Water-Energy-Climate Nexus : An Assessment of Long Term Energy Scenario in South & South-East Asia

Anindya Bhattacharya

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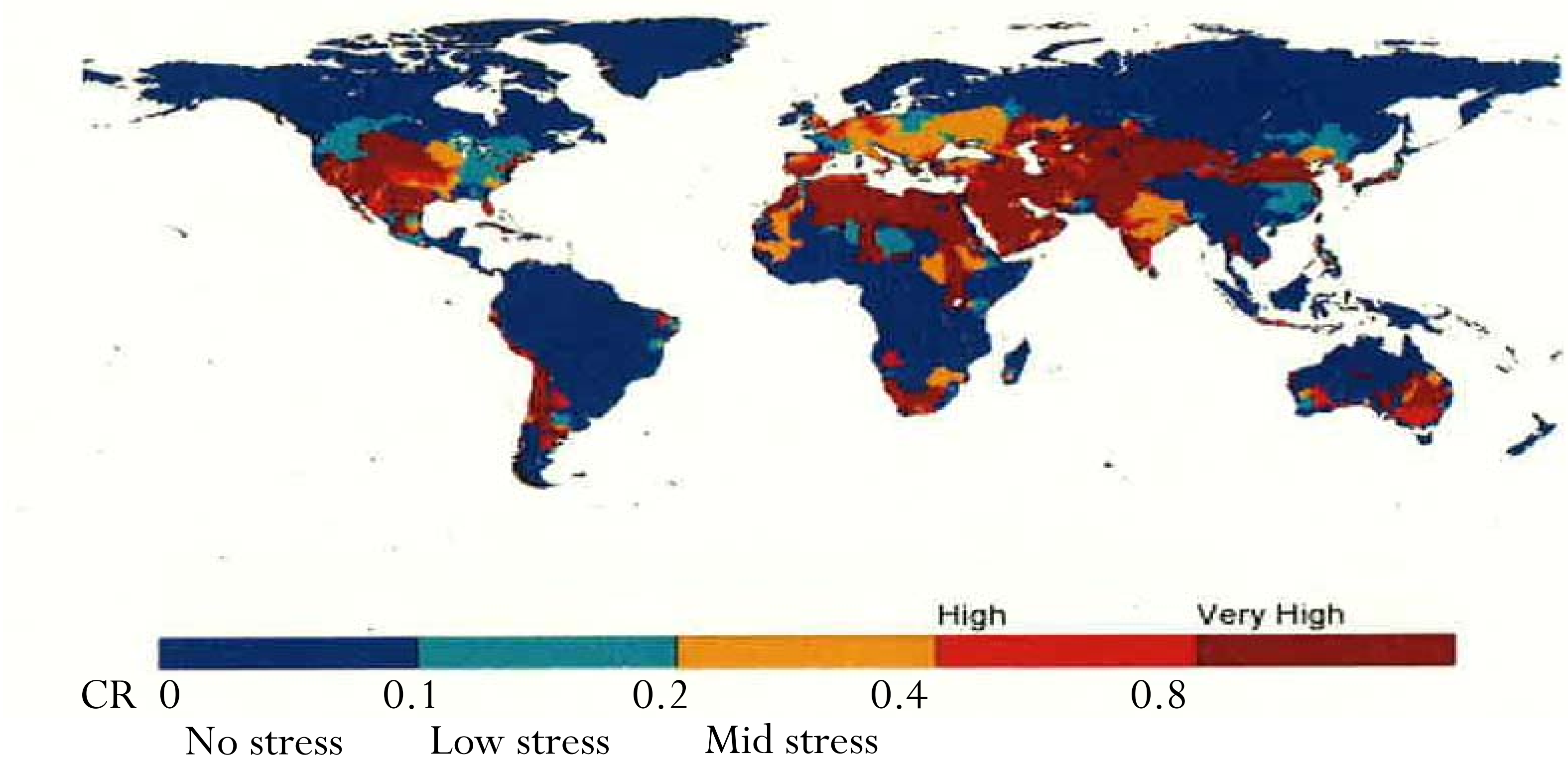
Background

- Asia is the driest continent in the world : availability of freshwater is less than half of the global annual average of 6,380 cubic meters per inhabitant.
- Asia has less than one-tenth of the waters of South America, Australia and New Zealand, less than one-fourth of North America, almost one-third of Europe, and moderately less than Africa per inhabitant.
- By 2030 the word will face nearly 40% of supply shortage of water to meet the demand (WRG, 2010)
- In India total water demand will increase by 100% (750 BCM) and in China it will be around 200 BCM by 2030.
- 80% of the glaciers in western China are in retreat (Piao et.al.) and 5 to 27% of China's glacial area is suspected to disappear by 2050 (IESSD & CASS,2010).

Climate Impact on future water availability and demand – Uncertain

- Different climate models project different worldwide changes in net irrigation requirements, with estimated increases ranging from 1–3% by the 2020s and 2–7% by the 2070s.
- If we use per capita water availability indicator, climate change would appear to reduce overall water stress at the global level. This is because increases in runoff are concentrated heavily in the most populous parts of the world, mainly in eastern and south-eastern Asia.
- Unless extra water flow is stored in a systematic manner, additional flow of water will have very less use for human being. It may not alleviate dry-season problems if the extra water is not stored; and would not ease water stress in other regions of the world.

Water Stress Indicators: Withdrawal to Availability Ratio (Criticality Ratio)



25% of the earth's surface is under severe water stress. Approximately 2.1 billion people live in the water stressed riven basins and 50% of them live in South Asia and China.

Future water demand and availability in South Asia

Major drivers:

- Demography (domestic use, agricultural use)
- Economic activities (industrial and commercial use)
- Climate variability

Estimated change in domestic use

- Water use intensity annual avg. growth rate until 2025 : 8.0%
- Water withdrawal annual avg. growth rate until 2025 : 11%

