



MATCHING or “Materials & Technologies for Performance Improvement of Cooling Systems performance in Power Plants” is a collaborative project, funded by the EU Horizon 2020 program, aims to reduce the cooling water demand in the energy sector.



CAN WE REDUCE THE COOLING WATER DEMAND IN THE ENERGY SECTOR?

Power generation is a sector requiring great amounts of water. Cooling water for energy production accounts, for 45% of total water abstraction in the European Union, second only to agriculture. Water is fundamental for electricity production and with water becoming increasingly scarce, the power industry cannot afford the risk of having to compete for water resources with other industries including agriculture and household uses.

This document shows the results of the part of the MATCHING project focusing on the implementation of water treatment technologies for reduction of water use in wet cooling towers at fossil fueled power plants. A broad set of technologies are proposed acting on intake, blowdown, and evaporated water.

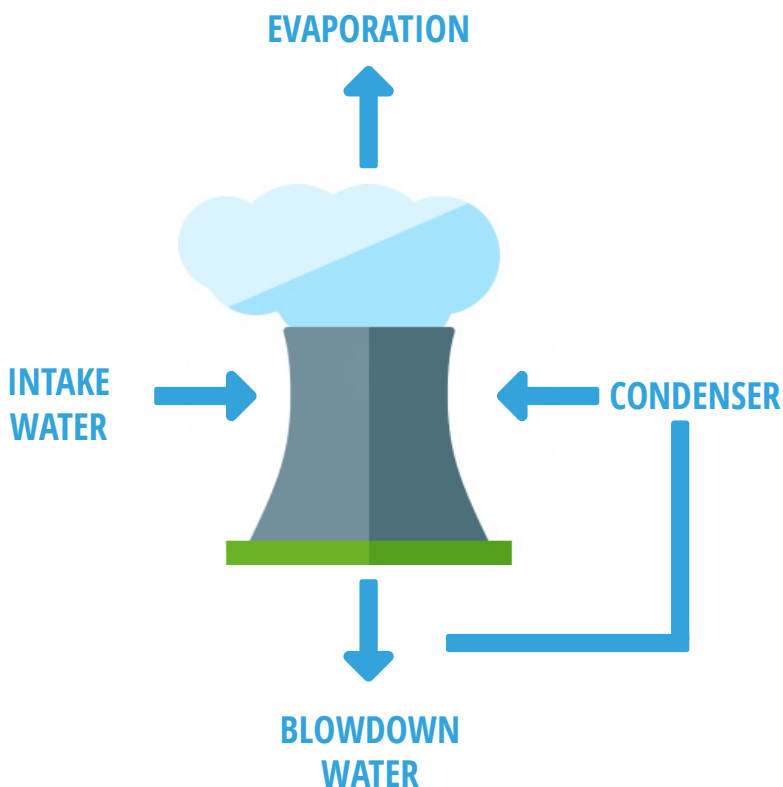


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COOLING TODAY

Fossil fueled power plants, that are not located in coastal areas, normally make use of natural or forced draft wet cooling towers to provide cooling obtained through the evaporation of water. The amount of water evaporated depends on the climatic conditions and is proportional to the cooling demand. As a consequence of evaporation and water circulation through the condenser, the concentration of salts in the cooling water increases leading to scaling and corrosion.

To avoid this, a portion of the water, called blowdown, is discharged from the cooling tower system and compensated by intake of fresh surface water. The water efficiency of a cooling tower is expressed as the Cycle of Concentration (COC) representing the amount of intake water divided by the amount of blowdown water. In Europe, typical COC values for cooling towers vary between 1,1 and 3,0 avoided drought risks and additional income for power plants.



WATER TREATMENT

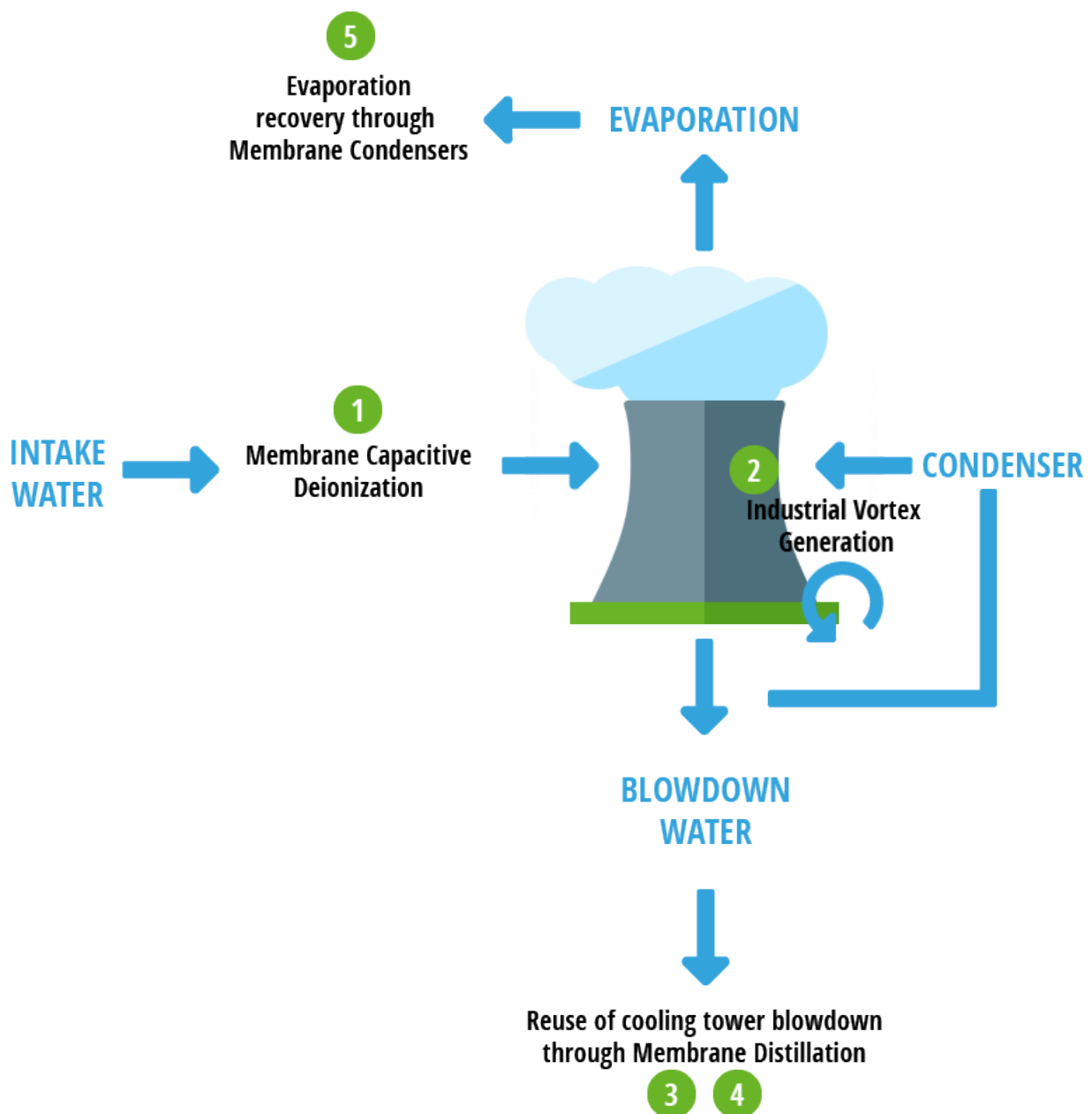
Today's most applied techniques for minimizing the amount of intake water is pH control by dosing of acid and antiscalant products. This results in the discharge of non-biodegradable components into the surface water. Pretreatment of intake water using chemical precipitation and softening is also applied at some power plants. These treatments require large amounts of chemicals, a large footprint is needed for the installation and large amounts of sludge are produced.

