Climate Change–Water–Energy Nexus

A Synthesis of Understanding

The Energy and Resources Institute

Acknowledgement

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Contributors

Dr Shresth Tayal (PI), Ms Sonia Grover, Dr M P Ram Mohan, Dr Ritu Mathur, Mr Nathaniel B Dkhar, Mr M V Shiju, Lt Maneesh Manjunath

Reviewers

Mr Ashok Jaitly, Mr S Vijay Kumar, Mr K Ramanathan, Mr Anshuman

Research Interns

Mr Jitender Taneja, Ms Garima Vats, Mr Poojan Gor, Ms Gunjan Singh, Mr Pradeep Vashisth, Mr Dharmesh Singh

For more information

Dr Shresth Tayal
Fellow and Area Convenor – Centre for Himalayan Ecology
Water Resources Division
TERI
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003
India

Tel. 2468 2100 or 2468 2111
E-mail stayal@teri.res.in
Fax 2468 2144 or 2468 2145
Web www.teriin.org
India +91 • Delhi (0)11

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1 Climate Change–Water–Energy Nexus

An Overview

In today's dynamic world, the issues of climate change, water and energy are central to any attempt for bridging the gap between "developed" and "developing". These three critical issues have thus far been addressed in isolation from one other. The two-way relationship between energy and water, water and climate change, and energy and climate change have also been studied to some extent. However, a study of the three-way dynamic relationship between all three issues is necessary to develop national policies which meet India's development objectives in a sustainable manner and help in transformation from developing to developed.

The idea of Climate Change–Water–Energy (CCWE) Nexus was born at the international conference titled 'Managing Water Towards the Millennium Development Goals' held in Copenhagen in April 2007. During the lunch hosted by the Danish International Development Agency (DANIDA) between United Nations Environment Programme's (UNEP) executive director and small group of business leaders, the issues relating to energy, water and climate change were discussed and the idea of a joint initiative between interested groups were made. Since then a few initiatives have been taken to attain deep understanding of this important nexus. A draft concept note was proposed in the United Nations Climate Change Conference, COP 15 in Copenhagen 2009. This draft addressed the various linkages and proposed methods to develop linked policies in water, energy and climate change sectors. The World Business Council for Sustainable Development (WBCSD) has brought together businesses in researching and implementing sound technologies in the fields of this nexus study and has successfully created a roadmap for policy initiatives and operational frameworks in industries and business organizations concerning the nexus studies. Plan Bleu has sponsored a similar study in Egypt and is developing roadmap for instituting policies for the same in the country. The government of the Australian Capital Territory has established the Department of Environment, Climate Change, Water and Energy to consolidate and build on its capacity to respond to climate change. The Water Energy Technology Team (WETT) at Lawrence Berkeley National Laboratory is encompassing efforts to better understand applied technology and economics of the water, energy, climate change nexus focusing in the interaction between human and natural systems. The River Network group in America has been working on the nexus studies and has proposed an action plan for 2010 to 2015 to counter the climate change crisis head on. The International Water Association (IWA) has taken many initiatives and conducted conferences on the nexus concluding that addressing global climate change challenge ultimately boils down to water and energy considerations. It calls upon decision makers and the international community to recognize the relationship between water and energy and to create a policy environment that supports joint efforts in addressing global climate change. The Centre for International and Regional Studies (CIRS) organized a panel discussion on issues of water, energy and climate change in Gulf. The Pacific Institute located in California has come out with a Water–Energy–Climate Calculator (WE Calc) which asks a series of questions of home water use and estimates water use and water related energy use and associated greenhouse gas emissions and shows how much energy and water can be saved in the face of climate change. The Decision Centre for a Desert City at Arizona State University is working on the nexus and its research will focus on water and electricity supply and demand in the greater Phoenix metropolitan area and the effects of extreme heat and draught on them. At the 2008 International River Symposium held in Brisbane a dialogue regarding the critical need to understand and to respond to water–energy–climate change linkages was convened by Dannish Hydrology Institute, a water research and consulting organisation, together with several partners: the World Water Council, the International River Symposium, the Fenner Centre for Environment (Australian National University), the International Water Centre (Brisbane), and the Australian Water Association. Emanating from this discussion a number of principles for action were recommended, at both national and international levels, in order to progress proactive CCWE responses from policy makers.

Studies on Climate Change–Water–Energy (CCWE) Nexus have been done on a major scale across different regions of the world by different organizations. A lot of studies have been done to analyse the interactions between water and energy in various sectors of ground water utilization, hydro power, water and waste water treatment, domestic and industrial water use, mining, irrigation etc. Moreover, studies on the impacts of climate change on water and energy sectors are being conducted since early nineties. These studies have been carried out in varying capacities by various institutions and organisations.

In nutshell, Climate Change–Water–Energy interactions can be comprehended in terms of water for energy and energy for water as described in subsequent sections.

1.1 Water for Energy

Water, a limited resource, is required for most of the human activities and energy is the key ingredient for development. With almost one-fifth of the world population, India ranks fourth in the world in terms of energy demand[1]. In 2010–11, it produced 811 billion kWh of electricity, out of which 85 per cent was through thermal and nuclear power plants.[2] With its economy projected to grow by 7–8 per cent over the next few decades, demand for electrical energy is likely to be 1915 Tera Watt Hours with a peak electric demand of 298 Giga Watt[3]. For meeting the growing needs of the economy, Government of India plans to double the electricity

[1] http://www.eia.gov/countries/analysisbriefs/India/india.pdf

[2] http://www.ohpcltd.com/annual_report/OHPCAnnualR_2010-11.pdf

[3] http://www.isrj.net/UploadedData/1957.pdf

generation capacity every 10 years for next three decades at least[4]. To achieve this goal, it plans to develop Ultra Mega Power Projects (UMPPs) with capacity of 4000 MW each and involving an estimated investment of about $4 bn. At least 13 such thermal power projects have been envisaged which are at various stages of development.

Electricity production requires a reliable, abundant, and predictable source of water. Water is used intensively for thermal and nuclear power generation. It is estimated that on an average, for every 1000 kWh power, Indian thermal power generation plants (TPPs) consume as much as 80 litres of water[5]. The water consumption in the modern TPPs in developed countries is less than 10 litre for every kWh. However, with grim water security scenarios, fulfilling the energy ambitions for the country would be next to impossible. In other words, to achieve energy security for the country, water security needs to be ensured.

Energy production requires large volumes of water for various processes like extraction, processing, fuel conversion, cooling and flue gas treatment. The water required for energy production is called water footprints for energy production, which include

- water for extracting and refining raw materials such as coal, petroleum etc.
- Fuel conversions i.e. gasification or steam generation process
- Cooling for thermal and nuclear power plants
- Flue gas treatment for controlling emissions by scrubbing from all traditional plants
- Hydroelectric power generation

But, the increase in water variability and deteriorating quality is now becoming a concern for power generation. Climate change has been projected to impact water quality and availability which will further worsen the situation. Also, the water requirement for energy production will increase to provide energy for the nine billion populations by 2050. This will increase the dilemma of decreasing water availability and increasing energy demand thus resulting in increasing water energy stress.

1.2 Energy for Water

Water and energy are intertwined. Producing energy uses water, and providing freshwater uses energy. Both these processes face growing limits and problems.

A large amount of energy is spent to supply, treat and use water, meaning that water-oriented strategies can result in significant reductions in energy use and greenhouse gas emissions. With water demand growing and many local, low-energy supplies already tapped, water providers are increasingly looking to more remote or alternative water sources that often require a far greater energy and carbon cost than existing supplies. Furthermore, the adoption of higher water treatment standards at the state and national levels will increase the energy and carbon costs of treating our water and wastewater.

Energy for water is mainly used for the water production, processing, distribution and end-use processes. Energy is required to lift water from depth in aquifers, pump water through canals and pipes, control water flow and treat waste water, and desalinate brackish or sea water. Broadly energy consumption in water sector can be listed for the following requirements.

[4] http://www.powermin.nic.in/generation/pdf/ultra%20mega%20project.pdf

[5] http://www.cseindia.org/dte-supplement/industry20040215/misuse.htm

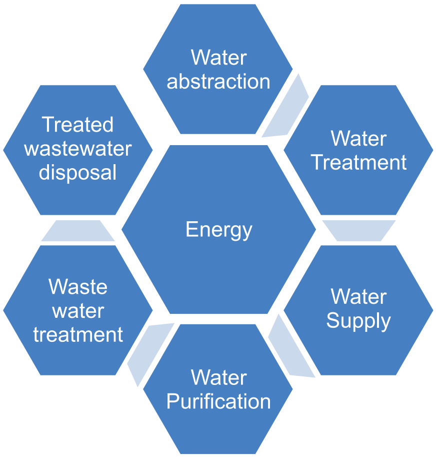


Figure 1.1 Energy usage in water provisioning

Energy requirement for water use is important for all the sectors, viz.. domestic, agriculture and industrial. Agricultural sector hugely depends on electricity for irrigational requirements.

Figure 1.2 shows the water energy nexus diagram with some of the possible linkages. It highlights the cause and effect relationship and the intricate linkages between the two. It also shows water value chain and linkages to various sectors like domestic, agriculture, industries and energy. Natural water available as rainfall, groundwater or surface water is used in different sectors, but before use it need to be purified which consumes energy. Also, the used water needs to be treated before being discharged into the rivers or being reused, which again uses energy.

Thus, the linkages water and energy are diverse and very complex, and individual linkages need to be assessed both individually as well as from the perspective of interactions and influences across the linkages.

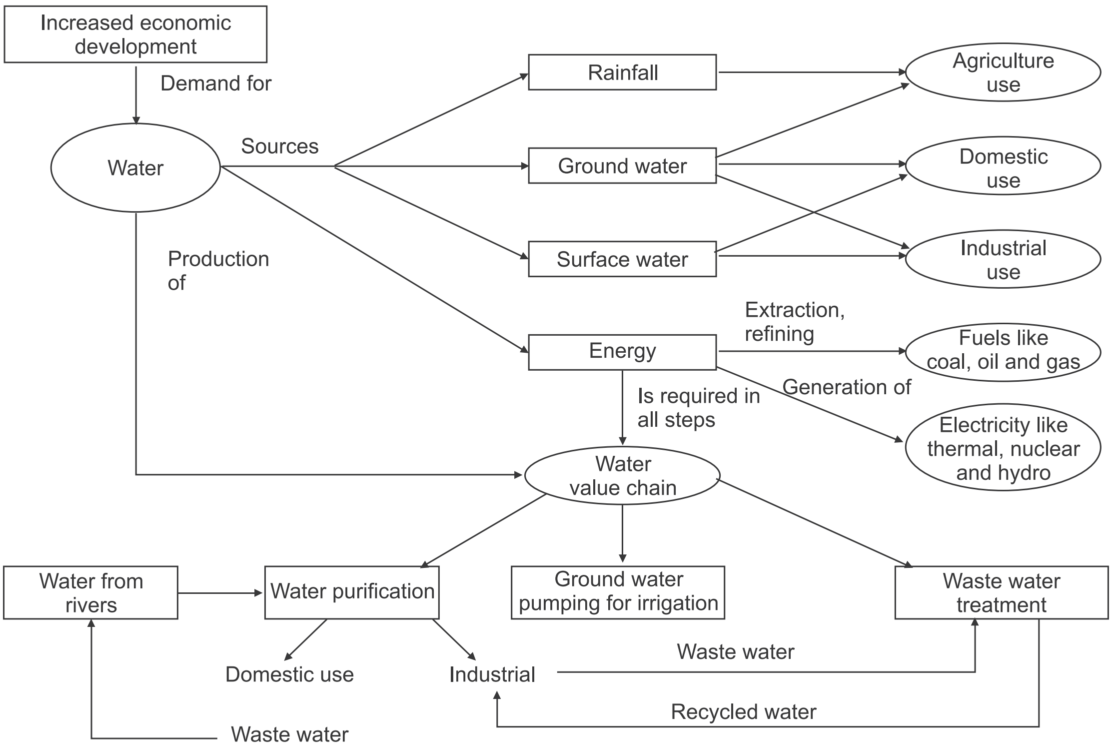


Figure 1.2 Nexus linkage diagram

1.3 Climate Change—Water—Energy Nexus

The water–energy nexus has third dimension also, which is inevitable and known as climate change.

