUS

Water and energy are essential requirements for an economy's development. While they contribute independently to development, the two are inextricably connected. Energy is vital for enabling the water value chain and is needed whenever it is extracted, moved, treated, heated, pressurized, reused, or discharged. Similarly, water is needed throughout the energy supply chain, sometimes as a direct input as in the case of hydropower or geothermal energy, as a coolant in thermal power plants or more often for the extraction and processing of energy fuels.

Demands for water and energy are expected to increase as the economy develops further. Additionally, it is anticipated that as climate changes, demand for water resources may be altered; potentially reducing water quality, quantity, and accessibility[1]. The multiple dynamics between the water and energy sectors need to be explored to understand how policies implemented in one sector could benefit or adversely impact the other and in turn be tested for their sustainability in the context of climate change. This paper attempts to present facts, address issues and propose recommendations for promoting sustainable linkages between water and energy sectors in the reality of climate change.

ENERGY FOR WATER

Water weighs 1000kg per cubic meter, and energy is needed whenever it is moved, treated, heated or pressurized. The energy intensity of water use (also called virtual or embedded/ embodied energy) is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location. The energy intensity of water varies based on type and quality of source water, pumping requirements to deliver water, efficiency of water system and the energy embedded by specific end uses[2].

---

[1] Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, et al., IPCC, "Summary for Policymakers, in Climate Change 2007: The Physical Science Basis", Cambridge University Press, 2007, Page 1-996.

[2] Wilkinson, Robert C., "Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures". Santa Barbara, CA: University of California, Santa Barbara, Environmental Studies Program, 2000.

As per the Water Footprint Network (WFN)[3], India has the largest total water footprint in the world, of 987 billion m^3/yr. Presently, the total water demand in the country is estimated to be 680 Billion Cubic Meter (BCM), which is projected to increase by 22% by 2025 and 32% by 2050 under Business As Usual scenario[4]. With increase in demand for water, energy intensity of water use will also increase.

As per the Central Electricity Authority[5], the electricity consumption in India has increased from 43,724 Giga Watt hours (GWh) during 1970-71 to 694,392 GWh during 2010-11. Of the total electricity sales in 2010-11, industry sector accounted for the largest share (38.6%), followed by domestic (23.8%), agriculture (19.6%) and commercial sector (9.89%). Also, rate of growth in electricity consumption is much higher in domestic and agriculture sector, as compared to industries since 1970-71, mainly due to increase in access to electricity. While several measures are being taken to incorporate energy efficiency across sectors, large unmet demands remain in some sectors and gets manifested as a rapidly increasing energy growth trajectory.

Under this perspective, growth in demand for water and consequential demand of energy for water will be an additional stress on the energy system of the country. Therefore, it is important to delineate inefficiencies and leakages from growth in water and energy requirements across various sectors.

The following sections look at energy and water linkages across different sectors.

Agriculture

According to findings by International Water Management Institute (IWMI)[6] considering a business as usual scenario, India's demand for food grain is set to increase from 178 million metric tonnes (Mmt) in 2000 to 230 Mmt and 241 Mmt in 2025 and 2050, respectively. To match the increase in demand and production of food grains, an increase in irrigation facility will be necessary; as India's crop production is dominated by three highly water intensive crops- rice, wheat and sugarcane, together accounting for 90% of the crop production. This will further increase the consumption of energy in agriculture sector. According to the statistics of Government of India, doubling the total food grain production since 1980-81, to offset the increase in population and maintain the per capita per day net food grain availability constant, has been at the cost of five times increase in electricity consumption for agriculture purposes[7].

---

[3] A. Y. Hoekstra · A. K. Chapagain, "Water footprints of nations: Water use by people as a function of their consumption pattern", Water Resource Management 2007, 21:35–48

4 Amarsinghe, U.A., Shah, T. and Anand, B.K. (2006). "India's water supply and demand from 2025-2050: Business as usual scenario and Issues", International Water Management Institute, New Delhi

[5] Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India, "Energy Statistics", 2012.

[6] U.A. Amarasinghe, T. Shah, H. Turral, B.K. Anand, International Water Management Institute, "India's water future to 2025-2050: Business-as-usual scenario and deviations", IWMI Research Report 123, 2007, 47p

[7] 'Agricultural Statistics at a Glance 2011', Ministry of Agriculture, Government of India

Indiscriminate abstraction of ground water has led to lowering of ground water table and also higher use of electricity for the sector. Over the last two decades, 84 percent of the total addition to net irrigated area came from groundwater, and only 16 percent from canals[8]. States with the highest production of rice/wheat are expected to face groundwater depletion of up to 75%, by 2050[9].

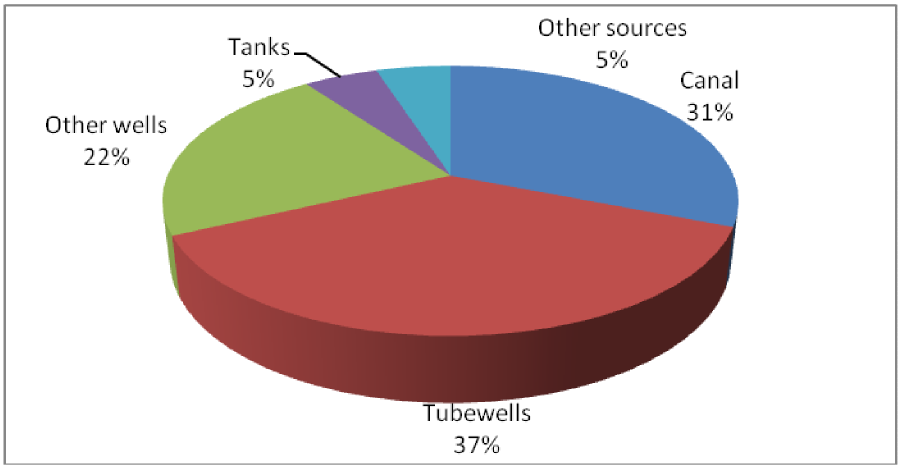


Figure 1: Distribution of various sources of Irrigation Water[13]

In 16 years between 1991-92 and 2007-08, after spending over Rs. 150,000 crores on big irrigation projects, there is decline of over 1.2 Mha in canal irrigated areas. In these 16 years, India's net & gross irrigated areas have steadily gone up. This increase in overall irrigated area, in spite of decrease in contribution from big dam irrigation projects was possible due to the steep increase in groundwater irrigated areas as shown by figure 3[10].