The main focus of the MATCHING project is on the technological assessment of selected technologies. The technical assessment includes the further development of technologies from laboratory scale to testing at pilot/ demonstration sites and the development of optimal designs for water saving. For technologies that pass the technical assessment successfully, a desktop assessment of the economic potential of the technologies is made, based on a simulation and assessment of water savings, costs and benefits of their implementation in power plants.



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TESTED TECHNOLOGIES



DEMONSTRATION SITES

Within MATCHING the treatment technologies are demonstrated at three different demonstration sites in Europe.

ENGIE - Merades

The mobile pilot unit Merades is located at Linkebeek, Belgium, on the Engie Laborelec site. The pilot consists of two identical independent cooling circuits which include their own condenser with ball cleaning system, forced cooling tower with fill, biocide and anti-scalant injection system, chemical and physical monitoring, circulation pumps, water intake, water blowdown, etc. The pilot works continuously and can be operated from a distance. Three different technologies were tested in the framework of the MATCHING project: Membrane Captive Deionization (MCDI) provided by VITO for treatment of intake water; IVG provided by PATHEMA for chemical-free circulation water treatment of the cooling circuit ; Membrane Distillation (MD) unit provided by VITO for cooling circuit blowdown reuse

EDF - Chatou Lab

The PERICLES facility consists of four mirror image pilot cooling systems that are able to operate independently. PERICLES is used to evaluate Membrane Condenser technology provided by ITM for the recuperation of water from the evaporative plume.

ENDESA - As Pontes

As Pontes is a coal fired power plant that belongs to ENDESA and is located in Coruña (Galicia), in the north-west part of Spain. The plant has a net nominal capacity of 1403 MWe, divided in 4 independent Units around 350 MWe each, burning imported subbituminous coal. All Units are equipped with their own independent natural draft cooling tower and share the same raw water, taken from the river Eume. This plant was the demo site for testing of Membrane Distillation provided by AQUASTILL for treatment of the cooling tower blowdown into high quality process water.

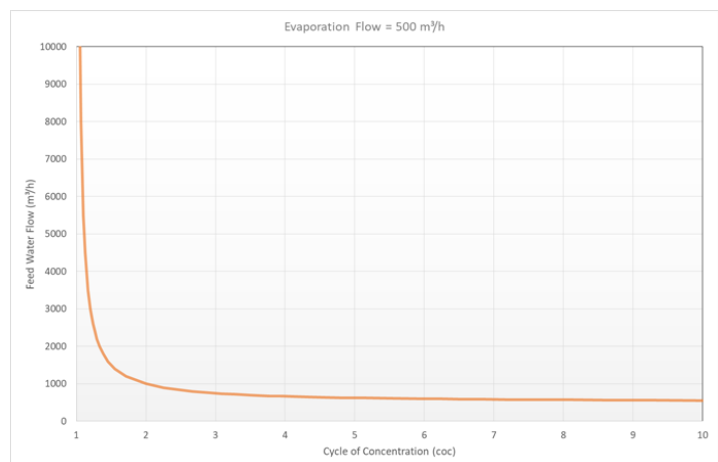
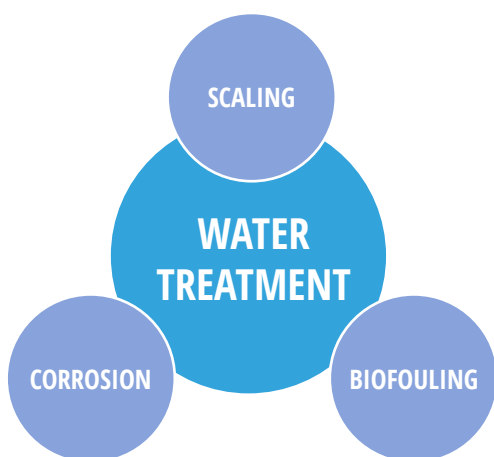


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CHALLENGES

Challenges and pilot/demonstration approach at Merades

Most power plants use surface or sea water as intake water for cooling. The cooling water composition depends on the specific location and impacts the 3 aspects of traditional cooling water treatment : scaling, corrosion and biofouling. Chemicals are used to avoid corrosion and biofouling issues. For scaling, chemicals (like acid, dispersant, etc.) are added but it is not possible to concentrate the water indefinitely. The cooling water cycle of concentration has to be limited in order to control calcium and alkalinity concentration. As a consequence the maximum COC is directly linked to the cooling water quality.



