Projection of Water Demand in India in a Macroeconomic Consistency Framework Incorporating the Food, Water and Energy Nexus

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3.1 Introduction

There are four major sources of water demand in India viz. (1) Agriculture, (2) Residential, (3) Industry, (4) Power Generation. Agriculture and Power are major water-consuming sectors. Higher economic growth would result in changing agricultural consumption patterns which in turn would imply a change in cropping pattern. This coupled with increasing population would impact the amount of water required by agriculture sector. At the same time higher economic growth would imply

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increasing power generation leading to an increase in water demand for cooling requirements. Economic growth would also result in higher water demand due to increasing urbanisation through expanding cities and increasing manufacturing bases to support such an economic growth. Climate change is expected to affect rainwater frequency, intensity and distribution as well as flows in rivers fed by glacier melts. This may lead to reduced water availability for irrigation and also lower groundwater levels. The decreased levels of precipitation and lower groundwater levels would imply an increase in use of groundwater pumps which would increase the demand for power. There exists a food energy water nexus (FEW nexus) which needs to be accounted for a sustainable economic growth path through a sustainable use of water resources across sectors and by private households. To understand the constraints that water demand can impose on economic growth and the water deficit that may appear in the future it is important to project future water demand from all sources by accounting for the FEW nexus. The issues highlighted above are analysed in this paper through the following research questions.

1. To assess the nexus between food energy and water and provide the most optimal strategy for energy sector growth through water conservation and water use efficiency
2. To project the water demand up to 2050 due to

   a. Irrigation accounting for changing cropping patterns due to changing food consumption patterns
   b. Population increase and urbanisation
   c. Industry and power sector

3. To assess the reduction in water use due to water conservation policies for the power generation sectors.

3.2   METHODOLOGY

The major usage of water is from, agriculture for irrigation purposes, residential sector for domestic consumption, power sector for cooling and ash cleaning purposes and Industry for Industrial purposes. However, each of these sectors is a part of the larger economy and their growth has common macroeconomic drivers and intersectoral linkages with other economic sectors. Therefore to assess the competing demands for water

from each of this sector, a consistent projection of outputs of each sector with respect to the economy-wide growth is needed. This is achieved through input–output-based models which ensure intersectoral consistency in computing production levels of each industry. We use an input–output dynamic optimisation model, The IRADe–Integrated Assessment model (IRADe–IAM), based on input–output framework to make consistent projections of outputs of all sectors. The input–output framework ensures intersectoral consistency and the macroeconomic relations imposed as constraints in the model ensures that the model solution is feasible and macroeconomically consistent. The IRADe–IAM model is an economy-wide model in activity analysis framework and covers all sectors of the economy. It is a top–down model with bottom-up specifications of technologies. In this sense the model is an integrated model that combines top-down macroeconomic structure and intersectoral linkages with bottom-up technological specifications. A brief description of the IRADe–IAM model is provided in Annexure 1.

The 78 × 78 sector Social Accounting Matrix for 2007 (Pradhan et al., 2013) forms the reference for the base year data of the model. The base year of the model is 2007–2008 and the sectors from the 78 × 78 sector Social Accounting Matrix for 2007–2008 are aggregated to 25 × 41 sectors for the most appropriate representation of energy sector and its linkages with the overall economy. There are 7 agricultural sectors, 10 industrial sectors (excluding energy sectors) and 3 services sectors. There are three primary energy sectors and two secondary energy sectors. The detailed sectoral structure is shown in Annexure 2.

Generally, energy and climate change models are long-term models which project for long time periods of 50–100 years using a benchmark base year data despite economy and energy systems changing substantially in 50 or 100 years. Structural changes occurring over such a long period of 50–100 years is addressed by the inclusion of futuristic technologies, sector-wise energy efficiency trends, factor productivity trends and change in consumer demand pattern. The model used assumes all these structural changes. Since 2007, the major change in the energy sector in India is adoption of new renewable power generation technologies. The model considers 16 current and future power generation technologies (Table 3.20, Annexure 2) with prescribed market penetration rates based on current trends (Table 3.6). In all other sectors,

the changes since 2007–2008 have been in terms of energy efficiency and factor productivity growth. Time trends in both these factors have been assumed and specified in Table 3.5. The most important factor that contributes to structural change in production over a long period of 50 years is the structural change in household consumer demand. The model combines a nonlinear demand system with endogenously changing income distribution (explained in Annexure 1). This helps the model compute changing demand structure in a realistic manner due to changing tastes with increasing income and due to upward economic mobility through growth. Thus the model manages to address all changes in the economy from 2007–2008 till today.

The choice of base year 2007–2008 is partly due to the non-availability of a SAM of more recent years that is suitable for the disaggregation required in the analysis. Besides many years in the recent past have been years of economic shock and intervention like oil price rise in early 2011–2012, demonetisation in 2016, GST in 2017 and COVID in 2020. Using 2007–2008 as base year is also helpful in estimating the impact of low carbon pathways on water demand as is one of the objectives in the paper. Selecting a more recent base year would not help in assessing the impact of low carbon transitions already achieved.

Water consumption in each sector is directly proportional to the output of these sectors in 2007–2008. These are technological coefficients and there is no reason to assume a change in them over time except for technological improvement which is a policy scenario considered in this paper. The calculation of sector-wise water consumption coefficients and model parameters and policy assumptions is presented in the section below.

3.2.1   Model Assumptions

The key parameters and assumptions that drive model results are provided below while the remaining details are provided in the Annexure.

a. Population

All the scenarios use the UN medium variant population for India. The population of rural and urban areas is assumed based on the UN medium variant population for India and is given in Table 3.1.

Table 3.1 Total, rural and urban population projection

Population[a] (in millions)

Year	Total	Rural	Urban	Urbanisation (in %)
2007	1158	812	346	30
2010	1206	833	373	31
2020	1353	883	471	35
2030	1476	893	583	39
2040	1566	864	701	45
2050	1620	806	814	50

[a]Population UN Medium Variant

Table 3.2 Resource growth assumptions

Resource	Reserves in 2007	Growth Rate in reserves (%)
Coal and lignite (million tonnes)	153,103	1.0
Crude petroleum (million tonnes)	725	0.0
Natural gas (billion cubic metre)	1055	1.1

Source http://www.coal.nic.in/content/coal-reserves

b. Resource Reserves and Growth Assumptions

The growth rate and stock of proven reserves of fossil fuel such as coal and lignite, crude oil and natural gas are provided in Table 3.2.

c. Macroeconomic Assumptions

The other major macroeconomic assumptions that drive the model include assumptions on discount rate, post-terminal growth rate, government consumption rate, maximum savings rate, bounds on per capita consumption growth rates and export and import bounds. The export bounds are provided as % share of total output and import bounds are provided as % share of total availability (output + imports). These assumptions are provided in Tables 3.3 and 3.4.

Table 3.3
Macroeconomic
assumptions

Parameter	Assumption (%)
Maximum growth rate of per capita consumption	8
Government consumption growth rate	7
Maximum savings rate	40
Discount rate	4
Post-terminal growth rate	3

Table 3.4 Trade, exports and imports bound (%) assumptions

	Commodity	Export upper bound	Import upper bound	Import lower bound
1	Food grains	10	10	0
2	Sugarcane	10	10	0
3	Oil seeds	10	10	0
4	Other crops	10	10	0
5	Animal husbandry	10	10	0
6	Forestry	10	10	0
7	Fishing	10	6	0
8	Coal and lignite	1	30	20
9	Crude petroleum	2	98	80
10	Mining and quarrying	99	45	0
11	Agro-processing	10	20	1
12	Textiles	50	30	0
13	Petroleum Products	20	20	5
14	Fertiliser	20	33	20
15	Cement	10	0.6	0.3
16	Non-metallic minerals	10	10	1
17	Steel	20	10	1
18	Manufacturing	40	30	1.5
19	Construction	0	0	0
20	Electricity[a]	0	0	0
21	Water supply and gas	0	0	0
22	Railway transport services	30	0	0
23	Other transport	30	20	3
24	Other services	20	10	6
25	Natural gas	0	80	20

[a]Imports and Exports of Electricity specification are explained in the methodology sections

d. Energy Sector Policies

The assumptions and policies that directly relate to the energy sector are, autonomous energy efficiency improvement, cost reduction for renewables (solar PV and wind) due to the efficient use of production factors and market penetration rates of various technologies based on announced plans of the Government of India. India has announced its intended nationally determined contributions (INDCs) and commitment towards low carbon growth. The government has announced various low carbon measures through support schemes and programme targets and these announced plans in power, energy efficiency, buildings and transport sector have been incorporated in the model scenarios. The details of these assumptions of AEEI, cost reduction and market penetration rates and low carbon policies are provided in Tables 3.5, 3.6 and 3.7.