---

[8] John Briscoe, R.P.S. Malik, World Bank report, Agriculture and Rural Development Unit, South Asia Region, "India's Water Economy: Bracing for a turbulent future", Oxford University Press, 2006

[9] Grail Research, "Water-The India Story", March 23, 2009, (http://www.grailresearch.com/pdf/ContenPodsPdf/Water-The_India_Story.pdf)

[10] Himanshu Thakkar of South Asia Network of Dams, Rivers and People as quoted in U.S Embassy of India Workshop on 'Water Issues in India: Opportunities and Challenges' March 01, 2011

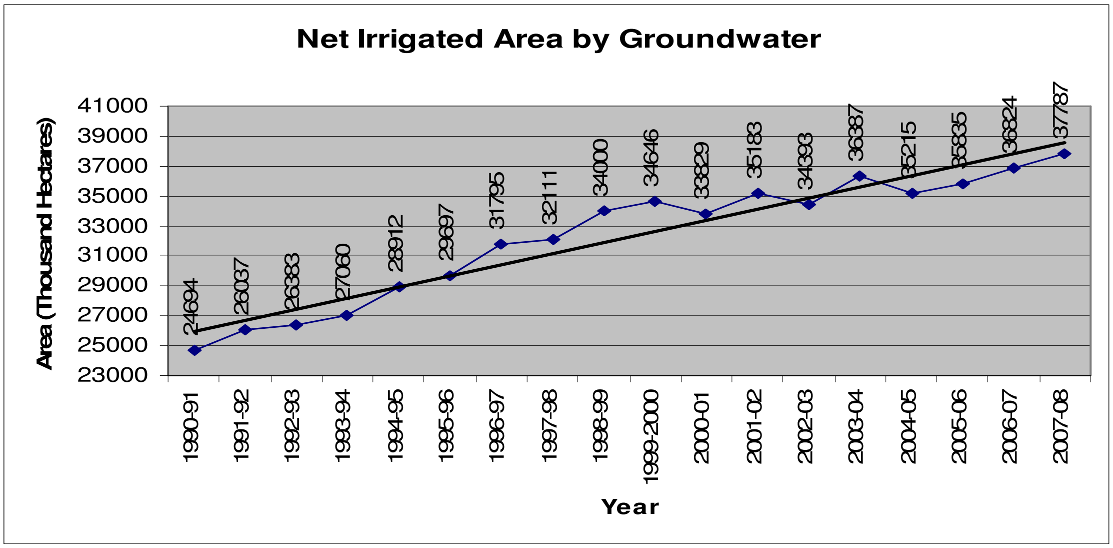


Figure 2: Time-Series Depiction of Increase in Net Irrigated Area by Groundwater[13]

Industry

Water use in industry can put immense pressure on local water resources. Additionally, wastewater discharged from the industries has potential to pollute the local environment. The water demand for the industrial sector is on a rise and will account for 8.5 and 10.1 per cent of the total freshwater abstraction in 2025 and 2050 respectively, which was 6 percent in 2010[11]. Among Indian industries, Engineering, Pulp and Paper, Textiles and Steel industries rank as biggest water guzzlers. Furthermore, water consumption in these industries is significantly higher than the globally best practices.[12]

Table 1: Industry wise data on water consumption also indicates ample scope for water conservation[16].

Sector	**Average water consumption in Indian industry**	**Globally best**
Thermal power plant	On an average 80 m^3/ MWh	Less than 10 m^3/MWh
Textiles	200-250 m3/ tonne cotton cloth	Less than 100 m^3/ tonne cotton cloth
Pulp & Paper	Wood based mills: 150 - 200 m^3 /	Wood based mills: 50 -

---

11 “Water use in Indian industry survey”, FICCI Water Mission, September 2011

[12] Chandra Bhushan, Associate Director, Industry and Environment Unit, Centre for Science and Environment, “CSE:Down to Earth Supplement on Water Use in Industry”, July 31 2004 (http://www.cseindia.org/dtesupplement/industry20040215/misuse.htm)

	tonne Waste paper based mills: 75 -100 m^3/ tonne	75 m^3 / tonne Waste paper based mills: 10-25 m^3/tonne
Integrated Iron & steel plant	10-80 m^3 per tonne of finished product (average)	5 -10 m^3 per tonne of finished product.
Distilleries	75-200 m^3/ tonne alcohol produced	Data not available
Fertilizer industry	• Nitrogenous fertiliser plant - 5.0 - 20.0 m3/ tonne • Straight phosphatic plant - 1.4 - 2.0 m^3/ tonne • Complex fertilizer - 0.2 - 5.4 m^3/ tonne	An effluent discharge of less than 1.5 m^3/ tonne product as P_2O_5

Also, the amount of water used by the Indian industries for production is 15 billion cubic metres (BCM) as compared to Argentina (2.6 BCM), Brazil (9.9 BCM), Korea (2.6 BCM), Norway (1.4 BCM), Sweden (0.8 BCM) and UK (0.7 BCM)[13].