Estimated change in agriculture use

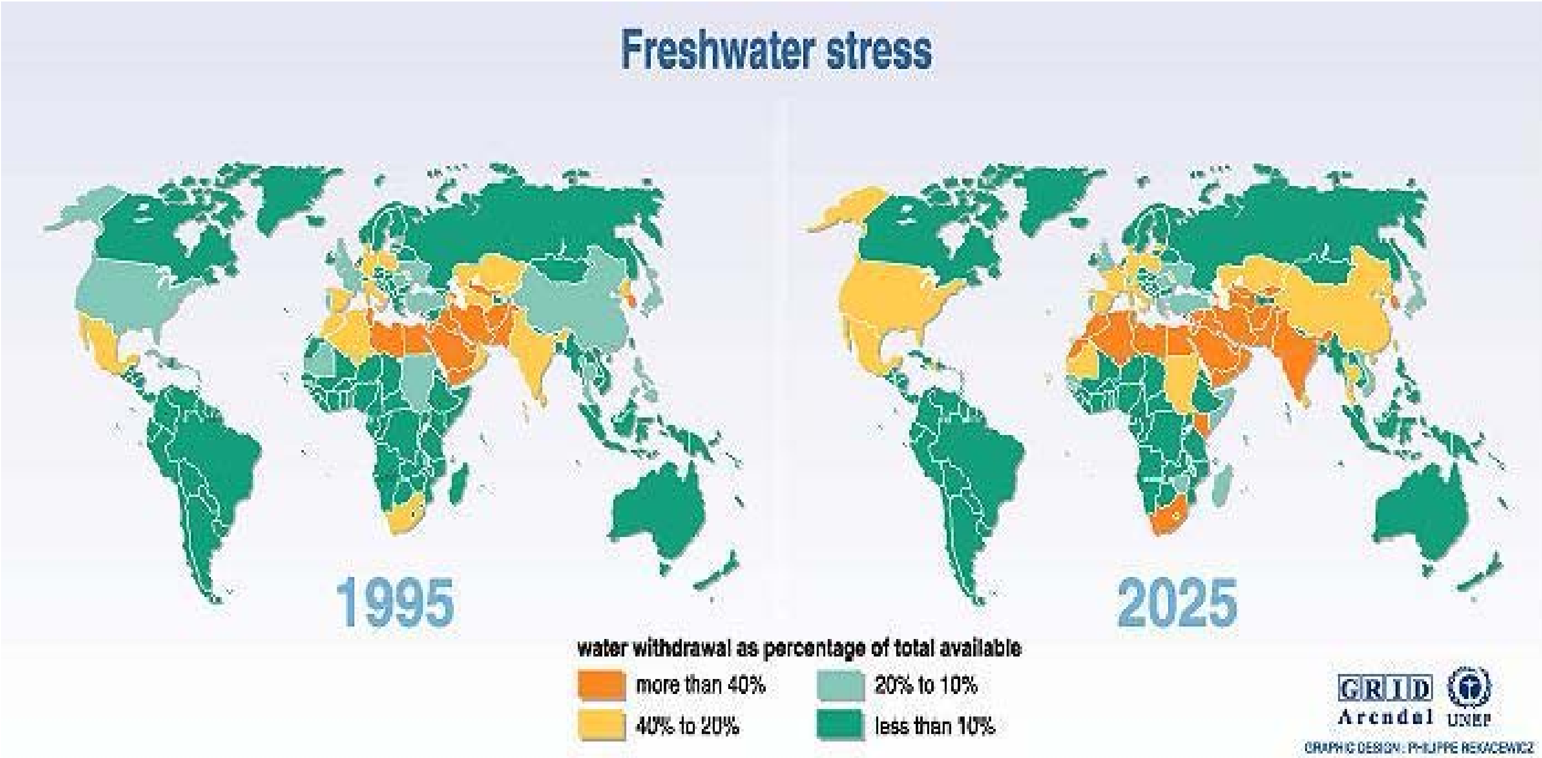
- Water withdrawal annual avg. growth rate : 0.8%

Estimated change in industrial use

- Water withdrawal annual avg. growth rate : -0.3%

Renewable water available in the region : 3800 BCM/year

Water stress level in South Asia



Source: Global environment outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

Shows the impact of expected population growth on water usage by 2025
South Asia region withdraws more than 40% of total available water. IGES estimates the ratio for India is around 68% by 2025.

Rationale of such study

- **Increasing water foot-print of energy sector in Asia**
- **Increasing threat of water shortages for energy production in future**
- **Availability of water efficient energy generation technologies brings the option of alternative planning.**
- **Uncertain climate impact on long term water availability**.

Reality picture (water-energy user's conflicts)

1. Opposition to Adani power projects is growing in Nagpur since local community believes that this power plant will create threats not only for Pench Tiger Reserves **but also for drinking water** and irrigation water availability.
2. In Kerela, power cuts ordered to deal with water scarcity in 2008 when monsoon rainfall was 65% less than normal
3. In Madhay Pradesh, power cuts made to alleviate the water shortage in the region in 2006
4. In Orissa State, farmers protest the increasing rate of water allocation for thermal power and industrial use. In response to the farmer's opposition, the state government decided to give conditional permission to construct thermal power plant that asking to use seawater for cooling purposes rather than river water to avoid placing further pressure on the Mahanadi river basin.

Objectives

- First, to estimate the water demand of the South Asia region for its energy supply including fossil fuel extraction, refining and use in electricity generation

and

- Second, to investigate the long term energy scenario of the region under certain water availability constraint due to climate and cross sectoral water demand variation.

Methodology used

Step-I

- Identification of energy technologies using water for activities
- Estimating the water use coefficients for all selected technologies (MCM/GJ or MCM/Gwh)

Step-II

- Developing the water module of the MESSAGE Model
- Running a scenario to estimate the total water demand for the energy sector.

Step-III

- Estimating long term water availability for energy sector using proportional sharing of water among different sectors and econometric analysis
- Estimating impact on water availability due to climate change using RGCM and Regional Hydrological Model.

Step-IV

- Identifying the water constraint mitigating technologies for energy sector.
- Running the water constrained scenario
- Analysis

Step-I :Identification of energy technologies using water for activities and estimating the water use coefficients for all selected technologies(MCM/GJ or MCM/Gwh)

Selection of energy technologies using water

- Using literature review and experts' interview we selected 75 different energy technologies that are using water for their activities.
- Energy resource extraction classified in to three categories : Biomass (only plant based) , Coal, Oil and Natural Gas. Oil and NG further divided into categories of conventional and non-conventional as the future of oil and gas depends on nonconventional sources like tar oil, oil sands etc.
- Clean coal technology, hydrogen and methanol production also added in the list.
- All power generating thermal technologies are selected –coal, gas, oil, nuclear
- Hydro (large/medium and small) –run off the river not added.
- Solar thermal and geothermal are selected under renewable energy category.

Major challenges in water coefficient estimates: Wide variation in data

Technology	Type of cooling	IIASA Data	IGES Data	Other source
		m3/Gwh	m3/Gwh	m3/Gwh
Coal ***Steam turbine***	*once-through*	*1135-1250*	*2495-4285* *Avg.: 3390*	
Natural Gas ***Steam turbine***	*once-through*	*1135-1250*	*3790-7490* *Avg: 5640*	
Oil ***Steam turbine***	*once-through*	*1135-1250*	*3790-7490* *Avg: 5640*	
Hydro		17,000-26,000		340,000

IGES data mainly derived from power plant survey in India and Thailand

There is no such structured information available on water requirement for energy production and generation. Wide variation is information and data.
Coefficient varies from country to country and in fact within a same country.

Step-II :Developing the water module of the MESSAGE Model and running a scenario to estimate the total water demand for the energy sector.

