Water for Power –

Alstom Thermal Power & Renewable Power strategies & solutions for the water challenge of the global power generation sector

March 2014

CLEAN POWER
CLEAR SOLUTIONS™

ALSTOM
Shaping the future

Water for Power – Alstom Thermal Power & Renewable Power strategies & solutions for the water challenge of the global power generation sector

The freshwater challenge of the global power generation sector

Globally, agriculture is the principal user of freshwater[1], accounting for 70% of water use, followed by industrial sectors (including mining and power generation) at 19% and municipal networks[2]. Water is required throughout the value chain of most power generation technologies[3]. Water use in upstream processes can be high for some of these technologies: in particular the extraction of fossil fuels – especially the exploration and processing of unconventional ones and also for biofuels production.

Approximately 90% of today's global power generation is water intensive. Water is used directly for hydropower generation as well as for all forms of thermal power generation .The operational "water footprint" of power generation units involves withdrawal, consumption and impact on quality of surrounding water resources. In 2010, the share of withdrawals for power generation is estimated at 90% of the total for energy production and the share of consumption at 65%[4]. In thermal power generation (Renewable and Non-Renewable), the impact on water is most important during the operation phase in comparison with any other life cycle phase, particularly for cooling purposes, accounting for more than 90% of total water withdrawal for global power generation, followed by emissions scrubbing processes at less than 10%.

Every year, thermal power plants account for 40% of the yearly freshwater withdrawn in the USA and for 43% in Europe, almost just as much as the agriculture sector[5]. Population and economic growth are expected to increase competition for finite water resources across sectors. According to the IEA[6], global

[1] The term water is, unless otherwise noted, refers to accessible renewable freshwater

[2] Source: United Nations Food and Agriculture Organisation (UN FAO) 2012 & International Energy Agency (IEA) World Energy Outlook (WEO) 2012

[3] According to the IEA WEO 2012, global freshwater withdrawals for energy production in 2010 are estimated at 583 billion cubic meters, corresponding to around 15% of the world's total water withdrawals. Water consumption by the energy production sector is about 11% of energy-related water withdrawals (or 66 billion cubic meters).

[4] Source: IEA WEO 2012

[5] Source: Vulnerability of US and European Electricity Supply to Climate Change (van Vliet & al. Nature Climate Change 2, 2012).

[6] Source: IEA WEO 2012 ("New Policies Scenario")

water withdrawal in the energy sector would increase by about 20% between 2010 and 2035, but consumption by more than 85%.

At the same time, high water-dependent power generation (thermal and hydro power generation) may be especially vulnerable to conditions of water availability and quality. Recent high temperatures and droughts have emphasised the importance of water as a risk to a secure power supply. Particularly for power generation, the availability of required water quantity and quality will be also challenged by many climate change impacts such as rising air and water temperature, extreme weather, rising sea levels and more recurring and longer droughts. These concerns pose a challenge to established power plant operations and to longer-term strategies for power market stability in several ways:

1. Increased temperatures can diminish the effectiveness of water-based cooling in thermal power plants: the efficiency of thermal power production in a steam-cycle turbine depends on pressure and temperature differentials. These are higher when cooling air or water is abundant and available at consistently low temperatures. Therefore, water stress poses a risk to plant efficiency and fuel consumption. Rising water temperatures increase costs for generators because they weaken plant thermal efficiency and lead to higher fuel consumption. A one degree Celsius temperature increase can reduce the thermal efficiency of thermal plants by up to 1%.

2. Significant thermal and hydro power installed capacity is at risk: higher water temperatures can also lead to reductions in output and to plant shutdowns owing to thermal pollution regulations. As estimated by the IEA, a 1°C temperature increase by 2040s could reduce global available summer power capacity by 19%. The reliance in many regions on thermal power plants based on Once-Through Cooling technologies[7] (OTC), being particularly vulnerable to water stress, raises the prospect of temperature-induced electricity supply interruptions and wholesale power price spikes. These risks may also undermine the case for extending the operational lives of certain power plants to back up renewable intermittency and can only be mitigated at considerable cost. In Brazil, a historical dependency to Hydro representing around 80% of electricity generation in 2011[8] makes the country vulnerable to droughts as experienced in 2012, resulting in huge price swings on the spot market and supply curtailments.

[7] Once-Through Cooling (OTC) systems extract water from rivers, lakes, seas, or oceans and circulate it through a system of pipes to absorb the heat from the steam. The resulting warmer water is then returned to its source. OTC requires much greater water withdrawal than Wet Recirculating (WR) cooling or Air based cooling. However, OTC actually consumes much less water than WR cooling systems.