Water savings can be reached by increasing the COC. Water abstraction is greatly reduced when shifting from a once-through cooling circuit with a COC = 1 to a cooling tower with water recirculation. When we increase COC from 1 to 2, we are able to save a large amount of water. The additional gain in water saving however decreases by an increased COC. As water quality and chemical dosing determine the maximal COC in a cooling circuit, implementation of water treatment technology in order to change the water composition can be used to further decrease the intake water amount.

The goal of the pilot tests in the framework of MATCHING is to compare water and chemical use between a wet cooling tower reference case and a wet cooling tower with water treatment technology. For this purpose, ENGIE Laborelec uses its pilot installation MERADES. This pilot installation is a mimic of 2 parallel and identical cooling water circuits which are able to work with a common cooling water intake but with two different cooling water treatments. For each tested technology, a reference case test was established. The reference case uses water from the Bruxelles – Charleroi canal as intake water. This water was treated with sulfuric acid in order to control the pH and avoid scaling. To have comparable results for the reference and technology circuits, the physical parameters at the cooling towers were fixed.



APPROACH

Pilot/demonstration approach at Merades

For all pilot tests, the same methodology and approach are applied. Tests start at a fixed pH of 8.0 at the inlet of the condenser using sulfuric acid. The blowdown flow is reduced step by step from 10 l/h to 0 l/h, increasing steadily the COC. The increase of COC is stopped when scaling occurs indicating the end of the test. If no scaling occurs, the pH of the cooling water circuit is increased step by step by reducing sulfuric acid injection until scaling. Scaling is determined by chloride, calcium and alkalinity trends. The COC of each parameter is followed continuously. When the COC of calcium and the COC of alkalinity drops, it means that scaling occurs in the cooling circuit.

Physical Parameters	MERADES
Temperature outlet condenser	37 °C
Temperature cooling tower	27 °C
Circulation flow rate	1,9 m3/h
Water volume	0,5 m3/h
Hydraulic halftime	0,25 h
Condenser material	Stainless Steel
Fill	Film Fill (1.5m)

The maximal achievable COC for each technology will be used for the calculation of the water abstraction in comparison with the reference. The results of the pilot test are valid only for a temperature of 37°C at the outlet of the condenser, the specific water quality and the type of fill. The results cannot be transposed directly to other cooling water circuits but are used within MATCHING as comparison tool.

In addition, the corrosion rate is measured by the Linear Polarisation Resistance method (LPR). This method allows to highlight eventual influence of the tested technology on the water aggressiveness. Biological development is also controlled. Total bacteria count and ATP measurements are made regularly to evaluate the influence of the technology on biofouling.

The results from the different pilot tests are not directly comparable. Indeed, the highest achievable COC in the pilot plant is around 4.8 because of the continuous blowdown needed for online analysers. If no scaling occurs at COC = 4.8, an increase of pH is needed to reach scaling. At the end, results from the different technologies have different COC and pH.

Subsequently, simulation data are also included in the pilot test. Laborelec's CoolWAT empirical model was used to create these simulations. Different temperatures, types of fill, water qualities and COC were tested on Merades and the data was analysed in order to develop a model very close to reality. Moreover, the model was validated on known power plants to assess the accuracy of the model.

For the reference case, the maximal reached COC is 2.2 at pH 8.0. If the pH is increased up to 8.3, the COC is limited to 1.5 and to 1.2 for a pH of 8.5. These results will be used as comparison for the calculation of the water saving for the tested technologies.

Parameter	Canal water
Conductivity	800 µS/cm
TAC	22 °F
THCa	25 °F
Cl	80 mg/L
SO ₄	90 mg/L

pH Reference	COC Reference
8,0	2,2
8,3	1,5
8,5	1,2



APPROACH

New built reference scenarios: water and acid use

NEW BUILT SCENARIOS FOR COOLING

In order to evaluate the effect on water saving when implementing the tested technologies, reference scenarios without water treatment technology are defined. A 525 MW gas fired, combined cycle power plant is selected as reference thermal power plant for new built scenarios

[Economic Evaluation of Alternative Cooling Technologies. EPRI, Palo Alto, CA: 2012. 1024805].

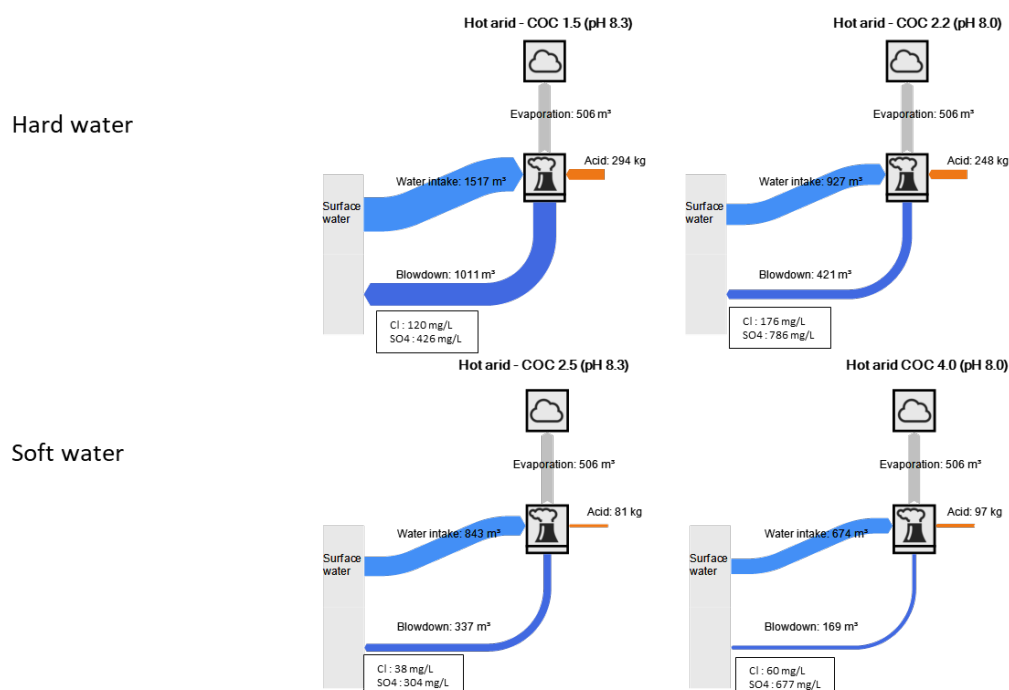
The new built scenarios designed for minimal water intake, assuming maximal COC are developed for two water qualities: hard water and soft water, 3 ambient conditions: hot, arid conditions, moderate (warm and humid conditions) and moderate (cool and dry conditions) and 2 different operating pH values: 8,0 and 8,3.