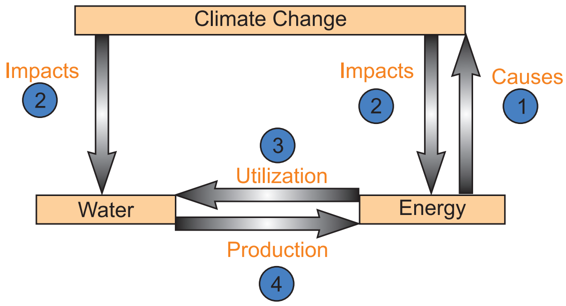


Figure 1.3 Schematic Diagram of CCWE Nexus

Figure 1.3 indicates the cause and impact relationship between water energy and climate change nexus. Burning of fuels for electricity production causes release of GHGs, which is one of the main reasons for climate change. Changing climate impacts water availability which in turn affects energy production cycle. This complete web is linked inextricably and teasing out these linkages is important to understand the cause-effect relationship.

Causes of Climate Change

The fundamental cause of climate change is emission of green-house gases (GHG) caused from burning fossil fuels such as coal, crude oil and natural gas for various activities. Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide, Methane, Nitrous Oxide and Fluorinated Gases.

Activities pertaining to fossil energy production and fossil energy consumption release greenhouse gases which cause climate change. In India the dominant source of fossil energy is coal with a share of more than 50 per cent in the total electricity generation capacity of India. The dominance of coal is because India is endowed with significant coal reserves of about 221 billion tonnes that is expected to last much longer than its oil and natural gas reserves which contribute to 1 per cent and 10 per cent of total electricity generation capacity respectively[6]. A number of steps are being initiated to develop renewable sources of energy in a systematic manner. However, coal being abundant, cheap and locally available would remain mainstay of the Indian energy system for energy security reasons. A report by Ministry of Environment and Forests, Government of India 2010[7] assess the carbon dioxide, methane and nitrous oxide emissions from anthropogenic activities at national level in India from energy, industry, agriculture and waste. Energy sector emitted 1100.06 million tonnes of CO_2eq, of which 719.31 million tonnes of CO_2eq were emitted from electricity generation and 142.04 million tonnes of CO_2eq from the transport sector. Industry sector emitted 412.55 million tonnes of CO_2eq. India's per capita CO_2eq emissions was 1.5 tonnes/capita in 2007.

Impacts of Climate Change on Water Sector

Climate change would significantly affect the

[6] www.cea.nic.in

[7] India: Greenhouse Gas Emissions 2007, Indian Network for Climate Change Assessment

temporal and spatial availability of the water resources in the country. It may lead to the re-allocation of the water for meeting the demands of the different sectors. As the climate change may change the rainfall characteristics in time and space, the surface runoff and rainfall recharge to the groundwater would also be significantly affected. Furthermore, because of adaptation in other sectors due to climate change; there may be other physical changes in the basin which would influence the hydrological cycle considerably.

Water is a precious natural resource supporting human activities and ecosystems, and at the same time very complex to manage judiciously. The hydrological cycle, a fundamental component of climate, is likely to be altered in important ways due to climate change. Using the SWAT (Soil and Water Assessment Tool) water balance model for hydro-logic modelling of different river basins in the country, in combination with the outputs of the HadRM2 regional climate model, preliminary assessments have revealed that under the IS92a scenario, the severity of droughts and intensity of floods in various parts of India is likely to increase. Further, there is a general reduction in the quantity of available runoff under the IS92a scenario. According to India's Initial National Communication to the United Nation's Framework on Climate Change Assessment river basins of Sabarmati and Luni, which occupy about one quarter of the area of Gujarat and 60 percent of the area of Rajasthan, are likely to experience acute water scarce conditions. River basins of Mahi, Pennar, Sabarmati and Tapi are likely to experience constant water scarcity and shortage. River basins of the Cauvery, Ganga, Narmada and Krishna are likely to experience seasonal or regular water stressed conditions.

Impacts of Climate Change on Energy Sector

Climate change has its influence on both the production and consumption of energy. For instance, average warming can be expected to increase energy requirements for cooling and reduce energy requirements for warming. Changes in precipitation could affect prospects for hydro power, positively or negatively. Increases in storm intensity could threaten further disruptions. Enhanced groundwater demand would increase water pumping requirements. These will enhance the electricity demand and add costs to the consumers for maintaining their lifestyles, as well as to the electricity production systems. The projected variability in precipitation can impact the irrigation needs and consequently increase electricity demand in agriculture sector. Concerns about climate change impacts could change perceptions and valuations of energy technology alternatives[8]. Any or all of these types of effects could have very real meaning for energy policies, decisions, and institutions in India, affecting discussions of courses of action and appropriate strategies for risk management.

As the climate of the world warms, the consumption of energy in climate-sensitive sectors is likely to change. Possible effects include decreases in the amount of energy consumed in residential, commercial, and industrial buildings for space heating and increases for space cooling, decreases in energy used directly in certain processes such as residential, commercial, and industrial water heating, and increases in energy used for residential and commercial refrigeration and industrial process cooling (e.g., in thermal power plants or steel mills), increases in energy used to supply other resources for climate-sensitive processes, such as pumping

[8] Effects of Climate Change on Energy Production and Use in the United States, U.S. Climate Change Science Program Synthesis and Assessment Product 4.5

water for irrigated agriculture and municipal uses, changes in the balance of energy use among delivery forms and fuel types, as between electricity used for air conditioning and natural gas used for heating; and changes in energy consumption in key climate-sensitive sectors of the economy, such as transportation, construction, agriculture, and others. Energy production in India is dominated by fossil fuels: coal, petroleum, and natural gas. Every existing source of energy in India has some vulnerability to climate variability. Renewable energy sources tend to be more sensitive to climate variables; but fossil energy production can also be adversely effected by air and water temperatures, and the thermoelectric cooling process that is critical to maintaining high electrical generation efficiencies also applies to nuclear energy. In addition, extreme weather events have adverse effects on energy production, distribution, and fuel transportation. Climate change is likely to affect energy planning, nationally and regionally, because it is likely to introduce new considerations and uncertainties to institutional (and individual) risk management. Such effects can arise either through anticipated changes in climate-related environmental conditions, such as hydro power potentials, possible exposure to storm damages, or changed patterns of energy demand, or through possible changes in policies and regulations.

The scientific analysis of Climate Change–Water–Energy (CCWE) nexus is multi-directional and complex. Each independent element of the nexus has a key role to play in the socio-economic and ecological development of the country. Climate change is an ugly truth and the years ahead are bound to witness its irreversible impacts particularly in the water and energy sectors if responsible actions are not taken to revert or mitigate the same. The utilization of water resources in India is inadequate and the issue of water scarcity and poor water quality still haunt various regions of the country. The energy sector is dominated by thermal power followed by hydro-electric, nuclear and renewable power plants respectively which hints at a pattern of excessive utilization of fossil energy (in thermal plants) and water resources (in hydro-electric, thermal, nuclear and renewable energy plants). Interestingly these three elements of Climate Change, Water and Energy are linked to each other in more ways than one and a thorough analysis of the same needs to be conducted on an exhaustive scale.

2 Quantifying the Nexus

An Approach

The study on Climate Change–Water–Energy Nexus at the state level was initiated with the primary objective, to assess existing and future water–energy demand, climate change impact, and institutional adaptive capacity in agriculture, industrial, domestic water supply, and energy production in four states in India.

2.1 Scope of Work

At the regional level, a number of studies and publications[9] are available which detail out the nexus linkages. But quantification of the nexus has been done in a limited way either through lifecycle assessments, foot-printing analysis or input output matrix. For this study, state level has been selected for the assessment as many policies and programs are implemented at state level, therefore an analysis at this level can help feed into the policies and planning.

Furthermore, the studies conducted at the national level are more subjective in nature, making a qualitative assessment of nexus between water and energy. However, it is more useful to quantify the degree of dependence between water and energy at the state level, for an effective policy formulation.

Hence, this study focuses on key areas, making an attempt to zoom in from national level to the state level and adopt an approach with modest data requirement to quantify the nexus and understand the current and future scenario of the intricate nexus. A preliminary assessment of nexus was done at the national level to identify the states for further assessment. Outputs of this study will lead to further and more intensive assessment of nexus at the district level, in future.

2.2 Approach and Methodology

For the assessment of nexus, a two way strategy was adopted which included simultaneous assessment of total energy required for water provisioning in the state as well as total water required for production of electricity with specific focus on thermal production was conducted. This assessment was done for two time slices 2010 (current) and 2020 (future). Future projections included two scenarios, Business as Usual (BAU) and Alternate scenario.

For estimating water for energy, water demand from energy sector was compared to water demanded by other primary sectors which included domestic, industrial, and agricultural

[9] Siddiqui, A., and Anadon, L.D., The Water Energy nexus in the Middle East and North Africa, Current Opinion in Environmental Sustainability 2013, 5:607–61

sector. Similarly for estimating energy for water, energy demanded by water sector was compared to total energy demand in the state for various other sectors.

These four parameters were used to estimate the proportional reliance of water on energy and energy on water. This proportion provided an indication of stress of energy on water sector and stress of water on energy sector.

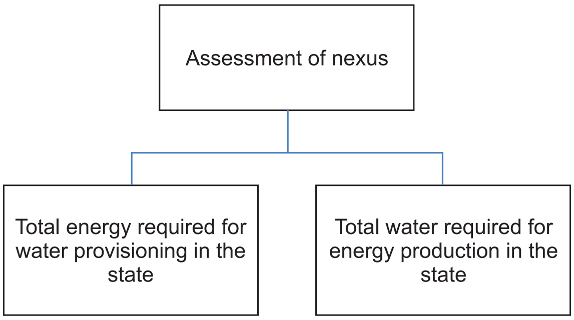


Figure 2.1 Parameters for nexus assessment

It is important to understand the intricacies of the nexus. The approach therefore adopted is presented in the figure below.

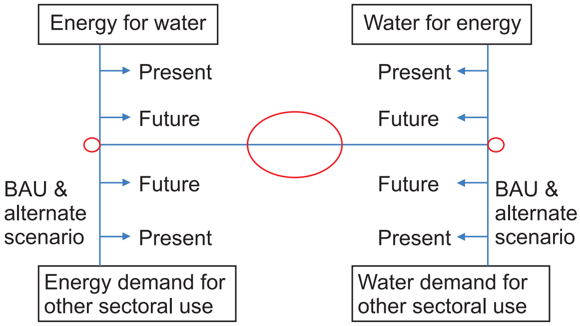


Figure 2.2 Approach adopted for the study

The two important aspects of the nexus—'Water for Energy' and 'Energy for Water' are analysed for both present and future time period to understand and estimate the magnitude of the stress with respect to other competing sectors.

Energy for Water

Energy for water encompasses assessment of energy requirement for provisioning of water to all the sectors. This includes abstraction of water, treatment of water & wastewater, distribution and transmission of water, etc. This is compared with requirement of energy for other uses than water provisioning.

Water for Energy

Water for energy includes, use of water in various processes for production of energy. This is compared to understand the friction caused between water demand from other sectors viz.-a-viz. demand from energy sector.

An attempt was made to quantify the friction for both these dimensions of nexus by estimating the following:

- Percentage of the volume of water demand for energy and water demand for all other sectors: indicates the amount of stress on available water due to the demand from energy sector as compared to other sectors.
- Percentage of the amount of energy required for meeting water demand and energy required for all other sectors: it indicates the amount of stress on available energy from water provisioning sector as compared to the other demands.