3.2.2   *Calculation of Water Demand Coefficients*

Water demand is calculated for four categories—(1) irrigation (2) Domestic (3) Industry (4) Power generation using estimated coefficients. The calculation of water consumption coefficient for each category is provided below.

Agriculture: Water is required for irrigation and depends on the area under irrigation coverage and the type of crops grown. The model projects output of each agricultural sector including food and non-food crops from irrigated and unirrigated areas. We use data from land use statistics at a glance from 2000–2001 to 2009–2010 to compute area under irrigation for each crops for the year 2007–2008, which is the base year for the model. The Gross Irrigated Area and Gross Cropped Area for each crop sector for the model base year 2007–2008 are provided in Table 3.8.

For each crop, the ratio of area under irrigation to the output of that crop from irrigated area for the year 2007–2008 is computed and used to project irrigated area based on irrigated production level for each crop for subsequent years up to 2050.

Crop-wise water requirement data in mm per growing period is collected from the website of Food and Agriculture Organisation and shown in Table 3.9. This crop-wise water requirement in mm/hectare of irrigated area for entire growing period of each crop multiplied by the total irrigated area is used to project total water demand aggregated over

Table 3.5 Assumptions of exogenous parameters for DAU scenario

Parameter	Sectors	
TFPG	Agriculture and power	1%
	Rest of the economy	1.5% for all except new technologies in power sector
AEEI for non-power sectors	Coal	1.5% per year
	Petroleum products	1.5% per year
	Natural gas	1.5% per year
	Electricity	1.5% per year
AEEI for power sectors	Coal	No AEEI for coal use in power sector technologies assumed
	Petroleum products	No AEEI for diesel use in power sector technologies assumed
	Natural gas	No AEEI for gas use in power sector technologies assumed
	Electricity	Reduction in transmission and distribution losses assumed
Reduction in energy use by government and households	Petroleum Products	1% reduction in marginal budget share of expenditure on petroleum products by households due to the use of more efficient vehicles
	Electricity	1.5% reduction in marginal budget share of expenditure on electricity by households due to the use of efficient appliances

all crops for each period. This calculation for 2007–2008 is shown in Table 3.10. The water demand for the subsequent years is also calculated similarly based on the model projection of crop-wise irrigate area.

Domestic: Water demand from the domestic sector is on account of drinking, cleaning and bathing purposes. In the IRADe–IAM model, the household residential sector is disaggregated into 10 expenditure classes each for rural and urban areas. Water consumption depends on the household's living standards which are captured by the expenditure levels of the household classes projected by the IRADe–IAM model. Water demand for each expenditure class is estimated using water consumption per capita

Table 3.6   Power sector policies scenario

Power sector policies	
Costs for renewable	Chapter 1 Cost reduction due to recent fall in solar and wind energy prices
Growth of renewable	Chapter 2 A minimum share for renewable of 8% by 2030 and 10% by 2050 is prescribed
Minimum share of solar	Chapter 3 A minimum penetration rate for solar power is prescribed to allow for minimum share of 1.4% in 2030 and increases to 1.6% in 2050
Nuclear power	Chapter 4 Nuclear generation capacity is projected to reach up to 8 GW by 2050
Thermal coal	Chapter 5 No investment in capacity and no fall in costs due to factor productivity for subcritical coal assumed from 2017
Hydropower	Chapter 6 Constrained to grow by 1% in keeping with the government plans
Gas-based power generation	Chapter 7 Maximum of 40% of domestic production of Gas is used for Power Generation
Minimum penetration rate for ECBC buildings	Chapter 8 The share of ECBC is specified to increase by 1%

Table 3.7   Transport sector policies in DAU scenario

Transport sectors policies	
Share of railways in total freight movement	Stipulated to increase by 1.5% per year, from around one-third in 2015 to almost two-thirds by 2050
Greater use of public and non-motorised transport	Reducing marginal budget shares for petroleum products by 0.2% per year beginning in 2015
Change in the fuel mix in road transportation sector	Reducing petroleum product inputs in the transport sector by 0.5% per year, and replacing them by increasing inputs of natural gas and electricity in the ratio 60:40, respectively, from 2015

Table 3.8 Crop-wise area under cultivation and irrigation (000 Hectares) for the year 2007–2008

	Crop	Gross cropped area	Gross irrigated area
1	Paddy	43,623	25,199
2	Wheat	28,596	26,101
3	Coarse Cereals	28,669	4227
4	Grams and Pulses	24,820	3925
5	Sugarcane	5151	4844
6	Oilseeds	28,686	7811
7	Fibres	10,431	3487
8	Plantations	1352	196
9	Fruits	4151	2560
10	Vegetables	5944	3666
11	Other Crops	13,711	5968

Source Land use statistics at a glance 2000–2001 to 2009–2010 Directorate of Economics and Statistics, Department of Agriculture and Cooperation Ministry of Agriculture, Government of India

per day coefficients from Shaban and Sharma (2007). The estimated coefficients used are presented in Table 3.11.

With economic growth and prosperity, per capita consumption increases and people shift from lower expenditure classes to higher expenditure classes. The model captures this using a non-linear demand system and a log-normal income distribution function to endogenously project the per capita household consumption expenditure for each expenditure class and number of people in each expenditure class in each year. With increasing economic prosperity, the household's water consumption patterns become similar to the patterns of high-income groups. The household water consumption coefficients (as mapped for each expenditure class in Table 3.11) per person per day are multiplied by the number of people in each expenditure class and aggregated to get the total water demand from domestic sector for each year from 2007–2008 to 2050.

Industry: Water is consumed by Industry in various production processes. The Centre for Science and Environment (CSE, 2004) report that estimates water demand for the year 2004 from major industrial sectors is used to calculate water demand in Industry. The report found that water is in optimally priced as it is provided either by municipalities or through extraction from ground using subsidised energy. This leads to

Table 3.9 Crop-wise water needs for irrigation

Crop	Crop water need (mm/total growing period)	Average
Alfalfa	800–1600	1200
Banana	1200–2200	1700
Barley/Oats/Wheat	450–650	550
Bean	300–500	400
Cabbage	350–500	400
Citrus	900–1200	1050
Cotton	700–1300	1000
Maize	500–800	650
Melon	400–600	500
Onion	350–550	450
Peanut	500–700	600
Pea	350–500	425
Pepper	600–900	750
Potato	500–700	600
Rice (paddy)	450–700	575
Sorghum/Millet	450–650	550
Soybean	450–700	575
Sugar beet	550–750	650
Sugarcane	1500–2500	2000
Sunflower	600–1000	800
Tomato	400–800	600
Tobacco[a]	400–600	500

Source http://www.fao.org/docrep/s2022e/s2022e02.htm#Top OfPage
[a]https://agriculturalinformation4u.blogspot.in/2016/02/irriga tion-water-requirement-for.html

inefficient use of water and so the industrial water productivity which is represented by the ratio of Industrial GDP to water consumption is one of the lowest for India among major industrialised countries. The Industry sector-wise water demand from the report (CSE, 2004) is presented in Table 3.12. Each of the industry sectors covered by the report is considered in the IRADe–IAM model either explicitly or as a part of a larger aggregated sector. We compute the ratio of water consumed to output in 2004 and multiply the ratio to output growth of the sectors for all the years from 2007–2008 to 2050.