Residential/Commercial

In domestic water, energy is required for water extraction from source, distribution of water to the domestic users, treatment of water and wastewater, and for end uses like in geysers, air coolers, refrigerators etc. The amount of energy consumed depends primarily on the total population, level of urbanization, population covered with piped water supply, distance of water pumping, elevation of water lift, technique of water purification/ wastewater treatment etc.

India is second most populous country of the world, with a decadal growth rate of 17.64% from 2001-2011. During 2001-2011, the proportion of urban population has increased by 3% points, with 377 million people living in urban areas. In general, people in urban areas consume higher levels of water than their counterparts in rural areas. The urban requirement for drinking water is assessed based on an average norm of 135-150 liters/capita/day[14] vis-à-vis 40 liters/capita/day in rural areas as per the Rajiv Gandhi National Drinking Water Mission. Water Supply to Class I cities and Class II towns in 2008 was 78000 million litres per day[15]. In rural areas, 30% of households are covered

---

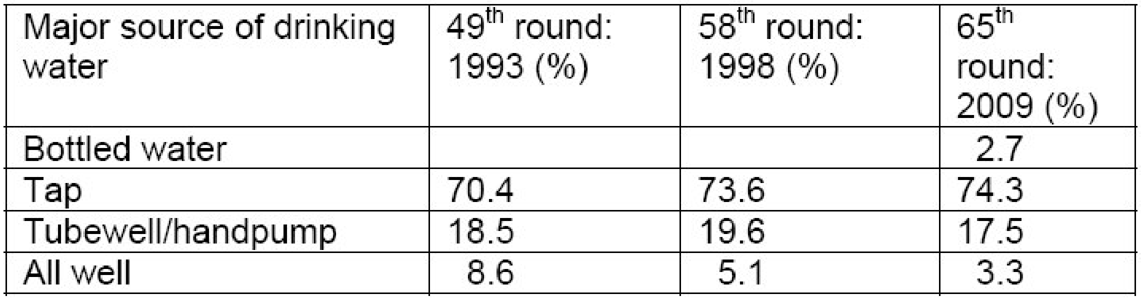
[13] World Bank, 2001 as quoted in “CSE:Down to Earth Supplement on Water Use in Industry”, July 31 2004 (http://www.cseindia.org/dtesupplement/industry20040215/misuse.htm)

[14] CPHEEO Manual, Ministry of Urban Development, Central Public Health and Environmental Engineering Organisation Manual on Water Supply and Treatment, Third Edition -Revised and Updated (May 1999), New Delhi.

15 “Status of Water Supply, Wastewater generation and treatment in Class I cities and Class II towns of India”, 2009, Central Pollution Control Board, Ministry of Environment and Forests, Government of India.

with piped water supply while in urban area upto 75% households are covered[16]. Government of India visions to cover 100% rural households with safe piped drinking water supply @ 70lpcd[17].

Table 2: Urban Water Sources in India



Major source of drinking water	49th round: 1993 (%)	58th round: 1998 (%)	65th round: 2009 (%)
Bottled water			2.7
Tap	70.4	73.6	74.3
Tubewell/handpump	18.5	19.6	17.5
All well	8.6	5.1	3.3

Most of the urban cities especially metropolitan cities in the country do not have enough local resource to fulfill the total demand of water. As a consequence, water is conveyed from the nearest source to the city. For example, water for Delhi is extracted from Tehri dam located about 300 km away, water for Bengaluru city is extracted from Krishraj Sagar dam through an almost 200km long pipeline system. Within the cities, municipal boards set up a network of pipeline system and booster pumps to distribute water to the households. At the individual households, water is lifted and stored in the overhead tanks. Metropolitan areas with multistory buildings are likely to spend much energy in lifting the water to overhead tanks.

To make water potable, it is treated before being supplied to the consumers. At households, families treat it again through systems like reverse osmosis etc. For each of these water treatment processes, energy is consumed. No records are available on exact quantity of energy used for domestic water in India, but in cities like Toronto, Canada (a city of about 4.6 million people[18]), this accounts for about 2.4% of the city's electrical consumption[19,20].

Thus, future water supply would become more and more energy intensive, and it is important to explore opportunities across different sectors to delineate inefficiencies and leakages.

---

[16] NSS 2010, Housing Condition and Amenities in India, 2008-2009, NSS 65th Round, July 2008-June 2009, National Sample Survey office, GOI, November.

[17] Report of working group on Rural Domestic Water and Sanitation, Twelfth Five Year Plan, 2012-2017; Ministry of Drinking water and Sanitation, Government of India; September 2011.

18 Statistics Canada. Population by selected ethnic origins. 2002 January 25, 2005 [cited 2007 September 16]; Available from: http://www40.statcan.ca/l01/cst01/demo27k.htm.

19 Cuddihy, J., C. Kennedy, and P. Byer, Energy use in Canada: Environmental impacts and opportunities in relationship to infrastructure systems. Canadian Journal of Civil Engineering, 2005. 32(1): p. 1-15.

20 Thirlwell, G.M., Madramootoo, C. A. and Heathcote, I.W. 2007. Energy-water Nexus: Energy Use in the Municipal, Industrial, and Agricultural Water Sectors. Canada-US Water Conference, Washington, D.C., October 02, 2007.

WATER FOR ENERGY

Indian energy system is dependent on a mix of conventional fuels such as coal, oil, gas, synthetic fuels and non-conventional sources such as biomass hydropower, nuclear, solar, wind, and geothermal. However, all these resources utilize water at various steps, as summarized in Table 3.

