Energy & Water linkages in the power sector – Implications for future planning

Presentation at
Conference on Water Optimization in Thermal power plants
Dr Ritu Mathur, Ms Garima Vats, Mr Anshuman (TERI)
June 12-13, 2013
Outline

- **Power Sector in India**
  - Demand for power
    - Current (total & per capita); comparison with other countries
    - Future: Business-as-Usual (BAU) Scenario

- **Water use in Power Sector**

- **Implications for water requirements**
  - BAU Vs. Alternative pathways

- **Variation in water use in conventional power plants** [Discussion on norms & water saving measures]

- **Water & Energy linkages**
  - Are there trade-offs?
  - What can we say for specific sites that may be water stressed or coastal/inland plants
  - Implications of increased water stress due to other sectors

- **Case Study—Thermal power plants water audits**
• India’s per capita electricity consumption is a fraction of that of other countries

![Chart showing per capita electricity consumption worldwide in 2008.](chart.png)

Source: IEA

• Electricity consumption expected to increase 5-6 times 2001 level by 2031 (TERI, 2009)
• Peak deficit of 9% in 2012-13; energy shortage 8.7% in 2012-13 (CEA)
• Power sector an important contributor to growth, but high use of energy, resources & implications on emissions.
  • Energy consumption for power generation: ~ 42% of total commercial energy (TEDDY 2012/13)
  • Accounts for ~ 53% of energy sector emissions in 2000 (MoEF, 2012)
  • Thermal power plants are highest water users amongst the industrial sector (1-2%);
  • Limited areas of land amenable for siting new plants
Need for rapid growth in power generation – HDI & development strongly linked

Highest power consumption in Industrial sector (35.34%) followed by Domestic (25.07%), Irrigation (21.02%) and Commercial (10.16%) and others (8.41%) in 2009-10

On the supply side, coal continues to be the mainstay, followed by hydro & gas; although capacities of nuclear, renewables increasing

Future transitions relevant from various perspectives (meeting energy & peak demands, adequacy of fuel supplies, land & water availability; environmental implications)

Fuel wise energy generation in 2011-12

All India Installed capacity as on 30th June, 2011
### Possible Future Energy Scenarios

<table>
<thead>
<tr>
<th>Scenario Name</th>
<th>Storyline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Energy Scenario (BAU)</td>
<td>Life continues pretty much as we know it, with autonomous efficiency improvements taking place where feasible, increase in use of renewable energy carrying on at the same pace and defined policy priorities being implemented with no real sense of urgency</td>
</tr>
<tr>
<td>Sustainable Energy Scenario (SES)</td>
<td>A determined effort is provided here for efficiency improvements both on the supply and demand sides, an accelerated push for renewable energy, nuclear and new technologies like CTL (coal to liquids) and GTL (Gas to Liquids). Energy Security concerns are paramount in this scenario</td>
</tr>
<tr>
<td>Global Equity Scenario (GES)</td>
<td>This scenario honours the Prime Minister on ‘common but differentiated responsibilities’ and equitable per capita rights and take on even more stringent emission reduction targets (reaching 1.24 tonnes/capita in 2031) towards influencing global response to the challenge of climate change.</td>
</tr>
</tbody>
</table>
Power generation capacity across scenarios

- Biomass
- Solar
- Wind
- Nuclear
- Hydro (large & Small)
- Diesel
- Gas based
- Coal IGCC
- Coal Supercritical/Ultra supercritical
- Coal Sub critical

TERI, 2009
Energy implications for power sector across scenarios

 TERI, 2009
What does this imply in terms of the pressure on energy requirements?

- Import implications
  - Huge imports in the BAU scenario; e.g. around 450 and 1282 MT of non-coking coal in 2021/22 and 2031/32 respectively

- Infrastructure implications
  - At ports and rail/road network for movement of fuels

- Emission implications
  - \(\text{CO}_2\) & local air/water pollution

→ BAU not feasible in terms of energy – need to diversify to other fuels
Water use in the power sector (macro assessment)

- Water—A key resource to extract, produce, process or to convert energy from one form to another.

- Hydroelectric power plants, as such, do not have any consumptive use of water.

- Most renewables like wind, solar and biomass are not associated with high water requirement
  - Within solar, solar thermal has a higher water requirement than solar PV technology

- Water in power generation from fossil fuels like coal, gas, diesel, naphtha & nuclear is mainly for generating steam and cooling purposes.

- Nuclear power plants use more water for cooling purpose as they dissipate all the heat through water as in contrast to coal, gas etc. that partly dissipate heat through flue gas

- Coal and Lignite also use a significant amount of water for ash disposal, apart from steam generation & cooling purposes.