Water intake, acid use and salt discharge of the blowdown are calculated for the selected scenarios. The hard water scenarios use the reference pilot results of the project, the soft water scenarios are based on simulation data.

Parameter	Hard water (Brussels - Charleroi canal)	Soft water (Rhine river)
Conductivity	800 µS/cm	370 µS/cm
TAC	22 °F	12 °F
THCa	25 °F	14 °F
Cl	80 mg/L	15 mg/L
SO ₄	90 mg/L	25 mg/L
Reference COC	2,2	4
Reference pH	8,0	8,0

EFFECT OF WATER QUALITY

In order to illustrate the effect of hard versus soft water on water intake, Sankey diagrams are presented for the hot arid ambient condition as an example. The Sankey diagrams represent the waterflows (in m³/h) and the acid use (in kg H₂SO₄/h) for the different conditions.



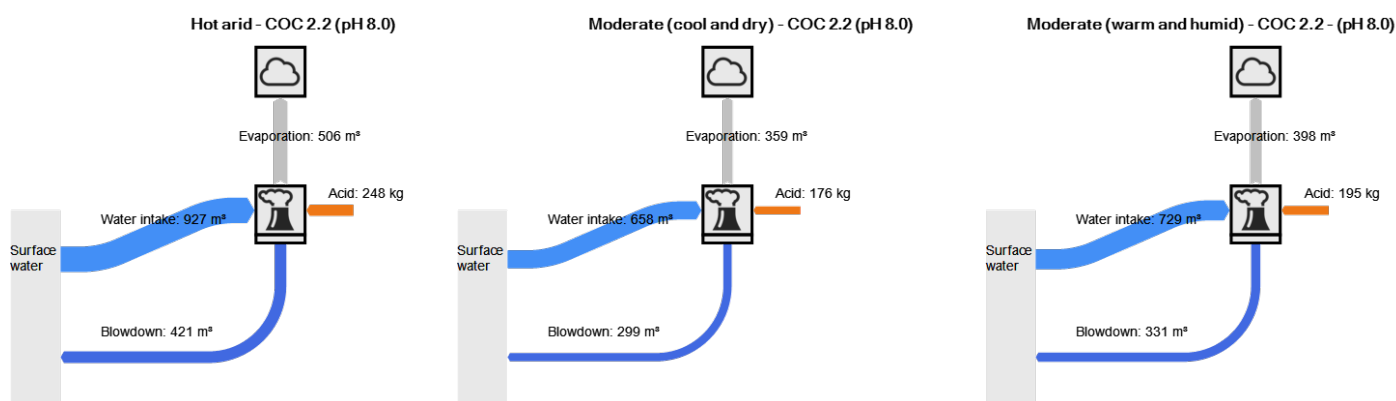
APPROACH

New built reference scenarios: water and acid use

The Sankey diagrams show that operating at pH of 8,0 results in significantly lower water use for both water quality types, acid use is comparable. Consequently, operation of pH 8,0 will be used as a reference for evaluation of the technologies. When surface water is 'soft' this results in 27 % less water use for the same cooling capacity compared to 'hard' surface water (for this specific water quality types).

EFFECT OF AMBIENT CONDITIONS

In order to illustrate the effect of operating a cooling tower in different ambient conditions, Sankey diagrams are presented for the hard water scenario at the 3 different ambient conditions. It is shown that the selected ambient conditions result in a difference of 29 % of water intake for the same cooling capacity.



These reference scenarios are used to evaluate the water and acid saving after implementation of the tested technologies.



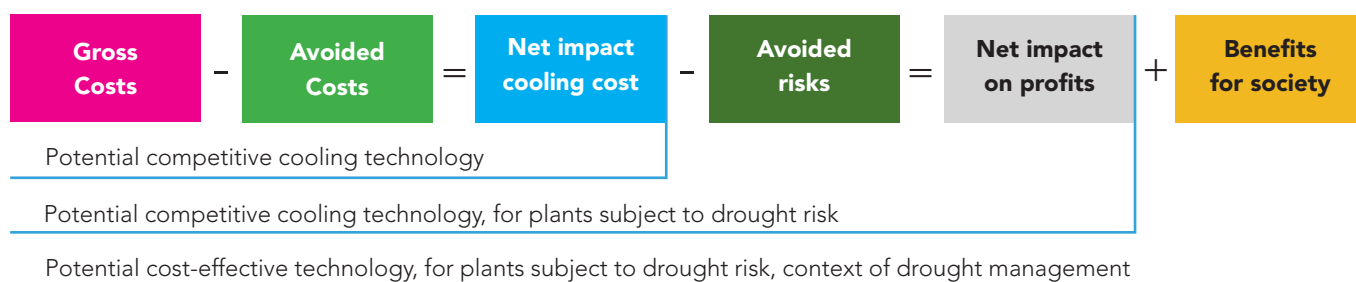
ECONOMIC POTENTIAL

The cost benefit analysis

ASSESSMENT OF THE ECONOMIC POTENTIAL

To explore the economic potential of the selected technologies, we simulate their implementation and compare costs, benefits and cooling water savings against current wet cooling towers. For the technologies relevant for thermal power plants, we assess their introduction in a newly built 525 MW combined cycle gas fired plant (CCGF), and explore the impact of different conditions within Europe, related to climate, intake water quality and drought risks.

The cost benefit analysis (CBA) uses different indicators to assess the potential of the technology, from the perspective of the power plant (competitiveness of technology with and without drought risks) and the perspective of society (context of drought management).



Gross Costs

Gross costs of new technologies: we assess in detail the equipment needs to implement the new technologies (e.g. number of MCDI cells) and estimate investment, operational and maintenance costs for these components. Estimates are based on cost information for current implementations, which are much smaller compared to configurations for the power plant. As we do not account for a potential decline in unit costs due to economies of scale or further, this cost estimate can be interpreted as a prudent upper estimate.

