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Environmental issues and challenges of water consumption for thermal power plant: Impact of new water consumption norms

The interdependency between water and energy, sometimes called the water-energy nexus, is growing in importance as demand for both water and energy increases with time. In the world, thermal power plants make up 70% of the existing fleet. These plants require large quantities of water, primarily for cooling, and account for 40% of the total fresh water withdrawals every year. This has an impact both on the aquatic organisms and on the water resources of the region where the power plant is located. A report from the US Department of Energy identified more than 60% coal-fired power plants as vulnerable to water demand and/or water supply concerns. Therefore, it is important to understand the water footprint of the different electricity generation technologies. Unfortunately, the primary source of data is from direct surveys of power plant operators, which are often unreliable and incomplete. In order to better understand the water footprint of thermal power plants, this paper presents a simple, generic model to predict their water usage.

Almost all energy generation processes require significant amounts of water, and the treatment and transport of water requires energy (mainly in the form of electricity). This trade off between energy and water resources is the energy-water nexus. Integrated planning is vital to ensure future social, political, and economic stability and to avoid unwanted and unsustainable scenarios.

Water scarcity is increasing. About 2.8 billion people live in areas of high water stress and 1.2 billion live in areas of physical scarcity. It is estimated that by 2030, nearly half of the world's population will be living in areas of high water stress affecting energy and food security (WWAP, 2012). Worldwide, decreasing water quality also impacts growth as it degrades ecosystems; causes health-related diseases; constrains economic activities such as agriculture, energy generation, industrial production, and tourism; affects the value of property and assets, and increases wastewater treatment costs.

Water is most abundant thing on Earth after air. As water is precious, priceless, pretty gift to human kind from almighty and now-a-days very valuable and its usability is increasing day by day. The electric power industry usually thermal power plant is a large water user and is dependent upon reliable water supplies. Adopting new water-conserving technologies for power production can help alleviate the impact of future water shortages. Several water use reduction technologies are available, each with different benefits and costs.

By far the largest use of water in power generation is for condenser cooling. Thermal power plants require a large amount of cooling water to condense the steam turbine exhaust steam. The lower the condensing temperature is, the lower will be the backpressure on the steam turbine, which increases plant thermal efficiency. The most effective method of rejecting this heat is through the use of cooling water. Traditionally, power plants have used three methods for condenser cooling: once-through, evaporative, and dry cooling. Each has unique advantages and disadvantages.

With once-through cooling, water is withdrawn (typically from a lake, river, or ocean), pumped through a condenser, and returned to the source at the same rate but at an increased temperature. Once-through cooling provides the best power plant efficiency of all the alternatives (such as cooling towers, natural draft or forced draft) because the source water tends to be the lowest temperature heat sink available for most of the year. In this paper we analyze the use of water in thermal power plant also the various water conservation management techniques in terms of water reuse/recycling, we can also elaborate the other techniques for water conservation by production of energy by renewable energy sources in place of thermal power plant.

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1.0 Introduction

The Government of India, in its National Water Mission (NWM) under the National Action Plan on Climate Change (NAPCC), has emphasized the need to develop a framework for optimizing water use efficiency by 20 per cent, through regulatory mechanisms with differential entitlements and pricing. It further emphasizes the need to focus on integrated water resource management through water conservation, wastewater minimization, etc. This would require various sectors, including industries, to optimize their practices ensuring conservation, recycling, and reuse. While we are aware that water is one of the most important resources nature has provided, we give little attention to how we use it.

Table 1: Percentage of water consumption in various industries

Industrial water use in India	
Sector	Percentage of water consumed
Thermal power plants	87.87
Engineering	5.05
Pulp and paper	2.26
Textiles	2.07
Steel	1.29
Sugar	0.49
Fertilizer	0.18
Others	0.78
Total	100.00

There is no exception when it comes to use in power stations. Power plant uses more water than any other industry. Thermal power plants generate around 65 per cent of the electricity produced in the India, by converting heat into power in the form of electricity. Most of them heat water to transform it into steam, which spins the turbines that produce electricity. After passing through the turbine, the steam is cooled down and condensed to start the cycle again, closing the so called steam cycle. The water is heated with different energy sources (coal, oil, natural gas, uranium, solar energy, biomass, geothermal energy) depending on the sub-type of power plant, but the principle is the same. All power plants need to cool down the steam and most of them use water to do so, which requires them to be near a water source (river, lake or ocean). Cooling methods in thermal power stations are highly water intensive process. A correct evaluation and by applying a few adjustments we can save on not only water but also on electricity bills. In thermal power stations consumption of auxiliary power, specific coal consumption, specific oil consumption and heat rate are generally monitored. Many, at the power plants may not know the specific water consumption, except in percentage terms DM water makeup. In the recent past, the water cost has gone up by more than 70 times in many states. There is a lot of prudence in monitoring the specific water consumption in terms of M^3/MW or liter/kWh. (The specific water consumption of coal based power plants varies between 1.7 and 8 liters/kWh). As per Government of India directive all the thermal power plants must reduce their specific water consumption to below 3.5 M^3/mWh by December 2017. By systematic water audit, one can reduce water consumption to the tune of 30-40 per cent. Water conservation also leads to reduction of auxiliary power consumption, since there is close nexus between water and energy. Typical range of specific water consumption figures of different power plants are shown in Table 2

Table 2: Range of specific water consumption for different range of power plant

	Power plant type	Power plant rating MW	Range m^3/MW
1	Gas based power plants	210	1,7-2.0
2	Total dry ash handling power plants	210	3.0-3.5
3	Coal based thermal power plants with once through system	210	3.0-3.5
4	Coal based thermal power plants	210	4.0-5.0
5	Coal based thermal power plants with ash water recycling	210	3.5-4.5
6	Coal based super thermal power plants	500	3.5-4.5
7	Coal based super thermal power plants with ash water recycling	500	3.0-4.0
8	Coal based old power plants	110	6.0-8.0
9	Coal based old power plants with air cooled condenser (captive use)	10 to 30	1.0-1.5

There is confusion over terminology when describing the energy/water nexus particularly between water use and water consumption.