The approach adopted is mainly dependent on secondary data. For one of the component of water demand estimation, PODIUM Sim model was used, which again needs secondary data for estimating values of sectoral water demand. This exercise made certain assumptions, for assessment of the above mentioned percentages. These assumptions were mainly made because of lack of requisite data. All the assumptions are mentioned at appropriate places in the report. The detailed methodology adopted for the aforementioned assessments is described in the subsequent sections.

Future Projections

As mentioned previously, two time slices were evaluated for the assessment of water–energy nexus; current (2010) and future (2020). Above mentioned four parameters were assessed using the available secondary data and other tools like PODIUM Sim (for water demand estimation).

For future projections, two scenarios were assumed: Business as Usual (BAU) scenario and Alternate scenarios. Following section details out the methodology used for future projection.

Future Projections under BAU Scenario

Future projections have been done for the year 2020 under normal BAU scenario. For future projection, the method of growth rates are as mentioned in the table below:

Using these growth rates, sectoral water demand was estimated for future for all the sectors. Water demand for energy was based on the 12th and 13th five year plan energy plans for each of the states. Based on the targets for installed capacity until 2017 (which due to slippage may be implemented until 2020), water requirement for energy production was estimated. Water requirement for energy production was estimated using data provided by National Commission for Integrated Water Resources Development (NCIWRD)[10] for different fuels.

Energy Demand for water was assessed based on the unit volume of energy required for water in each of the sector in the current year. This unit was then projected for the future estimated water demand from each sector to arrive at energy requirement in future time period as per the water demanded. Besides, this was also corroborated with available government records for both sectoral and total energy demand forecast.

Scenario	Parameter	Agriculture	Domestic	Industry	Water
Normal (BAU)	Sectoral water demand	CAGR for past 2 decades	Incremental Increase in population	Average Growth rate of water consumptive industries for last 5 years	Potential Availability with mean average rainfall

Future Projections under Alternate Scenarios

The stress between water and energy could be reduced through appropriate management strategies which could have an impact on reducing the total demand for water as well as demand of water for energy. One of the alternate scenario studied in the project was a demand side management strategy which assumed improvement in irrigation efficiency by 5 per cent over a decade.

[10] NCIWRD 1999. Integrated Water Resource Development: A Plan for Action. Report of the National Commission for Integrated Water Resource Development (NCIWRD). Volume-I. Ministry of Water Resources, Government of India.

2.3 Selection of States

India is a diverse country with various agro-climatic zones spread across length and breadth of its area. It receives uneven distribution of rainfall both temporally and spatially, and hence the availability of water resources in all the states is variable. In terms of demand also, each state has different dynamics and demand is majorly driven by irrigation requirement in the state, which is generally proportional to the net irrigated area in each state.

Following figure explains the approach adopted for selecting 4 states from four geographical zones of the country.

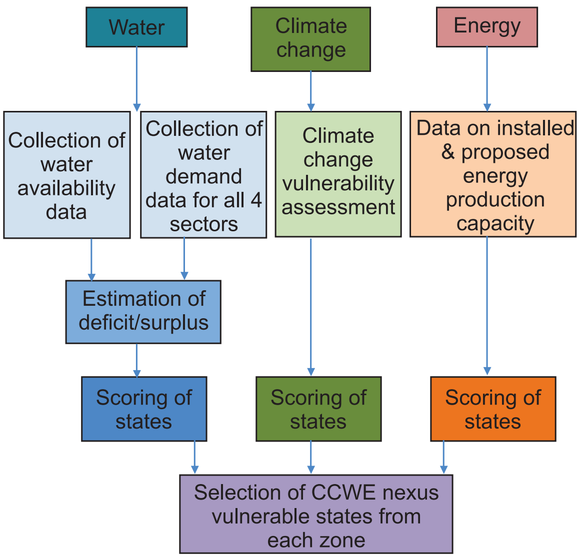


Figure 2.3 Approach adopted for selection of states

The approach mainly included comprehending the nexus from demand angle. Water being a common thread of complex web faces tremendous pressure from various sectors. Therefore it was thought to evaluate the stress causes by the demand of water from energy sector vs. demand of water from other primary sectors which include domestic, agricultural and industrial sector.

For each of the four major sectors, set of criteria were used to assess the overall demand from the sector. These sector specific criteria are mentioned in the table below.

Based on this approach, following four states were identified as the most vulnerable states in terms of water–energy nexus:

Tamil Nadu

Tamil Nadu is the southernmost state of India with the total geographical area equal to 130,058 sq. km. Tamil Nadu accounts for 4 per cent of the land area and 6 per cent of the population, but only 3 per cent of the water resources of the country (State of Environment Report). It receives relatively more rainfall during northeast monsoon, especially, in the coastal regions. The normal rainfall in south west and north east monsoon is around 322mm and 470mm respectively. The per capita water availability of the state is 800 cubic meters which is lower than the National average of 2,300m^3. The total surface water potential of the state is 36km^3 or 24,864m^3.

Sector	Criteria
Domestic	Population of the state, urban population, density, number of cities
Industries	Number of water intensive industries, water requirement of the industries
Agriculture	Area under irrigation of water intensive crops, amount of water required, water required for livestock rearing
Energy	Number of power plants with installed capacity (nuclear, thermal)

The total installed capacity of electricity production in Tamil Nadu was about 16720 MW as on 31st March 2011 (including share from central generating stations and co-generation capacity), of which thermal constitutes the highest share, followed by renewables, hydro, and nuclear. Tamil Nadu is among the leading states in India in terms of electrification, with 98 per cent of its rural hamlets electrified. The per capita consumption of electricity in Tamil Nadu has increased by more than 100 per cent from 510 kWh in 2000–01 to 1040 kWh in 2010–11.

Gujarat

Gujarat is the westernmost state of India with the total geographical area equal to 196,024 sq. km. Gujarat accounts for 5.96 per cent of the land area and 4.99 per cent of the population, but only 4.45 per cent of the water resources of the country. The average annual rainfall is 798 mm. During the last 10 year rainfall average has ranged from the minimum 647 mm per year to maximum 1291 mm per year. Total Water resources of state are estimated to be 50,000 MCM, which are highly heterogeneous in its distribution.

Power requirement in Gujarat has increased from 41513 MU per year in 2006–07 to 54079 MU in 2010–11, indicating an increase of 30 per cent in four years. In 2010, Gujarat declared itself a "power surplus" state. The per capita consumption of electricity in Gujarat was 1558 kWh in 2009–10 which was almost double the national average of 778 kWh.

Uttar Pradesh

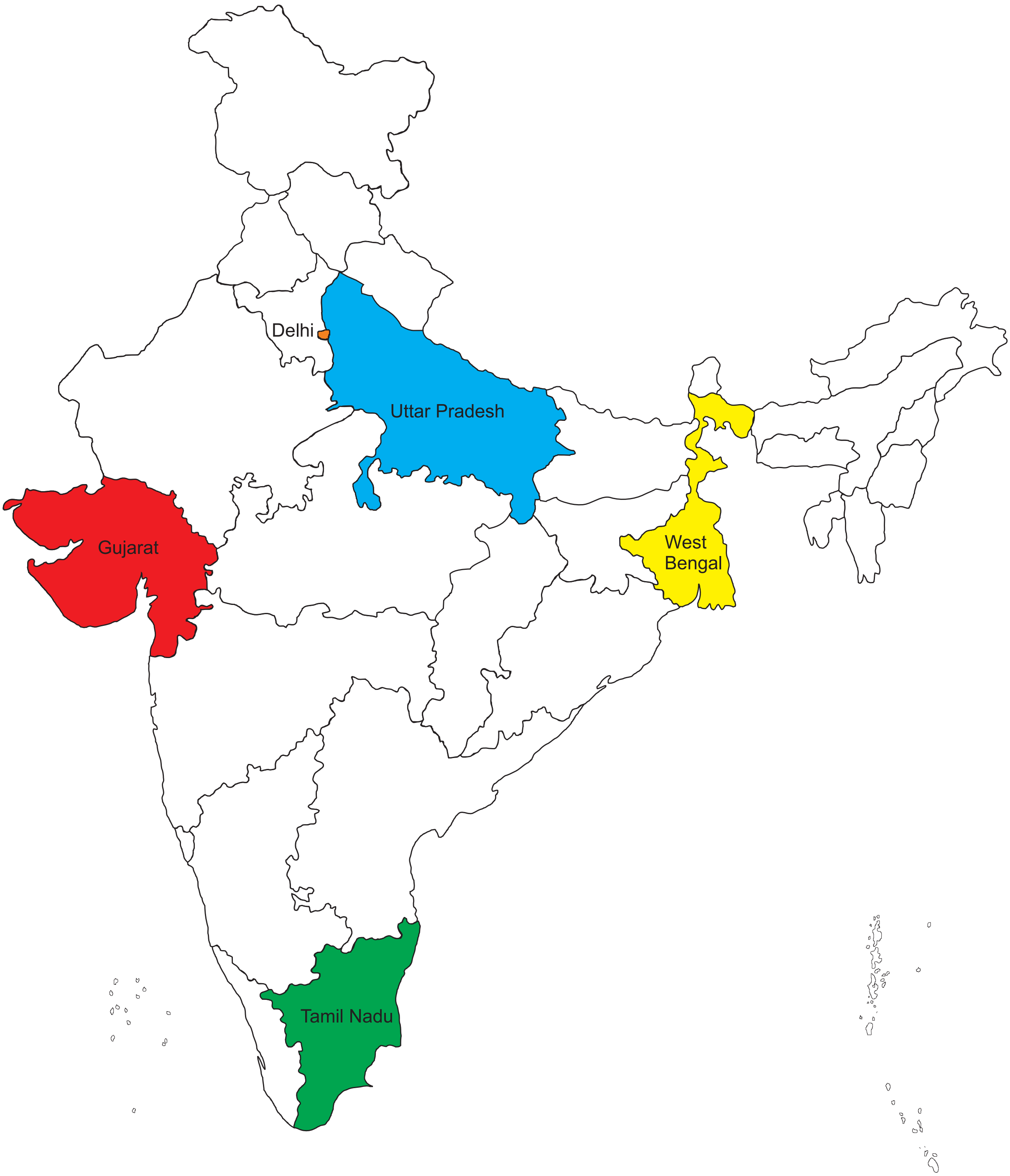
Uttar Pradesh is the northern state of India with the total geographical area equal to 24093 thousand hectare. Uttar Pradesh accounts for 6.88 per cent of the land area and 16.16 per cent of the population. The state receives its major share of rainfall from mid-June to mid-September from the monsoon clouds of the Bay of Bengal. Uttar Pradesh situated in Ganga basin is endowed with bountiful water resources, but is now being impacted by the scarcity due to competing demands for various purposes.

Electricity scenario in Uttar Pradesh is poor as compared to other major states of the country. The total numbers of electrified villages in UP are close to 88 percent of total number of villages in the state. The Census of India 2011 indicates that close to 76 percent of rural households in Uttar Pradesh continue to depend on kerosene for lighting.

West Bengal

West Bengal is located in the eastern part of the country with the total geographical area equal to 88,752 sq. km. West Bengal accounts for 2.7 per cent of the land area and 7.54 per cent of the population, (Census, 2011) and 7.5 per cent of the water resources of the country (State Water Policy, 2011). Primary source of water in West Bengal is rainfall, the annual average receipt of which is around 1762mm. The total annual water availability in West Bengal (surface and ground) along with contribution of interstate /international rivers, and resources from neighbouring states is around 172.52 billion cubic metre, out of which the utilizable resources for irrigation, drinking, industrial, power generation, municipal and other purposes is approximately 109.30 billion cubic metre.