Table 3.10 Crop-wise irrigation water demand (BCM) in 2007–2008

Model cropping sectors	Irrigated area (IA)	Water consumption (WC)	Water demand for total irrigated area (IA) of the crop
	(000 hectares)	(mm/hectare)	(BCM)
Paddy	25,199	575	145
Wheat	26,101	550	144
Coarse Cereals	4227	583	25
Grams and Pulses	3925	400	16
Sugarcane	4844	2000	97
Oilseeds	7811	600	47
Fibres	3487	1000	35
Plantations	196	500	1
Fruits	2560	1083	28
Vegetables	3666	521	19
Other Crops	5968	831	50

Table 3.11 Area-wise consumption of water per capita per day (in litres)

Resident household status	Model expenditure class in rural and urban areas mapped to	Mean
High-income group (HIG) areas with well planned building	H10, H9	99.9
Middle-income group (MIG) areas with well planned building	H8, H7, H8	94.2
Low-income group (LIG) areas with well planned building	H3, H4, H5	90.2
Slum areas	H2 and H1	81.9
Others (mixed areas)		91.3
Total		91.6

Source Shaban and Sharma (2007) H1, H2,…, H10 refer to households in different expenditure classes in rural and urban areas

3.2.2.1   Power Generation

Thermal power generation technologies require water for cooling purposes. Coal-based thermal power generation in addition requires water for ash cleaning. The power sector in the IRADe–IAM model is disaggregated into 13 technologies as shown in Annexure 2. The models

Table 3.12
Wastewater generation
and water use by
different industries in
India, 2004

Industrial sector	Annual consumption (million cubic metres)
Engineering	2019.9
Pulp and paper	905.8
Textiles	829.8
Steel	516.6
Sugar	194.9
Fertiliser	73.5
Others	314.2

Source CSE (2004)

provide output for each power generation technology in value and physical terms. The thermal power generation technologies included are subcritical coal, supercritical coal, ultra-supercritical coal, IGCC coal, Gas, Nuclear, biomass, solar PV and solar thermal with and without storage. We use India-specific water use coefficients of power generation technologies from CEEW (2017) to project water withdrawal and consumption from the power sector. The CEEW (2017) provides fuel technology-wise water coefficients for cooling tower (CT) and once-through cooling (OTC) technology separately. The IRADe–IAM model does not consider power generation technologies differentiated by cooling technique use and hence a weighted average of the water coefficients of CT and OTC for each fuel technology is assumed. The weights are the installed capacity with CT and OTC cooling technology under each power generation technology. The average water use coefficients considered for each technology are reported in Table 3.13. Water consumption in power sector is projected by multiplying the technology-wise water coefficients with technology-wise power generation from the model.

3.2.3   Scenarios

In trying to assess the future demand for water and the factors and policies that may impact it, we address the following three questions (1) Impact of Economic Growth on water demand (2) Impact of water conservation policies and low carbon policies in power sector on water demand (3) impact of implementing government schemes and climate targets on water demand. The first question is answered using a set of three scenarios—each representing a different rate of GDP growth rate.

Table 3.13 Technology-wise water withdrawal per unit generation

Technologies	Water withdrawal (m^3/Mwh)			
	2015	2016	2017	2018
Coal	41.87342	22.69972	3.5	3.5
Gas	1.62	1.62	1.62	1.62
Nuclear	152.7726	78.58846	3.5	3.5
Refined liquids	68.3	68.3	68.3	68.3
CSP	2.845	2.845	2.845	2.845
PV	0.1	0.1	0.1	0.1
Biomass	4.35	3.925	3.5	3.5

Source Weighted average from CEEW (2017)

> **Low Growth rate scenario**: GDP growth rate is simulated to 5.88% from 2011–2012 to 2047 by appropriately adjusting parameters and assuming MOEFCC guidelines on water conservation policies in power plants.
> **Medium Growth rate scenario**: GDP growth rate is simulated to 6.70% from 2011–2012 to 2047 by appropriately adjusting parameters and assuming MOEFCC guidelines on water conservation policies in power plants.
> **High Growth rate scenario**: GDP growth rate is simulated to 7.40% from 2011–2012 to 2047 by appropriately adjusting parameters and assuming MOEFCC guidelines on water conservation policies in power plants.

The second question of the impact of power sector policies on water demand and power sector water conservation policies is answered by another set of two scenarios.

> **Reference Scenario (REF)**: We use the Medium Growth rate scenario with MOEFCC guidelines on water conservation in power plants.
> **Water Conservation Policy Failure (WCF)**: The scenario assumes a Medium Growth rate scenario without MOEFCC guidelines on water conservation in power plants.

The Water Conservation Policy Failure scenario shows the additional water demand in the power sector if the MOEFCC guidelines are not adhered to.

The third question of the impact of government's announced power sector plans and capacity build-up and NDC commitments made in Paris is addressed by comparing the REF scenario with two additional scenario.

> **INDC Scenario (INDC)**: The scenario considers announced government policies of 175 GW of renewable power capacity, Nuclear and Hydro plans and attainment of the INDC targets.
> **AMBLC Scenario (AMBLC)**: The scenario considers announced government policies of 175 GW of renewable power capacity, Nuclear and Hydro plans and attainment of more ambitious targets of nearly 60% non-fossil fuel capacity by 2030.

3.3   Impact of Growth on Water Demand

GDP growth stimulates economic activity and increases the drivers of water demand leading to competing demand for water. The model accounts for this competing demands or the FEW nexus and projects demand for water under each scenario. To assess the impact of GDP growth on water demand we consider three scenarios (1) Low Growth rate scenario with a CAGR growth of 5.88% from 2011–2012 to 2047, (2) Medium Growth rate scenario with a CAGR growth of 6.70% from 2011–2012 to 2047 and (3) High Growth rate scenario with a CAGR growth of 7.40% from 2011–2012 to 2047.

The drivers of water demand and their growth rates under the three growth scenario are provided in Table 3.14. Higher GDP growth results in people moving from lower expenditure classes to higher expenditure classes which increases their per capita consumption. This increases the aggregate per capita consumption levels, which is an indicator of the improving levels of standards of living of households. The per capita consumption expenditure increases at a CAGR of 5.53, 6.41 and 7.11% in the Low Growth, Medium Growth and High Growth scenarios, respectively, from 2011–2012 to 2047.

An increase in consumption increases demand for Agricultural commodities including Food, Industrial products and Electricity. The increase in Agricultural GDP results in higher production of food and

Table 3.14 Drivers of water demand under various economic growth scenario

		Year			CAGR 2011–	
		1011	2030	2050	2030	2050
GDP (Rs. billion)	Low growth	59,577	229,671	496,225	7.36	5.59
	Medium growth	59,475	242,957	632,731	7.69	6.25
	High growth	59,482	242,542	781,130	7.68	6.83
Agriculture GDP (Rs. billion)	Low growth	5438	13,019	15,493	4.70	2.72
	Medium growth	5384	13,854	18,856	5.10	3.27
	High growth	5385	13,982	22,197	5.15	3.70
Aggregate irrigate area (000 Hectares)	Low growth	96,260	139,311	209,585	1.96	2.02
	Medium growth	96,260	139,311	209,587	1.96	2.02
	High growth	96,258	139,312	209,588	1.96	2.02
Industry GDP (Rs. billion)	Low growth	29,473	95,072	239,145	6.36	5.51
	Medium growth	29,459	102,650	286,259	6.79	6.00
	High growth	29,465	102,176	355,229	6.76	6.59
Power generation (billion Kwh)	Low growth	1074	3057	4857	5.66	3.95
	Medium growth	1074	3247	6365	6.00	4.67
	High growth	1074	3242	7746	5.99	5.20
Per capita consumption (Rs./person)	Low growth	23,783	84,608	193,852	6.91	5.53
	Medium growth	23,164	82,408	260,870	6.91	6.41
	High growth	23,179	82,462	337,151	6.91	7.11

non-food crops, requiring an increase in irrigation coverage over time. Agriculture GDP increases at a CAGR of 2.72, 3.27 and 3.70% in the Low Growth, Medium Growth and High Growth scenarios, respectively, from 2011–2012 to 2047. The water requirement for agriculture would depend on the area covered by irrigation. Figure 3.1 gives the crop-wise irrigated area.