Table 3: Interconnections of Energy Sector with Water Availability and Quality

Energy Element	Connection to Water Quantity	Connection to Water Quality
Energy Extraction and Production		
Oil and Gas Exploration	Water for drilling, completion, and fracturing	Impact on shallow groundwater quality
Oil and Gas Production	Large volume of produced, impaired water*	Produced water can impact surface and groundwater
Coal and Uranium Mining	Mining operations can generate large quantities of water	Tailings and drainage can impact surface water and ground-water
Electric Power Generation		
Thermo-electric (fossil, biomass, nuclear)	Surface water and ground water for cooling** and scrubbing	Thermal and air emissions impact surface waters and ecology
Hydro-electric	Reservoirs lose large quantities to evaporation	Can impact water temperatures, quality, ecology
Solar PV and Wind	None during operation : water use for panel and blade washing	
Refining and Processing		
Traditional Oil and Gas Refining	Water needed to refine oil and gas	End use can impact water quality
Biofuels and Ethanol	Water for growing and refining	Refinery waste-water treatment
Synfuels and Hydrogen	Water for synthesis or steam reforming	Wastewater treatment
Energy Transportation and Storage		
Energy Pipelines	Water for hydrostatic testing	Wastewater requires treatment
Coal Slurry Pipelines	Water for slurry transport; water not returned	Final water is poor quality; requires treatment
Barge Transport of Energy	River flows and stages impact fuel delivery	Spills or accidents can impact water quality
Oil and Gas Storage Caverns	Slurry mining of caverns requires large quantities of water	Slurry disposal impact water quality and ecology

*Impaired water may be saline or contain contaminants ** Includes solar and geothermal steam-electric plants;

Source: U.S Department of Energy[21]

Inspite of dependence of energy production on water, situation of power plants across the world is concentrated closer to the source of energy fuels, without considerations of their operational implications on water resources of the region. According to findings in a report by the World Resources Institute (WRI) and HSBC's Climate Change Centre of Excellence, more than half of existing and planned power plants in South and Southeast Asia are located in areas currently considered water scarce or stressed,[22]. In the case of thermal power in India, 79% of new capacity is proposed to be built in areas that are already water scarce or stressed. The new proposed plants by NTPC, Tata Power, and Reliance Infrastructure are increasingly located in water scarce or stressed areas. WRI found that water shortages pose a great risk for power generation companies in India, and identified that each 5 percent drop in power production due to water shortages could result in nearly a 0.75 percent drop in the project's rate of return. Hence, there is a need for specific strategies to optimize water use at the plant level.

Use of water for conventional energy

Conventional energy resources are used both for heat generation in different industries like steel, cement etc., as well as for production of electricity (Figure 3). The consumption of these resources has almost tripled since 1990-91 (Figure 3)[23]. Furthermore, it is projected that the total electricity generation capacity would increase to around 800 GW, by 2031 and even with the best intentions to diversify the fuel and technology mix in the power generation sector; India would continue to rely heavily on coal based electricity generation, accounting for at least 50-60 percent of the capacity even by 2031[24].

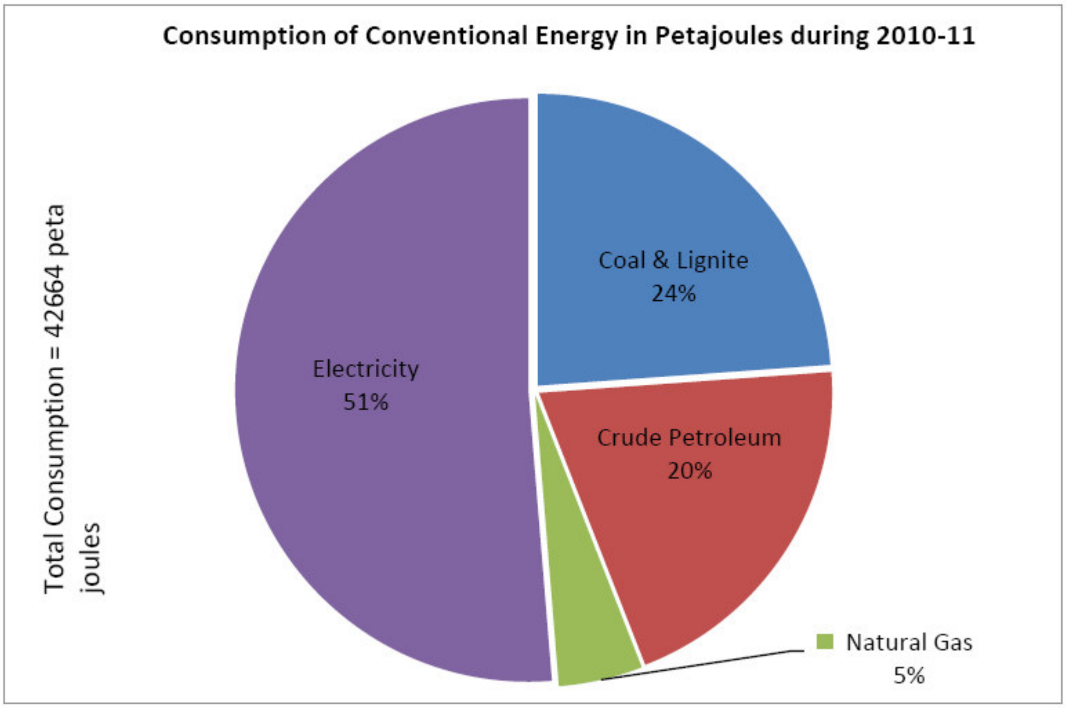
---

[21] Report to Congress on interdependency of energy and water, U.S. Department of Energy, "Energy Demand on Water Resources", December 2006

[22] World Resources Institute, "Over Heating: Financial Risks from Water Constraints on Power Generation in Asia India, Malaysia, Philippines, Thailand, Vietnam", 2010

[23] Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India, "Energy Statistics", 2012

[24] TERI. June 2009. India's Energy Security: New opportunities for a sustainable future.