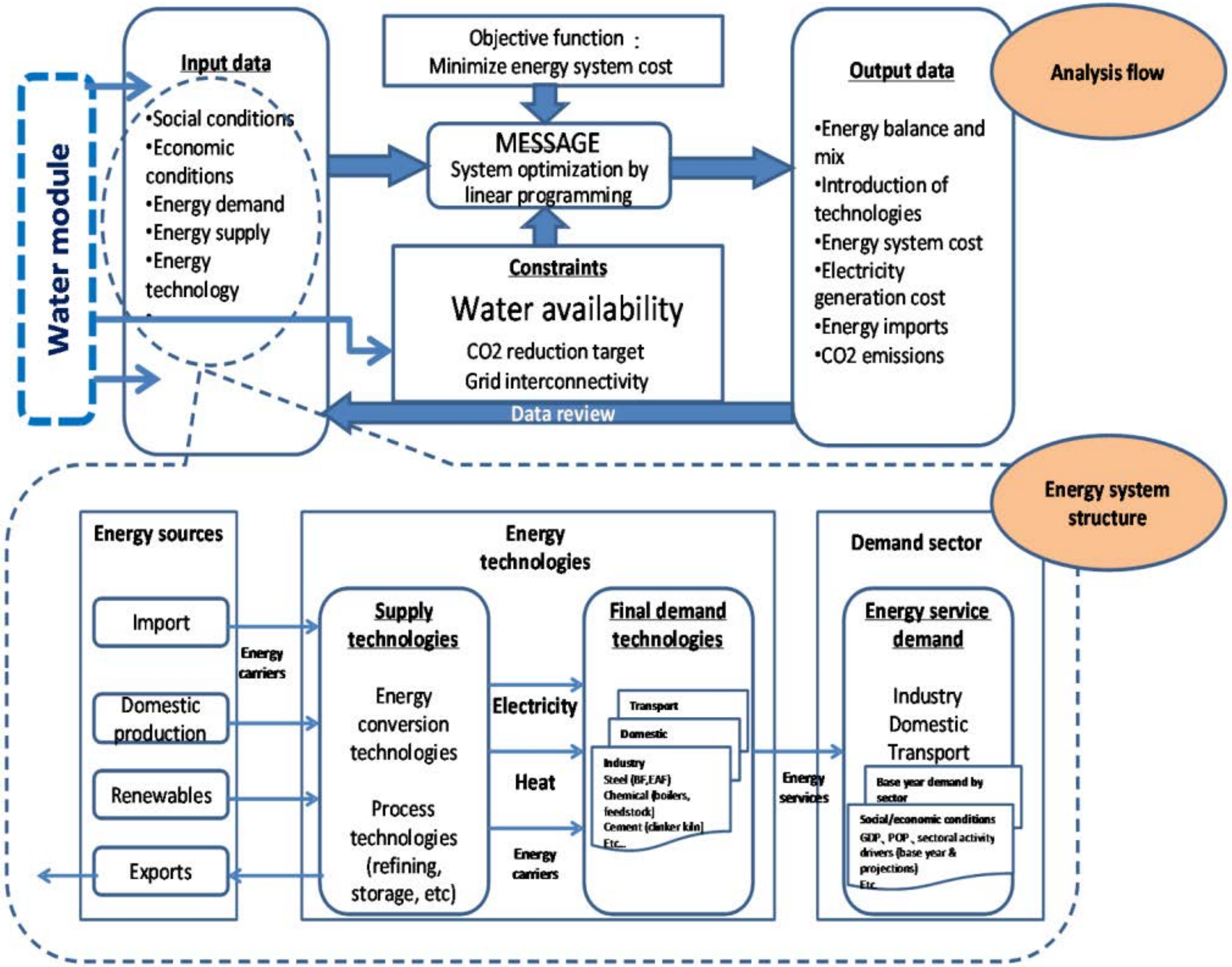
Model used

- The Model of Energy Supply Systems Alternatives and their General Environmental Impacts (MESSAGE), a systems engineering optimization model is used. MESSAGE model developed by the International Institute for Advanced Systems Analysis (IIASA) in Vienna. IGES contributed to develop the water module.

- This model finds the optimal flow of energy from primary energy resources to useful energy demands from the mathematical and engineering feasibility perspective and simultaneously leads towards the least cost investment option to meet the given energy demand in the system.

- MESSAGE is a 11 region model in general covering the major regions of the world. Asia is divided into three sub regions in the model.

Schematic diagram of the MESSAGE Model

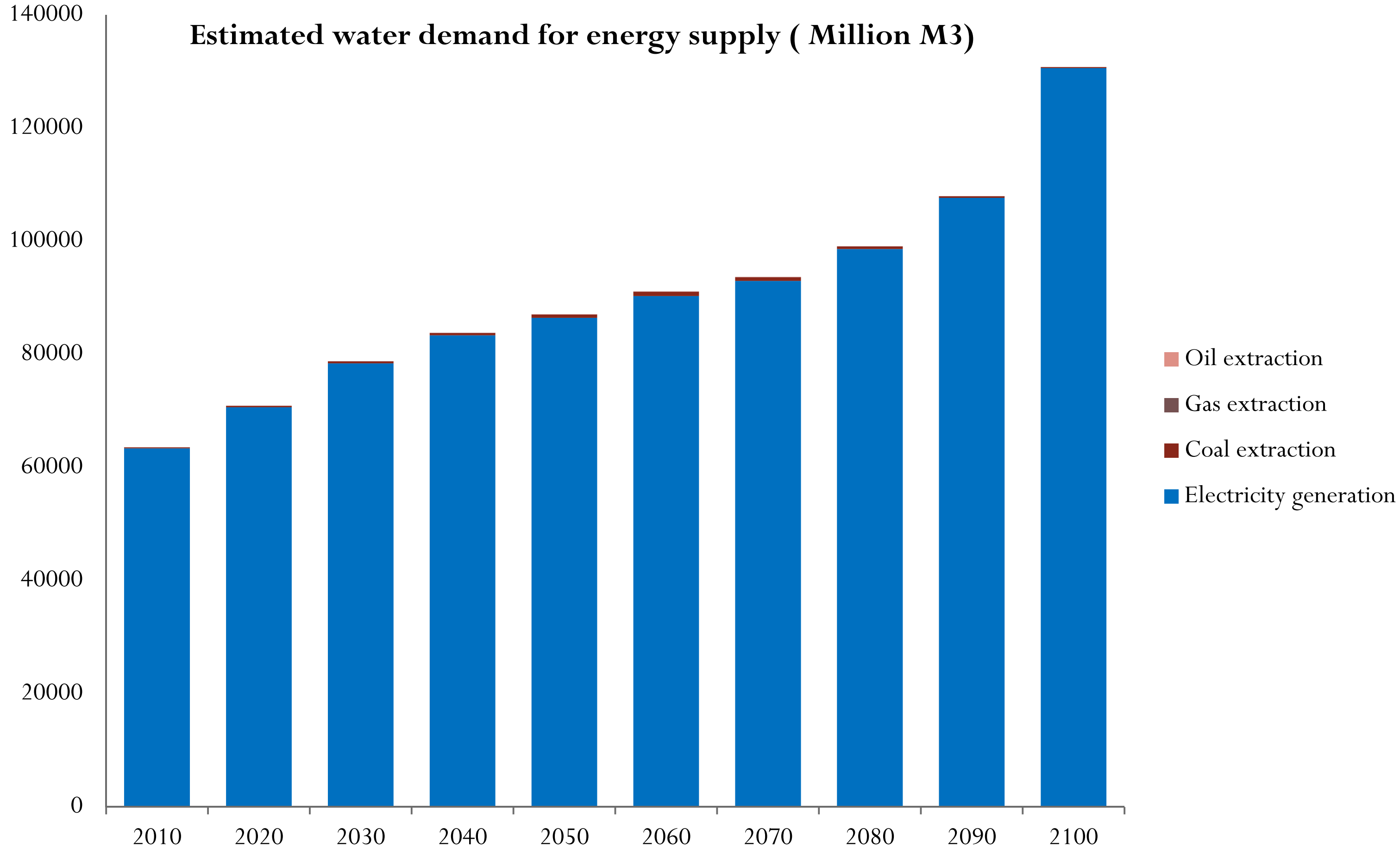


Water Module

- Sectoral water demand forecasting using econometrics and statistical method.
- National/regional long term water availability under climate influence using climate model and hydrological model.
- Water coefficients of energy technologies