[8] Source: IEA WEO 2013

The Alstom Power Sectors' approach to address the water challenge: A three pillars strategy

Alstom recognises the growing importance of the "water footprint" as a criterion for assessing the physical, economic and environmental viability of energy projects. The Alstom "Clean Power Clear Solutions" approach is particularly valuable to develop and adapt water solutions to the specific regional and site needs and regulatory constraints of its customers. Alstom's efforts to optimise the impact of its offerings on water resources while maximising asset values are organised around the following three main pillars (cf. Figure 1 for an overview):

1. Reducing water dependency and adapting to changes in water availability
2. Enhancing water use efficiency
3. Lowering impact on water quality

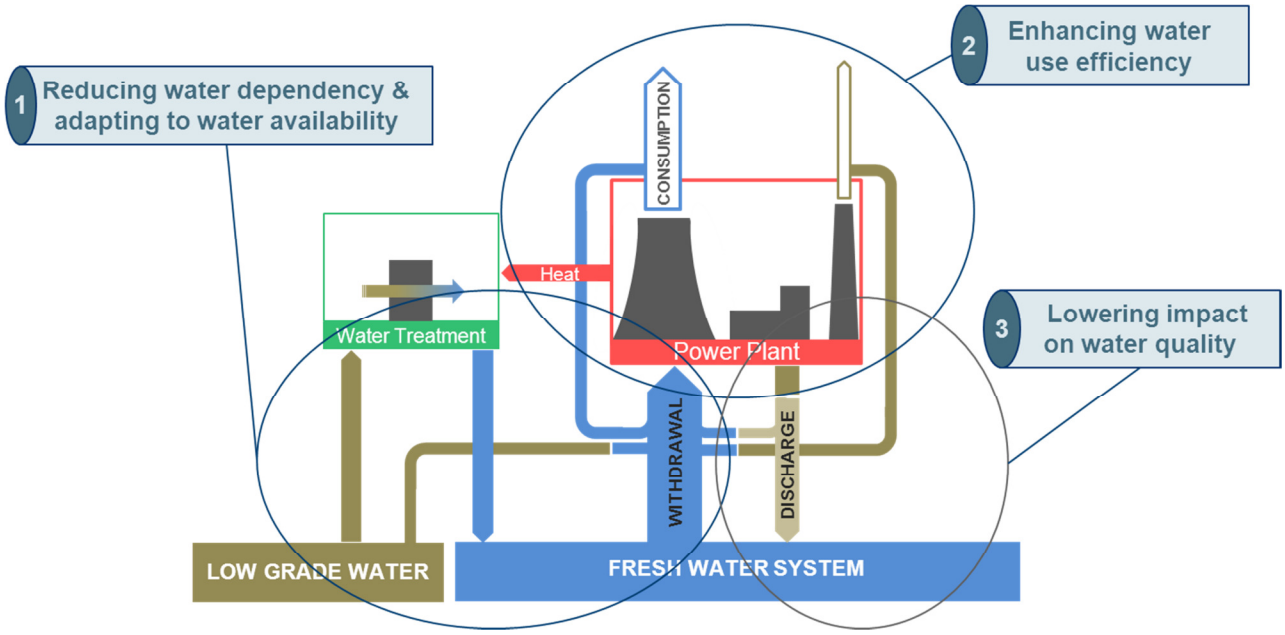

Figure 1: Overview of the three main pillars of the Alstom Power Sectors' approach to address the freshwater challenge of the global power generation industry

In the following, these three main pillars are briefly introduced including a selection of corresponding existing solutions as implemented in some of the recently completed or engineered power plant projects.

Pillar 1: Reducing water dependency and adapting to changes in water availability

Alstom offers a diversified portfolio of power generation technologies reducing the need for and the impact of water withdrawal from external sources. Power Sectors' portfolio enables also dealing with changes in water availability.

- ***Solutions for water-independent cooling and operations***: wind and open cycle gas turbine solutions require almost no water for operating[9]. Furthermore, Alstom has developed some of the largest and most efficient air-cooled applications for large coal and gas-fired plants (recently completed projects include: the 847 MW *LANGAGE* CCPP in UK; 4'800 MW each *MEDUPI* & *KUSILE* STPP in South Africa)

- ***Dealing with changes in water availability***: the only solution to deal with long-term climate change impact uncertainty and to compensate for seasonal changes in water availability (e.g. due to seasonal droughts…) is to develop a balanced portfolio of power generation assets and water storage. Climate change adaptation is primarily about water, as stated for example by the Intergovernmental Panel on Climate Change (IPCC), which identifies water as the fundamental link through which climate change will impact humans and the environment[10]. Hydropower can help with water management and irrigation but can also be vulnerable to changes in water flow. Alstom's Hydropower Global Technology Centres focus product development in areas of specific regional expertise or harsh environments. The resulting innovations can be applied to existing hydro power plants via retrofits or are incorporated in new projects. For example, retrofits can change operating ranges/regimes as a solution to cope with more or less water. Low head turbines can be designed to support wide seasonal variations in flow and abrasion resistant coatings for "Pelton" turbines have been developed to enable them to better withstand water with high silt content such as that found in the Himalayas. For nuclear power plants, the Alstom ARABELLE™ steam turbine platform can match any site cooling conditions thanks to different possible configurations of its Low-Pressure modules (up to four LP modules) and three different types of last stage blades.