Avoided Costs

Avoided costs relate to the costs savings driven by the reduction of the required volume of cooling water and associated savings in size of installations and use of energy and chemicals.

Net impact cooling cost

The net cost of cooling is a first indicator to compare different cooling technologies with the reference scenario. To explore the impact of different locations (climate, water quality) on (avoided) costs and water intake for cooling, we compare 6 different typical situations. We distinguish two reference scenario's, with a low COC (current practice) and a higher, optimal COC. This indicator is used to assess the competitiveness of the technology against current wet cooling towers and dry cooling, irrespective of drought risks.



ECONOMIC POTENTIAL

The cost benefit analysis

Avoided Risks

The water savings will reduce drought risk and will result in additional income for the power plants. Drought risks are driven by reduced electricity production during drought events, as low water levels limit water intake or high water temperature in rivers limit thermal discharges. Drought risk depends on the plant location and the associated climate, hydrological, legislative and competing water uses for the region. Based on a literature review of modelling studies, we estimated the risk for 3 typical situations with low, mid and high risks for the coming decades in Europe and account for climate change. In addition, we estimate the risk reduction thanks to water savings for different technologies and situations.

Net impact on profits

The net impact on profits compares for each technology additional costs, cost savings and additional income for a range of different conditions (climatic, intake water quality, drought risks). These indicators are used to assess the economic potential for power plants subject to drought risk.

Benefits for society

The reduction of water intake for cooling and lower thermal discharges will result in additional benefits for society at large. The reduction of the pressures of water abstractions on the ecosystem will be beneficial for ecosystems and the goods and services they deliver (e.g. fishing, boating). During drought, other competing water uses, ranging from other industrial, households or ecosystems, will face less drought damages or costs of drought measures. However, the state of the art does not allow to estimate these benefits.

Finally, the reduction of the drought risk will increase the availability of power plants which will reduce overall vulnerability of society and economy. This is especially relevant for larger, European wide droughts, that may widely reduce availability of hydropower. The benefits will be lower electricity prices and improved energy security for all consumers. It has been illustrated that droughts increase electricity prices, but we cannot further estimate this benefit.

Indicators of our assessment can be used in further studies to identify the potential of the technologies in the context of drought management plans (€/m³ water saved) and electricity security plans (€/MWh).



CLIMATE CHANGE

Assesment of drought risk

QUANTITATIVE ASSESSMENT OF THE DROUGHT RISK.

The main parameters used in the assessment are listed in the table below, and the approach is explained in more detail in the Matching summary report.

Based on the (limited) available data and model studies, we estimate the average drought risk for the period 2020-2050 at 2,9% (1%-6%) of total annual power production for riverine power plants in different European countries with wet cooling towers and for locations subject to drought risks. The information indicates that the variation in risks is limited between the different power plants studied, but varies a lot between dry-hot years and wet-cold years, and will increase due to climate change.

We distinguish duration for 3 drought categories with restrictions on available cooling water from 25% to 100%. For each category, we estimate the additional electricity output resulting from water savings in the different scenario's (reference and technologies IVG, MCDI and MD). Water use and related drought risks are significantly reduced in the reference, but the further water savings in the technology scenario's bring further benefits, especially in the medium drought category with restrictions from 50% to 90%.

We use an average price of 45 €/MWh to estimate the impact on additional gross income for power plants. In addition, we account for the higher price of electricity during periods of extreme, European wide drought and related unavailability of hydropower. Cause these periods have only a limited share in total risks, the impact on average prices is limited (max + 10%).

Finally, we account for the additional costs of gas to produce the additional electricity. The net impact on income or profits varies from 23 to 27€/MWh.

On average, we estimate that every % water savings brings additional net income of 1,3 k€ per day during drought periods, or 25 k€ per year for a plant with average drought risks.

Table: Key indicators used for the assessment of technologies on drought risks for European powerplants at low, medium and high risk, period 2020-2050.

Indicators	Parameter	Low	Mid	High
Avoided drought risk				
Drought risk	% of annual output	1%	2,9%	6%
Duration of drought (1)	number of days/year	6	15	31
Avoided risk	% of annual output	Technology specific (2)		
Avoided loss of income				
Electricity price	€ / GWH	45	45	45
Price during drought	% of average	100%	103%*	110%**
	€ / MWH	45	46	50
Avoided loss of profit				
Extra fuel costs	€ / MWH	22,5	22,5	22,5
Additional profits	€ / MWH	23	24	27

(1) Days with a reduction of electricity output, varying from -25% to -100%.

(2) Depending on the technology, water quality and related reduction of cooling water intake.

* Assuming a period of 10% with 25% higher electricity price

** Assuming a period of 20% with 50% higher electricity price



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Industrial Vortex Generation for cooling water treatment



Industrial Vortex Generation for cooling water treatment

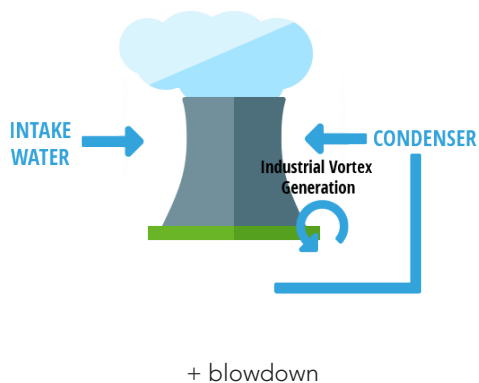
The Industrial Vortex Generator (IVG) system will degas cooling water and crystallize lime into calcite and aragonite. The crystallized lime will not scale in the system and the degassed water transfers the heat better leading to optimized cooling. By filtering the cooling water continuously the lime particles and other material is filtered out of the cooling water. UV-C treatment will radiate and eliminate all kind of biological material in the water. The continuous lightning of the water will lower biological existence to an absolute minimum. The system is implemented as an independent loop of the cooling tower. Circulating the buffer water of the cooling tower system to continuously treat the water and controlling blowdown. IVG system enables to operate a cooling water system chemical free, prevent lime scaling, corrosion and biological problems.

State of the art

So far IVG has been applied successfully in small industrial cooling towers resulting in significant savings in water and in use of chemicals. IVG can be combined with intake water treatment to optimize the performance. IVG is not yet applied on large scale cooling towers as used in the energy sector.