- Water stress more a site specific concern
  - Dependent on level of capacity by fuel & technology
  - Function of other competing demands
Water-for-energy—Current estimates and projections by various agencies

<table>
<thead>
<tr>
<th>Sector</th>
<th>Water Demand in km³ (or BCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standing Sub-Committee of MoWR</td>
</tr>
<tr>
<td>Year</td>
<td>2010</td>
</tr>
<tr>
<td>Irrigation</td>
<td>688</td>
</tr>
<tr>
<td>Drinking Water</td>
<td>56</td>
</tr>
<tr>
<td>Industry</td>
<td>12</td>
</tr>
<tr>
<td>Energy</td>
<td>5</td>
</tr>
<tr>
<td>Others</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td>813</td>
</tr>
</tbody>
</table>

- Wide variations in water requirement for energy; however, water requirement estimated to increase significantly as per both norms
  - NCIWRD, 1999; MoWR Sub Standing Committee, 2000
Variation in water use in conventional power plants

- Water intensity in power generation is a function of fuel type, technology used and water conservational practices followed during energy generation.

- Variations in water use can be because of following:
  - **Fuel type**—Nuclear > Coal/lignite > Gas/Diesel > Renewables
  - **Technology**—Subcritical, Supercritical, Ultra-supercritical, IGCC, CSS, etc.
  - **Processes**—Wet cooling vs. Dry cooling, Closed loop vs. open loop cooling, Lean slurry disposal system vs. High concentration slurry disposal (HCSD) system etc.
  - **Water conservational measures**—Utilization of cooling tower blow down for ash disposal, dry fly ash disposal, bottom ash water recycling, etc.
Inference: A shift towards renewables in the SES & GES scenarios could result in much lower water consumption as compared to that in the BAU scenario.
Comparison between CEA & NCIWRD norms

- CEA—3000 m\(^3\)/hr. for a typical 2 X 500 MW coal based inland plant or 3 m\(^3\)/MW/hr with closed loop cooling, dry fly ash disposal, bottom ash water recycling and cooling tower blow down used for ash disposal and a few more water conservational practices (CEA 2012)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>In-land plants using indigenous coal</th>
<th>Sea water based coastal plants(fresh water requirement)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In-land plants using indigenous coal</td>
<td>Plants with wet cooling tower</td>
</tr>
<tr>
<td>1.</td>
<td>Water requirement for first year of plant operation</td>
<td>3600</td>
</tr>
<tr>
<td>2.</td>
<td>Water requirement during subsequent period</td>
<td>3000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NCIWRD, 1999

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>2010</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Thermal</td>
<td>0.001 BCM/100MW/year</td>
<td>2.38</td>
<td>2.63</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>m3/MW/hr.</td>
<td>2.72</td>
<td>3</td>
<td>2.28</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0.001 BCM/100MW/year</td>
<td>2.85</td>
<td>3.15</td>
<td>2.85</td>
</tr>
<tr>
<td></td>
<td>m3/MW/hr.</td>
<td>3.25</td>
<td>3.6</td>
<td>3.25</td>
</tr>
<tr>
<td>Solar/wind</td>
<td>0.001 BCM/100MW/year</td>
<td>0.17</td>
<td>0.18</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>m3/MW/hr.</td>
<td>0.19</td>
<td>0.21</td>
<td>0.19</td>
</tr>
<tr>
<td>Gas Based</td>
<td>0.001 BCM/100MW/year</td>
<td>0.45</td>
<td>0.49</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>m3/MW/hr.</td>
<td>0.51</td>
<td>0.56</td>
<td>0.51</td>
</tr>
<tr>
<td>Hydro</td>
<td>BCM</td>
<td>LS*</td>
<td>LS</td>
<td>LS</td>
</tr>
</tbody>
</table>

*LS Live Storage
Comparison of results obtained from Norms

CEA norms imply slightly higher water consumption as compared to NCIWRD norms, although they consider several water saving measures.
Comparison of overall water consumption based on norms

- The norms specified by CEA for coal based thermal power plants seems to be an underestimate of water consumption. The norm of water requirement of $3m^3/MW/hr.$ is based on inclusion of several water saving measures.

- The norms suggested by NCIWRD for 2010 are even lower than those of the CEA [higher estimates are closer to CEA norms]
  - Water requirements of power plants as indicated in our scenarios therefore likely to be underestimates.

- However, all the power plants currently may not be following all these practices; important to consider technical / economic feasibility of applying measures / practical considerations.

- Understanding the water-use parameters (specific water consumption) and water-saving technologies/processes/practices followed by the power plants can help arrive at a better understanding of the likely water stress at various locations.
UP, Maharashtra, West Bengal are the top three water consuming states in the power sector including all renewable and non-renewable energy source.
Maharashtra (with 12.91% of total installed capacity) has a much lower percent share of water consumption as compared to percent share in installed capacity due to high penetration of renewables in the state.