Power requirement in West Bengal has increased from 47872 MU per year in 2005 to 85685 MU in 2012, indicating an increase of 79 per cent in seven years. However, power availability in West Bengal has increased from 47570 MU per year in 2005 to 76705 MU, indicating an increase of 61 per cent during the same period. This differential growth in power requirement and power availability has widened the power deficit scenario in the state.



Detailed analysis in all these 4 states were carried out using the methodology as explained above in the chapter. The results of the analysis are discussed in the subsequent chapters and are mainly dealt as two important relationships: water for energy and energy for water.

3 Quantifying the Nexus

Status and Projections

3.1 Water for Energy

Energy is the key for the development of a country and its transition from a developing to a developed nation. Government at both the central and state level are trying to deal with the electricity shortage problems, and are aiming to increase the installed capacity of electricity in the country. With coal being available in plenty, the stress is to fill the gap between electricity requirement and electricity available through installing power plants, including Ultra Mega Power Projects (UMPPs). However, thermal power production involves the consumptive use of water, and thus makes it dependent on availability of water. As per one of the estimates, energy uses about 8 per cent of all fresh water withdrawn worldwide[11]. Hence, estimating the dependence of energy on water is important for arriving at a crossroad for both water and energy security. Electricity production is one among different sectors competing for water. This competition creates stress on the common resource and friction between the competing sectors. With the burgeoning demand from all the sectors, this competition is likely become fiercer.

This study has made an attempt to understand the relation between water demand for electricity production and water demand from other sectors like agriculture, domestic and industrial production; as well as studies the correlation between the future targets of electricity production as well as future water availability. The analysis was carried out at the state level by selecting four states in four different geographical zones namely—Tamil Nadu in South; Uttar Pradesh in North; West Bengal in East and Gujarat in Western India. Selection of the states and methodology adopted has been explained in the previous chapters.

Out of the four selected states, Tamil Nadu and Gujarat are water stressed states and have higher installed capacity of power plants as compared to water surplus states of Uttar Pradesh and West Bengal. Moreover, in both these states ultra-mega power plant of 4000 MW capacity each has been sanctioned. Hence, this study provides an insight of water demand for energy production in water rich and in contrast energy rich states. Also, the states of Gujarat and Tamil Nadu produce electricity through a range of fuels including gas, oil and nuclear, besides coal and lignite based electricity production.

Among the selected states, Gujarat has the maximum per capita installed capacity for electricity production, followed by Tamil Nadu with 125

[11] Byers, E.; 2014

Watt per capita electricity production capacity. Uttar Pradesh, being the most populous state of the country has least per capita installed capacity among the states selected for study. Gujarat is one of the leading states in terms of providing continuous power supply to consumers, and has the highest power surplus among Indian states.

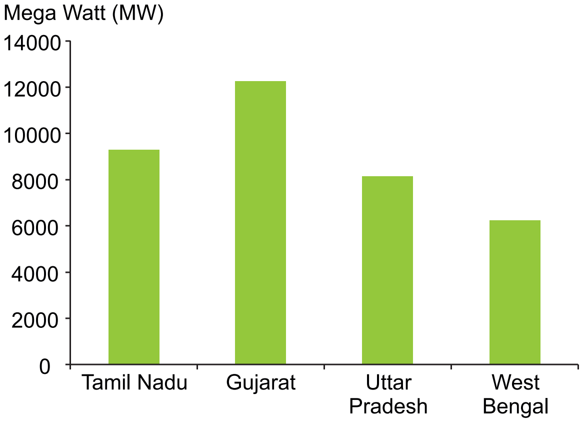


Figure 3.1 Total installed power capacity in the selected states

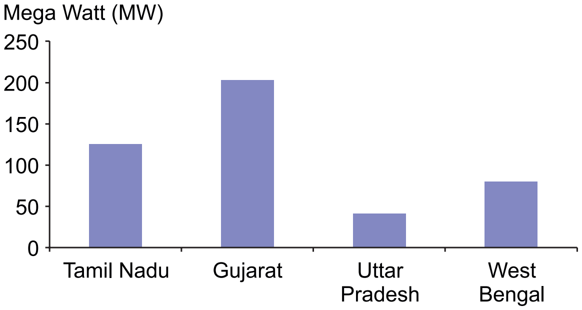


Figure 3.2 Per capita installed capacity in the selected states

Current Scenario

In present study, electricity has been taken as the source of energy excluding the use of other sources of energy like diesel and solar, the proportion of which is very less as compared to electricity. Also, thermal electricity production has been considered for assessment of water consumption for energy production.

Water demand for electricity production has been estimated using the standards proposed by NCIWRD. Different fuels require different amount of water for per unit electricity production. NCIWRD presents two different scenarios for each type of fuel, high and low. Average of these two scenarios has been used to estimate the total water demand for energy production.

Among the sources of thermal electricity production, nuclear energy production is most water intensive consuming about 2.85–3.15 X 104 m3/MW/ yr, followed by coal, oil and gas. However, coal is the most common source of electricity production across the country, with states like Uttar Pradesh and West Bengal producing almost 90 per cent of their total electricity through coal. Thus, coal based power production is responsible for maximum consumption of water for energy. However, a mix of other sources of electricity production like gas based and renewable resources, in states like Gujarat and Tamil Nadu offsets the total water consumption in comparison to their total installed capacity. For example, 50 per cent excess electricity production in Gujarat is achieved with only 6 per cent excess consumption of water, in comparison to Uttar Pradesh. This is mainly on account of 31 per cent share of gas based power plants in total installed capacity of thermal power plants in Gujarat.

Besides the implications of better fuel mix options on total water consumption for electricity production, it is also imperative to understand how energy sector puts stress on water demand from other sectors and vice-versa. As State water policies accord priority to domestic and agriculture sector, water allocation dynamics, sectoral water demands, existing policies and regulations and availability of water, cumulatively affect energy production.

Therefore to understand how energy sector is placed in the existing water demand dynamics, it is important to estimate the share of water for energy compared to share for other dependent sectors. PODIUM Sim was used to estimate sectoral water demand for domestic, agricultural and industrial sector. Figure 3.3 presents total water demand from different sectors vis a vis water demand for electricity production in each of the selected states.

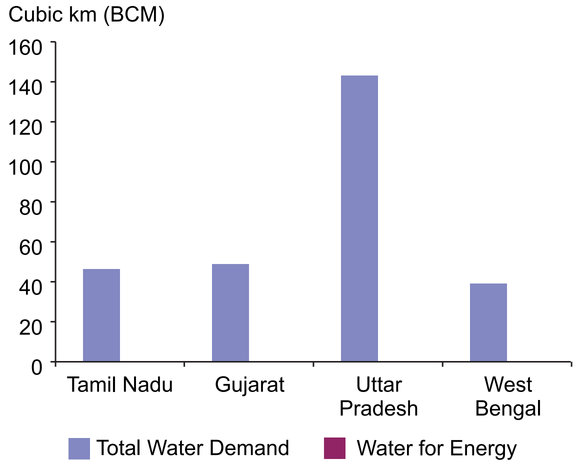


Figure 3.3 Total water demand vs. water for energy

Water demand in Uttar Pradesh is very high, almost thrice the demand from other states under study. One of the possible reasons could be that the state has larger area than other selected states and is the most populous state of the country. Therefore, more water demand from domestic and agricultural sectors. When compared to water demand from energy sector, larger demand from other sectors skews the share of water demand from energy sector in total water demand in the state. The table below presents percentage share of water demand from energy sector in each state compared to total water demand in these states.

Overall, water demand for energy is less than 1 per cent in all the studied states, as compared to water demand from other sectors. However, in actual terms, this is equivalent to 0.57 billion litres water per day, for the states like Gujarat and Tamil Nadu. Further, this is equivalent to 7–10 per cent of their domestic water demand. As power plants run on a continuous basis, a running water supply is necessary for their smooth functioning. Hence, any variability in water availability has the potential to affect the power production. For an instance, inadequate water supplies in the state of Chhattisgarh shut down the National Thermal Power Corporation's Sipat plant in 2008.

Table 3.1 Share of water demand from energy sector

State	Share of water demand from energy sector (%)
Gujarat	0.424
Tamil Nadu	0.449
Uttar Pradesh	0.136
West Bengal	0.398

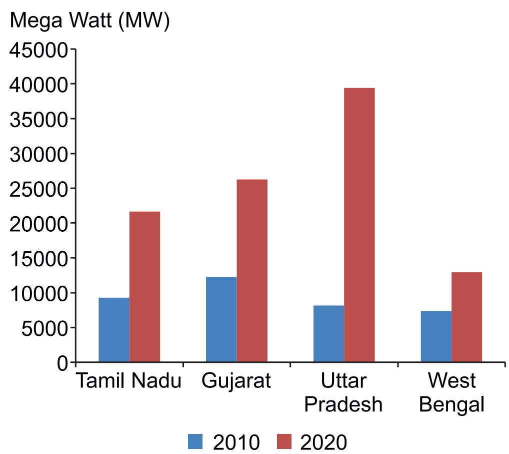


Figure 3.4 Total installed power capacity in the selected states for present and future time period

Governments at both the national and state level are striving to increase the electricity production capacity, by augmenting various fuel based installed capacity. Public-Private partnership (PPP) mode has been allowed in electricity generation, transmission and distribution. Primary focus has been on increasing the coal based thermal power production capacity, due to easy availability of coal in the country. The records related to 12th five year plan as well as state level Power and Energy policies indicate the targets set by governments for installed capacity. Aggressive expansion plans have been prepared by Uttar Pradesh state government. For example, Rs 200 crore has been allocated for new thermal power projects planned at Ghatampur, Kanpur in a joint collaboration with Neyveli Lignite Corporation Limited. If the plans are implemented then the change in the capacity would be around 400 per cent from the existing capacity.

Future Scenario

Increase in water consumption for electricity production is proportional to the increase in installed capacity in individual states. Uttar Pradesh leaps the maximum and the future water demand for energy increases almost 400 per cent as compared to the demand in the year 2010. This corresponds to the highest change in terms of future water demand for energy production as compared to current demand.

Figure below presents the change in water demand for energy sector for 2020 against 2010.

Thus, for states like Gujarat and Tamil Nadu, where water situation is already grim; accelerating demands from energy sector as compared to water demands from other sectors is not very promising. For both the states, projected water demand from other sectors also increases in the year 2020, with Gujarat witnessing around 41 per cent rise and Tamil Nadu witnessing around 13 per cent rise as compared to around 168 per cent rise in water demand for energy sector in Gujarat and around 146 per cent rise in water demand for energy sector in Tamil Nadu.

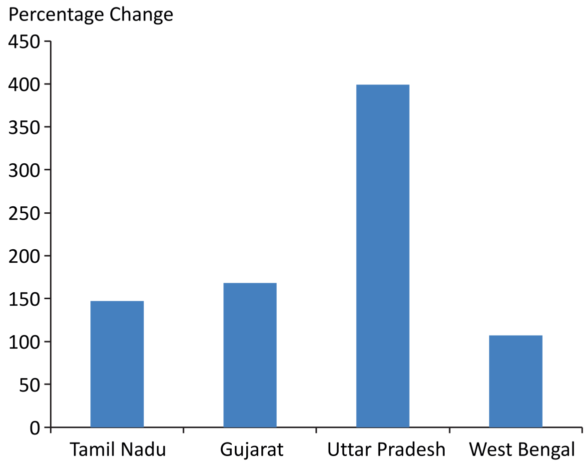


Figure 3.5 Percentage change in water demand for energy for the year 2010 and 2020

This analysis into projected future values, indicates the possible stress that energy sector could face due to depleting water resources, competing demands from other sectors, changing climate, and isolated policies. It points towards the need of conjunctive water–energy policies to ensure future power plant installation with due consideration to water availability in the region, and a mechanism of distribution of energy at all levels. This may need devising of better trade-offs to reach positive equilibrium between water and energy.