[9] In case of open cycle gas turbines water is not required for cooling purposes as there is no need for cycle cooling. Gas turbine performance is highly sensitive to ambient air temperature. Rising ambient air temperatures result in a decrease of turbine performance. In regions with severe ambient conditions, water may be used for cooling inlet air (the air at the compressor entry), in order to maintain turbine performance.

[10] Sources: IPCC (Intergovernmental Panel on Climate Change): Climate Change and Water. IPCC (2008) & United Nations (UN) World Water Development Report 2014 – Water & Energy (Volume 1).

- ***Operating with lower water quality***. Alstom solutions also enable the utilisation of seawater for cooling (e.g. 1'000 MW *SOHAR* CCPP in Oman) or for flue gas desulphurisation (Seawater FGD: 38 GW installed or currently under construction – e.g. 1'200 MW *SHOAIBA Stage III* STPP in Saudi Arabia) as well as treated wastewater for cooling and process requirements (e.g. 420 MW *MALAGA* CCPP in Spain). The withdrawal of fresh water can also decrease by reusing lower quality water (e.g. cooling tower blowdown) for flue gas desulphurisation (FGD) with the Alstom Wet FGD (e.g. 2x350 MW *MARITZA* STPP in Bulgaria) or semi-dry NID™ technology (NID: Novel Integrated Desulphurisation).

- ***Reducing the impact on aquatic ecosystems:*** water intake for thermal power cooling and water flowing through hydroelectric plants can have an impact on wildlife and other natural resources. Alstom has solutions to reduce these impacts. For example, Alstom fish-friendly runner solutions are designed to increase the survival rate of migrating fish passing through the turbine. Fish ladders can also be deployed by plant owners so that fish can pass around a dam.

Pillar 2: Enhancing Water Use Efficiency

Alstom offers solutions for reducing the net consumption rate of high quality water during plant operations[11]

- ***Enhancing thermal efficiency and reducing the need for cooling:*** for thermal power units, improving thermal efficiency and reducing the amount of heat discharged in the environment are the main levers to reduce water consumption in recirculating wet cooling processes (e.g. 876 MW *EMSLAND* CCPP with more than 59% net efficiency or 2'200 MW *NEURATH* BoA 2&3 STPP global benchmark for lignite with more than 43%). Particularly for nuclear power plants, maximising thermal efficiency is key for minimising total water consumption intensity as besides cooling, only boiler make-up water is required[12]. The Alstom conventional island solutions around the ARABELLE™ Steam turbine family for nuclear power plants offer unique features for maximizing efficiency and power output, and thus reducing specific cooling water

[11] It is worth mentioning that in case of Hydro projects it is difficult to estimate the water consumption of hydro solutions because evaporation in reservoirs can rarely be attributed to hydro power alone but to multiple uses (irrigation, water storage, flood control, recreation…).

[12] For safety reasons, nuclear power plants are operating at lower temperature and pressure, resulting into lower thermal efficiency levels compared to state of the art coal-fired power plants. At the same time and because of lack of fossil fuel combustion, no water is needed for emissions scrubbing. However, because of the higher need for cooling, total water consumption intensity of nuclear power generation with once through or wet recirculating cooling is somewhat higher than coal-fired. At the same time, a large quantity of water is needed to be made available for the core cooling system, in case of emergency.

consumption per MWh produced (Alstom commissioned in 2000 the world's largest operating steam turbines for the *CHOOZ/CIVAUX* nuclear plant in France and has been selected to support the *TAISHAN* power plant in China with two, world largest steam turbines, providing each 1'750 MW). The second lever to reduce cooling water consumption is to use the heat instead of dissipating it through a cooling system. Key applications in this regard include co-generation for district heating and fresh water production through seawater desalination (more than 13'000 MW installed capacity of power and heat production solutions for various industries; key recent integrated power and water project: 2'000 MW & 130 Million Imperial Gallons per Day *FUJAIRAH F2* IWPP in UAE).