Process parameters

The main process parameters of the IVG system are flowrate treated by IVG.



GOAL

Treating a side stream of the circulation cooling water with IVG will prevent deposition of scaling of the present calcium ions in the cooling circuit. This will result in an increase of the COC, a reduction of intake water and a reduction discharge of blowdown.



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Industrial Vortex Generation for cooling water treatment

PILOT TEST SETUP

The IVG skid (1,1 kW) is installed in parallel to the basin of the cooling tower. The circulation water is taken from the basin and will be treated via the IVG and will be returned to the basin. Depending on the test, particles formed by the IVG will be removed by a 10 µm filter.



Condenser pipe



Condenser pipe reference circuit



Condenser pipe IVG Circuit



The assessment of the impact of IVG on scaling at pilot plant could not be based on chemical measurements (calcium, alkalinity,.) such as for other technologies. This method allows to detect scaling in the reference circuit but not in the IVG circuit. IVG creates precipitation, that will not adhere to the piping surface. The induced precipitation will induce a decrease in the chemical parameters which is not anymore a representative follow-up parameter for scaling. Detection of scaling is therefore evaluated by inspection of the cooling circuit for both packing and condenser pipes.

During the first pilot test period the maximal COC at a fixed pH in the cooling towers was determined for both cooling systems. During a second pilot test period the effect of use of a filtration system and cleaning balls for cleaning of the condenser pipes was evaluated.

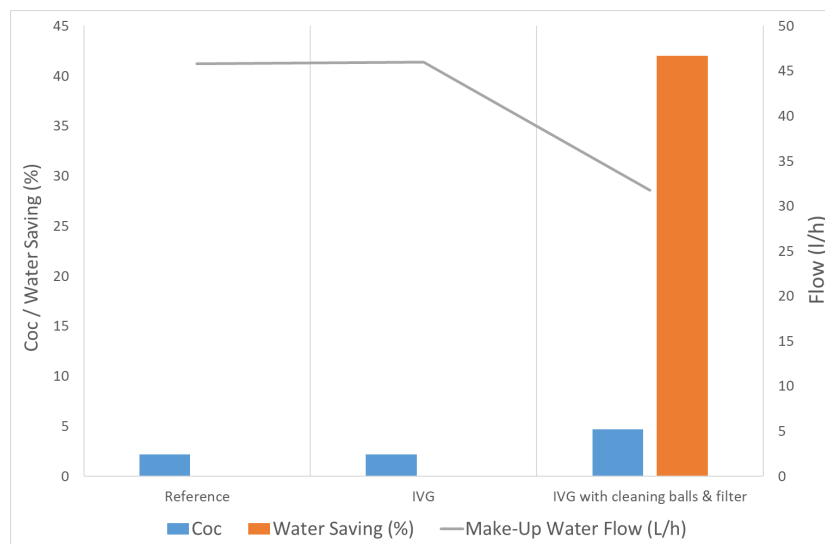
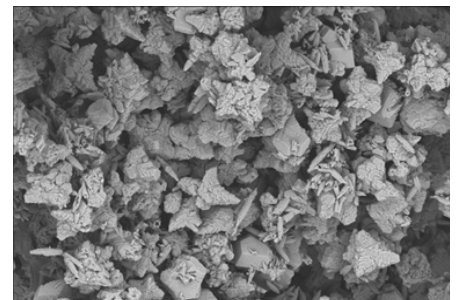


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Industrial Vortex Generation for cooling water treatment

TEST RESULTS

- In the cooling circuit using IVG scaling formation occurred at the same pH and COC as in the reference cooling circuit. The scaling particles however adhere significantly less on the condenser pipes in the circuit with IVG. Without removal of the particles the system cannot be operated due to pressure increase in the condenser.
- SEM analyses on the scaling particles show both aragonite and calcite crystals present in the scaling samples of the IVG circuit. Particle size distribution shows that 90% of the particles are smaller than 50 μm . Less than 10 % of the particles have a size below 10 μm .
- Using IVG combined with a 10 μm filter and the use of cleaning balls for cleaning of the condenser pipes two times a day results an increase of COC from 2,2 to 4,7 comparable with a water reduction of 42 %.
- No negative impact on biological growth in cooling tower, no increase of biocide dosing.
- No negative impact on corrosion rate.

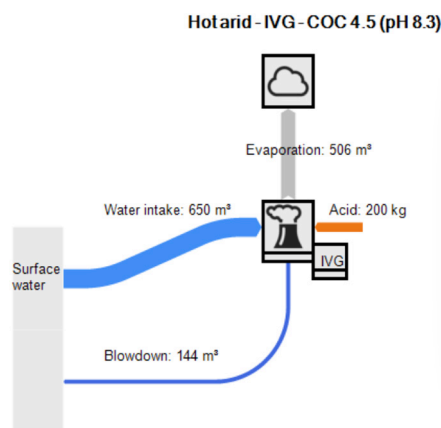
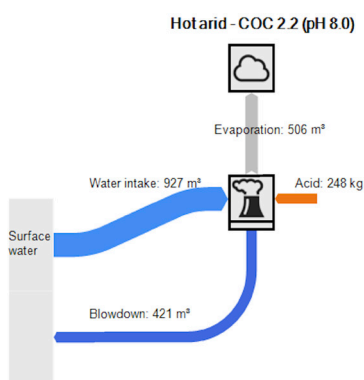


Industrial Vortex Generation for cooling water treatment

IMPLEMENTATION IVG FOR NEW BUILT COOLING TOWER

For three different ambient conditions, representative for the European situation, the design of a wet cooling tower for a 525 MW gross gas fired combined cycle plant was done taking into account two different types of surface water quality. The water volumes for minimal water use (maximal COC) only dosing acid for pH correction are calculated. Flow of intake water, blowdown discharge and acid dosing was determined based on the pilot test results.