Estimated water demand for energy sector in South Asia

(South Asia: India, Bangladesh, Nepal, Bhutan, Pakistan and Afghanistan)



Step-III :*Estimating long term water availability for energy sector and estimating impact on water availability due to climate change using RGCM and Regional Hydrological Model.*

Storyline of A2 and B2 Scenario and potential climatic impacts

Assumptions	A2 Scenario	B2 Scenario
	• Continuously increasing population • Regional oriented economic development • Slower and fragmented technology change	• Population growth rate is slower than A2 • Regional oriented economic development with slower growth rate • Diverse technological change
CO_2 concentration by 2100 (ppm)	850	616
Temperature Change at 2090-2099 relative to 1980-1999 (^{0}C)	2.0-5.4	1.4-3.8
Sea level Rise at 2090-2099 relative to 1980-1999 (m)	0.23-0.51	0.20-0.43

Water Availability Forecasting Modeling

Precipitation forecasting

Predicted Future Rainfall (GCM)

→

River basin run-off forecasting

HEC-HMS

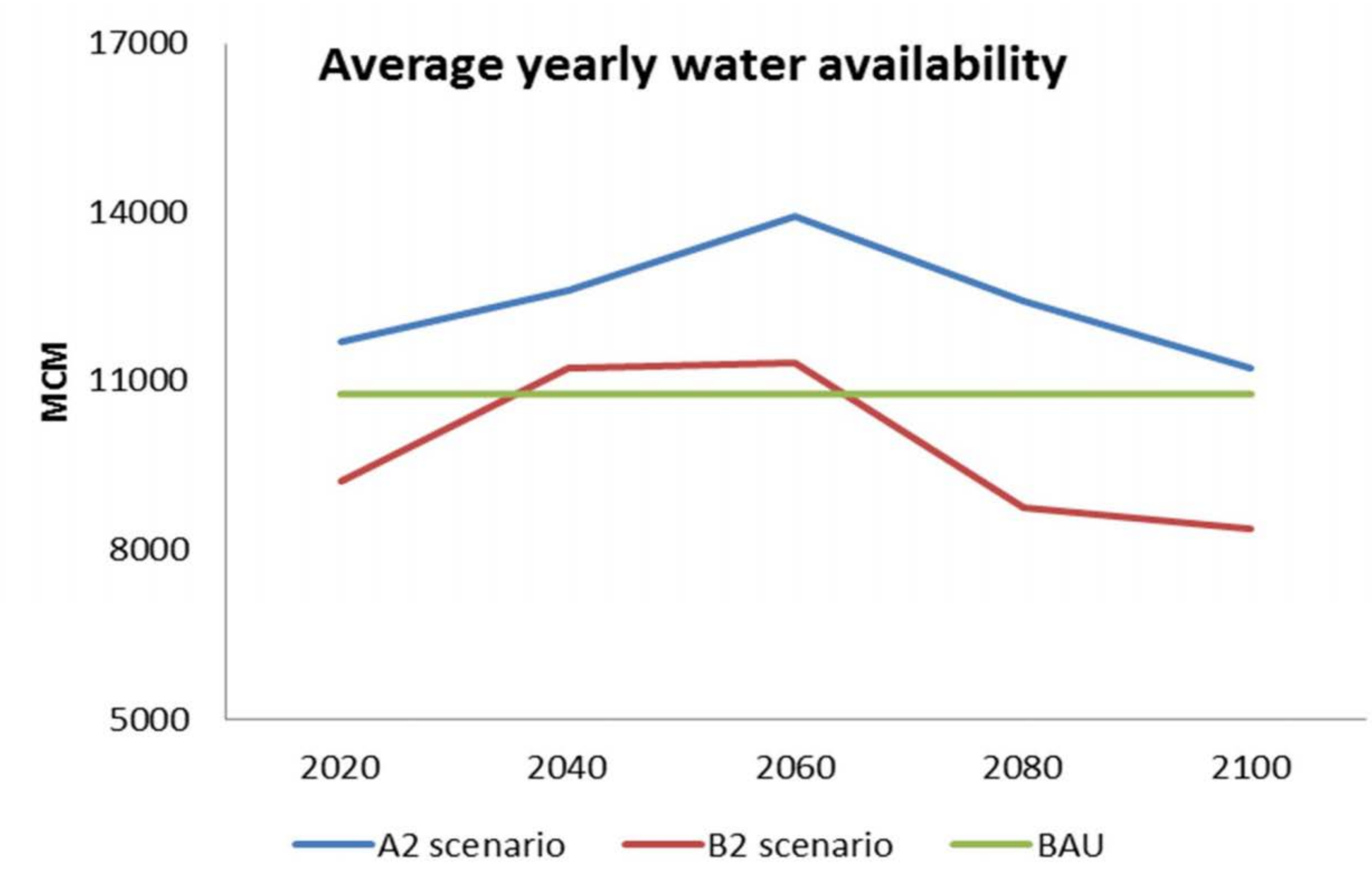
→

Available water volume forecasting

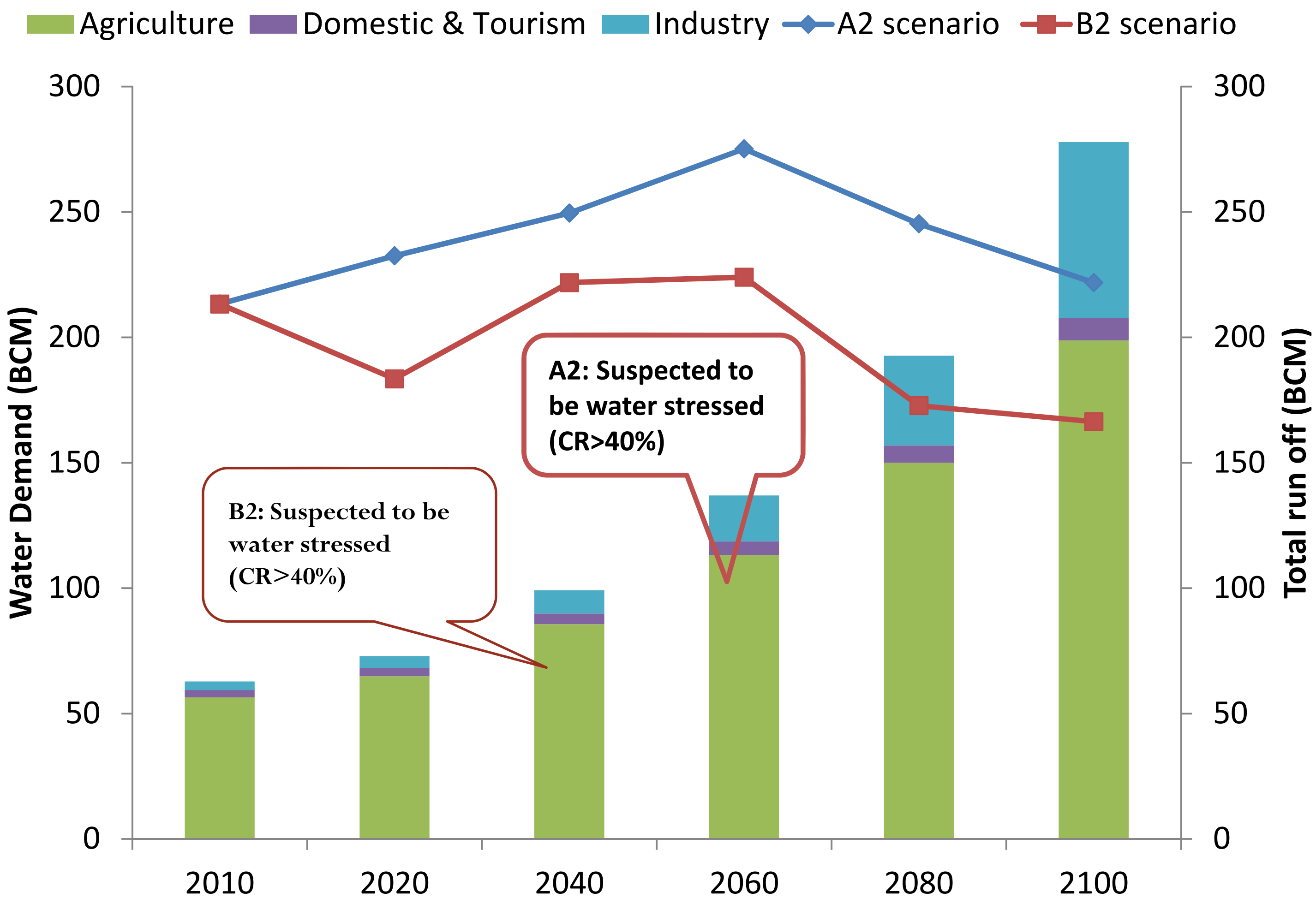
Predicted Future Water Availability

HEC-HMS: The Hydrologic Modeling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of dendritic watershed systems

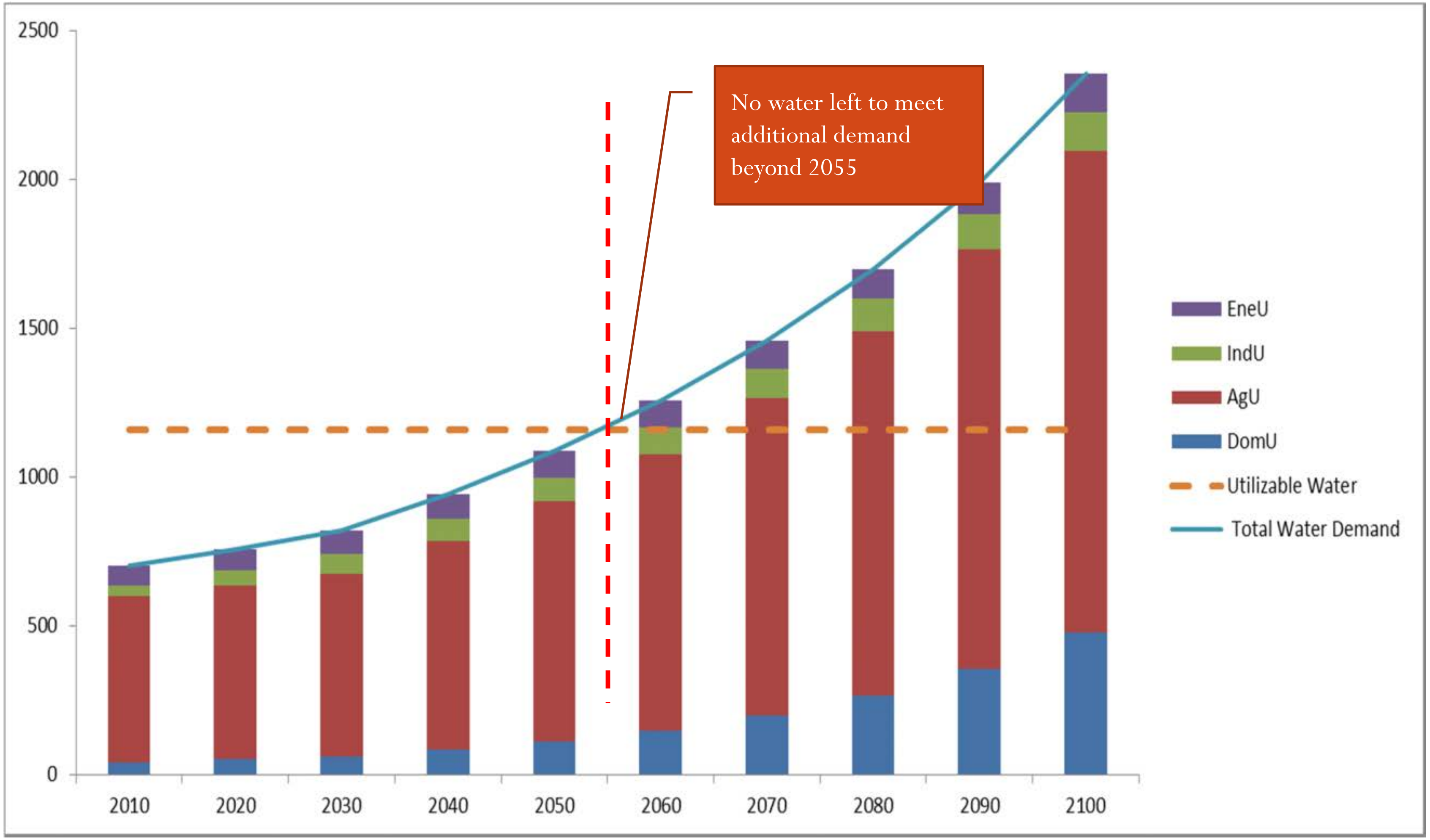
Water availability in Ping and Wang River under A2 and B2 climate change scenarios