Water use is a general term that can refer to either consumptive or non-consumptive use. Water consumption refers to a water use that makes it no longer available for other uses.

Making a distinction between these two terms is important in understanding the relationship because affordable electric power and water are two highly interdependent, essential resources that must be sustained if India is to preserve its economic health and prosperity, and position the state for future growth. Thermal power plants generate electricity using either the steam (Rankin cycle), combustion turbines (Braxton cycle), or both (combined cycle). Plants that use steam also require water to cool or condense the steam for re-use. Cooling water is the largest user of water at many thermal power plants.

Water is one of the key input requirements for thermal power generation. Water is required for process cooling in the condenser, ash disposal, removal of heat generated in plant auxiliaries, and various other plant consumptive uses. For power plants located on main land, the raw water is generally drawn from fresh water source such as river, lake, canal, reservoir, and barrage. Treated sewage water may also be used as source of raw water for the power plants located adjacent to the cities. For power plants located in coastal areas, water for cooling of condenser and auxiliaries is drawn from the sea or creek which provides for water requirement of the wet ash handling system also. The requirement of water for other plant consumptive uses is met from an alternative source or by installing desalination plant. Difficulties are already being faced insisting thermal power plants due to non-availability of water, particularly in coal bearing states like Orissa, Jharkhand and Chhattisgarh. This problem is expected to be aggravated in future when more sites would be required.

Thus there is a need to minimize consumptive water requirement for thermal power plants. In states like Rajasthan, the land is available in plenty but there is scarcity of water and naturally drinking and irrigation uses have got priority over industrial uses. In such areas where there is acute shortage of water, use of dry cooling system for condenser cooling can be explored. The condenser pressure achievable in dry cooling system is considerably higher than in wet cooling system and consequently dry cooling systems result in reduced power output and increased heat rate (lower efficiency) of the unit besides higher capital cost. There are considerable number of dry cooling installations including for large size units (>600 MW) operating in different parts of the world. In India also, some small size combined cycle plants, captive power plants and industrial units have been provided with air cooled condensers. There is regulation for industrial water use reduction as published by MoEF on 07th December 2015 are as follows:

- All plants with once-through cooling shall install cooling towers and achieve specific water consumption max. 3.5 m^3/MWh within 2 years period.
- All existing CT based plants shall reduce specific water consumption up to maximum 3.5 m^3/MWh within a period of two years.
- New plants to be installed after 1st January 2017 shall have to meet specific water consumption up to maximum of 2.5 m^3/MWh and achieve zero waste water discharge.

In the revised (Electricity) tariff policy notified by the Government of India on January 28, 2016, there is a provision that now requires that "the thermal power plant(s) including the existing plants located within 50 km radius of sewage treatment plant of any municipality/local bodies/similar organization shall mandatorily use treated sewage water produced by these bodies".

Thermal power plant water requirement

Water can leave the power plant in three ways:

(1) Evaporated in the flue gas,

(2) As discharge streams,

(3) As part of other products such as slag.

The amount of water lost in the flue gas is the total amount of water suspended in the flue gas minus the amount of water formed in the combustion process. The water from the combustion process can be estimated through stoichiometry, based on the hydrogen content of the fuel. For plants with an FGD system, it is a major source of water loss in the flue gas. In an FGD system, the flue gas can be assumed to be saturated with water at its exit temperature from the FGD. Therefore, the parameter C is generally bigger for PC plants with FGD than without.

If the quality of the water source is good, then less water blow down is needed. In many cases, this water is recycled. Otherwise, it is sent to the waste water treatment system and then returned to the water body.

Impurities also accumulate in the steam-cycle water (boiler water) and therefore, water is also blow down and replaced with clean water. However, the quantity of water necessary is in orders of magnitude smaller than the cooling water and is usually taken directly from the municipal water source instead of from the natural water source. Thus, this stream is almost negligible in terms of water consumption accounting for up to 1% of the total. However, blow down streams can be important at the plant level in terms of cost due to the expensive water treatment systems needed to comply with strict discharge regulations.

Water containing product streams can vary depending on the power plant type and includes streams such as the gypsum from the FGD, slag, etc. However, these water amounts are typically small and most of the times the water gets recycled internally.

For some types of power plants we will have to quantify also water used in other process not related to the steam cycle, such as the water used to clean the mirrors in solar thermal plants.

Plant consumptive water requirement is governed by a number of factors such as quality of raw water, type of condenser cooling system, quality of coal, ashutilization, type of ash disposal system, waste water management aspects etc.

