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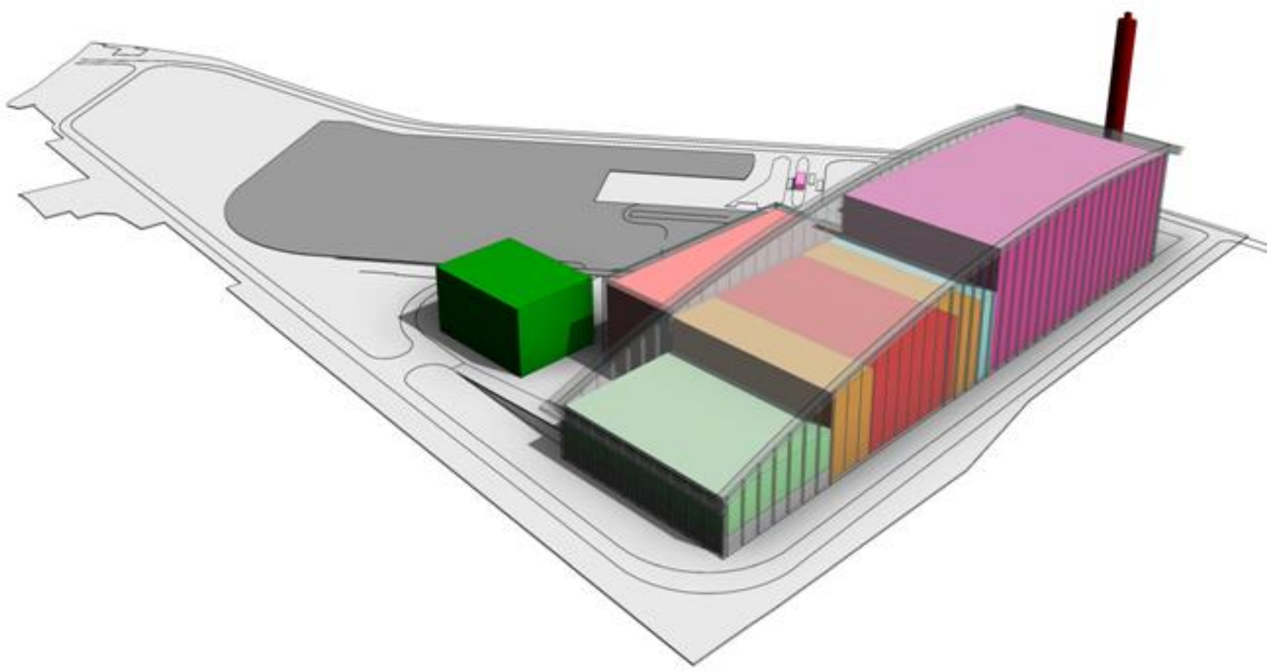
NORTH LONDON HEAT AND POWER PROJECT - COOLING PLANT TECHNOLOGY OPTIONS



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CONTENTS

1. EXECUTIVE SUMMARY

This report sets out Energy Recovery Facility (ERF) cooling technology options and evaluates key parameters to provide North London Waste Authority (NLWA) with information to support technology selection. The main technology options are air cooled condensers (ACC) and water cooling towers. A further option is a hybrid solution comprising a wet cooling tower with a dry section for plume mitigation.

A key difference between the ACC and the wet cooling tower system is the impact on power generation. The ACC is estimated to induce a turbine back pressure of 100 mbar at the ambient design temperature. A wet cooling tower solution will enable a back pressure of approximately 80 mbar. This leads to approximately 700 kWe of additional net power generation by the wet cooling tower solution. This is the result of longer steam expansion at the back end of the turbine with the lower exhaust pressure achieved.

The hybrid solution is also estimated to induce 80 mbar turbine back pressure. This solution requires more auxiliary power for the dry section fans. The net power difference compared to the ACC is 430 kWe.

The following table summarises the key findings for the cooling options considered.

