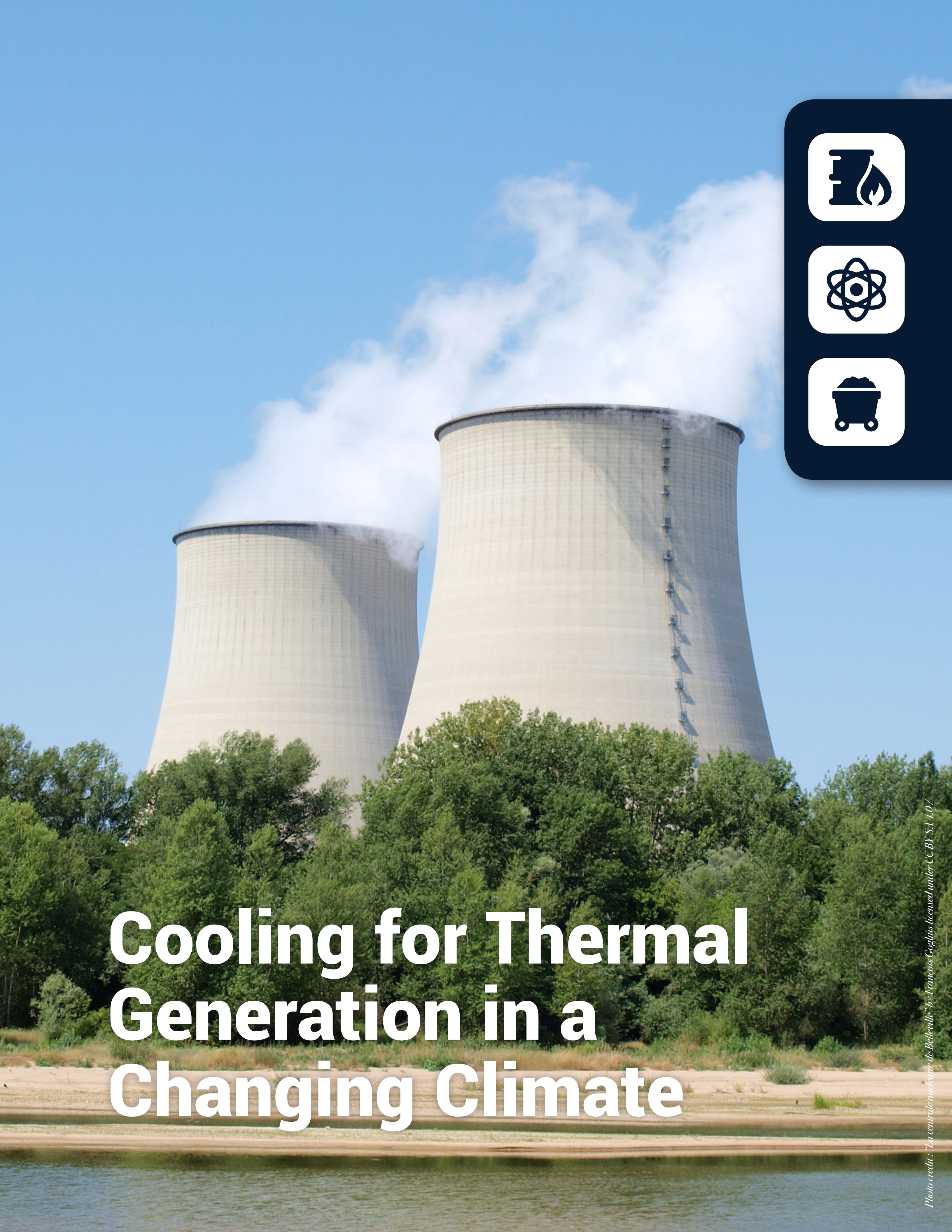

Cooling for Thermal Generation in a Changing Climate

"To comply with regulatory limits on the temperature of water discharges, power output reductions, and in some cases production interruptions have been necessary… Production losses have reached 5.5TWh in 2003 and 2.5 TWh in 2006."

Alain Vicaud, Director Environment and Prospection, and Éric Jouen, Director Projects, Électricité de France (EDF)[1]

SUMMARY

Thermal power plants have large cooling needs, usually met by using nearby water or outside air. Climate change represents a significant challenge for these cooling processes, as it changes the baseline conditions, such as air and water temperature. To meet the challenge, the power sector must pay greater attention to technologies and design options that reduce the vulnerabilities arising from changes in regional climate.

This case study highlights various challenges and respective solutions implemented by three companies around the world. Ontario Power Generation (OPG) invested in equipment to prevent clogging of water-intake structures due to ice particles suspended in the lake during freeze/thaw transitions. Électricité de France (EDF) is conducting research to quantify the trade-offs between cooling efficiency and environmental performance for available technologies. Eskom invested in dry-cooling technology for all of its new thermal-generation plants.

CONTEXT

Nuclear, fossil-fuel, and biomass power plants are built to transform their respective fuels into heat. To generate electricity, these thermal power plants use heat to convert water into steam and spin a turbine that drives an electrical generator. These plants typically rely on cold water (from a river, lake or ocean) and sometimes on air to convert steam back into water.