Gross irrigated area increase is exogenously prescribed and is same across all scenarios although its distribution across crops varies by production choices. Gross irrigated area increases at a growth rate of 2% from 88 million hectares to 139 million hectares in 2030 and to 209 million hectares in 2050. Paddy, Wheat, Coerce Cereals, Sugar cane, Oilseeds and other crops have a significant share in gross irrigated area. The share of crops in gross irrigated area changes, driven by changing consumption pattern and availability and cost competitiveness of imports. With economic growth, increase in income and urbanisation, diet preferences of households change from cereal based to high-value foods like fruits
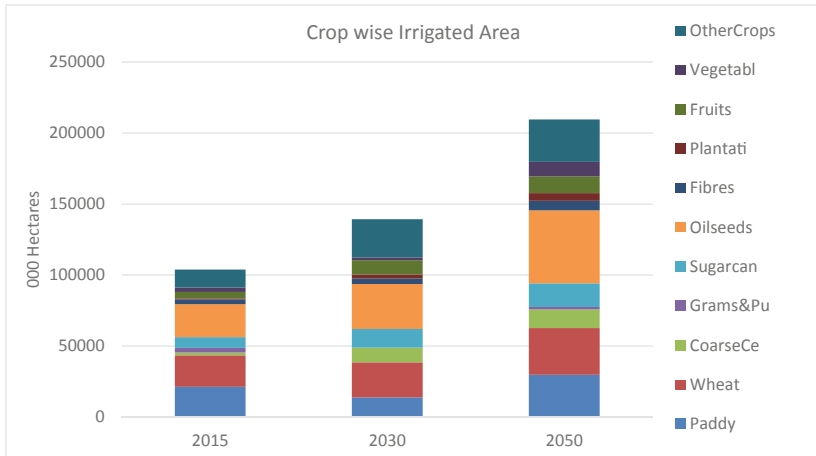
Fig. 3.1 Crop-wise irrigated area in thousand hectares in reference medium growth scenario

vegetables, fibres, etc. Even within cereals, food pattern may change from rice eating to wheat, jowar and bajra. As shown in Table 3.9, fruits, vegetables, fibres and cereals like wheat, jowar and bajra have high water consumption coefficients and are likely to increase water dependence.

Industry includes sectors like Engineering, pulp and paper, Textiles, Steel, Sugar, Fertilisers and other miscellaneous manufacturing sectors. Higher economic growth and household consumption demand increase industrial GDP. Industrial GDP increases at a CAGR of 5.51, 6.00 and 6.59% in the Low Growth, Medium Growth and High Growth scenarios, respectively, from 2011–2012 to 2047.

Increase in GDP growth, Agriculture, Industry GDP and residential sector expenditure results in higher demand for power and corresponding increases in generation from various technologies. A major share of power generation is from Thermal technologies which require water for cooling requirements and for ash cleaning in coal-based thermal technologies. The technology-wise generation is provided in Figs. 3.2, 3.3 and 3.4.

Power generation is projected to increase from 1074 billion Kwh in 2011–2012 to 4857, 6365 and 7746 billion Kwh by 2050 at a growth rate of 4.18, 4.97 and 5.51% for Low, Medium and High GDP growth scenarios, respectively. Coal-based thermal power generation is the most
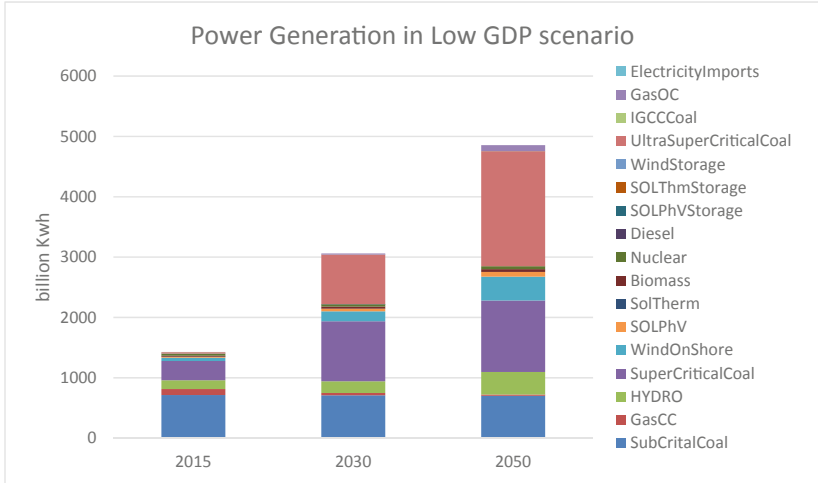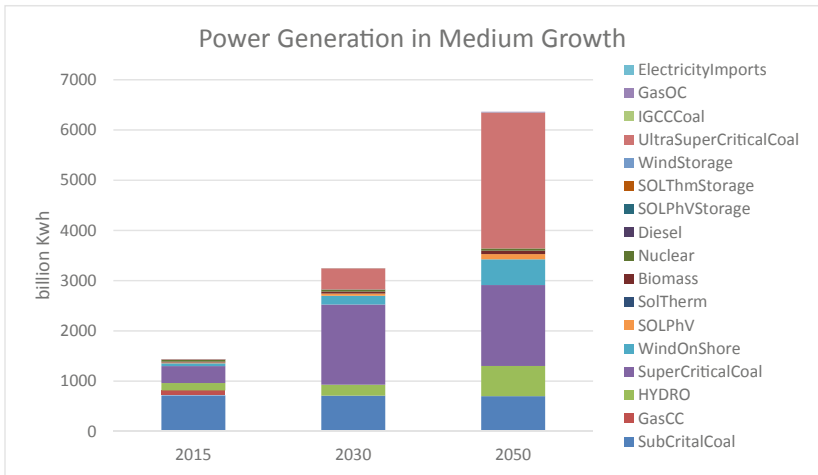
Fig. 3.2 Power generation in low GDP growth scenario

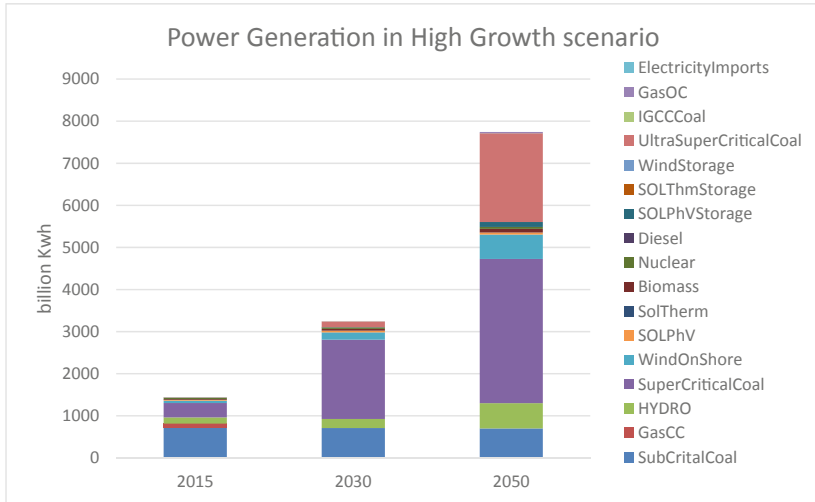**Fig. 3.3** Power generation in medium GDP growth scenario

Fig. 3.4 Power generation in high GDP growth scenario

preferred choice of generation. The share of subcritical coal decreases due to the government's stated policy of not having any new subcritical-based plants after 2017. However, coal-based thermal power generation still remains the preferred choice as generation shifts to supercritical coal and ultra-supercritical coal despite its higher capital cost. Thermal power generation will have a major impact on water demand as thermal power generation would require water for cooling purposes and coal-based thermal power generation would require water for ash cleaning.

The water demand by various sectors based on the growth of the above-mentioned drivers for the three GDP growth scenarios are provided in Table 3.15.