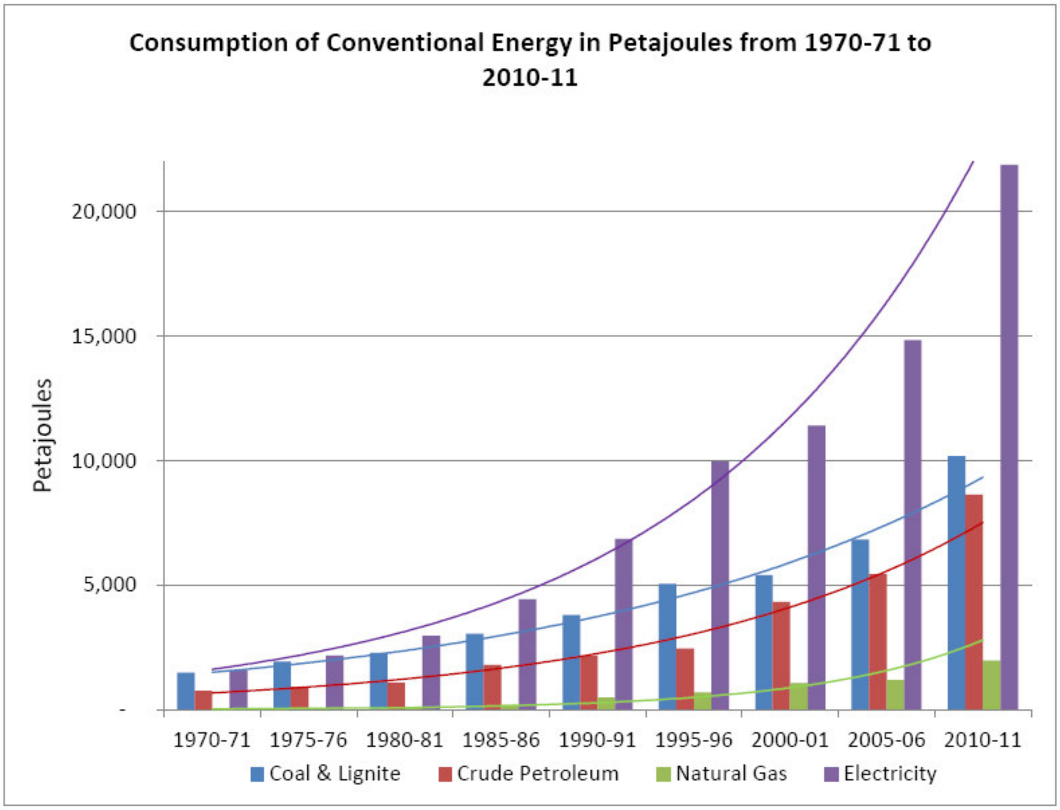


Figure 3: Trends in Consumption of Conventional Sources of Energy in India[8]

The two widely implemented types of cooling for power production are once-through cooling and closed-loop cooling; the minor type is termed dry cooling. For once-through cooling, river or lake water is passed through a heat exchanger to condense the steam. The exiting condenser water is pumped back through the cycle and the river water is returned to the stream. Although the consumptive water use is minimal, the amount of water withdrawn from the river is significant because the water is only used for a short time before it is returned to the stream. A closed-loop cooling system consumes much more water than once-through types because the entire energy exchange is through evaporation of the water, a consumptive use. Dry cooling typically requires a fan to aid in heat removal. The advantage to dry cooling is the water withdrawals and consumptions are zero[25], but dry cooling systems result in reduced power output and increased heat rate (lower efficiency) of the unit besides higher capital cost.

It is estimated that water withdrawal for electricity generation for ‘once through cooling’ technology range from 100-180 L/kWh for coal, 80-140 L/kWh for gas/oil, and140-200 L/kWh for nuclear power plants. However, for ‘closed loop cooling’ technology, water withdrawal range from 2-4 L/kWh irrespective of fuel used[26]. As per Ministry of Environment and Forest’s stipulation dated 2.1.1999, the power plants installed in India after 1.6.1999 and based on fresh water sources are not permitted to go for once through condenser cooling system. Thus, water withdrawal from the freshwater source has reduced considerably in recent years, but consumptive use has increased which is proportional to the number of hours, a plant operates. The consumptive water requirement for coal based plants with cooling tower in India is about 5-7 L/h per kW[27]. The total installed capacity of power generation in India (as on 31 December 2012) was 210,951 megawatts (MW), of which thermal power generation accounted for 66.82 per cent[28]. As such, thermal power plants in country are consuming atleast 705 million litres of water every hour.

In India, the share of nuclear power is 2.26% of the total installed capacity. With exponential growth in energy demand coupled with a finite availability of coal, oil, and gas; there is a renewed emphasis on nuclear energy[30]. India has a flourishing and largely indigenous nuclear power program and expects to have 14,600 MWe nuclear capacity on line by 2020 and 27,500 MWe by 2032 as compared to 4780 MWe at present. The aim is to supply 25% of electricity from nuclear power by 2050[29]. Nuclear power plants consume more water as compared to coal based thermal power plants[30]. While new plants

---

[25] P. Torcellini, N. Long, R. Judkoff, “National Renewable Energy Laboratory Consumptive Water Use for U.S. Power Production”, December 2003

[26] EPRI 2008, Water Use in Electric Power Generation, EPRI Report 1014026.

[27] Central Electricity Authority, 2012, “Report on minimization of water requirement in coal based thermal power stations.”

28 http://www.cea.nic.in/reports/monthly/executive_rep/dec12/8.pdf; accessed on Feb 10, 2013

29 World Nuclear Association, “ Nuclear Power in India”, February 2011, (http://www.world-nuclear.org/info/inf53.html)

30 NEI 2012, “Fact Sheet: Water use and nuclear power plants”, Nuclear Energy Institute, Washington DC.

are being constructed at coastal locations and are based on desalinated water, still almost 35% of nuclear power is from inland locations.