	Air Cooled Condensers (ACC)	**Wet Cooling Tower**	**Hybrid Cooling Tower**
Relative cost of cooling technology option	Highest	Lowest	Middle
Turbine back pressure	100 mbara	80 mbara	80 mbara
Net power gain over ACC cooling	-	700 kWe	430 kWe
Estimated footprint	1,156 m^2	422 m^2	807 m^2
Plume visibility	None	Normally visible	None down to 0°C ambient conditions
Approximate water consumption (figures calculated at 10.3°C ambient, 77% humidity)	-	2.0 m^3/t_{waste} (range: ~ 1.7 to 2.3 m^3/t, mainly dependant on ambient temperature)	1.7 m^3/t_{waste} (with 14% dry cooling)

The wet cooling tower option has a lower capital cost than the ACC option and produces more power than the ACC option. However, a wet cooling system requires water and results in a visible plume. Furthermore, wet cooling towers can sometimes result in water settlement/condensation outside of the site boundary and will be taken into consideration in planning/permit applications. The water used for wet cooling is treated with chlorine to prevent microbial growth. If evaporated water settles on local buildings and structures this may accelerate corrosion.

The hybrid ("wet/dry") solution has similar advantages to the wet cooling tower, when compared with the ACC system. However, visible plumes may be avoided if the ambient conditions fall within the design range for certain parameters (e.g. temperature, humidity and pressure). The hybrid option costs more than the wet solution and requires more auxiliary power.

A hybrid cooling tower with a dry section to minimise plume formation is detailed as an alternative to the wet cooling tower. A reduction in plume visibility may be perceived as an advantage when compared to a wet tower solution.

2. INTRODUCTION

This study sets out Energy Recovery Facility (ERF) cooling technology options and evaluates key parameters to provide The North London Waste Authority (NLWA) with information to select a cooling plant technology. The options are broadly air cooled condensers (ACC) and wet (water) cooling towers. A hybrid cooling tower with a dry section to minimise plume formation is a wet cooling tower variant and is also presented in this report.

This report takes account of NLWA's proposed 700 ktpa ERF with a design calorific value of 10 GJ/t and annual availability of 8,000 hours. Waste calorific value and actual annual operating hours achieved will influence overall plant performance. However, this will not influence cooling technology option evaluation.

The plant is assumed to comprise two process lines supplying steam to a single steam turbine. This yields a waste processing rate of 88 t/h, equating to a heat input of 244 MW_{th}. The low grade heat to be dissipated by the cooling plant is estimated as 135 MW_{th}.

ERF cooling options are as follows:

1. Sea water or river water cooled once-through a surface condenser – site dependent
2. Air Cooled Condenser (ACC) – site independent
3. Wet cooling tower - site independent, but requires access to water (approximately 1.7 to 2.3 m^3 per tonne of waste processed)
4. Wet cooling tower with a dry section to mitigate plume ("hybrid" cooling tower, or "wet/dry" cooling tower)

NLWA's ERF will be located at EcoPark, Edmonton, by the existing facility that employs wet cooling. This study focuses on comparing the ACC, wet cooling towers, and the hybrid cooling option available to NLWA.

The following parameters influence design/selection of the cooling plant:

- Ambient temperature and relative humidity across the year;
- Allowable turbine back pressure: Turbine exhaust steam will contain water droplets, leading to erosion of the last stages of the turbine.
- Turbine power output: generally a wet cooling tower can obtain lower turbine back pressure compared to an ACC, leading to a higher gross power generation.
- Plume visibility. A visible plume should be expected with a wet cooling tower, thus public perception may play a role in technology selection. Cooling tower plumes at ERF and other thermal power plants are often perceived as smoke.
- High water consumption by wet cooling systems can be costly and the environmental impacts must be considered
- Layout considerations: ACCs have a much larger footprint than wet cooling systems. Additionally the turbine is connected to the ACC via a large exhaust duct, circa 4 m diameter, that needs to fit into the ERF plant layout.

Ramboll's evaluation has focussed on the following:

- Capital expenditure;
- Operational expenditure; and
- Layout considerations.