Total water demand in 2015 is estimated to be at 868 bcm, of which irrigation demand is about 768 bcm and demand for power is about 50 bcm. Industry has a very small share of 7 bcm and domestic demand is at 43 bcm. The total demand increases to 1145, 1189 and 1203 bcm in 2030 in the Low, Medium and High Growth rate scenarios, respectively. In 2050 the total water demand increases to 1703, 1713 and 1731 bcm for the Low, Medium and High GDP scenarios. Demand from irrigation increases from 768 bcm in 2015 to 1069, 1110 and 1125 bcm in

Table 3.15 Impact of economic growth on water demand (billion cubic metres)

	2015			2030			2050		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Irrigation	764	768	768	1069	1110	1125	1604	1600	1602
Domestic	43	43	43	52	52	52	59	59	60
Industry	7	7	7	16	17	17	27	36	47
Power Generation	50	50	50	9	10	10	14	18	22
Total	864	868	868	1145	1189	1203	1703	1713	1731

2030 and to 1604, 1600 and 1602 bcm for Low, Medium and High GDP growth scenarios. The demand for water from Power of course decreases as we assume MOEFCC guidelines for water conservation in power plants are adhered to from 2017. The demand for water in power sector decreases from 50 bcm to 9, 10, 10 bcm in 2030 and to 14, 18 and 22 bcm in 2050 for the Low, Medium and High GDP Growth rate scenario, respectively.

3.4   IMPACT OF LOW CARBON PATHWAY ON WATER DEMAND

To assess the impact of low carbon pathway and Government of India's proposed power sector policies on water demand we provide a comparative analysis of three scenarios (1) Ref-Medium GDP Growth rate (2) INDC Scenario and (3) AMBLC scenarios as described in Sect. 3.2 for scenarios. The low carbon scenario requires investment in non-fossil power generation capacities like Renewables, Nuclear and Hydro technologies. Coal is the cheapest source of power generation in India and is also confirmed by the choice of supercritical and ultra-supercritical as the preferred technology for Low, Medium and High GDP growth scenarios. A low carbon path would imply a shift in India's power generation from being coal based to other technologies like Gas, Hydro, Solar, Wind, Nuclear and Biomass. Many of the alternative technologies have significant water requirements, though may be much less than coal-based thermal power generation. Thus, low carbon pathways would reduce CO_2 emissions and may also reduce water demand in the power sector. Thus,

the net impact on water demand in power sector may be of interest to policymakers. This section deals with the extent to which low carbon pathways reduce the water stress in the economy and secure energy from any likely future water scarcity. The Government of India has come out with many low carbon policies which include no subcritical plants after 2017, 175 GW of renewable energy capacity by 2022, the ambitious Nuclear energy programme and Hydropower plans. In one of the most significant announcements, the Indian Government announced at the Paris COP, its INDCs to reduce emissions intensity by 33–35%, to increase its non-fossil fuel capacity to 40% of its total capacity by 2030. We assess the impact of the announced government plans and policies on water demand in the power sector by comparing the REF scenario with INDC and AMBLC scenario as defined in Sect. 3.2 in the sub-section scenarios.

Table 3.16 shows the impact on various drivers of water demand due to low carbon policies. The results show that impact on GDP is insignificant, but household consumption is lower in the low carbon scenarios.

The power generation decreases in the low carbon scenario due to feedback effect. Power generation increases from 813 BU in 2007 to 3247 BU and 6365 BU, an increase of 4 times and nearly 8 times in 2030 and 2050, respectively, in the Reference Medium GDP growth scenario. The INDC scenario which assumes the 175 GW by 2022 target and the INDC commitments of the Government of India in COP at Paris and the AMBLC scenario which represents a more ambitious low carbon scenario with 60% non-fossil fuel capacity by 2030 brings down power generation. Figures 3.5, 3.6 and 3.7 show the impact on power generation and capacity mix for REF-medium, INDC and AMBLC scenario, respectively.

In the medium growth reference scenario (Fig. 3.5), coal is the dominant source of power generation and has the most major share in capacity. Coal-based thermal power technologies share in generation is 84% (subcritical: 22%, supercritical: 49%, ultra-supercritical: 13%) in 2030 and reduces to 79% in 2050 (subcritical: 11%, supercritical: 25%, ultra-supercritical: 42%). Among non-fossil fuel technologies, share of hydro is 7 and 9%, share of wind onshore is 5 and 8% and solar Phv is 1 and 2% in total generation in 2030 and 2050, respectively. In terms of capacity also Hydro, Wind onshore technologies are major contributors in addition to Solar Photovoltaic. Total capacity increases from 146 GW in 2007 to 575 GW and 1208 GW in 2030 and 2050, respectively. Coal share in total capacity decreased from 68% in 2030 (subcritical: 18%, supercritical:

Table 3.16 Impact of low carbon policies on drivers of water demand

		Year			CAGR 2011-	
		2011	2030	2050	2030	2050
GDP (Rs. billion)	REF-Medium	59,475	242,957	632,731	7.69	6.25
	INDC	59,361	240,404	635,777	7.64	6.27
	AMBLC	59,368	241,660	645,575	7.67	6.31
Agriculture GDP (Rs. billion)	REF-Medium	5384	13,854	18,856	5.10	3.27
	INDC	5353	13,813	18,849	5.12	3.28
	AMBLC	5365	13,793	19,068	5.10	3.31
Aggregate irrigate area (000 Hectares)	REF-Medium	96,260	139,311	209,587	1.96	2.02
	INDC	96,258	139,313	209,587	1.96	2.02
	AMBLC	96,259	139,311	209,585	1.96	2.02
Industry GDP (Rs. billion)	REF-Medium	29,459	102,650	286,259	6.79	6.00
	INDC	29,382	101,045	328,328	6.72	6.38
	AMBLC	29,391	102,295	471,475	6.78	7.38
Power generation (billion Kwh)	REF-Medium	1074	3247	6365	6.00	4.67
	INDC	1074	3177	6188	5.87	4.59
	AMBLC	1074	3186	6094	5.89	4.55
Per capita consumption (Rs./person)	REF-Medium	23,164	82,408	260,870	6.91	6.41
	INDC	23,024	81,909	260,454	6.91	6.42
	AMBLC	22,877	81,386	258,794	6.91	6.42

40%, ultra-supercritical: 10%) to 59% in 2050 (subcritical: 8%, supercritical: 19%, ultra-supercritical: 32%). Share of hydro increases to 12 and 16%, share of wind onshore to 13 and 18% and solar Phv is 4% in 2030 and 2050, respectively. The share of Solar Photovoltaic is insignificant in generation because it has a low PLF.

Figure 3.6 shows the technology-wise generation and capacity in the INDC scenario. INDC scenario reduces power generation in 2030 to 3177 BU and in 2050 to 6188 BU. The share of non-fossil fuel in power generation and capacity increases mostly because of Solar Photovoltaic without storage. The share of supercritical coal in total generation decreases to 39 and 21% in 2030 and 2050, respectively. Solar Photovoltaic increase its share to 6 and 4% and Nuclear to 3 and 2%, respectively in 2030 and 2050. The total capacity requirement increases to 609 GW and 1237 GW in 2030 and 2050, respectively. The share of supercritical coal in total capacity decreases to 29 and 15%. Solar Photovoltaic share increases to 16 and 10% in 2030 and 2050, respectively.
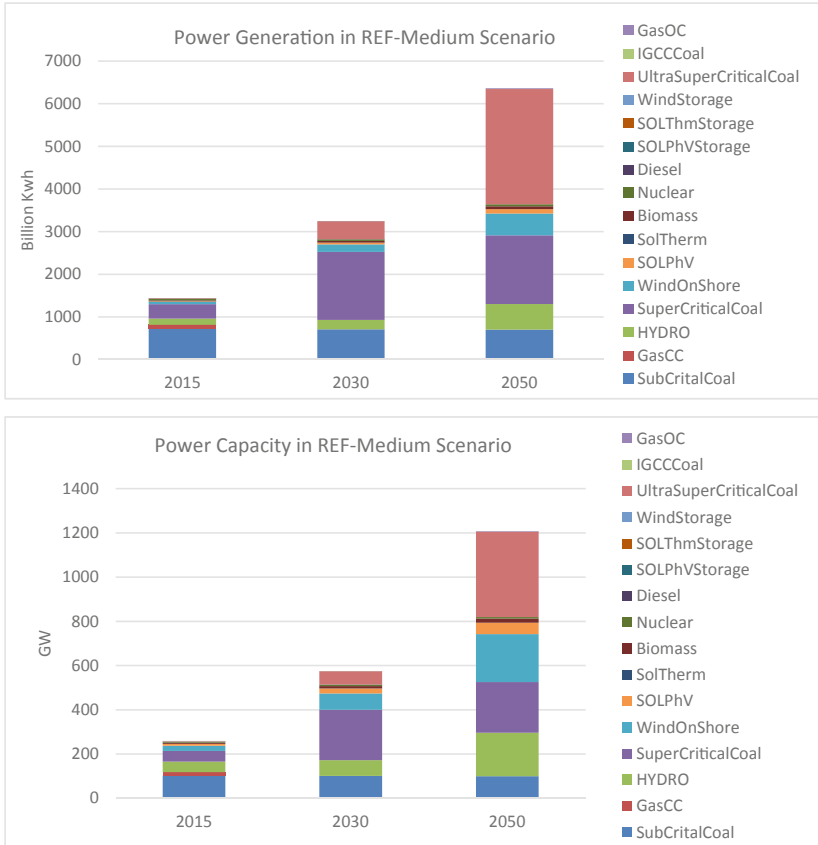
Fig. 3.5 Power generation and capacity in reference medium scenario