Thus, water is an important resource for thermal power sector, and water scarcity can lead to sub optimal capacity utilization, and even closing down of plants. The water resource in the states like Jharkhand, Chhattisgarh, Madhya Pradesh, and Orissa where the coal reserves are located, face tremendous pressure when large capacity additions are proposed. For example, in Chhattisgarh alone almost 50,000 MW of new capacity is proposed to be set up by various developers. It remains to be seen if all these plants will have adequate water. In the States like Gujarat and Rajasthan there are already serious problems faced even by the existing power plants due to scarcity of water. As a result, the plants have had to face partial or full dislocation of power generation. Water scarcity is already impacting power projects in India, causing delays and operational losses. For example, Maharashtra's Chandrapur Super Thermal Power Station (CSTPS), one of the largest power generation plant of Maharashtra State Power Corporation Ltd, was forced to shut down on 15 May 2007 due to an unprecedented scarcity of water. Similarly, the NTPC's Sipat plant was shut down in 2008 due to lack of water supplies from the state of Chhattisgarh. Thermal plants under construction in Orissa state are also reportedly witnessing delays due to water allocation problems.

Mining, extraction and refining

Natural gas extraction is considered water efficient because the withdrawn groundwater (used for gas purification) is mostly re-injected back into the aquifer. Significant quantities of water are being produced in the course of coal seam gas water exploration and production[31]. There have been reports across the world on aquifer depletion and pollution in areas where coal seam gas wells have been established and also cases on its impact on crops and farm lands[32]. Drilling process for oil extraction requires minimal amounts of water but a large amount of water called produced water is withdrawn with the extracted oil. On average, a barrel of oil brings up about six barrels of produced water.Water is also used during the petroleum refining process such as desalting and alkylation. Refineries use about 1 to 2.5 gallons of water for every gallon of product, meaning that the United States, which refines nearly 800 million gallons of petroleum products per day, consumes about 1 to 2 billion gallons of water each day to produce fuel[33]. India refines 182 million gallons of petroleum product per day[34].

Use of water for non-conventional energy

---

[31] Geoff Penton, Queensland Murray-Darling Committee Inc., "National Water Initiative 2009 Biennial Assessment of Progress in Implementation", 20 February 2009
(http://www.nwc.gov.au/resources/documents/Submission_QMDC.pdf)

[32] Des Houghton, Courier mail, "Lee cattle empire near Roma under threat from coal seam gas project", 29 May 2010 (http://www.couriermail.com.au/news/opinion/lee-cattle-empire-near-roma-under-threat-from-coal-seam-gas-project/story-e6frereo-1225872688646)

33 http://www.epa.gov/region9/waterinfrastructure/oilrefineries.html, last accessed February 10, 2013

34 http://petroleum.nic.in/refinery.pdf, last accessed February 10, 2013

Hydroelectric power generation depends completely on water availability. Water flowing through the turbines and into the river is not considered consumptive because it is still immediately available for other uses. However, the increased surface area of the reservoir, when compared to the free flowing stream, results in additional water evaporation from the surface and it is important to note it as a function of the amount of energy produced. Hydropower projects could alter flow regimes below storage reservoirs or within diverted stream reaches leads to water quality degradation and flooding of terrestrial ecosystems by new impoundments and may get affected by climate change impacts on the hydrological cycle[35]. Intense flooding can also affect power generation by increasing turbidity levels in intake water. These water events are episodic in nature and their frequency and severity are projected to increase over time. Hydro plants generally have a long life span (around 80 years). As a result, the impacts of climate change may dramatically change local water flows from when they were first studied during project development.

Bioenergy is considered environmentally benign and climate friendly. But bioenergy crops are water intensive and the water foot prints are much higher than that of non-renewable fuels as shown in table 9. In the case of biofuels, the crop irrigation water demand for production of biofuels like ethanol from sorghum, sugar cane and cellulose depends on its geographic location, climate, and type of feedstock. Bio-diesel in India is mainly produced from the tree-based oil crop Jatropha. Major water use for ethanol production is for irrigation.[36]

Table 4: Water footprint of energy sources[6]

Primary energy carriers		**Global average water footprint (m^3/GJ)**
Non-renewable	Natural gas	0.11
	Coal	0.16
	Crude oil	1.06
	Uranium	0.09
Renewable	Wind energy	0.00
	Solar thermal energy	0.27
	Hydropower	22

---

[35] T. Randall Curlee, Michael J. Sale, "Water and Energy Security", as presented in the conference 'Water Security in the 21st Century', July 30-August 1, 2003

[36] S.P. Gupta, Chairman, Planning Commission, Government of India, "India Vision 2020", 2002

	Biomass energy	70 (range: 10-250)

Source: Water Footprint Network

The water footprint of energy from biomass is 70 to 400 times larger than the water footprint of the other primary energy carriers (excluding hydropower). Besides, tradeoffs between land use for food production and biofuel production are widely debated and the policy shifts will have to address the bioenergy impacts on water and food security of the region/countries.

CLIMATE CHANGE IMPLICATIONS

Climate change is one of the most significant long term threats to water resources management[37]. Based on global and Indian projections, the key phenomena and trends likely to impact water resources are summarized in the table below.