- ***Reducing non-cooling fresh water consumption rate:*** further non-cooling, fresh-water consuming processes are addressed. For solar thermal technologies, the technology of "Alstom/BrightSource Energy Inc. Central Receiver Concentrated Solar Power" is air-cooled and consumes one third of the water required for makeup and mirror cleaning compared to other solar thermal technologies.

- ***Increasing water recovery for reuse:*** Alstom also develops solutions to increase the recovery of water from internal plant processes. As realised in recently executed geothermal projects, process (condensate) water replaces fresh-water for cooling (e.g. 2x25 MW *LOS HUMEROS II* Geothermal PP in Mexico).

Pillar 3: Lowering Impact on Water Quality

Alstom offers also solutions to control the thermal and chemical impact of operational discharge on the quality of surrounding water resources by:

- ***Reducing the volume of discharge into external water resources:*** this is achieved by integrating of zero liquid discharge (ZLD) concepts, as implemented in some recently-provided gas and coal-fired power plant projects (e.g. 800 MW *GISSI* CCPP in Italy). The ALSTOM NID™ technology also operates with ZLD avoiding the need for water treatment before discharge as in the case of Wet FGD systems (e.g. 800 MW *DUKE CLIFFSIDE 6* STPP in USA).

- ***Limiting the thermal and chemical impacts of discharge:*** for coal-fired power plants, the Alstom Seawater FGD system produces no waste while almost restoring sea water quality before discharge. For hydro, when required Alstom can provide dissolved oxygen enhancement solutions to improve downstream oxygen levels necessary to maintain aquatic ecosystems.

Furthermore, Alstom can offer guide bearings and turbine hubs that use water as a lubricant, eliminating the possibility of petroleum-based lubricants leaking into the water.

The way forward: Towards an effective management of the water-energy nexus

This Alstom commitment to provide economically and environmentally viable solutions to lower the dependency and impact of its offering on water resources is based on many dedicated and comprehensive R&D programmes aiming at:

- Providing an Alstom technical water dependency and use baseline for different types of power plants;
- Identifying key water use improvement areas and
- Evaluating most promising advanced technologies and developing future water footprint optimization solutions

Building on these technical opportunities, Alstom is also actively engaged with key stakeholders towards an effective management of the water-energy nexus. Beginning of 2014, Alstom has been invited by the World Bank to launch the new "Thirsty Energy Initiative" and to join the associated "Private Sector Reference Group". Alstom strongly believes that the water challenge of global power generation is manageable, in many regions of the world. This will, however, require the deployment of further water footprint management and improvement technologies and a greater integration of energy and water policies, in order to consider water risks while managing the trade-offs of a secure, affordable and environmentally friendly power supply in longer term. In this regard, Alstom recommendations to policy makers are summarized as follows:

- ***Good governance***: public-private collaboration to share information and agree on solutions is essential. Risks may be highly localized but the lessons learnt help develop best practice and build capacity whilst engaging relevant stakeholders in key decisions and the inevitable trade-offs that will accompany them.

- ***Regulation***: regulation of water quality and waste management helps to ensure that high basic standards are observed by all users. It is also important to remove any regulatory barriers that might hinder efficient use or investment in new technology[13].

- ***Planning***: integrated water-energy planning is essential and should involve a wide range of parties – not only planning authorities, utilities and investment partners (like IFIs) but also water-intensive industrial sectors to support efficient use right along the value chain. Initiatives such as the World Bank "Thirsty Energy" is very timely as it allows to bring together all relevant stakeholders to share best practices, build necessary capacity and come up with the best investment options/technology solutions for power plant operators and local and national authorities in developing countries.

- ***Supporting investment***: developing and deploying further water footprint management and improvement solutions needs appropriate financial (and risk management) frameworks to encourage long-term investment, especially to support the demonstration of new technologies and the upgrade of existing power plants to deploy new technologies or to adapt to a changing environment.

.

[13] As an example, US EPA has recently issued a draft rule to clarify treatment of CCS storage facilities under water and waste management legislation).

For more details and feedback please contact:

Ghazi Kablouti

Alstom Thermal Power

Corporate Social Responsibility

Alstom (Switzerland) Ltd.

Brown Boveri Strasse 7

CH-5401 Baden, Switzerland

tel: +41-56-205-8283

mob: +41-79-540-9372

email: ghazi.kablouti@power.alstom.com

Arnaud Chaffoteaux

Alstom Renewable Power

Corporate Social Responsibility

Alstom Hydro France

3 Avenue André Malraux

92300 Levallois-Perret, France

tel: +33-1-4149-3006

mob: +33- 6-89-33-78-63

email: arnaud.chaffoteaux@power.alstom.com

Alstom

www.alstom.com/power

ALSTOM