All other technical details of the ERF facility are considered equal for all cooling options considered.

Ramboll's analysis assumes an average ambient temperature of 10.3 °C and humidity of 77.1 %. These parameters impact ERF power generation. Our assumptions correspond to annual averages for London, based on a 30 year period.

Further detailed assessment on a month-by-month basis for evaluating power production differences and water usage may be considered if the outcomes on broad assumptions are found to be found relevant.

The final "ambient design temperature" for ACC or a cooling tower system, for determining the physical size and cost of the equipment can differ from the average temperature of 10.3°C. The power output with an ACC solution is more dependent on ambient temperature than a wet cooling solution.

Thermoflex, an industry recognised software, has been used to estimate engineering design and investment cost of various key components.

3. COOLING OPTION IMPACT ON POWER OUTPUT

The nature of steam turbine technology and steam expansion is such that the final expansion pressure, turbine "back pressure", is governed by the cooling system. Thermodynamic theory dictates that the colder the medium to cool the steam turbine exhaust the longer the steam expansion, thus a higher power yield.

Even relatively small differences in cooling and final exhaust steam temperature may result in substantial changes to power production. This is related to steam flow because turbine power outputs are governed by steam volumes (m^3/s) passing across blades. When the condensing temperature (or saturation pressure) of the turbine exhaust steam drops, the final specific volume (m^3/kg) of the steam increases. Therefore, the higher the final specific volume of exhaust steam (m^3/kg) the higher the final volume flow, thus more expansion to turn the turbine blades and more power output.

Steam at 0.5 bara (saturation temperature of 81 °C) has a specific volume of 3.2 m^3/kg. Steam at 0.04 bara (saturation temperature of 29 °C) has a specific volume of 35 m^3/kg. Hence, the additional cooling of the steam from 81°C to 29 °C yields a 10 times higher volume flow to turn the turbine and produce power.

The relationship between steam temperature and saturation pressure is shown below in **Figure 1**. The red arrow, as an example, indicates that steam cooled to 45 °C at the turbine exhaust will produce a pressure of 100 mbar.

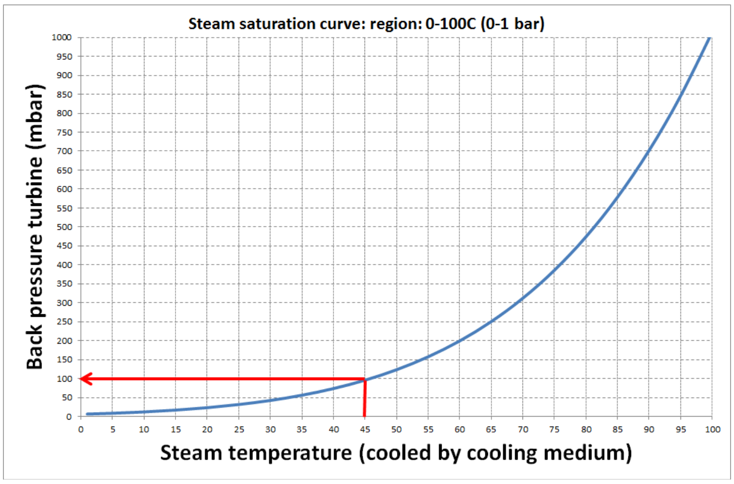


Figure 1: Relationship between saturation pressure and temperature

Note: To be considered as part of turbine back pressure comparisons with ambient conditions (heat rejection). Average ambient conditions of 10.3 °C and 77.1% relative humidity are assumed for this study.

Steam cycle power stations in colder regions of the world have higher efficiencies than power stations in hotter regions due to their ability to expand steam to lower temperatures. Thus, power stations are often placed close to the sea for access to cold water.

Steam expansion across the turbine is illustrated further in **Figure 2**. The figure illustrates the difference in expansion for back pressures of 100 mbara and 300 mbara. Expanding to a back pressure of 100 mbara instead of 300 mbara yields a 12 % increase in power generation.