In the past, power stations were designed with water systems having liberal considerations for various requirements and high design margins. Ash handling system used to be designed for disposal of both fly ash and bottom ash in wet form using lean slurry with ash to water ratio of typically 1:10. The consumptive water requirement for coal based plants with cooling tower used to be about 7m^3/h per MW without ash water recirculation and 5 m^3/h per MW with ash water recirculation. In recent past, plants have been designed with consumptive water requirement in the range 3.5-4 m^3/h per MW. The typical break-up of plant consumptive water, taken as 5300 m^3/h, for a typical 2×500 MW plant with wet ash disposal without recycling of ash pond water is indicated in Table 3:

Report on minimization of water requirement in coal based Thermal Power Stations

Water circuit in Thermal Power Stations

In thermal power stations, by quality considerations and end use considerations, water can be classified as: Raw

Table 3: Water requirement of different system in thermal power plant. Water circuit in thermal power station (TPS)

Description	Quantity	In %
Cooling tower make up	3450 m^3/h	65.09%/*89%
Ash disposal	1370* m^3/h	*24.53%/0%
DM water make up	120 m^3/h	2.26%
Potable and service water	250 m^3/h	4.72%
Clarifier sludge etc.	110 m^3/h	2.08%
Coal dust suppression and etc	70 m^3/h	1.32%
Total	4000 m^3/h	100%

*To be tapped from CW system as blow down water, so not considered as consumptive use.

water, clarified water, drinking water, DM (De mineralized) water, service water, ash water, cooling water, or circulating water, Fire water, etc. For all these, raw water is the main source. Normally the raw water is sourced from nearby river, irrigation canal or a pond. For handling all these different types of water streams, number of pumps and pumping stations are employed. Plant consumptive water and optimization/minimization aspects water is used in almost all areas/facilities of thermal power stations in one way or other.

The water use in TPPs can be majorly classified into the following types depending upon the quality of water and end use considerations:

1. Raw water: Water will be drawn through open intake channel, river, ponds, lakes. Water received from the source will be further treated in clarifiers and pre-treatment plant and then used for power plant purposes.
2. Freshwater: The fresh water to cater the plant needs such as power cycle make up, auxiliary cooling water, services, potable water, etc., shall be fed from a water treatment plant for the proposed plant.
3. Cooling tower water: Water used in the cooling towers.
4. Make-up water: Water used to compensate the loss due to evaporation or drift losses of water in the cooling tower.
5. De mineralized water (DM water): Water used in the boilers for generating steam to be de mineralized. DM water comes at a higher cost as compared to cooling tower water and its use is limited for specific function.
6. Ash handling water: water used for handling ash generated during the combustion process into slurry for disposal. It is ideal to use treated water for ash handling and coal dust suppression.
7. Service water: Water used for processes like coal dust suppression, fire fighting measures, use in toilets and other utilities, plantation and greening activities. It is ideal to use treated water instead of fresh water for these purposes.
8. Potable water: Water used for drinking water for the plant and the colony is known as potable water.

Water consumption in thermal power plants

A typical list of plant systems/applications requiring consumptive water is indicated as below:

I. Cooling water system for condenser and plant auxiliaries
II. Ash handling system
III. Power cycle make up
IV. CPU regeneration, if applicable
V. Air conditioning and ventilation system
VI. Coal dust suppression system
VII. Service water system
VIII. Evaporation from raw water reservoir
IX. Water for desulfurization

Optimization/minimization of plant consumptive water includes measures such as judicious utilization of water in different applications, adoption of reduced margins in various consumptive uses, adequate treatment for deteriorating quality of raw water, use of plant waste waters in various low grade applications and recycling of plant waste waters to maximum extent. The requirement and scheme for utilization of plant waste water is also governed by stipulation of MOE&F and CPCB/SPCB in this regard. In some recent projects, MOE&F has stipulated the requirement of zero effluent discharge from plant boundary which as a large bearing on plant water scheme and treatment of waste water to be adopted. A brief description of above plant systems which have potential for further reduction in water consumption and aspect of waste water minimization is given below: major water uses areas are following:

1. Cooling water system

Cooling water is required for condensing of steam in a surface condenser and for secondary cooling in heat exchangers of equipment cooling system for plant auxiliaries. For a typical 500 MW coal fired unit, the amount of cooling water required for condenser and auxiliary cooling is of the order of 60,000 m^3/h with temperature rise across the condenser about 9.5°C. Cooling water system may be of once through type or closed cycle type using cooling tower, the details as tabulated in Table 4:

2. Ash handling system

Combustion of coal in a thermal power plant results in generation of ash which needs to be disposed off. The amount of ash generated depends upon the quality of coal particularly its calorific value and its ash content. For a 500 MW unit burning typical Indian coal (of 40% ash), the amount of ash generated is about 140 tonne/h with distribution of fly ash and bottom ash as 80:20. Fly ash and bottom ash generated in the plant has traditionally been disposed to ash pond in the form of wet slurry.

Over a period of time, environmental concerns associated

Table 4: Cooling system requirement and Impact

Cooling system tradeoff's					
Cooling type	Water withdrawal	Water consumption	Capital cost	Plant efficiency requirement	Ecological impact
Once through	Intense	Moderate	Low	Most efficient	Moderate
Wet cooling tower	Moderate	Intense	Moderate	Efficient	Moderate
Dry cooling	None	None	High	Less efficient	Low

with ash generation in thermal plants have resulted in various measures to be adopted viz. reducing water requirement for wet ash disposal, dry disposal of fly ash and utilization of ash in various applications. The measures for reducing consumptive water requirement include reducing water to ash ratio for slurry disposal, recirculation of ash pond water and use of high concentration slurry disposal (HCSD) system for fly ash.

In recent plants, wet disposal of ash has been adopted with slurry concentration of 30% for fly ash and 25% for bottom ash. In the plants using ash water recirculation, typically 70% of ash pond water can be recovered and reused in ash handling plant. Thus, net water to be supplied for ash disposal gets reduced to about 30% of requirement of ash handling plant.