Hard water

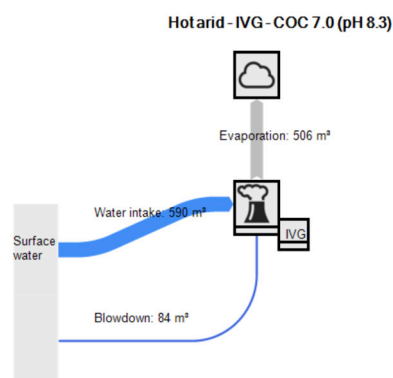
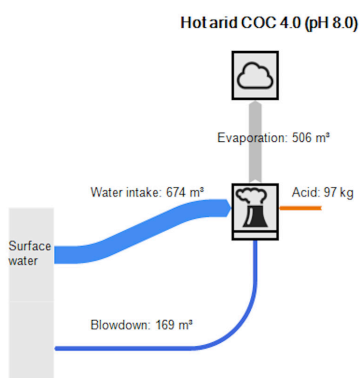


30% water intake reduction
19% acid reduction

Blowdown:

- Cl: 176 to 360 mg/L
- SO₄: 786 to 1793 mg/L

Soft water



12% water intake reduction
2% acid reduction

Blowdown:

- Cl: 60 to 105 mg/L
- SO₄: 667 to 1308 mg/L

- IVG implementation for the Brussels – Charleroi Canal, water reduction of 30 % is reached, for the Rhine water 12 %
- IVG also results in a reduction of acid use of 19 % for the Brussels – Charleroi Canal water. No significant acid reduction for Rhine water.
- Due to the lower amount of blowdown the concentration of chloride and sulphate increases. For Brussels – Charleroi Canal water without technology the blowdown contains 176 mg/L Cl and 786 mg/L SO₄. Sulphates are mainly coming from the acid dosing. After implementation of IVG the concentrations increase to 360 mg/L Cl and 1793 mg/L SO₄. As often discharge limits are set in environmental permits this needs to be discussed with the authorities.



Industrial Vortex Generation for cooling water treatment

ECONOMIC EVALUATION

Gross Costs

The gross additional cost account for the IVG installation and the filter and cleaning balls. The latter account for one third of total annual costs. These total gross costs vary from 0,16 million €/year, for both cool&dry and warm&humid climate zones, to 0,20 million €/year for hot&arid climate zones, reflecting that in the latter case, 40% more water needs to be treated. Capital costs account for 75% of total costs.

We estimate gross costs will add 9% to 11% to the total costs of wet cooling towers. This represents less than 0,1 % of total costs of electricity production.

The uncertainties around these estimates are lower than for other technologies because investment costs for IVG are based on market prices from the producer. The uncertainties relate to the costs of additional measures (for filter and cleaning balls) and discount rates.

Avoided Costs

IVG can bring important costs savings, as less water intake and discharge requires less infrastructure and energy and, in addition, IVG reduces costs for chemicals. For the hard water cases, avoided costs vary from -0,27 to 0,30 million Euro, with higher estimate for the hot&arid zone. For hard water, the avoided costs are about 150% to 170% the size of the gross costs .

For soft water, avoided costs are lower compared to hard water. First, the reductions in water intake are lower (-12% versus -30%) because we estimate that in the reference scenario the COC is higher (4 compared to a COC of 2,2 for hard water). In addition, the total costs for chemicals are 60 % lower in the ref for soft compared to hard water, and in addition the % reduction is lower (-2% versus -20%). Consequently, avoided costs vary from -0,07 to -0,08 million €/year, which corresponds from 39% to 46 % of the gross additional costs of the soft water cases.

There uncertainty boundary for avoided costs is larger than for gross costs, as avoided cost are based on case specific cases and estimates. The main component in our estimates are avoided costs of infrastructure. Although it is clear that 12% to 30% less water intake will allow for costs savings, it is uncertain how big the cost reductions will be in practice. There is more certainty related to avoided costs of less chemicals use, but this only represents 3% to 20% of total avoided costs. On the other hand, in specific cases, IVG may reduce other costs of chemicals or maintenance, not accounted for in our estimates.

Net impact cooling cost

The net impact on cooling costs varies depending on the quality of the intake water. For hard water, the avoided costs fully compensate gross costs for IVG and filter and cleaning balls. We estimate it can reduce total wet tower cooling cost with around -6%, and reduce total cost of electricity production with - 0,05%.

Thus, for hard water, IVG technology is potentially a competitive cooling technology, both for new installations and – to a lesser extent – for retrofit. For new installations, optimal design of the installation will allow to reap all the benefits of smaller installations and related cost reductions. In case of retrofit, investment costs have been made and cannot be avoided. We expect gross costs and avoided operational costs to compensate for each other, but more detailed analysis of the specific project is needed to calculate the net impact.



Industrial Vortex Generation for cooling water treatment

For soft water, conclusions are different. As avoided costs are lower there is a small additional net cost, in the order of 5% to 8% of wet tower cooling costs, which will add 0,05 % to the total costs of electricity. For these cases, IVG is unlikely to be a competitive cooling technology, unless the benefits of reduced water intake are taken into account.

Avoided Risks

The reference is already a significant reduction for water use compared to current practice, and IVG will bring some further reductions, both for water intake and discharges. As water savings are higher for hard (-30%) compared to soft water (-13%), benefits are also higher.

Also smaller savings are estimated to generate additional output and related benefits.

For hard water, the avoided risks range from 0,4 to 1,5 million euro/year, for plants with low to high drought risks. For soft water, we estimate the benefits of avoided risk to range from 0,1 to 0,5 million euro/year.

Net impact on profits

For the hard water cases, IVG is a competitive cooling technology for all new plants, irrespective of drought risks. The related benefits in terms of avoided risks are likely to further increase the net benefits of the application of IVG. For retrofitting, gross costs and avoided costs are very similar, and in the best cases, the impact on profits will be positive. For plants subject to drought risk, the net impact on profits will be positive, irrespective of the size of the risk.

For soft water cases, we estimate that the net impact on profits will be positive for power plants with average drought risks, and if avoided risks are accounted for. Only for plants with low drought risk, avoided risks may be too low to compensate for the costs. These conclusion are valid for new plants and for retrofit of existing plants.