Ramboll's ERF modelling indicates that a back pressure of circa 100 mbara is achievable with an ACC solution. A wet cooling system will be able to achieve a back pressure of circa 80 mbara (or lower). A lower back pressure with a the wet system means live steam pressure to the turbine needs to be reduced by approximately 5 bara to keep the moisture level in the turbine exhaust unchanged. The wet cooled solution has a longer overall steam expansion and results in approximately 700 kWe of additional power generation.

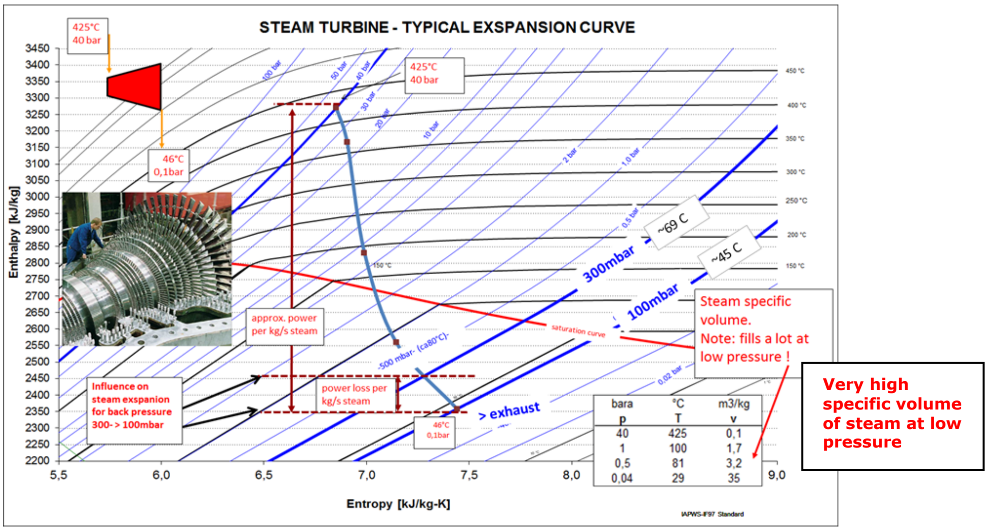


Figure 2: Typical steam expansion curve (425 °C example)

Note: Reading on the y-axis (kJ/kg difference) multiplied by steam flow (kg/s) yields approximate power output of the turbine (kW). The curve is based on modelling of a turbine with 20 kg/s steam, but can be used generically.

4. THERMODYNAMIC MODELLING

The cooling options described above differ in physical setup, performance and investment needs. The options have been thermodynamically modelled to determine cooling plant size, performance and costs estimates. These should be considered preliminary, and may change during detailed design, based on the final contractor optimisations.

The cooling plant options have been modelled using the boundary conditions presented in **Table 1**.

Parameter	Value	Unit
Waste throughput	88	t/h
Waste LHV	10.0	GJ/t
Fuel energy input	244.4	MW
Live steam temperature	440	°C
Turbine back pressure (wet tower)	80	mbar(a)
Turbine back pressure (ACC)	100	mbar(a)
Ambient temperature	10.3	°C
Relative humidity	77.1	%

Table 1: Boundary conditions used for modelling

Figure 3 shows ambient temperature and relative humidity for London, England. This is based on 30 years of data. The data shows large deviation between annual and monthly temperatures.

Ramboll's modelling is performed using the annual average ambient temperature of 10.3 °C. This means, especially for the ACC option, that the cooling unit will be over dimensioned for colder months and under dimensioned for warmer months. The wet cooling tower is less sensitive to variations in ambient conditions.

Ramboll has not performed month-by-month calculations comparing the cooling options. A month-by-month analysis will lead to a lower performance of the ACC, compared to the "average annual temperature" calculation. This level of analysis is usually performed at the detailed design stage. A detailed study considering moth-by-month analysis is not expected influence the technology choice.