3.2 Energy for Water

Water Demand Pattern (Base year 2010)

Agriculture is the biggest consumer of water, followed by domestic and industrial water consumption. Agriculture accounts for more than 90 per cent of total water consumption in Tamil Nadu, Gujarat and Uttar Pradesh, while in West Bengal, agriculture consumes 83 per cent of total water demand.

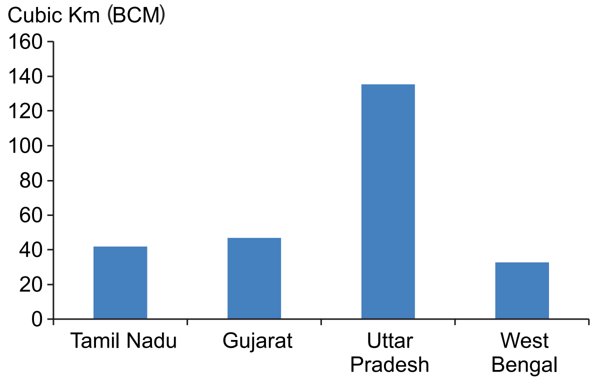


Figure 3.6 State wise agricultural water demand

Agricultural water demand is proportional to the area under irrigation for different crops. Total irrigation water requirement in Uttar Pradesh was 135.37 km^3 in 2010–11. Wheat, sugarcane and paddy are the three most water intensive crops of Uttar Pradesh, consuming 42 per cent, 26 per cent and 20 per cent of total agricultural water, respectively.

Gujarat and Tamil Nadu with 60 per cent and 30 per cent net crop area consume 35 per cent and 31 per cent of water for agriculture, as compared to Uttar Pradesh. This is mainly due to difference in primary crop being grown in the state. While paddy consumes almost 50 per cent of total agricultural water in Tamil Nadu, cotton and sugarcane account for 50 per cent of total agricultural water in Gujarat.

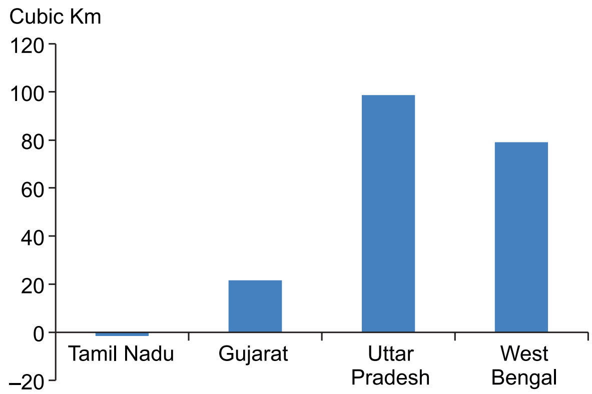


Figure 3.7 Water deficit or surplus situation in the states

As per the demand patterns in 2010, Tamil Nadu shows a water deficit of 1.57 BCM which is close to 3.5 per cent of total utilizable water potential of the state. On the contrary, West Bengal has maximum water surplus with 67 per cent of total utilizable water potential as unutilized. However, Uttar Pradesh has maximum amount of actual water available as surplus. Gujarat had a water demand equivalent to only 70 per cent of its total utilizable water potential, indicating a water surplus of 21.6 BCM. Out of the four states, West Bengal and Uttar Pradesh are mainly water surplus states, while the other two are water stressed states.

Water Demand Pattern (Future Scenario)

Under future scenario, agriculture continues to be the largest consumer of water, though its share reduces due to higher increase in water demand from other sectors. Tamil Nadu shows the highest reduction in proportional share of water demand from Agriculture in comparison to other sectors.

Gujarat shows a maximum increase in water demand from all the sectors. While Agriculture and domestic water demand increases by 40 per cent and 45 per cent by 2020, industrial water demand increases by almost three times the present levels. Uttar Pradesh and Tamil Nadu show almost 100 per cent increase while West Bengal indicates a 59 per cent increase in water demand from industries.

A higher increase in agricultural water demand in Gujarat may be attributed to extension of irrigation facility to unirrigated areas, as well as increasing area under cultivation especially for wheat. On the other hand, a lower increase in agricultural water demand in states other than Gujarat may be attributed to increasing encroachment of agricultural land for urbanization leading to a lower rate of growth of area under cultivation for different crops.

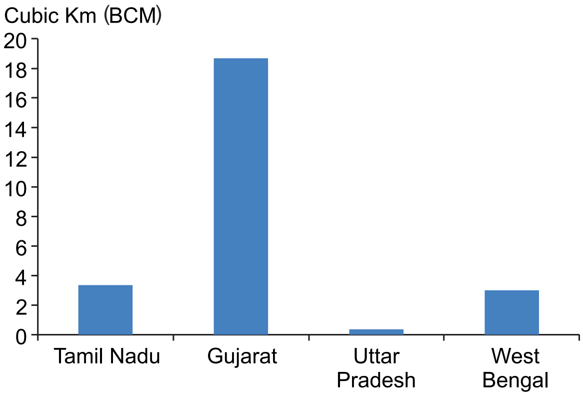


Figure 3.8 Increase in Agricultural Water Demand by 2020 under BAU scenario.

Energy Demand Pattern (Current)

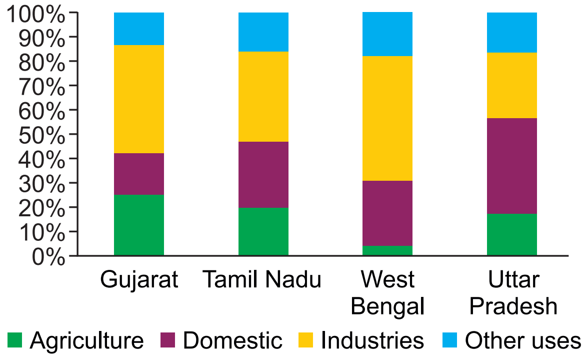


Figure 3.9 Percentage distribution of electricity demand from different sectors

Agriculture is the most water intensive sector, but in terms of energy demand, industrial sector takes the lead in almost all the states, except for Uttar Pradesh, where domestic sector dominates the energy demand patterns. Agriculture accounts for 25 per cent of total electricity consumption in Gujarat, 20 per cent in Tamil Nadu and 17 per cent in Uttar Pradesh. This is almost inverse trend to the trend related to agricultural water demand in these states. Pilferage of electricity due to unauthorized electricity connections as well as prevalence of diesel based pump sets due to unreliable power supply may be the reason for lower consumption of electricity for agriculture in Uttar Pradesh and West Bengal.

Energy Demand Pattern (Future)

Percentage increase in future electricity demand from various sectors for each of the state shows an interesting trend, with state of Uttar Pradesh leading in all the sectoral demands. For all three major sectors and for other uses, projected energy demand in future for Uttar Pradesh is more than from other states. Energy demand in the state of Uttar Pradesh is estimated to increase almost 300 per cent of current value, while for West Bengal rise will be little less than 150 per cent. Moreover, increase in energy for agriculture shows contrary trends as compared to increase in water for agriculture, for Uttar Pradesh. Increase in water for agriculture in Uttar Pradesh is only 0.3 per cent while increase in energy for agricultural water is 311 per cent. Similarly, West Bengal with 9.16 per cent increase in water for agriculture shows 147 per cent increase in energy for agricultural water. Such a trend may be attributed to future projections assuming the extension of electricity supply for agriculture in Uttar Pradesh and West Bengal, along with reduction in pilferage. On the other hand, trends in Gujarat and Tamil Nadu for increase in water for agriculture and energy for agricultural water are in consonance with each other. Gujarat with 40 per cent increase in agricultural water shows an increase of 106 per cent in energy for agricultural water, and Tamil Nadu with 8 per cent increase in water for agriculture shows 37 per cent increase in energy for agriculture.

After agricultural sector, major increase in energy demand is witnessed in industrial sector, where the percentage increase for Uttar Pradesh has been estimated to be around 220 per cent, followed by West Bengal with roughly 130 per cent.

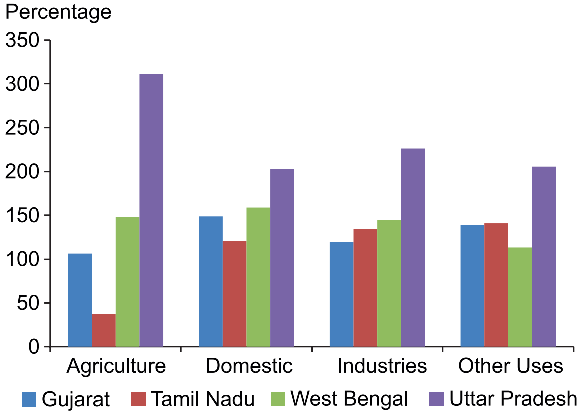


Figure 3.10 Percentage increase in electricity demand from different sectors

It also indicates that both Uttar Pradesh and West Bengal could grow as energy intensive states.

Energy for Water (Current)

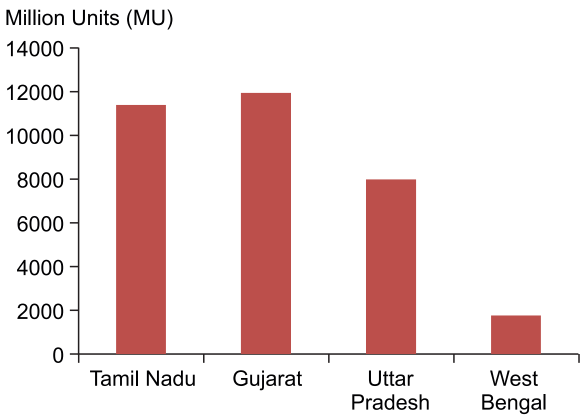


Figure 3.11 Energy demand for water for current year

Energy is needed for various water related processes in each sector. Gujarat leads other states in terms of energy consumption for water related uses. In 2010 Gujarat state used nearly 12000 MU of energy, followed by Tamil Nadu with close to 11000 Million Units of energy. Uttar Pradesh and West Bengal consumed around 8,000 MUs, and 2,000 MUs of energy for water related processes in various sectors.

Irrigation sector needs electricity to pump water and generally these pumps are energy intensive, making irrigation an energy intensive process. As an estimate, 85 per cent of total electricity consumed in agriculture is for irrigation. In Gujarat, agriculture accounts for almost 21 per cent of total electricity consumption in the state. In Tamil Nadu and Uttar Pradesh, this ranges between 16–18 per cent. These trends do not follow the trends for water consumption in agriculture, as explained previously.

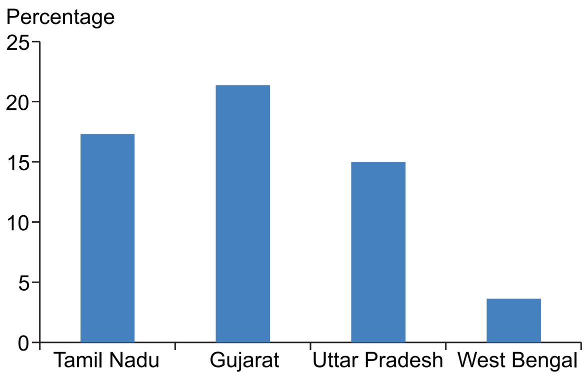


Figure 3.12 Percentage consumption of total electricity demand for irrigation

Energy for Water (Future)

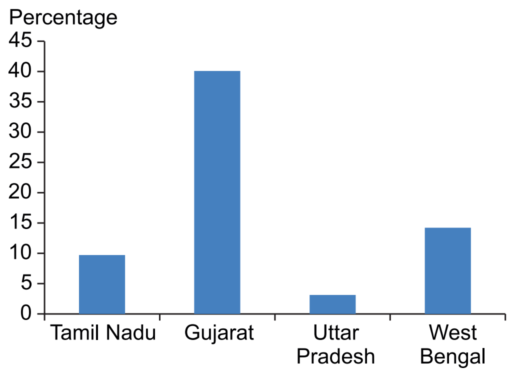


Figure 3.13 Percentage increase in energy for water in 2020 in comparison to present levels

Under BAU scenarios, energy demand for water increases in consonance with the increase in demand for water over a decade. Gujarat shows very high increase in energy demand as compared to the current year, most of which could be attributed to increase in energy demand for water use in agriculture sector. On the contrary, West Bengal shows the maximum increase in energy demand for water in domestic sector, due to increase in population as well as urbanization in the state.