3. Power cycle make-up

Power cycle make up refers to DM water added in condenser hot well to compensate for loss of water due to boiler blow down and other losses from the system. The quantum of blow down water depends on boiler steam parameters and quality of make up DM water. In the past, the DM water make up requirement of power cycle has been amply considered even up to the order of 8% of BMCR flow. Over a period of time, this requirement has been reducing, and now a day, design power cycle make up is generally taken as 3% of BMCR flow. As per this, power cycle make up requirement for a typical 500 MW unit shall be about 50 m^3/h. In actual, plants are being managed with further reduced make up also as large size units are provided with condensate polishing units (CPU) and materials of better metallurgy are used in feed heating and boiler components. In the present study, power cycle make has been considered as 2% of BMCR flow.

4. CPU regeneration

For maintaining the feed water purity condensate polishing plant will be provided in the feed water cycle at the downstream of condensate extraction pumps. The function of the CPU will be to purify the condensate from the condenser by removing solids and dissolved salts with the intent of reducing corrosion and depositions in the steam-water cycle. The resins to be used would be strong acid cation and strong base anion type appropriate for the influent condensate quality. The resins will be separated and regenerated externally by transferring to a dedicated regeneration station. A common external regeneration facility will be provided. The CPU will be provided with associated chemical feed system for preparing, measuring and dosing the required chemicals.

5. Air conditioning and ventilation system

The main purposes of a heating, ventilation and air-conditioning (HVAC) system are to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort. HVAC systems are among the largest energy consumers in thermal power plants. The choice and design of the HVAC system can also affect many other high performance goals, including water consumption (water cooled air conditioning equipment).

6. Coal dust suppression system

Water is sprayed over heaps of crushed coal, belt conveyors, and transfer points and during coal unloading in order to reduce nuisance due to fugitive dust emission. Amount of water required for coal dust suppression depends upon size of coal stockyard, coal consumption rate, volatility of coal and ambient conditions. Normally, low-grade water such as CT blow down or plant waste water is used for coal dust suppression. In order to reduce plant water consumption, water available from drains of coal yard can be recovered and reused for coal dust suppression water system.

7. Service water system

Thermal power plant needs various water qualities for differing applications, e.g. boiler feed water and treated condensate for boiler plants and service water either as a supplement in cooling towers, or for general purposes. Service water is necessary for preparatory processing phases. Typical applications include, e.g. the supply of thermal power stations and petrochemical plants with cooling water, water for fire-fighting systems and the cleaning of machinery. During treatment, flocculation, sedimentation, filtration, membrane filtration, full and partial desalination by softening, reverse osmosis, ion exchange and thermal desalination processes can be combined or used alternately. Service water of an appropriate quality is taken from the corresponding point in the water treatment plant.

8. Evaporation from raw water reservoir

The storage requirement of raw water reservoir for plant depends upon availability of raw water from the source. The rate of evaporation from the surface of the reservoir depends upon surface area of the reservoir and prevailing ambient conditions. In the present study, the power plant is considered to have been envisaged with a raw water reservoir of capacity for 10 days plant requirement with effective water depth taken as 8m. The evaporation from surface of the reservoir has been estimated considering loss of 20 cm water depth in a month which is equivalent to average evaporation of about 1.2 m^3/h per acre of reservoir surface. As per above, for a typical 2×500MW plant, the evaporation from surface of raw water reservoir amounts to about 30 m^3/h. In case surface area of the reservoir envisaged is more than that worked out as per above criterion, the quantum of reservoir evaporation shall increase accordingly.

9. Water for desulfurization

To protect the environment, most present coal-fired power plants need to equip the desulfurization equipment, and many plants adopt the wet smog-air desulfurization technology, i.e. gushing the mixes of water and limestone powders into the smog and gas to remove the sulfur dioxides in the smog air. The desulfurization effect of this method is very good, and 99% sulfur could be removed, and part of water can be recycled. In addition, to save the water consumption of the thermal power plant, the dry desulfurization could be adopted to save water. For example, to grind the limestone and coal and gush the mixes into the furnace, and add the limestone ash at the region of about 800 centigrade degrees in the furnace, could remove 75% sulfur.

2.0 Available scope of water management

1. Water audit

A water audit is an accounting procedure. The purpose of a water audit is to accurately determine the amount of unaccounted-for water (UAW) in a water distribution system.

UAW is calculated from verified supply and consumption records, factoring in various estimated usage figures. Due to potential short-term inaccuracies, a water audit generally considers data from the most recent 12-month period. Any period less than 12 months will not reflect seasonal climatic and population variations. The forms found in this manual are also acceptable for the purpose of documenting a water audit. Water audits, thus, help in the development of an integrated industrial water management strategy, which optimizes efficient use of water, improves water productivity, reduces losses, and helps in identifying alternative methods of water conservation. It reduces specific water consumption and helps in setting benchmarks.

2. Minimizing effluent discharge

Waste water generated in a thermal power plant typically includes clarifier sludge, filter back wash, CT blow down, regeneration waste of DM plant and CPU, and boiler blow down etc. Normally, clarifier sludge is disposed off along with ash slurry and boiler blow down is led to central monitoring basin (CMB) of the plant. Water required for wet ash disposal is tapped from CT blow down, and unutilized blow down water, if any, is led to the CMB. In the present study, clarifier sludge is considered to be treated for removal of solid waste, and recovered water is recycled to inlet of the clarifier. Filter backwash water from filters of DM plant and potable water system is also considered to be recycled to inlet of the clarifier. The boiler blow down is considered to be used in CW system to supplement the make up water as it is expected to have negligible impact on CW inlet temperature. The plant drains and side stream filter backwash are treated in effluent treatment plant (ETP), and recovered water is collected in the CMB. Requirement of water for low grade applications such as coal dust suppression and gardening is met from CMB. The balance waste water of CMB is handled in line with stipulations of MOE&F/CPCB/SPCB, as applicable. The waste water in CMB has high TDS on account of regeneration waste and CT blow down water. If water is to be recovered from this waste water for recycling in the plant, its treatment would require application of reverse osmosis technology. The requirement of plant input water shall reduce by the quantum of water recovered from RO plant. The concentrated brine reject of R.O plant can be used for coal dust suppression or it can be used for wet disposal of bottom ash.