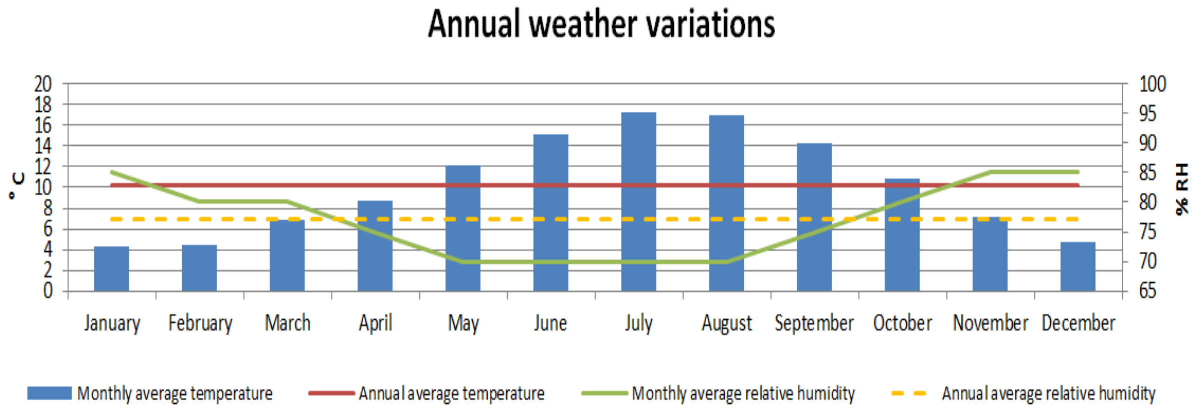


Figure 3: Average temperature and relative humidity for London, based on 30 years of data

Source: http://www.weatherbase.com/weather/weather.php3?s=67730&cityname= London-England-United-Kingdom&units=metric#mapinline

5. AIR COOLED CONDENSERS

5.1 Configuration

The air cooled condenser is configured as per **Figure 4**: steam exits the turbine through a large exhaust duct and is routed to air cooled condensers. It is recommended that the plant layout considers the significant duct size and costs.

Turbine suppliers usually have solutions with both radial and axial steam exhaust. An axial steam exhaust enables placing the turbine at ground level, if helpful to overall ERF layout. This is illustrated in **Figure 4**, on the right hand side. A radial exhaust means the steam exits the turbine perpendicular to the casing (i.e. upwards or downwards).

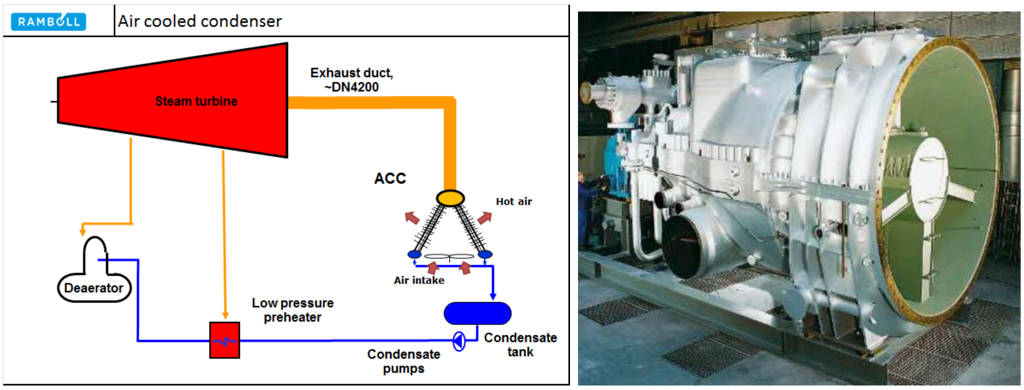


Figure 4: Process setup for air cooled condenser (left). Turbine with axial exhaust (right)

ACC cooling units are usually placed outside in open air and elevated with free space around it to allow inflow of air to the cooling units. This elevation also creates a net positive suction head (NPSH) i.e. inlet pressure for condensate pumps. **Figure 5** shows an ACC unit and describes the working principles.