Energy for Water (Future): Alternate Scenario

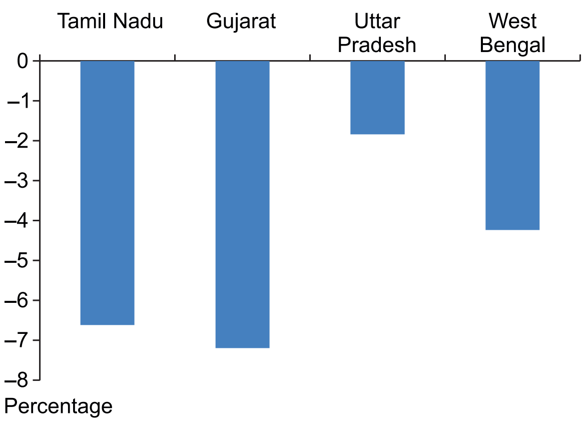


Figure 3.14 Percentage improvements in electricity consumption for water under ALT1 scenarios against BAU scenarios

Alternate scenario, assuming an improvement in overall irrigation water efficiency by 5 per cent over the decade, indicates a simultaneous reduction in energy requirement for irrigation purpose. The graph above depicts the percentage improvement in terms of electricity consumption for irrigation purpose as compared to BAU scenarios for the future time period. Gujarat and Tamil Nadu show the saving of 6–7 per cent because of improvement in irrigation efficiency. Uttar Pradesh and West Bengal show a similar potential of saving energy when irrigation as well as pump efficiency are improved simultaneously, which could have better implications for energy security scenarios in these energy stressed states.

4 Water–Energy Nexus
Assessing Institutional and Policy Framework

For all the selected states, comprehensive policy and institutional analysis was carried out in the context of water–energy nexus. For each of the states, some of the key observations are described below. It also highlights some of the projects or initiatives taken by the state government which may help to achieve positive equilibrium in W–E nexus.

4.1 Tamil Nadu

Water and energy sector in Tamil Nadu is governed by various policies and acts. Policy and legal framework for water and energy in Tamil Nadu has both the element of positive and negative nexus. The state has not carried out any study at the state level on water–energy–climate change nexus. Subsequent sections detail outs specific acts regulations and programs and their impact on water energy nexus.

Governance and Policy Framework (WATER)

Tamil Nadu Water Policy is the main policy related to water in the state. The policy hasn't been revised yet since 1994 but the state has vehemently implemented water recharge components mixed with amendments as rules of municipality, municipal corporations and PRIs in 2003. This policy emphasized on better water resources management and need for conservation but this decades old policy doesn't recognize any linkage with energy sector. Tamil Nadu has an Institute for Water Resources for providing technical expertise in the formulation of water policies and plans, and for capacity building to undertake advanced research on water resources.

Another major policy in water sector is The Tamil Nadu Groundwater (Development and Management) Act, 2003, which has put a cap on over-exploitation of ground water resources which indirectly also regulated electricity consumption. But, unfortunately as reported in many media sources the law has not been implemented and is only on the papers. Many blocks of the state have over exploited the groundwater in absence of stringent law and are now in critical and semi-critical category of ground water level.

One of the important policies of the state; Agricultural Policy emphasises on water conservation efforts using drip and sprinkler irrigation and other techniques. But it doesn't promote energy efficient device use. Linkage of all these polices with energy sector is clearly missing.

The apex body for water resource planning in Tamil Nadu is Water Resources Control and Review Council (WRCRC). The main function of the council is to oversee multi sectoral water planning and allocation. The council plays an advisory and approval role. WRCRC has five sub-committees—(i) Irrigation and Agriculture (ii) Urban and Rural Domestic and Live-stock Water Supply and Sanitation (iii) Power and Industrial (iv) Ground Water Regulation (v) Environment. All other organizations are under this main council and perform their set roles and responsibilities are per the decided mandate. But there is no linkage with the institutes involved in power sector.

Governance and Policy Framework (ENERGY)

Electricity generation is an area where there seems to be a possible strong confluence of water–energy institutional nexus. One of the main policies, Electricity Act 2003, lays emphasis on use of renewable energy sources and it also provides an institutional mechanism for water use (small hydel) for power, and in turn power is priced appropriately under the guidance of the ERC.

Tamil Nadu has set up specific agencies for the regulation, generation, transmission and distribution of electricity in the state. These agencies have clearly distinct roles and responsibilities for the management of electricity sector in Tamil Nadu

While an excellent institutional set up exist in the state for the governance and management of water and energy, there is lack of any institution for coordination between the two in respect to use or achieving efficiency. The two institutional set up are working in isolation without the involvement of decision makers from other sector. Many of the decisions thus seem to be taken unilaterally without the extent of importance attached to the other.

However government of Tamil Nadu has initiated some projects which may help to harmonize the water energy nexus. Some of these key projects are described below. But all these initiatives are subject to further analysis and consideration in terms of their actual implication on the nexus.

- TN govt. has replaced power guzzling pump-sets of the small and marginal farmers with energy efficient ones in few villages of the state. This project has shown positive outcomes and the power consumption has been reduced by 3 million units.
- In 2013, Government has announced 80 per cent subsidy to solar powered irrigation pumps, for promoting renewable energy sources. This is one of the remarkable examples of positive trade-off between water and energy.
- WaterGY project implemented in Tamil Nadu is one of exemplary case of energy and water efficiency in municipal water supply system of the state. It was implemented in 29 municipalities of the state and made water supply system energy efficient, resulted in energy and cost savings, besides reducing CO_2 emissions.

4.2 Gujarat

Water is a critical resource for Gujarat. In the past, lack of water resources in the State has often been perceived to be a constraint to growth and the State accordingly accorded the highest priority to investments in the water sector. Gujarat is rich in solar energy, biomass and wind energy. As part of its renewable energy promotion policy, Gujarat enacted the country's first Wind Energy policy in 1993 and become the first state with a Solar Policy in 2009 (Source: Green Clean Guide). Increasing power generation capacity in each year along with the growing share of Renewable energy in its total energy mix has made Gujarat a prominent renewable energy producer in the country. However as the two sectors are dealt in isolation, the section below provides insight of existing policies and programs which have potential to harmonize or disturb the nexus equilibrium.

Governance and Policy Framework (WATER)

In terms of water, Gujarat follows State Water Policy formulated in 2004, which is on the lines of old National Water Policy of 2002. Another initiative is the Gujarat Irrigation and Drainage Act, 2013. The main object of the act is to increase the performance efficiency of irrigation schemes in the State with a view to bringing about equitable distribution of water for irrigation with the help of farmers and maximizing the benefits from irrigation through canals in terms of increased agricultural production without additional cost. It is proposed to achieve the aforesaid objectives by providing for realisation of optimum use of water for irrigation and participation of farmers towards water management.

The Narmada Water Resources Water Supply and Kalpasar Department is the apex body for water resources development planning within Gujarat. Its objective is the maximum harnessing of water resources for the use of the people of Gujarat. At an institutional level, the responsibility of ensuring sustainable water supply, sanitation services and the implementation of water schemes has been delegated to the Gujarat Water Supply and Sewerage Board. Even at institutional level, linkage with other relevant departments like energy is missing.

In water sector, Sardar Sarovar Project is one of the largest water resources projects in India covering four major states—Maharashtra, Madhya Pradesh, Gujarat and Rajasthan. The numerous benefits of the project include water supply for irrigation, drinking water supply, power generation and flood protection (Sardar Sarovar Narmada Nigam Limited website). A visible positive nexus is observable in the case of the Sardar Sarovar Dam. News reports have established that the installation of solar panels on a 0.75 km stretch over the canal (India Today, April, 2012) would serve dual purposes towards water–energy efficiency. One, water evaporation is avoided, leading to prevention of water wastage. Two, micro turbines are planned to be installed within the metallic structure of the solar panels to produce low density hydro-power. However, there are reservations over whether the regular cleaning of these solar panels would lead to wastage of large amounts of water [KCET(California based news agency), 2014], rendering the Gujarat government's innovative ideas moot.

Governance and Policy Framework (ENERGY)

Energy sector of the state is governed by some key policies and acts like Electricity Act, 2003; Electricity Regulatory Commission Act, 1998; Gujarat Electricity Industry (Reorganisation and Regulation) Act, 2003; and Jyotigram Yojana. The Gujarat Energy Development Agency, a Government of Gujarat organization, is involved with the promotion and popularization of alternate and 'energy efficient technologies'. Essentially, it is involved with the development of renewable energy and energy conservation. The organization proposes to foster the development of sustainable, equitable and resilient energy systems suitable for the development of the State's economy. With reference to the policies for the promotion of renewable energy, a positive nexus is created by providing for institutional mechanisms for water use.

Jyotigram Yojana Scheme has helped achieve the aim of providing 24/7 three phase electricity to farm/non-farm useRs Under the scheme, separate electricity feeder lines for agricultural and non-agricultural users were setup to make farm power rationing effective and tamper profits. Water and Land Management Institute was established in Anand (now relocated to Gandhinagar) in 1980–81. The institute conducts applied research in the field of water management and land development. Here again, we observe a positive water–energy nexus towards efficiency since research responsibility for better electricity and water management may be assigned to the institute .

The Gujarat Energy and Resource Management Institute was established as a centre of excellence in industry learning and was setup to develop HR to cater to the petroleum and allied energy fields. The Gujarat Industrial Policy of 2009 provides for the facilitation of investment and sustained growth. Towards achieving an improved water–energy nexus, one can find investments that are planned to be facilitated through PPPs in areas such as power, water and gas could be well thought through so that wastage of any resources is minimised. These organisations are suitable since resources and efficiency studies could be interlinked. PPPs are planned to be initiated for the recycling of water. Energy and water audits (and conservation) are planned in a bid to make SMEs more technologically advanced. Energy and water conservation are explicitly mentioned and emphasized. This would potentially lead to a more efficient and judicious of limited resources. The government does recognize that the state has very limited potential for hydro-electricity. This has led to a shift in focus to other renewable sources of energy including wind/biomass and the solar. The government targets for a total of 10 per cent of the State's energy requirements to be fulfilled by renewable energy sources. Centres of excellence are also planned to be established for research on non-conventional sources of energy.

It is in this context that The Gujarat Green Revolution Company Limited seems to be an innovative structure. It is an implementing agency for the implementation of the micro irrigation scheme on behalf of the Government of India and the State of Gujarat. The company endeavours to bring a second green revolution in the state. This would be made possible by saving of water, electricity and enhancing agriculture productivity resulting in the farmers' prosperity at large. The necessity for micro irrigation forms a positive water–energy nexus.

But one of the challenges in energy sector faced by the state is the provision of electricity at subsidised rates. Not only does it establish a credible threat to the already depleting ground water in Gujarat, the continuous and un-audited use of limited resources leads to large amount of wastage.

4.3 Uttar Pradesh

The state of Uttar Pradesh is endowed with considerable water resources. However, economic development of Uttar Pradesh is hampered due to inadequate availability of power. The demand supply gap has been widening year after year and not much has been done to create additional capacities in all the segments of the sector. The gravity of the situation is proved by the fact that the State's annual per capita consumption is 340 units as against the national average of 672 units (State Energy Policy, 2009).