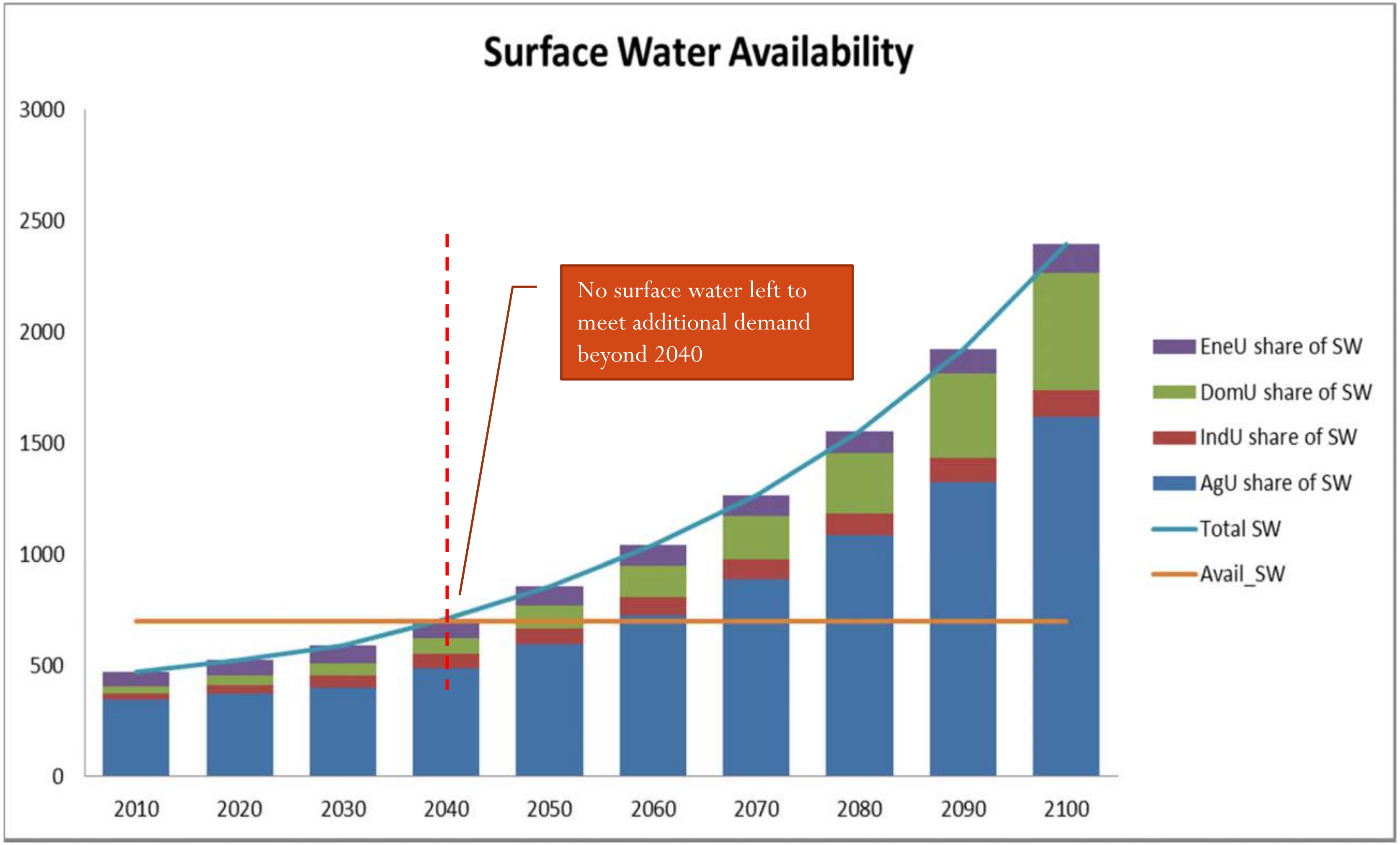
Water availability in Thailand under A2 and B2 climate change scenarios



Projection of long-term total water availability and demand in India (in BCM)



Projection of long-term surface water demand in India (in BCM)



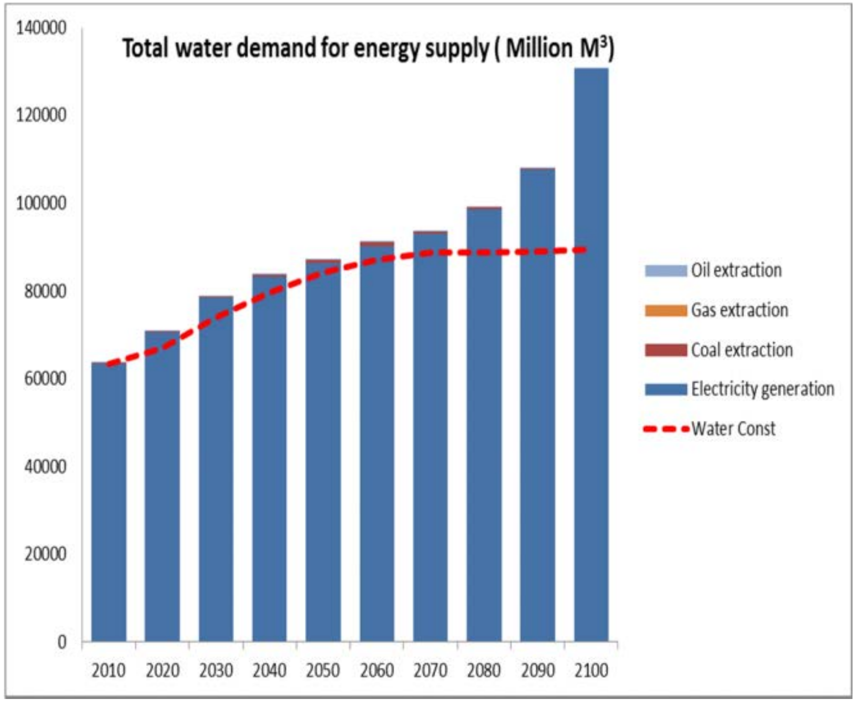
How significant energy sector water demand is for South Asia?

	1975	1980	1985	1990	2000	2010	Growth rate (%)
	Billion Cubic Meter (BCM)						
Total water availability	3808	3808	3808	3808	3794	3790	-0.01
Total water withdrawal	544	438	497	510	819	761	1.0
Domestic use	13	14	18	25	49	56	4.3
Agricultural use	514	412	468	470	756	688	0.8
Industrial use	17	13	11	15	14	15	0.3
Water for energy				33	35	64	3.3

Using the CAGR method we projected all the 6 indicators in the table above for next 100 years to derive the long term criticality ratio which is further used To derive the water constraint. We did not consider the efficiency improvement In water use technologies including irrigation system. But we did that for energy related water demand estimation.

Deriving the water constraint for energy sector in the South Asia region

- India projected energy sector water demand by 2050 is around 70BCM (NCIWRD, 1999) starting from 20 BCM in 2010.
- Following CR projection total water availability in the South Asia region exclusively for energy sector fixed to 90BCM / year until 2100.
- *Water availability variation due to climate effect is under investigation in AIT (Some results obtained)*



Step-IV-A: *Identifying the water constraint mitigating technologies for energy sector.*

Selection of water use mitigating technologies

- We added mainly two different categories of technology: Dry Cooling and Sea Water Cooling for electricity generation.
- Dry cooling is done with compressed air only and no water is required. This technology is commercially available.
- Dry cooling system in the power plant increases the investment cost by around 10% compared to wet cooling system.
- Dry cooling also decreases the thermal efficiency of the plant by around 2.5%.
- Power plant also faces higher auxiliary consumption (approx. 10%).
- Sea water cooling has no impact on thermal efficiency.
- Power plant with sea water cooling has higher O&M cost (5% more compared to fresh water cooling).
- Need fresh water as make-up for boiler operation.