Table 5: Indicative Climate Change Impacts on Water Resources[38]

Phenomenon and trend direction	Impact
Increased frequency of heavy precipitation	1. Increased run-off and higher levels of sediment loading affecting hydropower, and reducing ground water recharge. 2. Damage to crops, increased soil erosion,
Increased variability in rainfall patterns	1. Erratic river flow patterns along with reduced hydropower production 2. Impact on non-irrigated crops.
Increased likelihood of water shortages or drought	1. Reduced dry season flows. Drying up of minor tributaries and springs. 2. Reduction in water availability for power production, domestic, commercial and industrial purposes. 3. Major impacts on rain fed cropping, medium impacts on irrigated cropping.
Loss of glacier	1. Initial increase in dry season flow followed by reduced dry season flows in the long term. 2. Long term reduced hydro-electric power, irrigation and water supply.
Increased temperature	1. Increased river and lake temperatures 2. Change in suitability of crops at different altitudes and possible impact on aquaculture

Source: Asian Development Bank, 2010

---

[37] Santa Clara Valley Water District, "From Watts to Water, Climate Change Response Through Saving Water, Saving Energy and Reducing Air Pollution", 2007

[38] Asian Development Bank, "Climate Change Adaptation in Himachal Pradesh, Sustainable Strategies for Water Resources", 2010

Ongoing studies indicate that the production and consumption of energy will be affected significantly as a consequence of impacts of climate change on availability of water. Moreover, increase in temperatures are likely to cause an increase in cooling loads and irrigation demands due to increased water needs, and the need to extract water from greater depths.

SUSTAINABILITY ISSUES

Sustainability is defined as the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs[39]. Water supply sustainability has to inherently include a discussion of the energy needs of water supply, as without energy we cannot use water. On the other hand, some of the future energy sector technologies and processes may well be more water intensive than the conventional ones. The following sections outline some of the issues related to water supply sustainability, as linked to energy.

Globally, energy is among the top three cost items to water utilities, often coming second after labor costs[4]. Since the cost component of energy in water supply systems is significant, it is essential to examine the potential for energy saving in the water supply chain. This may be through change in technologies or processes used as well as by minimizing wastage of water attributed to leakages and/or inefficiencies due to irrational pricing or wasteful consumption habits.

Prevalent inefficiencies

Indian water supply systems are notorious for high levels of losses, called “non-revenue water”, the difference between water entering the system and water being billed to customers. In many cities in India, non revenue water (NRW) is as high as 60%[40]. In Asian cities, NRW ranges from 4%-65%, with an average of 30%[41].

As energy is used in all steps of the water chain, every unit of water that is extracted, treated, stored, pumped and used has an inherent “energy footprint” associated with it. Thus, water wasted is energy wasted. Consequently, water saved is energy saved. Recognizing this connection helps water utilities place an adequate monetary value on efforts to reduce NRW such as the purchase of sophisticated leak detection instrumentation, regular maintenance of pipes to minimize leaks, accurate billing and metering, and crack-down on illegal connections.

---

[39] World Commission on Environment and Development (Bruntland Commission), United Nations, “Our Common Future”, 20 March, 1987.

[40] Workshop on “Non revenue Water Management” organized by the Ministry of Urban Development, Government of India and the Asian Development Bank, Introduction, November, 2009

[41] Arthur C. McIntosh, Asian Development Bank, “Asian Water Supplies, Reaching the Urban Poor”, Chapter 9, Non Revenue Water, 2003

Out of total water supplied, 15% is assumed as the minimal percentage of leakage as per CPHEEO norms. This accounts for 2,634 million m^3/year of water lost during the water supply phase of municipal distribution. In reality cities estimate that as much as 40-50 per cent of the water is 'lost' in the distribution system[42], which is equivalent to 8771 million m^3/year of water lost. No account of the water lost at the end user has been maintained till date. Hence the total water lost could be much more than the assumed value. However for preliminary calculations we account for the minimal losses of water from poor governance and mismanagement. Assuming 0.4 kWh/m^3 of energy used in water supply and distribution (mostly considered by Indian and US Standards) the amount of energy saved on reducing actual water loss to minimum acceptable water loss is 2457 million kWh / annum which accounts for carbon offset of 2.273 million tonnes CO_2 eq.

Effect of power tariffs on groundwater levels

Currently in India, electricity is heavily subsidized or provided free for farmers. While the intent of this subsidy is noble, the unintended consequences include rapidly depleting groundwater levels, and a non-existent price signal to farmers regarding the value of the water. As per WENEXA, a joint body set up by the Ministry of Power, Government of India and USAID to study the Water, Energy, Nexus Activity, agricultural users consume about 83% of the water in India annually[43] and 30-40% of India's total power consumption is accounted for under the head of consumption for irrigation. Figure 4 shown below shows a comparison in tariffs between industry and agriculture. As can be seen, agricultural tariffs are minimal, and have remained relatively constant since the mid-seventies.

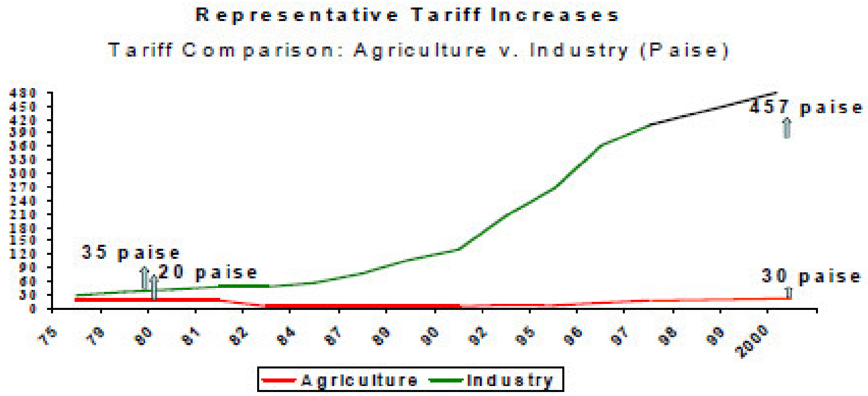


Figure 4: Year-wise Tariff Comparison between Agriculture and Industry[44]

---

[42] Report of the Working Group on Urban and Industrial Water Supply and Sanitation for the Twelfth Five-Year- Plan (2012-2017), Planning Commission of India, November 2011.