3. Water minimisation by use of dry cooling systems

In a conventional wet cooling tower, hot water is cooled by direct mixing with ambient air resulting in evaporation of a part of circulating water, and make up water is required to compensate for loss of water due to evaporation, drift and blow down water. Dry cooling systems do not require any make up water as rejection of power cycle waste heat from condenser to atmosphere takes place by sensible cooling in finned tubes by ambient air and no evaporative cooling is involved.

Dry cooling systems can be broadly classified in two categories viz. direct dry cooling systems and indirect dry cooling systems. In direct dry cooling system, exhaust steam from LP turbine is directly cooled in a system of finned tubes by ambient air using mechanical draft fans or natural draft hyperbolic tower. In an indirect dry cooling system, exhaust steam from the turbine is cooled by watering a surface or jet condenser and hot water is cooled by air in finned tube bundles using mechanical draft fans or natural draft hyperbolic tower. In case dry cooling system is adopted for the condenser, wet cooling tower is required only for ACW flow and requirement of plant make up water inconsiderably reduced. Since CT make up water constitutes major part of plant consumptive water, use of dry cooling system results in reduction of plant consumptive water by about 80%. The requirement of plant consumptive water can be further reduced by adopting dry cooling mode for ACW flow also using air cooled heat exchangers.

4. Optimised plant water requirement

As can be seen from above, various options exist for reduction of plant water consumption which need to be applied on case to case basis. In the present study, the following three cases have been considered for optimization/ minimization of water consumption in 2x500 MW coal based thermal power plants (fresh water in case of coastal plants):

i. In-land power plants with wet cooling tower using indigenous coal;

ii. In-land power plants with dry condenser cooling system using indigenous coal;

iii. Coastal plants based on sea water cooling.

5. Optimizing ash water ratio

In wet ash handling power plants, about 50-60 per cent of water is consumed just for ash handling. Either raw water can be used directly for ash handling or the condenser outlet water is tapped for ash water purpose. High pressure ash water is used for flushing both bottom ash/fly ash and trench jetting etc. and low pressure ash water is used for bottom ash hopper filling etc. The bottom ash slurry and fly ash slurry can be either handled separately or together by mixing both of them in a common pit. The ash slurry is evacuated by a series of ash slurry disposal pumps to an ash dyke to a distance of about 15 km. Typical design ash water ratios are around 1:5 for fly ash and 1:8 for bottom ash. However, the actual combined ash water ratios are found to be around1:20 or even more.

A typical 210 MW thermal power plant generates about 60 tonnes of ash/hr (@40% ash content in the coal and 0.7 tonne/MW specific coal consumption). For every per cent reduction of ash water ratio, there is a saving potential of 60 m^3/hr of water. In addition to water savings, the associated auxiliary power consumption reduction would be 0.2 million U/annum for every ash water ratio reduction in the HP/LP ash water pumps and ash slurry series pumps. Normally, the ash water system is designed for catering to the needs of entire stage consisting of 2 to 3 units. So, when any unit in that stage is under shutdown, they will be registering very high ash water ratios.

After initiating water conservation measures, many thermal power plants have brought down their ash water ratios to a reasonable level to 1:10 to 1:12.

6. Recycling ash water from ash dyke

As already mentioned, about 60 per cent of water is consumed for ash handling purpose alone. Normally, the ash slurry is sent to ash dykes, which are normally located about 14-15 km away from the main power plant. After the ash gets settled in the ash dyke, the clear water can be recycled. This water can be re-used for ash handling purpose after minor treatment (if necessary). Since many power plants have to shut down or reduce their load, particularly during summer due to the need of sufficient water, the recycling of ash water from the ash dyke would be justified, even if it calls for huge investment. Many power plants have already initiated action towards setting up ash water recycling systems.

7. Increasing cycles of concentration (COC)

The maximum water loss in the thermal power plants will be in the cooling towers, in the form of evaporation. We need around 180 m^3/hr cooling water flow to the condenser to generate 1 MW. Empirical relation often used to calculate evaporation ratio (m^3/hr) = (circulation rate in m^3/hr × temperature difference in ºC)/675. Based on this formula, the expected evaporation ratio for every 1 MW of power generation is 2.6 m^3/hr. To compensate this evaporation loss, the blow down losses and drift, make up water is provided. Since water is circulated many times in the closed loop, the concentration of dissolved solids increases over a period. The cycles of concentration (COC) is the ratio of dissolved solids in the circulating water to the make up water.

8. Reducing drinking water consumption

For colony water requirements, water is supplied from the drinking water line of the main plant. Based on number of water balance studies carried out by the authors in different thermal power stations, around 500-600 m^3/hr water is supplied continuously to the colonies. The per capita water consumption works out to 600-800 liters/day/person, which is very high, when compared to WHO norms of 115 liters/day/person. This indicates tremendous scope for water conservation in the colonies. In fact, water is a luxury in majority of the colonies. This is mainly due to continuous supply and wastages due to lack of awareness. By restricting the water supply timings limited to main water consumption periods, such as mornings, noon and evenings etc. and rectifying the float valves of all the overhead tanks, the water consumption can be greatly reduced by more than 30-40 per cent. By installing sewage water treatment plant in the colony and recycling the treated water and using it for gardening purpose, another 10-20 per cent precious drinking water can be saved.