Step-IV-B: *Running the water constrained scenario and analyse the results*

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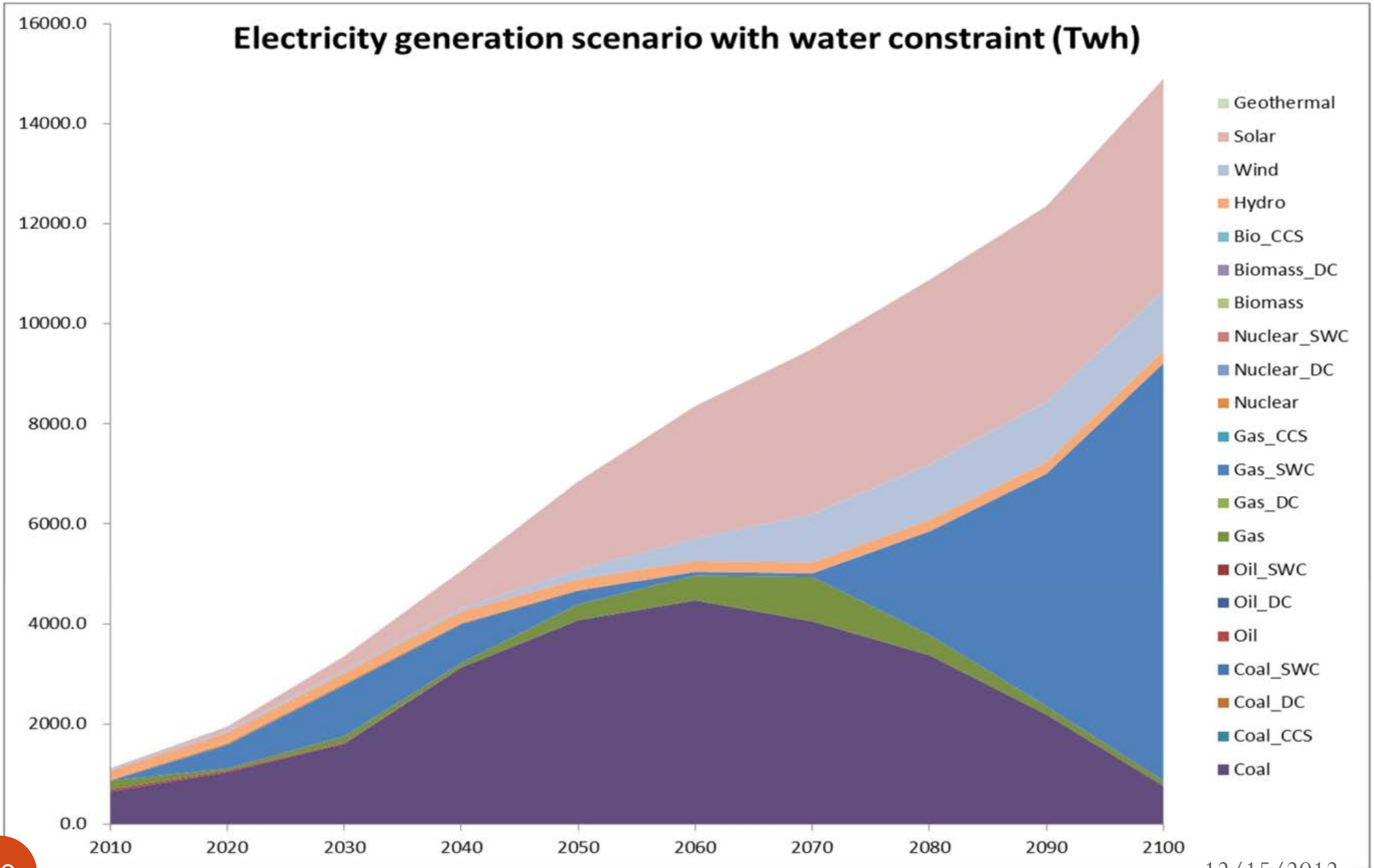
1(a). Long term electricity supply mix



1 (b). Long term electricity supply mix

- Total electricity generation unchanged. Water elasticity of power generation technology is found to be very high (> 2).
- Due to water scarcity main technological substitution happen in gas based power generation with sea water cooling.
- Renewable energy technologies (with no water requirement) are also getting predominant. Solar PV increase at a much faster rate than solar thermal and CSP.
- Gas and RE are the technology game changer in the region in the long term energy scenario with water scarcity situation.

2. Long term energy price effect

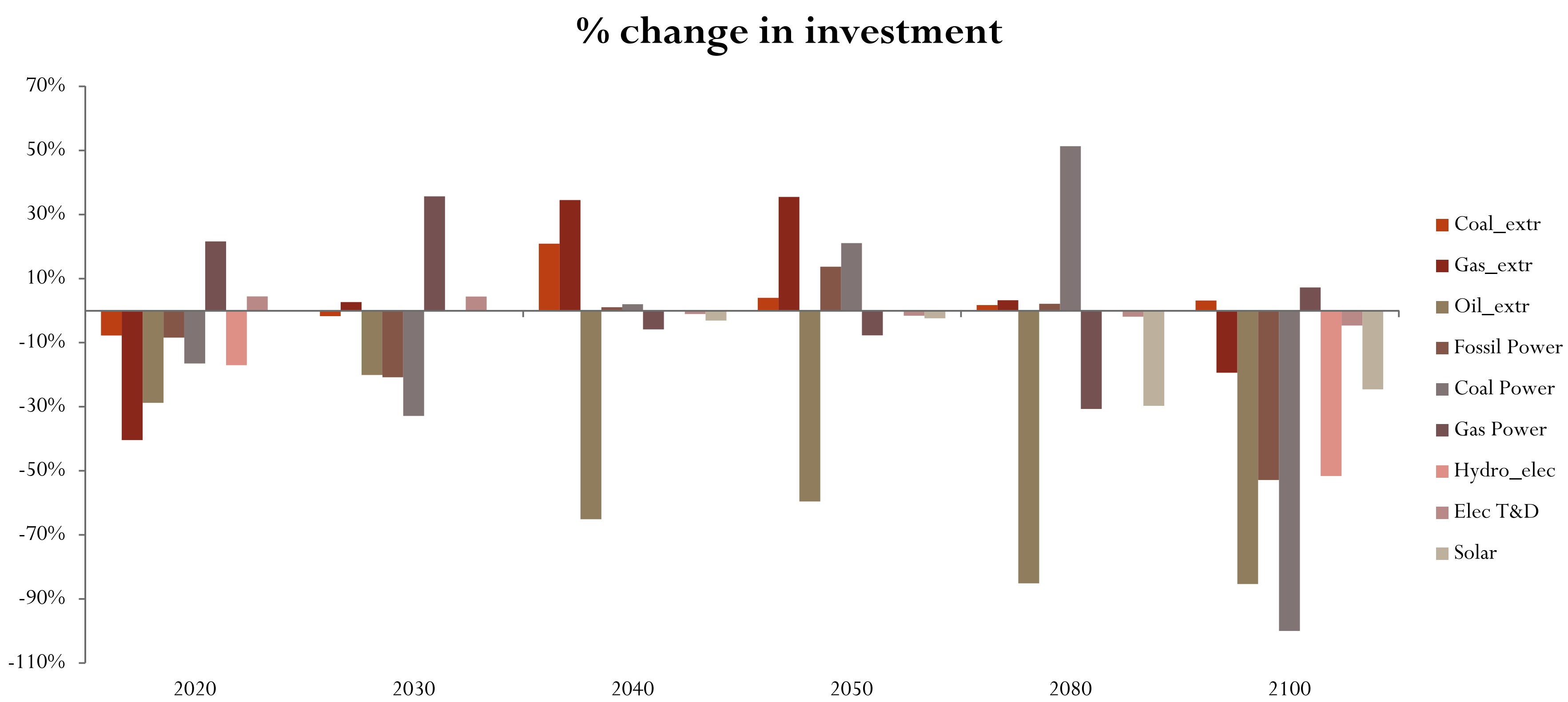
- Natural gas price is expected to increase significantly in the long run up to 20% due to water shortage.
- Coal price is expected to decrease as its demand reduces due to water shortage but not very high decrease is expected as coal demand continues in other sectors.
- Oil price remains almost unaffected.
- Electricity price overall increases.