Governance and Policy Framework (WATER)

The Uttar Pradesh state water policy was introduced in 1999. The policy lays focus on Research and Development for the effective and economical management of water resources including assessment of water resources, enhanced water management practices and the re-cycling and reuse of water. The policy also emphasizes the improvement in efficiency of water usage through efficient management, conservation, demand side management through the spread of efficient irrigation technologies.

The water policy also provides for harnessing the untapped potential and bringing about an improvement in the management of water resources. It also recognizes the need for the management of other agricultural inputs. By not limiting itself to water and by recognizing the need to manage other agricultural inputs, the Policy has been made coherent. The setting up of a Tariff Regulatory Body for water pricing will ensure that water is priced optimally. This would ensure maximum compliance with Tariff Regulations and conservation of limited resources.

The focus of the water policy seems to be towards efficient usage of resources and the management and regulation of water usage. Steps towards implementing water efficient irrigation systems (drip irrigation ensures minimal wastage of water) are also proposed. Private sector participation has also been encouraged. The State must also ensure that effective administrative steps are taken towards fulfilment of these policy measures.

Water Management and Regulatory Commission is responsible for facilitation of water conservation, optimal utilization of water resources for environmental and economic stability and fixation of water rates. The Commission has been provided with considerable powers and responsibilities thorough the act. It has also been assigned a broad range of functions. It is imperative for the Commission to reflect on the water–energy nexus since one of its primary objectives is the effective management and conservation of limited resources. Ideally, it should work in tandem with the Electricity Regulatory Commission in order to ensure optimum pricing for the usage of resources. Thus, the Act presents immense potential for the establishment of an efficient energy–water nexus.

Uttar Pradesh Participatory Irrigation Management Act, 2009 empower water users' associations for their role as instruments of participatory irrigation management. Owing to the diminished/low productivity of agricultural lands, inability of individual farmers to adopt modern techniques and shoddy input management, the act will encourage co-operation between farmers. This would result in use of canal water in the desired manner, bring long term stability in irrigated agriculture and secure community cooperation. Such an initiative could make the irrigation system extremely efficient, if adequate steps are taken towards performing these functions. These Associations may also be given the responsibility of encouraging and ensuring ideal usage of electricity. This may potentially lead to the creation of a positive water–energy nexus thereby leading to the attainment of an efficient system.

The Uttar Pradesh State Agriculture policy endeavours to improve input use efficiency, promoting the utilization of non-conventional energy sources and encouraging the development of rural infrastructure. The policy highlights that maximum emphasis will be placed on on-farm water management to improve Water Use Efficiency (WUE) by promoting efficient systems such as sprinkler, drip irrigation, HDPE pipes, which help to optimize the benefits from the available water resources.

The Uttar Pradesh Water Restructuring Project is a step in the right direction towards achieving an efficient water–energy nexus. The objectives of the project (integrated water resources management and increased water productivity) are an indicator of the potential steps that may be taken towards achieving optimal resource utilization. Since a major restructuring of the water sector is being undertaken, the Government must ensure that the water–energy nexus is recognized and that the power and water sector take steps towards improving resource use efficiency.

Governance and Policy Framework (ENERGY)

Following the rule from Central government, Uttar Pradesh also has four separate bodies to govern regulation, generation, transmission and distribution of electricity in the state. The Department of Energy is the apex body in the energy sector in the State of Uttar Pradesh. As part of the power sector restructuring process, the government of Uttar Pradesh enacted the U. P. Electricity Reform Act 1999 and set up the U. P. Electricity Regulatory Commission (UPERC), as an autonomous body. The commission is responsible to regulate the power sector in a manner that uninterrupted and cost effective electricity is available to each and every household of Uttar Pradesh. Towards achieving the reforms objective, UP has created Uttar Pradesh Power Corporation Limited (UPPCL), Uttar Pradesh Power Transmission Corporation Limited (UPPTCL) and Uttar Pradesh Jal Vidyut Nigam Limited (UPJVNL). The purpose of Jal Vidyut Nigam is to establish hydroelectric projects across the State, sell generated electricity to the UPPCL and modernize running projects in a most efficient and economical manner.

The establishment of an organization for the sole purpose of hydroelectric projects is encouraging. The scope for such an organization to recognize and work towards bringing efficiency in the water–energy nexus is very high. Therefore, the possibility of adopting measures towards attaining optimal utilization of resources and resource management is considerable.

Uttar Pradesh government introduced the Energy Policy for the state in 2009. The objectives of the Policy are to achieve economic growth in the power sector, to encourage the efficient usage of electricity and facility conservation through demand side management, among others. The policy also lays emphasis on setting up new small hydro projects, to improve efficiency of agricultural pump sets and all electrical installations. Thus, the focus of the Policy, along with economic growth, is on the efficient usage of available electricity. This presents a potential to harmonize water–energy nexus. With increased monitoring, effective administration and the promotion of measures to conserve resources, optimal utilization of resources could be achieved. Demand side management would ensure that usage is kept under a check and resources are used judiciously.

It is encouraging to see a holistic policy being framed. Despite there being no recognition of the water–energy nexus, the language is suggestive of an interest in the efficient utilization of resources. Further, the inclusion of industries may potentially lead to positive water–energy nexus in the industrial sector as well.

Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) is responsible to facilitate the sustainable generation of power through new and renewable energy resources and to promote energy conservation measures. Research and development, the promotion of energy conservation, promotion of sustainable and clean energy programmes and promotion of energy efficiency measures feature as prominent functions of the Agency.

The State is well endowed with dams, irrigation canals and perennial rivers (including the Ganga, Yamuna, Sharda, Sarju etc.). The Government, recognizing the potential for Small Hydro Power (SHP) projects in light of the growing electricity needs of the population, initiated the SHP Programme. Proposed efficiency measures include the direct transmission of electricity to remote villages. This would significantly reduce loss due to transmission. Private participation is also being encouraged in order to increase the efficiency of processes. Approximately 110 KW of energy is expected to be harnessed.

Since the tremendous hydro power potential is recognized it is hoped that the water–energy nexus is also recognized and positive measures are taken towards increasing efficiency. The onus is on policy makers to understand the benefits of the careful usage of limited resources and develop coherent policy addressing this issue.

4.4 West Bengal

West Bengal has an abundance of water resources. About 60 per cent of the surface water and 28 per cent of the ground water in West Bengal is in North Bengal that supports only 18 per cent of the population of the region. Whereas 82 per cent of the population residing in South Bengal depends only on 40 per cent of the surface water and extracts 78 per cent of the total ground water for its needs. Thus, spatial variation in terms of water availability may be observed in the state. In electricity production, thermal power sector makes major contribution. The total installed capacity of electricity generation in West Bengal is 8507 MW (Central Electricity Authority). Further, the State of West Bengal is blessed with abundant sources of Renewable Energy in the form of Solar, Wind, Biomass, Biogas, Hydro, Tidal etc. The state has a mini and small hydro potential of 394 MW out of which the existing installed capacity is 97 MW.

Governance and Policy Framework (WATER)

The development and management of water resources is the responsibility of the State. Recognizing the need to systematically develop and properly harness the water resources available to the State, the State decided to bring out a new water policy. The objectives of the water policy are in harmony with the State's developmental plans. 'The State water Policy is required to achieve the objective of conservation, development utilization and management of this precious resource (water) in conformity with the National Water Policy, 2012.'

The water policy, brought out in 2011, lists out the allocation priorities in a hierarchical order. It lists hydro-power as second-last in priority followed only by navigation and ecology. In contrast, however, provisions have been made in the operational action plan for maximizing hydro power generation. Interestingly, for projects based out of hilly areas, a policy for the exploration of hydro power possibilities has been made. The policy recognizes the need for a unified water policy to achieve utmost efficiency in water utilization. With respect to the management of Irrigation water, the Policy states that, in order to realise fuller benefits from the investments made in irrigation sector, efficient management, economic use and conservation of harnessed water is imperative. Further, the policy accounts for the creation of a comprehensive Management Information System which would work as a database (for better planning) and would help analyse the consumption patterns thereby, curbing wastage.

Moreover, proper education to stimulate awareness, incentives and disincentives is proposed. Also, measures taken towards proper conservation of water are proposed. These include the judicious use of water, conjunctive use of surface and ground water in a scientific manner and adoption of irrigation systems (low water consumption) such as drip irrigation are discussed. The intention to conserve limited resources is visible. It is essential to take a holistic view in order to ensure efficient use of resources.

The Policy Makers have recognized the need for inter-departmental communication in order to increase the efficiency in use of resources. The setting up of a cohesive multi-disciplinary unit is recommended for maintaining liaison among departments. This opens up endless possibilities, not only for the water–energy nexus, but for various other potential collaborations.

The Water Resources Development Directorate is concerned with the implementation of minor irrigation schemes, and State Water Investigation Directorate is concerned with the investigation of Ground water resources. Irrigation & Waterways Department on the other hand is concerned with harnessing surface water resources of the State through all forms of interception and facilitates the utilization of the same for different purposes. This Department looks after water resource management of all the river basins of the State other than Damodar.

A State Agriculture Plan was prepared by NABARD (as commissioned by the Agriculture Department, Government of West Bengal), which recommend identification of low water intensive location specific crops and cropping sequences under command areas, and introduction of water saving technologies under irrigated rice (boro / aus crops) like System of Rice Intensification where feasible. The technology has the potential to reduce the irrigation requirements by 30 per cent, among several other recommendations. These are encouraging sign towards achieving energy–water efficiency since the focus is on better management of resources. However, measures recommended are limited to increasing crop/land/water use efficiency. The water–energy nexus is not adequately addressed. This is worrying for a document that has been prepared as recently as 2009.

Governance and Policy Framework (ENERGY)

In the past power sector development has lagged in the State and this has had an adverse impact on industrialisation and agriculture development. While government is in the process of increasing installed capacity through conventional sources, at the same time is very serious in its efforts to harness alternate sources of energy to supplement its energy needs for domestic, institutional, commercial and industrial purposes. The New and Renewable Energy Sources are closely linked with Energy Efficiency, Energy Conservation and Climate Change.

The Department of Power and Non-Conventional Energy Sources was established under the Government of West Bengal for cooking into matters pertaining to power. It is the apex body in the power sector. Functions of the department must be moulded in such a way as to create a positive influence on water–energy nexus. Since energy audits and energy management are an essential function of the Department, it must be ensured that an efficient system is created wherein limited resources are used judiciously and sparingly.

The West Bengal Renewable Energy Development Agency was created in 1993 as a state nodal agency under the Department of Power and Non-Renewable Energy Sources. Its functions include the implementation of a renewable energy programme and the promotion of renewable energy technologies. The Agency has also been actively working towards the advancement of the Hydro Power sector (mini-micro hydel) in West Bengal. Again, the policy framework does not reflect on the efficiency of the water–energy nexus. However, being a dedicated department for renewable energy development, it presents tremendous potential for the purposes of the present study. It is hoped that this potential is recognized and steps are taken towards enhancing efficiency.

The electricity policy (from renewable energy sources) presents positive signs and has potential for reducing trade-offs in water energy nexus dynamics. The policy explicitly discusses funding for adaptive research in 'areas of interest' for the state for the enhancement of efficiency in generation and availability of electricity from RE sources. When this is read together with the ambitious policies for extracting maximum hydro potential (target of 120 MW of Hydro Power by 2017 from small and mini-hydro projects), encouraging signs emerge towards an efficient water–energy nexus.

4.5 International Case studies

Interdependence of water and energy can be noticed across the world, irrespective of the major source of electricity production in individual countries. For example, in United States, the electricity industry is second only to agriculture as the largest user of water. According to the National Renewable Energy Lab, electricity production from fossil fuels and nuclear energy requires 190,000 million gallons of water per day, accounting for 39 per cent of all freshwater withdrawal in the nation. Similarly, about 4 percent of U.S. power generation is used for water supply and treatment and about 75 percent of the cost of municipal water processing and distribution is electricity.