For thermal power plants using water to cool steam, water requirements depend on the cooling technology used. Older thermal-generation assets, and assets located near large water bodies, commonly use once-through cooling systems that draw water and circulate it through pipes to absorb heat from condensers. The water is then discharged back into the environment at a hotter temperature, and with little net loss to the watershed. Newer closed-loop systems use a similar process to cool exhaust steam, they circulate heated water into cooling towers exposed to draft air, leading to water loss through evaporation. Closed-loop cooling draw less water than open-cooling systems, but it involves treating water with chemicals and leads to water loss for the watershed.[2] Where water is scarce, dry-cooling becomes and interesting option. These systems use little to no water; instead, they use air to cool steam. Dry-cooling technology is, however, more expensive to build and is less efficient.

Climate change is expected to disrupt thermal generators around the world in multiple ways. Governments regulate thermal discharges to protect aquatic life (in Canada, through the Fisheries Act).[3] As already experienced in France in 2003 and 2006, and in the United States in 2012,[4] it will be more difficult to comply with temperature limits on thermal discharges of once-through cooling systems. Rising temperatures will increase the risk that peak-power demand (due to increased use of air conditioners) coincides with periods of elevated temperatures in the bodies of water designated to receive discharged water. In August 2012, Dominion Resources was ordered to shutdown a nuclear reactor in Connecticut after high temperatures had been recorded in Long Island Sound, resulting in several million dollars' worth of losses.[5] Another impact of climate change is the in diminishing efficiency of the cooling process due to higher air or water temperature. For dry-cooling, high ambient temperatures can reduce generating capacity by up to 15%, for instance.[6] Northern countries can face an additional challenge: changing ice conditions may increase the quantity and frequency of suspended ice particles in water — also known as frazil ice — resulting in clogged water intakes. Other potential impacts include clogged intakes and filters due to algae blooms, reduced dilution capacity of the receiving water body due to droughts, and increased water restrictions due to reduced water availability.

OPG RESPONDING TO TODAY'S CLIMATE

The impacts of today's climate on nuclear power-plant cooling are already felt in Canada. For example, one of the nuclear stations operated by Ontario Power Generation (OPG) on the shores of Lake Ontario is directly affected by seasonal climate fluctuations and their impacts on lake conditions, because it draws its water from the surface of the lake. During winter, OPG runs, specialized equipment to prevent ice particles suspended in the lake from clogging the main screenhouse and the emergency water system.

"We have also had problems with algae blooms in recent years," says Kimberley Melo, Senior Analyst with OPG's Enterprise Risk Management. The Pickering station recently experienced several episodes of unwanted blooms of *Cladophora* algae during periods of sustained high lake temperatures. In 2007, OPG had to shut down one of its reactors and reduce its power output because of clogged screens and filters in one of its water intakes.[7] In contrast, OPG's other nuclear station draws water from the bottom of the lake, where temperatures are cooler and algae blooms are not a significant issue. Kimberley Melo adds that "climate change can also favour aquatic invasive species, such as zebra mussels, which stick to, and clog, water intakes and outlets." Scientists have linked Zebra mussels with large algae blooms in Lake Ontario because the mollusks filter water enabling sunlight to penetrate more deeply into the water.

In some parts of the United States, power producers face thermal constraints on water discharge. For instance, in August 2012 a nuclear reactor operated by Dominion Resources in Connecticut was forced to shut down after record-high temperatures had been recorded in Long Island Sound. The event resulted in a loss worth several million dollars.[5] In states with warmer climates and water scarcity, such as California, the impacts of rising temperatures have serious implications for energy security.[6]

Overall, the risk to OPG facilities of higher water temperatures and other climate-related hazards remains relatively low because its nuclear stations have large design margins. However, should new nuclear or thermal power-generation assets be commissioned in Canada, rising temperatures could become an important design consideration for cooling systems.

ADAPTATION RESPONSES AROUND THE WORLD

In the European Union, rising temperatures and cooling efficiency are centre stage in upcoming regulatory changes for thermal discharge. The 2010 *Industrial Emission Directive* requires basing industrial water-use permitting on Best Available Techniques (BATs). The European Commission (EC) is planning to start consultations shortly with power producers and other industrial water-users to inform its revision of the 2011 *Industrial Cooling Systems Best Techniques Reference Document* (BREF) containing BATs for industrial cooling design. The EC explicitly decided to take climate change projections into account to identify the cooling techniques that best balance industrial requirements with environmental performance over the long term.

To address the risks associated with changes in climate extremes and normals, French nuclear-power producer Électricité de France (EDF) put in place a four-pronged climate adaptation strategy:

1- Project in a timely manner climate changes by the 2030s for existing assets and by the 2050s for planned projects
2- Assess the vulnerability of existing assets, and strengthen their coping capacity
3- Enhance the resilience of assets and projects to current and future climate risks
4- Integrate knowledge of climate change projections in the design of future projects

EDF also commissioned a research project to quantify and compare various environmental-performance indicators (e.g. water withdrawals, heat emissions, air emissions, energy efficiency and energy use) for a range of cooling technologies in a changing climate.[8] This integrated assessment relies on estimates of future air and water temperatures, relative humidity, and rainfall and streamflow levels, based on downscaled climate-model projections and hydrological models.