[43] Water and Energy Nexus Activity (WENEXA), United States Agency for International Development, March 7, 2011 (http://www.waterenergynexus.com/about-us.html)

[44] Water and Energy Nexus Activity (WENEXA), United States Agency for International Development, "Concept Note on Agricultural Demand Side Management", January 15, 2008

WENEXA found that irrigation decisions at the farm level are not made based on crop needs, rather on electricity available. In other words, farmers are not sure when water or electricity will be available next, so they pump as much as they can, unhindered by electricity prices, when there is electricity. It is estimated that flat rate tariffs lead to 40%-250% higher utilization of electricity when compared to diesel powered pumps.

Energy requirements of water supply options

The energy requirements of water supply sources vary widely based on type and location. For instance, desalination, in which there is increasing interest, could vary in its energy footprint based on the technology used. Earlier desalination plants relied on large scale thermal distillation of salty water. As the raw water needs to be heated, this process is energy intensive and typically uneconomical in areas with high energy prices. Nowadays, desalination is typically carried out using Reverse Osmosis (RO) membranes. Significant external energy is required in this process as well.

Thus, while seawater desalination is certainly a water supply option to be considered especially for coastal communities or island states, due consideration should be given to the energy footprint as well as the economic viability of the water that would be produced. For instance, an analysis for San Diego County, California shows that sea water desalination is the most energy intensive option available, even more intensive than transporting water hundreds of miles through canals from Northern California using the State Water Project.

Faced with poor water supply services, farmers and urban dwellers alike have resorted to helping themselves by pumping out groundwater through tube-wells. Although this ubiquitous practice has been remarkably successful in helping people to cope in the past, it has led to rapidly declining water tables and critically depleted aquifers, and is no longer sustainable. As per the Ministry of Water Resources, by the year 2025, water requirement for irrigation would be 561 km^3 for low-demand scenario and 611 km^3 for high-demand scenario. These requirements are likely to further increase to 628 km^3 for low-demand scenario and 807 km^3 for high-demand scenario by 2050[45].

Of late, there is a growing shift in focus towards tapping unconventional sources such as seawater, brackish groundwater and recycled water (advanced treated wastewater). This, together with increasing scarcity of inland water resources and saline contamination of groundwater aquifers, promote desalination as an important choice to meet freshwater requirement. Lack of sewage treatment is the main source of pollution of rivers and lakes[46], and Central Pollution Control Board (CPCB) estimates indicate that the existing treatment capacity is just 30% of present sewage generation. Accordingly, higher priority would need to be accorded to sewage treatment and reutilization of treated sewage water as well in future.

---

[45] Report of The National Commission for Integrated Water Resources Development, Ministry of Water Resources, “Integrated water resources development – A plan for action”, 1999.

[46] Central Pollution Control Board, Ministry of Environment and Forests, Government of India, “Status of Water Supply, Wastewater Generation and Treatment in Class I Cities and Class II Towns of India”, 2009

SUGGESTIONS

Reducing waste in water supply systems – reducing non-revenue water

There are several pilot efforts underway in Indian cities to reduce NRW. With support from the Government of India, the state of Madhya Pradesh has partnered with the Asian Development Bank to set up pilot cities for reducing NRW in India. Additionally, municipal corporations in cities like Calcutta, Jaipur, are assiduously improving their systems to reduce NRW.

Implement groundwater tariffs for agricultural users to reduce waste; implement targeted subsidies for subsistence farmers

As discussed earlier, absence of groundwater tariffs for the agriculture sector leads to wasteful use of water and energy. Some states like Maharashtra, Punjab, New Delhi, Andhra Pradesh, Kerala, Tamil Nadu, and West Bengal have enacted legislation to regulate the use of groundwater[47]. It is recommended that the application of a groundwater tariff be enacted widely across the country as appropriate on a state by state basis. Financial relief for impoverished farmers should be provided independent of the groundwater tariff, using targeted subsidies. This enables an appropriate price signal to be sent to the agriculture community, thus encouraging efficient use.

Evaluation of energy footprint of water supply sources

Water and energy are inextricably linked. It is recommended to evaluate the energy footprint of various water supply sources before selecting one. For example, desalination, advanced recycling, and river interlinking projects could require large amounts of energy. Thus, evaluating energy needs could enable improved water security through minimizing risk due to energy scarcity, or energy price fluctuations. Additionally, it provides decision makers with information on the carbon footprint, or the greenhouse gas emissions, from each water supply source, thus enabling better informed decision making.

Assessment of present and future regional water sensitivities before setting up industrial and power production units

It is necessary to assess the current and future regional water availability before setting up any industrial and power producing unit. The World Business Council of Sustainable Development (WBCSD) has devised the ‘Global Water Tool’ which simplifies the process of determining water sensitivity of a region. This tool is widely used by many industries globally and proves effective in making right decisions with regard to water and energy for water utilization by industries. It is recommended that assessing the quality, quantity and future availability of water resources be made mandatory for industries so that over –exploitation of water and energy resources is avoided.

---

[47] “Authority soon to regulate groundwater exploitation”, The Hindu, Bangalore edition, March 3, 2011.

Decentralized water distribution systems and rain water harvesting

Decentralized water distribution system reduces the distance for water conveyance. Metropolitan cities need to be divided into hydrological zones, and based on specific local conditions water distribution plans should be designed. Also, availability of water treatment facility at the zonal level will reduce the distance for water conveyance. Rainwater harvesting can play a significant role in ensuring the water availability, locally. Rainwater harvesting should be made mandatory for major commercial buildings like hotels, hospitals, multiplexes etc, which will reduce the pressure on municipal water supply system.

Integrating policies of adaptation and mitigation of climate change with linked effects on water and energy sectors

Water, energy and climate are inextricably linked. Currently, India does not have policies which look at these three sectors in an integrated manner. Policies in the energy, water, or climate change sector can only be successful when they account for the linkage with the other sectors. Unpredictable futures may be better prepared for by putting in place an integrated system of policies.