States like Uttar Pradesh and West Bengal draw significantly more water than their share in total installed capacity of India due to very high share of coal/ nuclear based power generation and insignificant renewable based power generation in these states.
**Water and Energy Trade-offs**

<table>
<thead>
<tr>
<th>Cooling Type</th>
<th>Water Withdrawal</th>
<th>Water Consumption</th>
<th>Capital Cost</th>
<th>Plant Efficiency</th>
<th>Ecological Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once-Through</td>
<td>intense</td>
<td>moderate</td>
<td>low</td>
<td>good</td>
<td>intense</td>
</tr>
<tr>
<td>Wet Cooling Towers</td>
<td>moderate</td>
<td>intense</td>
<td>moderate</td>
<td>good</td>
<td>moderate</td>
</tr>
<tr>
<td>Dry Cooling</td>
<td>none</td>
<td>none</td>
<td>high</td>
<td>bad</td>
<td>low</td>
</tr>
</tbody>
</table>

**Summary of Cooling Systems Trade-offs (Delgado, 2012)**

- Closed loop has lower water withdrawal, but higher water and energy consumption.
- Lean slurry versus high concentration slurry disposal: HCSD system has lower water requirement but high energy consumption.
- Some increase in auxiliary energy consumption may be associated with water conservation measures.
- What factors need to be evaluated in considering trade-offs?
- Several options may exist to simultaneously look at energy and water saving at existing power plants.
- What incentive do power plants have to follow water conservation practices?
- Siting of new plants should also examine future water stress along with other factors.
Maharashtra: Parli power plant shuts down after severe water crisis

Reported by Rashmi Rajput, Edited by Amit Chaturvedi | Updated: February 17, 2013 17:33 IST

Mumbai: All six units of the Parli thermal power plant in Beed district of Maharashtra have been shut down because of severe water shortage in the Marathwada region. The plant used to receive water from the Khadka dam but the supply was stopped as the water level in the dam has almost dried up.

"Due to water shortage we had to shut down the plant. 1160 MW energy was generated by the plant. Two units were shut in October last year and all the six units were shut yesterday," said MM Chavan, chief engineer of the plant. The power plant has an installed capacity of 1130 MW.

Power or water for Vidarbha?

Jayashree Nandi, TNN Aug 7, 2012, 04:23PM IST

Tags: Vidarbha Statutory Development Board | vidarbha | thermal power plants | Greenpeace

NEW DELHI: Water starved and already plagued by a massive agrarian crisis, Vidarbha may now have to deal with more woes. Large clusters of thermal power plants proposed in Vidarbha will dramatically intensify the water crises in the region and eat into the irrigation sources.

An IIT Delhi study commissioned by Greenpeace India released on Tuesday revealed that the proposed power plants may bring down the future availability of water in the Wardha river in Vidarbha by 40% and affect irrigation for about one lakh hectares of farmland in the future.
Though the magnitude of water consumption/withdrawals by power sector may not be that high in magnitude but local water stress that they create also due to demand from other competitive users can be quite significant.
Water Audit

(Reducing water consumption & improving efficiency)

Case Study

Thermal Power Plant
Approach & Methodology

Secondary data collection

Reconnaissance survey

Flow monitoring and establishment of water balance
- Entire water supply network of Stage-I, II & III
- Drinking water supply and sewage water discharge from township.
- Leak detection & estimation of UFW
- Estimation of cycle of concentration (COC) and water consumption/MWH

Water Quality Monitoring & Characterization
- Water sampling (at various locations at Stage-I, II & III eg. for Intake Water, Process Water, OAC, Drinking Water, and Wastewater discharge)
- Laboratory testing & analysis

Data analysis & Recommendations for water & wastewater management
Establishment of Water Balance:
(Water flow & quality profiling)
Specific Water Consumption (m$^3$/MW)

Actual Overall Specific Water Consumption – about 5 m$^3$/MW

Scope for optimizing (Achievable SWC) – 3 m$^3$/MW
Total Wastewater Discharged (unused) = 64000 m³/day (About 18% of Intake water)

Wastewater quality reasonably good for recycling (Zero Discharge)
Recommendations for water conservation

- **Water** for boiler auxiliary (discharged as waste) should be reused.

- High water loss (80-50%) in ash handling should be brought down (overflows should be recycled, leakages plugged, Specific water consumption brought down)

- **Cooling Towers**: COC must be increased, Specific water consumption should be reduced (to about 1.5 m³/MW), overflows must be checked.

- **Township**: Reduction in per capita water consumption (to 150 lpcd)

- Recycling of about 64000 m³/day of wastewater being discharged from the plant to achieve Zero discharge through a treatment plant.

- **Township STP discharge water** (suitable for horticultural uses) should be reused entirely thus saving significant water and ensuring zero discharge.
Potential for water saving

- Immediate saving potential of about (81000 m$^3$/day) 23% of total intake water

- Significant financial savings from water saving interventions of about INR 7-9 Crores.

- Cost benefit of water recycling system was positive with a payback period of just 2.3 years.
India Water Forum

2011: Water Security and Climate Change: Challenges and Opportunities

International Water Conventions

2013 (October): Water use efficiency

2013: Water use efficiency
Thank You!