9. Reducing leaks and over flows

Invariably, we find a lot of water leaks from valves, flanges, taps, firefighting hoses, underground firefighting lines, cooling tower basin, gardening hoses etc.

Overflows from cooling towers of AC plants, air washers, and overhead tanks due to nonfunctioning of float systems are also a common feature in thermal power plants. Huge water leaks from the condenser pipe ducts were also noticed in some of the plants. By bringing underground firefighting lines to over ground, attending various water leaks, providing ball and cock float systems for overhead tanks and smaller cooling towers, 3-5 per cent water consumption can easily be reduced.

10. Installation of effluent treatment plant (ETP)/STP

A typical thermal power plant will have 3-4 main drains. All this drain water gets collected and finally goes out of the plant boundary. The measured drain quantities alone are found to be in the range of 800-1000 m^3/hr. This is a large quantity. By installing effluent water treatment plants and recycling this water for the ash handling purpose, 80-90 per cent of this water can be saved. The drains from the coal handling plant will be blackish due to coal dust. They need to be treated separately by installing additional settling ponds. By installing sewage treatment plant (STP) in the colony also, the treated water can be recycled and can be used for horticulture purposes.

11. Waste water treatment plant

The liquid waste shall be collected and treated/recycled generally as per the following way:

A. The waste water from neutralization pits of condensate-polishing plant, DM plant shall be collected in the respective neutralization pits and neutralized before pumping to the central monitoring basin before final disposal.

B. Cooling tower blow down water quantity shall be sent to plant outfall.

C. The oily waste from main plant area shall be treated using oil water separator and the treated water shall be led to the tube settler provided for service water waste for further treatment.

Similarly separate system shall be provided for oily water in fuel oil unloading and storage area. From central monitoring basin water will be pumped to outfall channel for discharge.

12. Rain water

Rain water rainfall runoff from the coal pile will contain mainly suspended solids. This runoff will be routed to the settling basin for retention and settling of suspended solids, and the clear water from there may be used for dust suppression system. The rain water is collected in the storm water drain running all around the project. Rain water harvesting pit is connected to the storm water drain. Excess rain water will flow to common collection pit from where water can be pumped for use in the ash handling system.

13. Automation

Automation should be introduced in water quality and flow monitoring with a centralized control system and management information system.

3.0 Conclusions

Like any other resource, water availability is also likely to become scarce in the years to come. Much progressive management has already initiated measures for water conservation in their thermal power plants. It can be seen from the above study that water cost is going up every year including the cess paid to the pollution control boards. Many thermal power plants are reducing their plant load mainly due to water shortage particularly during summer. Now with the new government directive all the thermal power plants must reduce their specific water consumption to below 3.5 m^3/MWh, by December 2017 also other regulation are from 01st of Jan 2017 all new thermal power plants shall have to meet specific water consumption of 2.5 m^3/MWh. Those thermal power plants whose specific water consumption is higher than the norm should put a lot of efforts in reducing/recycling and take up concrete action plans to conserve water. Based on the various water audits in different thermal power stations, savings worth Rs.3.3 crore/annum, equivalent to 40 per cent water use reduction have been identified as possible. Since there is a close nexus between water and energy, energy savings to the tune of 3.57 Mu/annum is also identified by adopting various water conservation measures. Monitoring specific water consumption is the key for success in achieving water conservation.

There is few elaborated points which can control the evaporation and drift loss in cooling towers:

1. Replacing the cement filling as the high-performance plastic filling, and replacing the porcelain-mouth-porcelain-dish spraying equipment as the plastic reflecting spraying equipment.
2. Strengthening the maintenance, and clearing the cooling tower periodically and repairing the damaged equipment, and replacing the damaged filling and spraying equipment, to ensure the efficient water drenching area and degree.
3. Installing the water collector to reduce the wind-blow loss.
4. Setting up the water-level gauge in the pool of the cooling tower to link the water-level signal with the weak acid treatment system, and correspondingly increasing or reducing the water level of the weak acid treatment system according to the water-level of the pool.
5. Setting up the water-level control threshold in the water-make up pipe of the cooling tower to avoid the flooding of the circulating water.

Establishing the wastewater recycle system for power plant:

Comprehensive treatment and recycle of waste water: the thermal power plant is the big water user, and produce quite large industrial waste water, so the recycle of the industrial waste water from the thermal power plant could reduce the pollution of waste water to the environment. The waste water recycle mode includes the decentralized treatment and the centralized treatment, and the thermal power plant with the single unit of the capacity of 500 MW should adopt the centralized treatment mode of waste water.

Because the centralized treatment mode has perfect establishments and good water quality, it has been gradually accepted by many power plants such as the Vindyachal power plant, Singraulli MP. Because the water quality of waste water from the power plant is very complex, and various equipment and systems use different standards of water quality, so for different waste waters, different treatment methods should be adopted.

For energy saving there is lot of space for substitute the use of thermal energy by solar power plant for colony power demand, use of LED light in place of vapour light, automation system for street light, public awareness for power conservation etc.

BHELs initiative for substitute of Thermal based power plant BHEL set a new record in its solar photovoltaic (PV) business in a single year by supplying SPV modules with generating capacity of 100 MW at Bangalore plant. BHEL offers EPC solutions from concept to commissioning for grid connected and standalone PV applications ranging from kW to MW size plants which include supply of PV modules and balance of system (BOS), civil, E&C and O&M. BHEL has commissioned 50 MW SPV plant at Anantpur, Andhra Pradesh. BHEL has bagged prestigious award for 50 MW SPV plant at Madsaur, Madhya Pradesh, 3×10 MW in West Bengal, 65MW SPV plant at Neyveli, Tamilnadu, 15MW at Ordinance Factory, Medak, Telangana and presently has set up solar plants in India totaling about 400MW including Lakshadweep Islands for island electrification etc.