Benefits for society

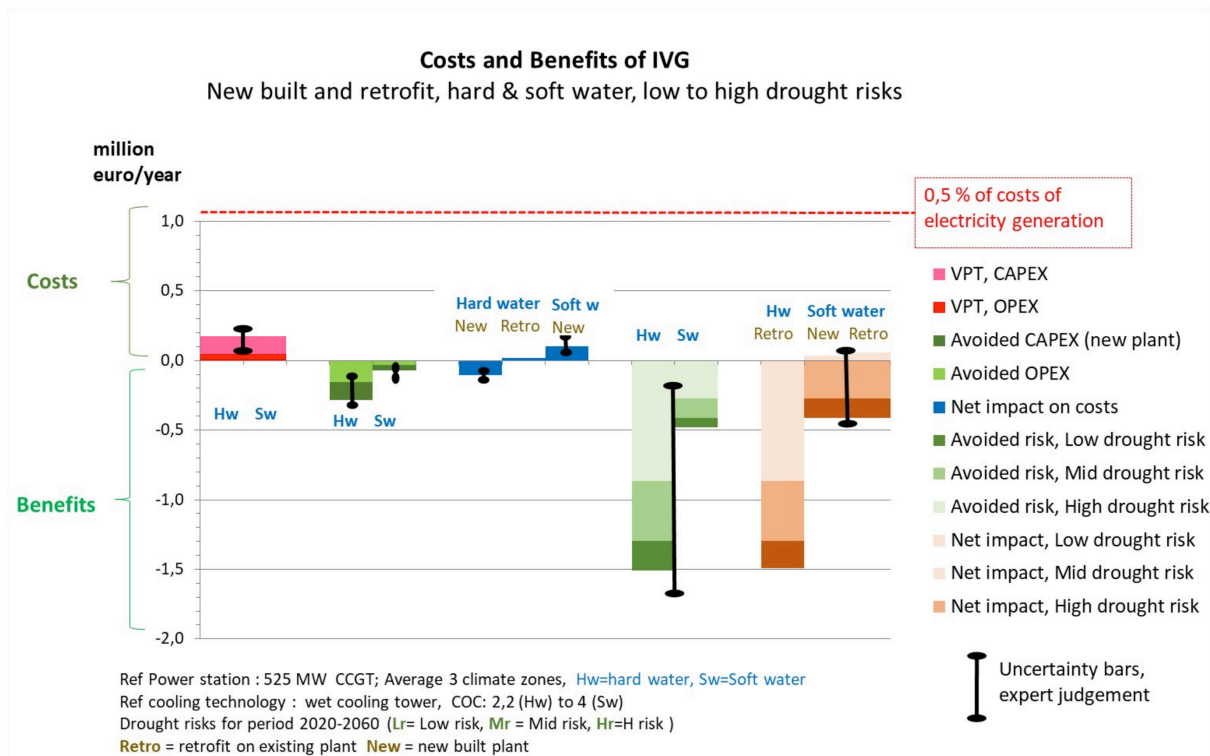
First, it should be noted that – compared to the current practice - there are important avoided risks for the reference case, which are not accounted for in the analysis of the MCDI. These benefits for the power plant and economy amount to 2,5 million euro per year.

We cannot estimate the additional benefits of the water savings (less abstraction) for other sectors of society.

IVG is an interesting technology from the perspective of drought management, as it is a low cost technology. On the other hand, the impact of IVG on the reduction of water intake is lower compared to other technologies.



Industrial Vortex Generation for cooling water treatment



CONCLUSION



CONCLUSION

Technical and economic feasibility

Many riverine thermal plants in Europe using wet cooling towers are already or will be at risk for production losses due to water scarcity resulting from low water levels and/or high water temperatures. These risks are estimated at 2.5 % of annual electricity production, varying between locations.

There are several technological options to reduce water intake for cooling, varying in stage of development. In MATCH-ING, 5 technology options were assessed in detail from a technological perspective and were further developed from lab scale to pilot testing. Membrane condenser technology was successfully tested at lab scale conditions. During future demonstration at pilot scale the technical feasibility can be evaluated. For three technologies (MCDI, MD and IVG) the technical feasibility was demonstrated successfully and a further analysis was made, simulating their application in a new built power plant (CCGT-gas fired) in different locations with varying climate and water quality.

MCDI, MD and IVG are able to reduce the water intake for wet cooling for thermal power plants with 30 % or more, compared to current practice or optimised reference (CC-gas fired). Reductions are site specific, depending on climate and water quality. Reduced intake water will however result in discharge of increased salt concentration of blowdown water. This needs to be evaluated for each specific situation.

The technologies (IVG, MCDI and MD using industrial waste heat) increase gross costs of cooling with 10 % - 75% compared to the (optimized) reference. As less water intake results in cost savings for infrastructure, chemicals, energy and taxes, important costs savings are possible, compared to the reference (and especially compared to current practice). The net impact on cooling costs varies between technologies. As the IVG technology is estimated to result in net cost savings, this technology can be considered a competitive technology. On the other hand, the reductions of water intake are lower, and may not be sufficient for power plants at risk of drought.

For MCDI and MD using industrial waste heat, the net impact on cooling costs varies from 20% to 40%, which corresponds to 0,2% to 0.4% of costs of thermal electricity generation. They would only become competitive technologies if costs can be reduced due to economies of scale or costs reductions.

If no industrial waste heat is available, the high energy demands for MD will increase costs significantly (x5) whereas avoided costs will remain the same. The net impact on costs is higher than for other technologies (+ 190 % on average).

MCDI and MD using industrial waste heat technology can be competitive for power plants subject to drought risk. Reduced water intake will lower drought risk and will bring additional income compared to the reference. It may range from 0.5% to up to 4 % of total incomes. We estimate that if these avoided risks are accounted for MCDI and MD using industrial waste heat will become competitive for power plants with drought risk of 0.5 % or more. Although we could not compare all costs and benefits in detail of these technologies versus dry cooling, they are likely to be competitive, as net cooling costs are lower compared to the cost figures for dry cooling in literature.

If waste heat is not available, MD can only become competitive in situations with low costs (soft water, no hot&dry climate) combined with high drought risks.

In addition, the reduction of water abstraction will bring additional benefits to society that are not accounted for. The benefits include an improvement of ecological status for the river (water levels, thermal stress,...) and will allow other sectors to use more water during droughts. It will improve electricity security and lower electricity prices in periods of European wide droughts with limited availability of hydropower.

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