In AMBLC scenario the power generation in 2030 is 3186 BU and in 2050 it is 6094 BU. The share of supercritical coal in 2030 and 2050 decreases to 32 and 2%, ultra-supercritical also decreases to 4 and 16%, share of solar Phv is 4 and 2%, wind onshore increases to 7 and 11%, nuclear increases to 14 and 10% and solar Phv with storage increases to 4 and 33%, respectively. Total capacity requirement increases to 660 GW and 1936 GW in 2030 and 2050, respectively. The share of supercritical decreases to 22 and 1% and share of ultra-supercritical coal decreases to 3 and 7% in 2030 and 2050, respectively. The share of wind onshore
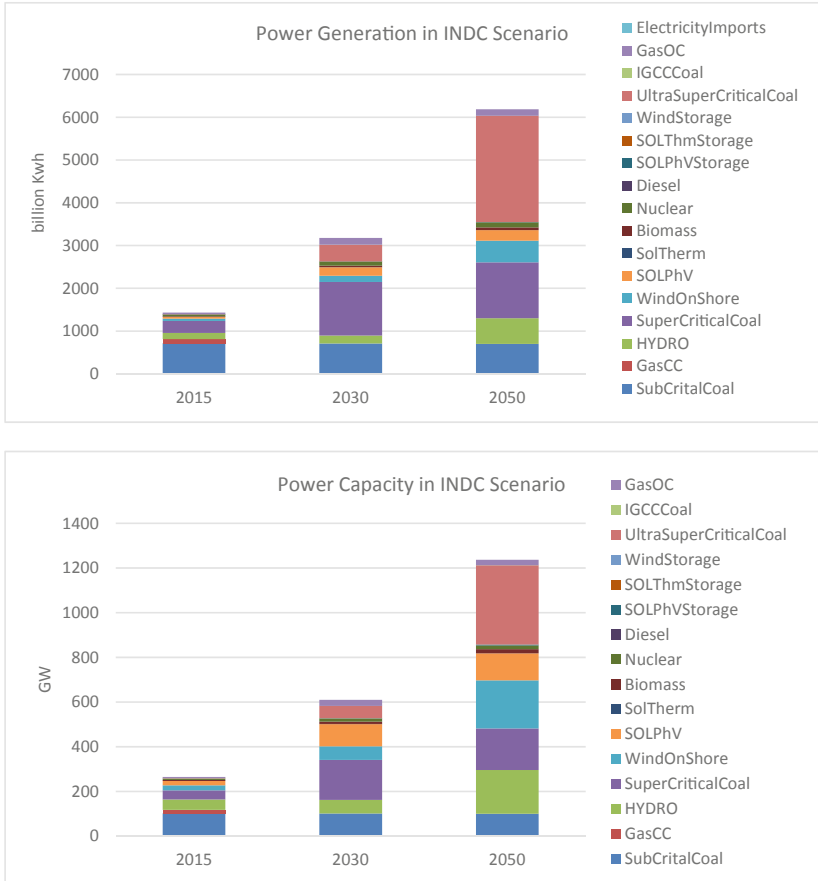
Fig. 3.6 Power generation and capacity in INDC scenario

increases 14 and 15%, nuclear increases to 10 and 5% and solar Phv with storage increases to 9 and 51%, respectively in 2030 and 2050.

Thus, low carbon pathways and government's announced policy and programmes would shift power generation from coal-based thermal power technologies to more wind onshore, solar photovoltaic, solar photovoltaic with storage and nuclear technologies all which have much less water requirements and hence is likely to reduce water demand in power sector. However, low carbon pathways are expected to increase
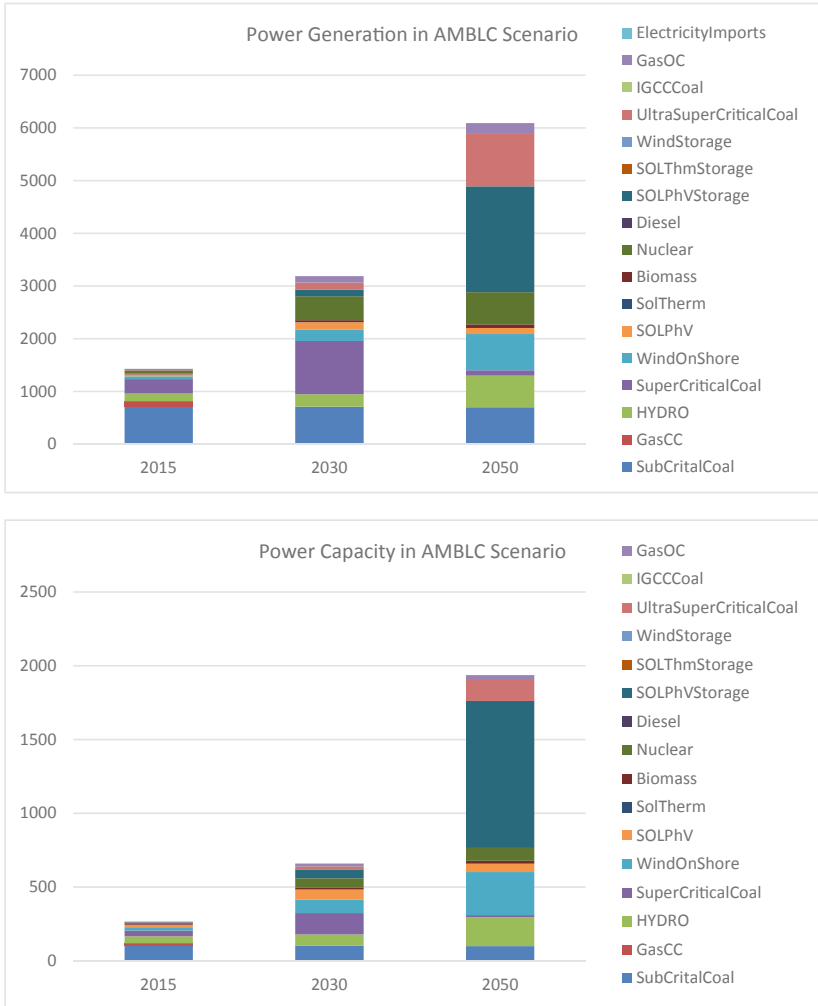
Fig. 3.7 Power generation and capacity in AMBLC scenario

Table 3.17 Impact of low carbon pathway on water demand (billion cubic metres)

	2015			2030			2050		
	REF-Medium	INDC	AMBLC	REF-Medium	INDC	AMBLC	REF-Medium	INDC	AMBLC
Irrigation	768	768	769	1110	1109	1108	1600	1600	1600
Domestic	43	43	43	52	52	52	59	59	59
Industry	7	7	7	17	17	17	36	36	38
Power generation	50	49	50	10	9	8	18	17	9
Total	868	867	869	1189	1186	1186	1713	1712	1706

industrial demand due to higher investment requirement of low carbon technologies. Higher industrial demand may increase water demand from the industrial sector.

The impact on water demand for each sector is shown in Table 3.17. The water demand from irrigation and domestic residential households is not affected. Water demand by the Industry too is not much affected except for 2 bcm increase in the case of AMBLC scenario in 2050. Water demand from the power sector is in general decreasing however INDC reduces it by 1 bcm in 2030 and 2050, while AMBLC decreases water demand in power sector by 2 bcm in 2030 and by 9 bcm in 2050.