Now we are elaborating the country total power production status in consecutive two years status are shown in Table 5 and 6.

From the above two tables it very much augurs that our country is shifting from thermal base power plant to RES power plant, as total energy production from RES sources increases from 42849 MW to 57244MW, i.e. 30% increase in a year, compared to 4% increase in thermal based power plant. So it is a very good sign for conservation of energy also water.

At last we want to elaborate the conservation of water in general as access to safe water is one of the essential

Table 5: The total installed capacity in India as on 31.03.2016

Region	Ownership/ Sector	Modewise breakup							Grand Total
		Thermal				Nuclear	Hydro	RES * (MNRE)	
		Coal	Gas	Diesel	Total				
Northern Region	State	17038.00	2879.20	0.00	19917.20	0.00	7502.55	661.56	28081.31
	Private	16606.00	108.00	0.00	16714.00	0.00	2478.00	7968.57	27160.57
	Central	12000.50	2344.06	0.00	14344.56	1620.00	8266.22	0.00	24230.78
	Sub Total	**45644.50**	**5331.26**	**0.00**	**50975.76**	**1620.00**	**18246.77**	**8630.13**	**79472.66**
Western Region	State	22800.00	2993.82	0.00	25793.82	0.00	5480.50	311.19	31585.51
	Private	36455.00	4288.00	0.00	40743.00	0.00	447.00	15003.73	56193.73
	Central	12898.01	3533.59	0.00	16431.60	1840.00	1520.00	0.00	19791.60
	Sub Total	**72153.01**	**10815.41**	**0.00**	**82968.42**	**1840.00**	**7447.50**	**15314.92**	**107570.84**
Southern Region	State	16882.50	556.58	362.52	17801.60	0.00	11558.03	506.45	29866.08
	Private	7670.00	5557.50	554.96	13782.46	0.00	0.00	17647.67	31430.13
	Central	11890.00	359.58	0.00	12249.58	2320.00	0.00	0.00	14569.58
	Sub Total	**36442.50**	**6473.66**	**917.48**	**43833.64**	**2320.00**	**11558.03**	**18154.12**	**75865.79**
Eastern Region	State	7540.00	100.00	0.00	7640.00	0.00	3168.92	225.11	11034.03
	Private	8731.38	0.00	0.00	8731.38	0.00	195.00	250.28	9176.66
	Central	14351.49	90.00	0.00	14441.49	0.00	925.20	0.00	15366.69
	Sub Total	**30622.87**	**190.00**	**0.00**	**30812.87**	**0.00**	**4289.12**	**475.39**	**35577.38**
North Eastern Region	State	60.00	445.70	36.00	541.70	0.00	382.00	254.25	1177.95
	Private	0.00	24.50	0.00	24.50	0.00	0.00	9.47	33.97
	Central	250.00	1228.10	0.00	1478.10	0.00	860.00	0.00	2338.10
	Sub Total	**310.00**	**1698.30**	**36.00**	**2044.30**	**0.00**	**1242.00**	**263.72**	**3550.02**
Islands	State	0.00	0.00	40.05	40.05	0.00	0.00	5.25	45.30
	Private	0.00	0.00	0.00	0.00	0.00	0.00	5.85	5.85
	Central	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sub Total	**0.00**	**0.00**	**40.05**	**40.05**	**0.00**	**0.00**	**11.10**	**51.15**
ALL INDIA	State	64320.50	6975.30	438.57	71734.37	0.00	28092.00	1963.81	101790.18
	Private	69462.38	9978.00	554.96	79995.34	0.00	3120.00	40885.57	124000.91
	Central	51390.00	7555.33	0.00	58945.33	5780.00	11571.42	0.00	76296.75
	Total	**185172.88**	**24508.63**	**993.53**	**210675.04**	**5780.00**	**42783.42**	**42849.38**	**302087.84**

Figures at decimal may not tally due to rounding off

Abbreviation: SHP=Small Hydro Project (≤ 25 MW), BP=Biomass Power, U&I=Urban & Industrial Waste Power, RES=Renewable Energy Sources