EDF is well equipped to implement resilient nuclear-generation cooling practices. Since the historic heat waves of 2003 and 2006, EDF has become a world leader in climate change adaptation by investing in a portfolio of preventive actions. As part of the *Grands Chauds* project, water- and air-temperatures used in the design of cooling systems were revised to account for climate change. Consequently, EDF decided to increase the cooling capacity of two nuclear plants. EDF also benefits from a sophisticated in-house meteorological and hydrologic forecasting system. Finally, a risk-management unit coordinates responses and stakeholder management during climate-related crises. The unit also helps operational teams to determine when exceptional criteria justify temporary derogations from regulatory limits on thermal discharges.[1]

In southern parts of the world, rising temperatures have already justified large investments in alternative cooling-technologies that rely on air rather than water. This is the case with Eskom, South Africa's power utility. Most of Eskom's generation portfolio consumes fossil fuels, and it is one of South Africa's largest consumers of freshwater.[9] In the 1980s, the company made a strategic decision to invest in dry cooling. Dry-cooling technology is more expensive to build and requires more fuel per kilowatt-hour produced. For instance, 2% of the total generating capacity of Eskom's Matimba coal-fired plant is used to operate its cooling fans.[6] Furthermore, generating performance at a dry-cooled plant is sensitive to meteorological conditions. In particular, high ambient temperatures can reduce generating capacity by up to 15%.[6]

Eskom's investments in dry-cooling technologies for its thermo-electric plants began as a response to water scarcity in South Africa. They were later further justified by projected reductions in freshwater resources due to climate change.

In its corporate climate change strategy, Eskom identifies dry-cooling technologies as a short-term adaptation solution for its new thermal power-plants. All new plants powered by fossil fuels incorporate dry-cooling systems. Since the mid-1980s, the company has increased its installed air-cooled capacity by 12,000 MW.[10] Eskom currently operates the world's largest air-cooled power plant, Kendal Power Station, with an installed capacity of more than 4GW.[9] It also plans to add 4.8GW worth of dry-cooled generation capacity through its newly commissioned Medupi coal-fired plant. Medupi will be the first of its kind to combine dry- and wet-cooling technologies.

LESSONS LEARNED

Physical climate change adaptation can usually be implemented during either the design or operational phase of a power asset. One of the only options for coping with the impacts of rising temperatures and water scarcity on thermal generation is to build resilience into asset design. For instance, an appropriate water-intake system or cooling technology can help a power plant accommodate projected climate changes, and avoid output reductions and shutdowns. Locating power plants near the coast enables the use of seawater for cooling. Thermal-generation units can be retrofitted with increased cooling capacity or with a new cooling system, although this is usually a very expensive option.

Taking action on climate change adaptation sometimes requires making trade-offs between economic performance and resilience, especially when power plants draw water from scarce resources. For instance, dry-cooling technologies cost more than conventional wet-cooling technologies to build and operate. They also lower overall power output; they consume more energy for each kilowatt produced.[2] Because reduced access to cooling water is projected to cause disruptions, Eskom has accepted that resilience overrides financial considerations.

In the case of wet-cooling technologies, EDF's research also shows that there are trade-offs between thermal discharges, consumption of water/energy and pollutant release. In a regulated context for cooling-technology performance, as in the European Union, regulators must determine whether climate resilience justifies the reduced environmental performance and/or higher costs associated with closed-loop systems.

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AT A GLANCE

KEY TAKEAWAYS

1. **Resilience to rising temperatures and water scarcity needs to be built into the design of generation assets**

2. **Projected climate change can have an important bearing on the performance of Best Available Techniques**

3. **Astute adaptation investment involves trade-offs between resilience, and environmental and technical performance**

ORGANIZATION(S)

Électricité de France (France), Eskom (South Africa), Ontario Power Generation (Canada)

POWER SUB-SECTOR(S)

- Electricity generation from thermal power plants

ADAPTATION TYPE(S)

- Informational – Monitoring equipment and technology
- Management – Regulatory exemptions and contracts
- Physical – New generation, carrying and transformation capacity

CLIMATE CHANGE IMPACT(S)

- Rising ambient temperatures and number of hot days
- Increased water temperatures
- Changes in surface runoff, aquifer recharge and water levels

ADAPTATION COSTS

- The costs of power-plant slow-down or shutdown to comply with thermal-discharge regulations is high.
- Capital costs of switching to closed-loop or dry-cooling technologies are very high.
- The operational costs of cooling technologies that minimize thermal discharges is high.

ADAPTATION BENEFIT(S)

- Enhanced capacity to cope with hot days and low streamflows
- Better environmental performance

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FULL REPORT

https://ouranos.ca/en/programs/energy-adaptation-case-studies/