State legislatures and natural resource managers have traditionally addressed water and energy as two separate issues. However, water and energy are deeply connected and sustainable management of either resource requires consideration of the other. Thus, resource managers and lawmakers across the world are beginning to take a comprehensive and interdisciplinary approach to the management of water and energy. A number of striking examples indicating the integrated governance of water and energy are available throughout the world.

USA

In United States, at least eight states (Arizona, California, Colorado, Connecticut, Nevada, Washington, West Virginia, and Wisconsin) have statutes that recognize the nexus between water and energy. Moreover, statutes in Arizona, California, and Nevada even mention the appropriation of water for generating electricity. The statute in California intends to promote all feasible means of energy and water conservation and all feasible uses of alternative energy and water supply sources. Further, the Legislature declared that waste or unreasonable use of water imposes unnecessary and wasteful consumption of energy to deliver or furnish the water, and it is necessary, therefore, to determine the quantities of water in use throughout the state to the maximum extent that it is reasonable to do so in order to reduce that energy consumption. In Nevada state, based upon the public interest and the economic welfare of the State of Nevada, the State Engineer may approve or disapprove any application of water to beneficial use or any application, which contemplates a change in the place or beneficial use of water to a use involving the industrial purpose of generating energy to be exported out of this state.

Washington State outlines the objectives of its watershed planning strategies to supply water in sufficient quantities to satisfy the minimum instream flows for fish, provide water for future out-of-stream uses for water, and ensure that adequate water supplies are available for agriculture, energy production, and population and economic growth under the requirements of the state's growth management act. Moreover, several states in USA define "environmentally sound and economically feasible water conservation measures" as those measures, methods, technologies or practices for efficient water use and for reduction of water loss and waste or for reducing a withdrawal, consumptive use or diversion that, among other things, are environmentally sound, reflect best practices applicable to water sector, and consider energy impacts. (Source: National Conference of State Legislatures).

Canada

Climate change can affect both the timing and the duration of water flow as well as water temperature, with implications for the production of hydroelectricity. In British Columbia (B.C.), the vast majority of electricity is provided by hydro power on the province's river systems. Current practices of water management are impacting drinking water sources and may even limit future availability of water-derived energy, thus requiring proper safeguards to assure these valuable resources are available for future generations. Legal and governance reforms to better address the challenges and opportunities of the water–energy nexus—solutions that are economically, socially, and ecologically sustainable—need to be the overarching goal for the Government of British Columbia. The current Water Act Modernization process underway in B.C. to update the 100-year-old act offers a strategic opportunity to strengthen protection and conservation over the province's freshwater resources –measures that will directly impact the water–energy nexus.

Europe

In Europe, the relationship between energy and water is particularly significant, given that the energy sector is the biggest user of EU water resources (energy accounts for approximately 44 per cent of water abstraction in the EU, according to the European Environment Agency, though the vast majority of this water is returned to the water body.) The good news is that Europe is the only region likely to see a fall in water use for energy production through to 2035, according to the WEO's New Policies Scenario – the IEA's primary scenario. This is likely to be driven in part by EU-vide energy efficiency efforts and the shift towards renewables. Similarly, water efficiency measures will themselves save energy (in water heating particularly). There are more and more discussions about the water, energy and food nexus and how we should be linking these three areas. This perspective thinks about taking the ideas a step further on how to practically plan and implement infrastructure and technology that can link the three elements while minimizing trade-offs. One such instance is looking at providing different qualities of water for different uses. Victoria Falls applied this approach by encouraging the use of river water for watering gardens, hotel grounds and golf courses, thereby reducing the cost of energy and chemicals for treatment.

Among European countries, German government is especially active in managing water–energy nexus both within the country as well as through sponsoring projects in other developing countries:

Germany

The German Government has recognized a clear need for new approaches which address the interconnections within the water, energy and food security nexus. In order to develop these integrated solutions, the German Government initiated a yearlong participatory process including an international multi-stakeholder-dialogue that prepared the Bonn2011 Nexus Conference. By hosting the conference, organized under the auspices of the Federal Ministry for Economic Cooperation and Development and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the German Government pursued three objectives:

- To develop policy recommendations based on multi-stakeholder consultations and taking a Nexus perspective,
- To position the water, energy and food security nexus perspective as an important dimension within the 'Rio2012' process as well as the Green Economy and Green Growth concepts, and
- To launch concrete initiatives to address the water, energy, food security nexus in a coherent and sustainable way.

Besides dealing the water–energy nexus in an integrated manner, Federal Government of Germany is supporting some initiatives outside the country:

- Improvement of Energy Efficiency of the Water Authority of Jordan – The project "Improvement of Energy Efficiency of WAJ" (IEE) tackles the electricity consumption of water pumps, the main consumer of electricity in Jordan's water supply. It was the first project worldwide to be financed within the International Climate Initiative (ICI) of the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU).
- Integrated Water, Energy and Agriculture Programmatic Approach in Bolivia – In Bolivia, German Development Cooperation agricultural, water and energy programmes are developing joint indicators, in a more nexus-driven approach. Moving forward, activities could include things such as increased energy efficiency of water utilities, production of the required energy in the processes of drinking water treatment and provision and reusing wastewater in agriculture.

Australia

Responding to climate change and sustaining freshwater resources are two of the greatest challenges facing society, and they are not mutually independent. To different degrees, all forms of energy draw on water in their production, and so climate policy choices between different sources of energy have considerable implications for water. AUSCEW is three-year collaboration between the US Studies Centre and the Australian National University (ANU), which aims to identify the links between climate, energy and water policies to avoid perverse impacts and favour mutually beneficial solutions across sectors. AUSCEW focuses on identifying examples of good practices from industries; government and academia in Australia and the United States, then synthesizing and sharing this information to better inform decision-makers in business and government. Ultimately, AUSCEW aims to identify and communicate decision-making tools to avoid perverse cross-sectoral impacts and promote co-benefits for a more sustainable society.

Through its Dow Sustainability Program, the US Studies Centre brings together academic and policy experts from Australia and the US to develop action-oriented solutions to a range of sustainability challenges concerning energy, water, food and biodiversity. The ANU is driven by its mission to advance the cause of learning and research in Australia. Through the ANU Water Initiative, it is undertaking research and communications on the nexus between climate, energy and water policies.

There are significant challenges imposed by the links between water and energy. These challenges are surfacing at a time when important decisions are being made regarding future supply options in both sectors. The New South Wales government, for example, recently commissioned the "Owen Inquiry into Electricity Supply in New South Wales" to examine the need and timing for baseload generation options. There appears, however, to be an absence of modelling frameworks that can comprehensively quantify these links and the implications for the Australian economy.

However, there is a rich array of experience and practical knowledge across professional fields including farming, energy-production, natural resource management, and engineering. The challenge is to bringing these together to provide active learning and knowledge exchange. The International Water Association (IWA) and the International Union for Conservation of Nature (IUCN) are looking at how to make this happen through the Nexus Dialogue on Water Infrastructure Solutions, which provides a forum for sharing experiences, lessons, tools and guidelines on how portfolios of water infrastructure and technologies can address nexus challenges. The Water, Energy, & Food Security NEXUS Resource Platform is one such body taking initiatives to promote dialogue on this issue around the world. Water Stewardship Initiative – The "Water Stewardship Initiative" intends to scale up cooperation with the private sector. It will create innovative partnerships to mobilise bottom-up action between government, business and civil society for improved water (energy and land) management in developing countries. It recognizes that water is a shared resource and cannot be secured by one actor alone. Similarly, IWA/IUCN Nexus Dialogue on Water Infrastructure Solutions – The International Union for Conservation of Nature (IUCN) and the International Water Association (IWA) offer a space for the linkages across water, energy and food to be discussed through the Nexus Dialogue on Water Infrastructure Solutions. The Dialogue is a call to action to those, leading transformations in water infrastructure planning, financing and operation.

4.6 Strategic Recommendations

The study developed an understanding about the intensity of water–energy nexus in the identified states at the macro level. Present study also tried to understand the existing policy and governance framework regulating the water and energy sector in these states. While a number of initiatives taken by the individual state governments can be noticed at the state level which have a positive impact on the degree of dependence between water and energy, there is no explicit mention about reducing the trade-offs between policies governing the two sectors. A study about international status on water–energy governance in comparison to state level analysis in the country, provide an insight about the possible measures that could be adopted in the country to harmonize the water–energy nexus. Some of these measures are being listed below, which need further deliberations for adoption in the local context:

- **Updation of Policies:** In order to ensure that recent environmental and technological changes in the power and the water sector are accounted for, state policies and legislations need to be updated /amended in order to make explicit reference about water–energy nexus, and set specific targets to reduce trade-offs. It should also include scope of technological advancement wherever needed. Also an integrated policy framework should be developed which should not only connect water and energy but also encompass scope of possible adaptation strategies against projected climate change impacts.
- **Institution for coordination:** A number of institutions can be observed at the state level dealing with different aspects related to water and energy, though individually. Multiplicity of authorities lead to the development of trade-offs in the regulations framed by individual agencies. This could be reduced by putting a coordination mechanism which could study the friction between two sectors and could suggest measures to remove such incongruities.
- **Efficient water resource use:** Through efficient polices it is important to conserve the resources and use them efficiently. It is imperative to reduce water loss in water supply system. Reducing Non-Revenue water should be one of the key strategies which state governments should implement. In terms of irrigation water, implementing tariffs for groundwater will help reduce water wastage. This can include targeted subsidies for subsistence farmers.
- **Efficient energy resource use:** Energy Efficient Pump Sets & Solar Powered Pumps (as in Uttar Pradesh) should ideally be encouraged through policy in order to ensure resource efficiency. Since India has agrarian economy, irrigation is the major water user and it consumes high amount of electricity also. Therefore this challenge also provides an opportunity in terms of energy efficient pump sets and solar powered pumps. Another remarkable step has been taken by the Gujarat Government who has made a major breakthrough in ensuring metering of power lines, energy efficiency and 24-hour electricity supply in rural areas under this scheme through separation of electricity feeder lines. Other schemes on similar lines may be implemented in all the States.
- **Assessment of energy footprint of water supply system:** for exploring new alternative sources of drinking it is important to first

assess the energy footprint of such projects. Evaluating energy needs could enable improved water security through minimizing risk due to energy scarcity, or energy price fluctuations.

- **Need for IMIS:** States must recognize the need for Integrated Management Information Systems in order to monitor water and power usage. This is a primary step towards ensuring accountability in usage of water. There should be a common platform where in information and data for both the sectors is available for end users as well as for other stakeholders, including policy makers, researchers and utilities.
- **Increased Conservation through stakeholder involvement:** The Administration should encourage programmes where a community as a whole work towards resource conservation. This would ensure collective accountability. Community involvement is of utmost importance for ensuring success in any program and this has been evident in many of the cases across the country. Also PRIs have been given significant powers in number of States. These act as potent tools in monitoring usage and promoting optimal utilization of resources at a local level. This should be further promoted and institutions closer to communities should be empowered.
- **Future Resource Management:** Based on future demand predictions, management strategies for water and energy resource endowment and consumption should be implemented through soft path analysis, which is a back casting management tool aimed to generate methodologies for present functioning in these sectors in lieu of a future best case scenario.

About TERI

A dynamic and flexible not-for-profit organization with a global vision and a local focus, TERI is deeply committed to every aspect of sustainable development. From providing environment-friendly solutions to rural energy problems to tackling issues of global climate change across continents and advancing solutions to growing urban transport and air pollution problems, TERI's activities range from formulating local- and national-level strategies to suggesting global solutions to critical energy and environmental issues. With over 1,000 employees drawn from diverse disciplines, the Institute's work is supported by ministries and departments of the government, various bilateral and multilateral organizations, and

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Buoyed by more than 35 years of excellence in research and innovation, TERI is poised for future growth with a philosophy that assigns primacy to sustainable development and environmental governance.