Thus, low carbon policies are likely to reduce the dependence on water for the power sector and are likely to make the sector less susceptible to water scarcity in future.

3.5 Impact of Water Conservation Policies in Power Sector on Water Demand

Till now all scenarios discussed assumed that water conservation policy announced by the ministry of environment, forests and climate change (MOEFCC) are implemented. In this section we analyse the impact of policy failure of not being able to implement MOEFCC guidelines on power sector water conservation policies. The MOEFCC guidelines issued in 2015 are briefly mentioned Box 3.1.

Box 3.1: MOEFCC Guidelines on water conservation policies in power sector

Standards for Water Consumption vide Notification No. S.O. 3305(E) dated 07.12.2015

1. All plants with Once Through Cooling (OTC) shall install Cooling Tower (CT) and achieve specific water consumption up to maximum of 3.5m3/MWh by 07/12/2017.
2. All existing CT-based plants reduce specific water consumption up to maximum of 3.5m3/MWh by 07/12/2017.

3. New plants to be installed after 1 January 2017 shall have to meet specific water consumption up to maximum of 2.5 m3/MWh and achieve zero waste water discharged.

Policy failure for water conservation would imply continuation of water use technologies as existing in 2015. Hence referring to Table 3.13, to model a policy failure scenario we assume the water withdrawal coefficients in 2015 continue subsequently for all years. Since policy failure of implementing water conservation policies in power sector will only impact the power sector alone hence we restrict the discussions here only to the power sector. We analyse the impact of policy failure here by comparing the Reference medium growth rate with water conservation policy (Ref-Medium) with Reference medium growth rate without water conservation policy (WCF).

Figure 3.8 shows the impact on water demand if water conservation policies of MOEF are not implemented. The comparison of water withdrawal under the two policies from power sector shows that water withdrawal demand from power sector would be nearly 12 times in 2030 and nearly 20 times in 2050. Implementation of water conservation policies in power sector is essential to make the power sector growth secure from uncertainties of water availability in future. This will also make power generation more sustainable.
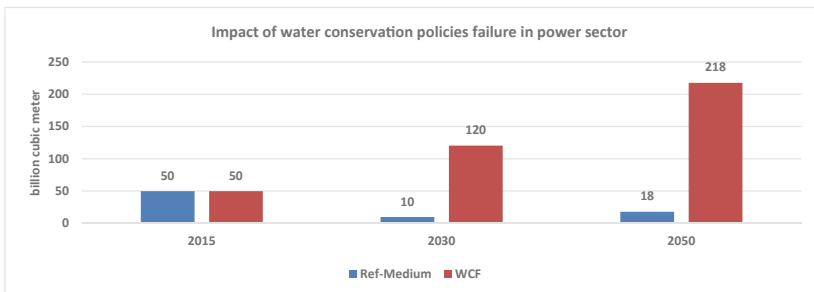

Fig. 3.8 Impact of water conservation policies failure in power sector in the medium scenario

3.6 Conclusions

Water demand for the entire economy is projected in a consistent manner using a macroeconomic model that takes care of macroeconomic relationships, intersectoral linkages and competing demands for water through the FEW nexus. The water demand calculated is consistent with the overall economic growth projected and the structural change that accompanies such a growth. There have been other researchers' and official estimations of water demand in India. Table 3.18 provides two such official projections of sectoral and total water demand.

The official projections from Table 3.18, if compared to the projections in this paper under various scenarios provided in Table 3.19, we can conclude that the total demand projection using the IRADe–IAM model is in the close range of projections by official government agencies for the starting year. The projections in this report in 2015 for irrigation and domestic use are not too far from the projections for 2010. However, there are differences in estimates between the projections by the Ministry of water resources (MOWR) and the National commission on integrated water resources (NCIWRD).

Table 3.18 Government of India agency's projection of water demand

Projected Water Demand in India in BCM (Billion Cubic Metre)

Sectors	Standing Sub-Committee of MOWR			NCIWRD					
	2010	*2025*	*2050*	*2010*		*2025*		*2050*	
				Low	*High*	*Low*	*High*	*Low*	*High*
Irrigation	688	910	1072	543	557	561	611	628	807
Drinking Water	56	73	102	42	43	55	62	90	111
Industry	12	23	63	37	37	67	67	81	81
Energy	5	15	130	18	19	31	33	63	70
Other	52	72	80	54	54	70	70	111	111
Total	813	1093	1447	694	710	784	843	973	1180

Source Basin Planning Directorate, CWC, XI Plan Document., Report of the Standing Sub-Committee on 'Assessment of Availability & requirement of Water for Diverse uses-2000'
Note NCIWRD (1999): National Commission on Integrated Water Resources Development, BCM: Billion Cubic Metres, MOWR: Ministry of Water Recourses

Table 3.19 Summary projection of water demand from various scenarios analysed

	2015			2030			2050		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Irrigation	764	768	768	1069	1110	1125	1604	1600	1602
Domestic	43	43	43	52	52	52	59	59	60
Industry	7	7	7	16	17	17	27	36	47
Power generation	50	50	50	9	10	10	14	18	22
Total	864	868	868	1145	1189	1203	1703	1713	1731
	INDC	AMBLC	WCF	INDC	AMBLC	WCF	INDC	AMBLC	WCF
Irrigation	768	769	768	1109	1108	1110	1600	1600	1600
Domestic	43	43	43	52	52	52	59	59	59
Industry	7	7	7	17	17	17	36	38	36
Power generation	49	50	50	9	8	120	17	9	218
Total	867	869	868	1186	1186	1299	1712	1706	1913

In 2030 and 2050, the IRADe model estimates of water demand are higher than those of either MOWR or NCIWRD. The highest projection of water demand in 2050 is 1447 bcm by MOWR. This is still lower than the lowest projection among all scenarios of 1703 bcm for Low GDP growth scenario. This could be due to two factors. First, this paper assumed water conservation policies only for the power sector and not for other sectors like irrigation and industry. Secondly, the paper assumed 100% irrigation coverage by 2050 on the basis of the government's slogan of '*har khetme paani*' (water in every field), which increases water requirement for irrigation. Also if one were to assume that sprinkler and drip irrigation would be widely used, the water requirement for irrigation can be reduced by 30%, in which case in 2050, IRADe–IAM model-based projection of water needed for irrigation will be around 1120 BCM close to MOWR projection of 1060 BCM.

The estimate of domestic water in this paper is also much smaller than those by MOWR and NCIWRD. The current norm for supplying water to urban households is 140 litres/day/person, which is higher than the norm of around 90 litres/day/person taken here. Given the severe water crisis faced by Cape Town and similar ones staring in the face of other cities, such as Bengaluru, underscores the need for water conservation

in households. India where much of the housing is yet to be built has an opportunity to make them water efficient and build in as much of recycling as possible.

Official estimates (water and related statistics 2010) suggest that India's estimated annual precipitation including snowfall is 4000 bcm. The estimated annual average potential in rivers is 1869 bcm. The utilisable water is estimated to be around 1123 bcm. Climate change is likely to further reduce the utilisable water availability. Both MOWR (1447 bcm) and the scenarios in this paper report higher water demand (around 1700 bcm) than the estimated utilisable water. This further highlights the importance of water conservation in major sectors like irrigation and industry.

The lowest total water demand is of 1703 bcm for Low GDP growth scenario and the highest water demand is of 1913 bcm for water conservation policy failure in power sector scenario. The result underscores the importance of water conservation in power sector. If water conservation policies suggested by the MOEFCC are not implemented, then it can increase water demand in the power sector by almost 200 bcm. Implementing MOEFCC guidelines for water conservation would secure future power generation from uncertainties related to water availability. The scarcity of water is far more serious than indicated by these projections that exceed the estimate of utilisable water as water is distributed unevenly in space and time. Thus not only conservation and efficiency but also storage and transport of water need highest priority.