Table 6: The total installed capacity in India as on 31.03.2017

Region	Ownership/ Sector	Modewise breakup							Grand Total
		Thermal				Nuclear	Hydro	RES * (MNRE)	
		Coal	Gas	Diesel	Total				
Northern Region	State	16598.00	2879.20	0.00	19477.20	0.00	8543.55	663.56	28684.31
	Private	22100.83	558.00	0.00	22658.83	0.00	2502.00	10859.80	36020.63
	Central	12630.37	2344.06	0.00	14974.43	1620.00	8266.22	0.00	24860.65
	Sub Total	**51329.20**	**5781.26**	**0.00**	**57110.46**	**1620.00**	**19311.77**	**11523.36**	**89565.59**
Western Region	State	23170.00	2993.82	0.00	26163.82	0.00	5480.50	311.19	31955.51
	Private	31465.67	4676.00	0.00	36141.67	0.00	447.00	17993.24	54581.91
	Central	13657.95	3533.59	0.00	17191.54	1840.00	1520.00	0.00	20551.54
	Sub Total	**68293.62**	**11203.41**	**0.00**	**79497.03**	**1840.00**	**7447.50**	**18304.43**	**107088.96**
Southern Region	State	17832.50	791.98	287.88	18912.36	0.00	11739.03	512.55	31163.94
	Private	12124.50	5322.10	473.70	17920.30	0.00	0.00	25619.52	43539.82
	Central	13425.02	359.58	0.00	13784.60	3320.00	0.00	0.00	17104.60
	Sub Total	**43382.02**	**6473.66**	**761.58**	**50617.26**	**3320.00**	**11739.03**	**26132.07**	**91808.36**
Eastern Region	State	7025.00	100.00	0.00	7125.00	0.00	3537.92	225.11	10888.03
	Private	7451.38	0.00	0.00	7451.38	0.00	195.00	765.63	8412.00
	Central	14101.64	0.00	0.00	14101.64	0.00	1005.20	0.00	15106.84
	Sub Total	**28578.02**	**100.00**	**0.00**	**28678.02**	**0.00**	**4738.12**	**990.74**	**34406.87**
North Eastern Region	State	60.00	492.95	36.00	588.95	0.00	382.00	259.25	1230.20
	Private	0.00	24.50	0.00	24.50	0.00	0.00	21.88	46.38
	Central	520.02	1253.60	0.00	1773.62	0.00	860.00	0.00	2633.62
	Sub Total	**580.02**	**1771.05**	**36.00**	**2387.07**	**0.00**	**1242.00**	**281.12**	**3910.19**
Islands	State	0.00	0.00	40.05	40.05	0.00	0.00	5.25	45.30
	Private	0.00	0.00	0.00	0.00	0.00	0.00	7.27	7.27
	Central	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sub Total	**0.00**	**0.00**	**40.05**	**40.05**	**0.00**	**0.00**	**12.52**	**52.57**
ALL INDIA	State	64685.50	7257.95	363.93	72307.38	0.00	29683.00	1976.90	103967.28
	Private	73142.38	10580.60	473.70	84196.68	0.00	3144.00	55267.33	142608.01
	Central	54335.00	7490.83	0.00	61825.83	6780.00	11651.42	0.00	80257.25
	Total	**192162.88**	**25329.38**	**837.63**	**218329.88**	**6780.00**	**44478.42**	**57244.23**	**326832.53**

Figures at decimal may not tally due to rounding off

Abbreviation:- SHP=Small Hydro Project (≤ 25 MW), BP=Biomass Power, U&I=Urban & Industrial Waste Power, RES=Renewable Energy Sources

Note : - 1. RES include SHP, BP, U&I, Solar and Wind Energy. Installed capacity in respect of RES (MNRE) as on 31.03.2017 (As per latest information available with MNRE)

***Break up of RES all India as on 31.03.2017 is given below (in MW) :**

Small Hydro Power	Wind Power	Bio-Power		Solar Power	Total Capacity
		BM Power/Cogen.	Waste to Energy		
4379.86	**32279.77**	**8181.70**	**114.08**	**12288.83**	**57244.23**

2. Earlier circulated installed capacity was 305162.50 MW wchich includes RES installed capacity 57260.23 MW as on 31.03.2017. Now, MNRE vide their letter no. 146/16/2017-P&C dated 23.08.2017 has intimated the revised RES capacity as on 31.03.2017 as 57244.23 MW. Therefore, All India installed capacity as on 31.03.2017 has been revised to 326832.53 MW. The change in the total installed capacity is due to the reduction in Biopower of Delhi by 16 MW.

elements for sustainable development and poverty reduction. However, the past few decades has seen an increase in demand amongst various water using sectors putting enormous stress on the natural resource. FICCI constituted a 'Water Mission' to promote and provide thought leadership in the area of water efficiency.

It aims to facilitate the sharing and dissemination of best practices across industry sectors in order to encourage corporate and industry players to imbibe a culture of water conservation within their organizations. The Mission is working to create awareness on the existing situation pertaining to water scarcity, quality and generate a discourse on sustainable use of water amongst various users. With growing and extensive depletion and pollution of our water resources, our current work is being restructured to bring this issue back in focus to provide a sense of urgency to the debate of water management.

The objectives of the divisions work are:

1. To formulate suggestions for changes in policy framework in India for better water resource allocation, conservation and management;
2. To promote fresh water conservation strategies across the irrigation, industry and domestic sectors;
3. To document and disseminate best practices across various sectors and create a forum to facilitate exchange of information and experiences in the country;
4. To promote new innovative technologies of water saving and management like rainwater harvesting, watershed management, desalination, water auditing and accounting across water intensive sectors through projects, workshops, conferences and training programmers.

The competition between water and energy is asymmetrical. Water scarcity threatens energy production, and energy is also needed for water production, yet water availability is not threatened by energy scarcity. Water consumption for energy generation contributes to water scarcity; as more energy is generated significantly less water may be available. On the other side of the equation, the energy use for the treatment, transport and pumping of water can be significant, but it is not seen as a major determinant of energy scarcity. This study focuses on addressing this imbalance; in particular, the trade offs between these resources, by proposing solutions that emphasize their common dependence given that they are inextricably linked. This interdependence is already critical in many regions, and the resulting stresses are compounded as demand grows from emerging economies and "graduating" countries. The impact of climate change on water and energy resources is also a factor. Projected consequences of these factors are alarming enough to require the urgent development of more accurate integrated planning tools.

An integrated energy and water planning approach can ensure that both resources are developed sustainably as well as explore synergies more effectively. It is important to create innovative approaches that encourage cross-sectoral cooperation and assess water and energy trade offs at the regional and national levels, thereby ensuring that future demands will be met. There is an array of opportunities and technical solutions to reduce water use in power plants and to exploit the benefits of possible synergies in water and energy.

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