3. Long term energy sector investment scenario

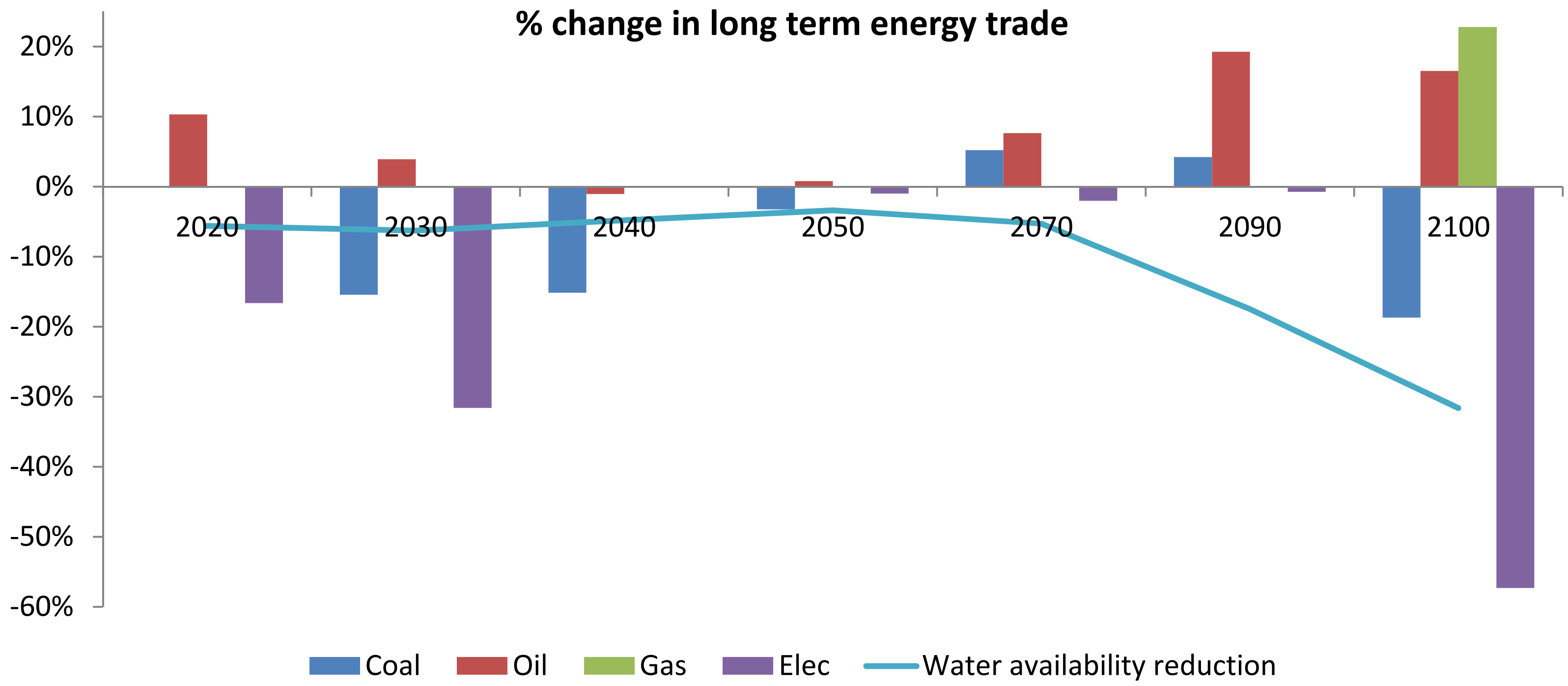
Billion USD	2020		2030		2040		2050		2080		2100	
	WWC	WC	WWC	WC	WWC	WC	WWC	WC	WWC	WC	WWC	WC
Coal_extr	3.8	3.5	6.0	5.9	7.4	8.9	9.0	9.3	9.2	9.3	7.1	7.3
Gas_extr	9.5	5.7	13.1	13.4	8.3	11.2	9.1	12.3	7.3	7.5	7.4	6.0
Oil_extr	2.7	1.9	4.3	3.5	6.2	2.2	6.0	2.4	6.0	0.9	3.3	0.5
Fossil Power	13.8	12.6	27.0	21.4	42.4	42.8	35.6	40.4	28.2	28.8	46.1	21.7
Coal Power	10.8	9.1	22.2	14.9	37.4	38.1	26.5	32.0	11.3	17.1	25.8	0.0
Gas Power	2.9	3.5	4.7	6.4	5.0	4.7	9.1	8.4	16.9	11.7	20.2	21.7
Hydro_elec	1.4	1.2	1.9	1.9	2.6	2.6	3.0	3.0	2.2	2.2	6.9	3.3
Elec T&D	22.1	23.0	39.6	41.4	58.5	57.9	73.5	72.3	96.2	94.4	156.2	148.9
Solar	2.8	2.8	6.9	6.9	17.0	16.5	41.6	40.6	78.9	55.5	89.1	67.2
Wind	0.0	0.0	0.6	0.0	1.9	1.3	1.0	2.7	15.0	5.7	6.9	12.8

- All water intensive technology investment gets reduced. Nonconventional oil and gas production gets affected and subsequent investments.
- Solar thermal and CSP related investment slows down while wind investment goes up at least until 2050.
- Electricity T&D investment for new transmission and distribution system reduces.
- Infrastructure investment for cross border energy project development also reduces as hydro power generation reduces due to water scarcity.

3 (a). Long term energy sector investment scenario



4. Long term energy trade scenario



4(a). Long term energy trade scenario

- Regional coal trade negatively affected as the use of coal gets reduced due to shift in electricity supply mix.
- Oil trade continues to grow as its other than electricity use (transport) remains unaltered.
- Gas trade almost remains same except the last period of the simulation when the water availability reduces by more than 30%.
- Electricity trade also affects adversely due to water scarcity as in this region almost 100% traded electricity is hydro.

5. Long term energy resource extraction impact

- Water scarcity adversely affects the non conventional fossil fuel extractions. All these technologies are highly water intensive (tar oil, oil sand etc.)
- Until 2050 non conventional fossil fuel extraction continues to grow but after that again conventional fuel extraction started picking up. Cost also increases subsequently.
- Water availability thus has long term impact on investments and technological development of non conventional fossil fuels. Currently, all major energy companies across the world is heavily investing in R&D for promoting non conventional fossil fuel technologies.

7. Other environmental impacts

- It is observed that CO_2 emissions from the electricity sector reduces significantly due to fuel shift caused by water scarcity.
- SO_2 and NOx emissions reduces under the water constrained scenario mainly due to fuel shift in power generation.
- Back carbon and other air pollutants increases in the atmosphere.
- P2.5 also increases significantly under water stressed scenario.

8. Summary of findings

- In the long term energy planning , water needs to be considered at the basic planning level.
- Water scarcity can jeopardize the energy sector investment return.
- Seasonal and geographical variation changes water availability in the long run and it complicates the matter further. However, it is important to consider such variation.
- Acute inter sectoral water demand conflict is envisaged. This conflict can further slow down the economic growth.
- Systematic R&D funding for advanced water efficient energy supply technology is essential.
- Water efficient energy technology development can be considered as climate adaptation mechanism.

Thank you for your attention!

For further contact:

Anindya Bhattacharya
Senior Energy Economist
Institute for Global Environmental Strategies,
2108-11 Kamiyamaguchi
Hayama, JAPAN 240-0115
E-mail: bhattacharya@iges.or.jp