Annexure 1

Structure of the Model

The IRADe–IAM model is a multi-sectoral, inter-temporal dynamic optimisation model that is bottom-up in the sense that it includes alternative technology options, and top-down in the sense that it covers the whole macroeconomy (similar to Parikh & Ghosh, 2009) and captures the characteristics considered essential by Urban et al. (2007) for models of developing countries. The model is set up in an activity analysis framework and is solved as a linear programming problem using the GAMS programme (Brooke et al., 1998).

The model maximises present discounted value of the total sum of private consumption over the planning period using a real discount rate

of 4% subject to various macroeconomic, technological and resource constraints. It uses the Social Accounting Matrix (SAM) for the year 2007–2008 (estimated by Pradhan et al. [2013]) to represent the whole economy and the sectoral interlinkages. The SAM used in the model is aggregated into 25 commodities and 38 production activities. The model ensures that demand and supply balance in the optimal path for each commodity for each period.

$$C_{it} + G_{it} + Z_{it} + IO_{it} + E_{it} \leq Y_{it} + M_{it} \quad \text{for each } i \text{ and } t \qquad (3.1)$$

where, $\Upsilon_{i,t}$ denotes output and $M_{i,t}$ denotes imports, $C_{i,t}$ denotes Private consumption, $G_{i,t}$ denotes Government consumption, Z_{it} is vector of investment goods, $IO_{i,t}$ denotes Intermediate demand and exports are denoted by $E_{i,t}$. Intermediate demand ($IO_{i,t}$) is determined using the Input–output coefficients from the SAM.

The private household consumption is disaggregated into ten expenditure classes each for urban and rural areas. The per capita household demand function of each commodity by each consumer class is empirically estimated as a Linear Expenditure System (Stone, 1954) based on an underlying common nonlinear expenditure system (Swamy et al., 1983).

$$C_{iht} = \alpha_{ih} + \beta_{ih0}\left(E_{ht} - \sum_i \alpha_{ih}\right) \quad \text{for each } i, h \text{ and } t \qquad (3.2)$$

where, C_{iht} = per capita consumption of the ith commodity by the hth household group in tth time period,

α_{ih} = minimum per capita consumption of the ith commodity by the hth household,

$\beta_{ih\ ih}$ = share of the ith commodity in the supernumerary expenditure (total per capita expenditure less the expenditure for minimum consumption) of the hth household and

E_{ht} = Total per capita consumption expenditure of the hth household.

The total number of people in each expenditure class is projected using an estimated log-normal distribution for a given level of total per capita consumption. As incomes rise, per capita consumption increases, which results in people moving from lower expenditure classes to higher classes

and adopting the consumption patterns of the higher expenditure classes. This is particularly relevant for energy commodities as with higher income levels people adopt more energy-intensive lifestyles for mobility, electricity and petroleum products. The Linear Expenditure System and the log-normal distribution together provide the estimate of $C_{i,t}$.

The output of any production activity $X_{j,t}$ is constrained by available capital stock in the activity. As incremental capital output ratio, ICOR, changes due to technical progress incremental output is related to incremental capital stock.

$$\left(X_{j,t} - X_{j,t-1}\right) \le \left(K_{j,t} - K_{j,t-1}\right)/ICOR_{j,t} \quad \text{for each } j \text{ and } t \qquad (3.3)$$

where, $X_{j,t}$ = domestic output of the jth sector at time t, $K_{j,t}$ = capital of the jth sector at time t and
$ICOR_{j,t}$ = incremental capital output ratio of the jth sector in period t.

The total output of a commodity is the sum of the output of all production activities that produce that commodity. Thus $\Upsilon_{i,t} = U_{ij}*X_{jt}$ where U_{ij} is a matrix with a entry of 1 if jth sector produces the ith commodity and zero otherwise.

Capital stock in sector j at time t depends upon the rate of depreciation, and investment at time t.

$$K_{j,t} = DEL(J) * K_{j,t-1} + I_{j,t} \qquad (3.4)$$

where $DEL(J)$ is the rate of depreciation in sector j, which is exogenous, and $I_{j,t}$ is the investment in sector j.

Aggregate investment resource available in the economy depends on aggregate domestic investible resources (domestic savings determined by the marginal savings rate) and foreign investments in the economy (net capital inflow).

$$\sum_i \sum_j P_{i,j} * I_{j,t} \le Z_0 + S * (VA_t - VA_0) + (FT_t - FT_0) \qquad (3.5)$$

Investment goods, are identified separately from other commodities and are also allocated to different sectors as fixed proportions $P_{i,j}$ (which

reflect the share of ith capital good in the jth sector) of the total investment ($I_{i,t}$) in jth sector at time t subject to the availability of investment goods.

$$\sum_{j}\left(P_{i,j} * I_{j,t}\right) \leq Z_{i,t} \tag{3.6}$$

where, $Z_{i,t} =$ demand of commodity i for investment at time t, VA_t $=$ value added at time t, $S =$ exogenously specified maximum marginal savings ratio, $Z_0 =$ investment in the base year (2007–2008).

The foreign investments in the economy (net capital inflow) are modelled as a positive but decreasing function of GDP (value added) to allow for developing economies to reduce their reliance on foreign investments over time with development as shown in Eq. 3.7.

$$FT_t = (a - b * t) * VA_t \tag{3.7}$$

where $FT_t =$ foreign investment at time t.

The balance of payment constraint requires that the foreign exchange earnings through net capital inflows, FT_t and total export earnings are used to meet the foreign exchange requirement from the total import bill. The balance of payment constraint is imposed on the model solution using Eq. 3.8. Trade, exports and imports are endogenous to the model. Upper and lower limits on trade levels are exogenously specified for the model to optimise export and import levels within a reasonable range.

$$\sum_{i}\left(M_{i,t} * MTT_i\right) = \sum_{i} E_{i,t} + FT_t \tag{3.8}$$

The model also imposes monotonicity constraints on outputs and per capita consumption to simulate a smoother pathway. Resource constraints as incorporated for fossil fuel coal, crude oil and natural gas.

Overall, the model's projections for commodity demand and production are sectorally consistent and it satisfies all macroeconomic relationships. This feature helps the model to assess the energy economy and resource linkages in a more consistent manner and hence provides a more consistent assessment of the environmental GHG emissions due to activities in the economy. The IRADe–IAM Model is thus able to give a detailed and comprehensive picture of feasible production levels for each sector given the availability of a scarce resource for which all sectors have a

competing demand. In this case the constrained resource is water and the IRADe–IAM model can be used to make an assessment for the feasible levels for agricultural and energy sector growth given the water resources available in India and the kind of water conservation strategy required to optimise growth.

The IRADe–Integrated Assessment Model (IRADe–IAM) was used to assess the water demand for power sector in India and the impact of energy efficiency and water use efficiency measures in power sector.

Table 3.20 Sectoral classifications

	Commodity name	*Production activity name*
Non-energy sectors		
Agriculture		
	Food grains	Food grains
	Sugarcane	Sugarcane
	Oil seeds	Oil seeds
	Other Crops	Other crops
	Animal husbandry	Animal husbandry
	Forestry	Forestry
	Fishing	Fishing
Industry		
	Mining and quarrying	Mining and quarrying
	Agro-processing	Agro-processing
	Textiles	Textiles
	Fertiliser	Fertiliser
	Cement	Cement
	Non-metallic minerals	Non-metallic minerals
	Steel	Steel
	Manufacturing	Manufacturing
	Construction	Construction
	Water supply and gas	Water supply and gas
Services		
	Railway transport services	Railway transport services
	Other transport	Other transport
	Other services	Other services
		Other services with ECBC

(continued)

Table 3.20 (continued)

Commodity name	Production activity name
Energy Sectors	
Primary energy sectors	
Coal and lignite	Coal and lignite
Crude petroleum	Crude petroleum
Natural gas	Natural gas
Secondary energy sectors	
Petroleum products	Petroleum products
Electricity	Subcritical coal
	Gas combined cycle
	Hydropower
	Supercritical coal
	Onshore wind
	Solar photovoltaic without storage
	Solar thermal without storage
	Biomass
	Nuclear
	Diesel
	Solar photovoltaic with storage
	Solar thermal with storage
	Offshore wind
	Ultra-supercritical coal
	Integrated gasification combined cycle coal
	Gas open cycle

ANNEXURE 2

See Table 3.20

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