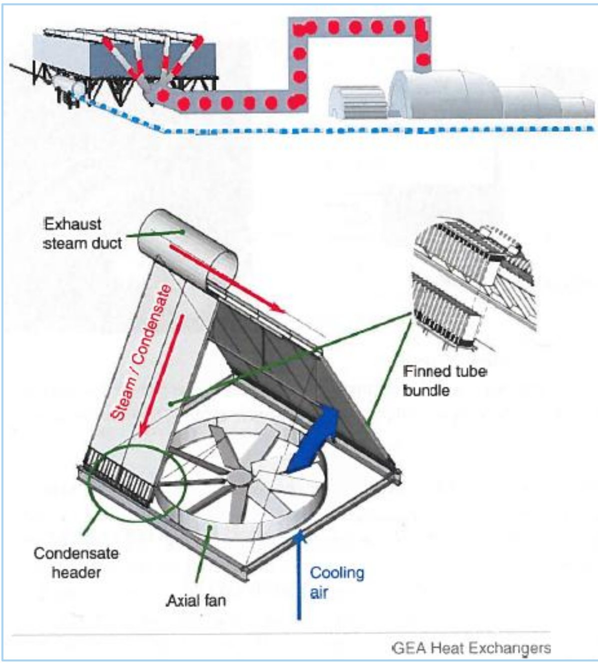


Figure 5: Air Cooled Condenser unit, elevated to allow inflow of air from beneath

Note: Figures from http://www.gea-energietechnik.com, courtesy GEA Energietechnik

5.2 Thermodynamic Modelling Results

The thermodynamic modelling results for the ACC cooling option are shown in **Figure 6**.

Turbine exhaust steam is expanded to a pressure of 100 mbara. Consequently, the specific volume is high, thus resulting in a very high steam velocity in the exhaust duct. The sizing of the exhaust duct is a trade-off between pressure loss, price and noise issues; a common design parameter is an exhaust steam velocity of 60 m/s. The exhaust duct diameter is estimated to be 4 m.

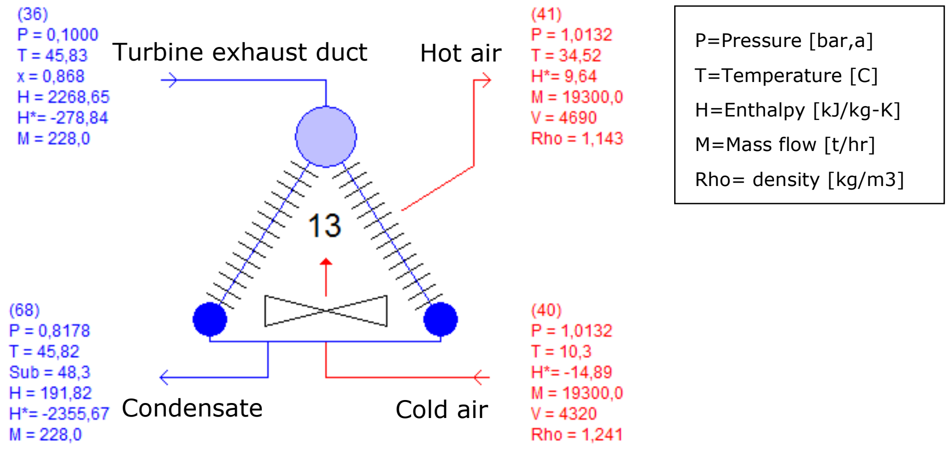


Figure 6: Modelling results for the ACC system

Note: Red denotes incoming and outgoing ambient air.

The air flow through the ACC is ensured by means of large fans. Ramboll modelling estimates a total fan power consumption of 0.75 MWe.

Figure 7 shows how air temperature (red line) rises as it is drawn through the ACC cooling unit. The steam (condensate) temperature is shown by the blue line, and remains constant (~46 °C) with steam condensation taking place.

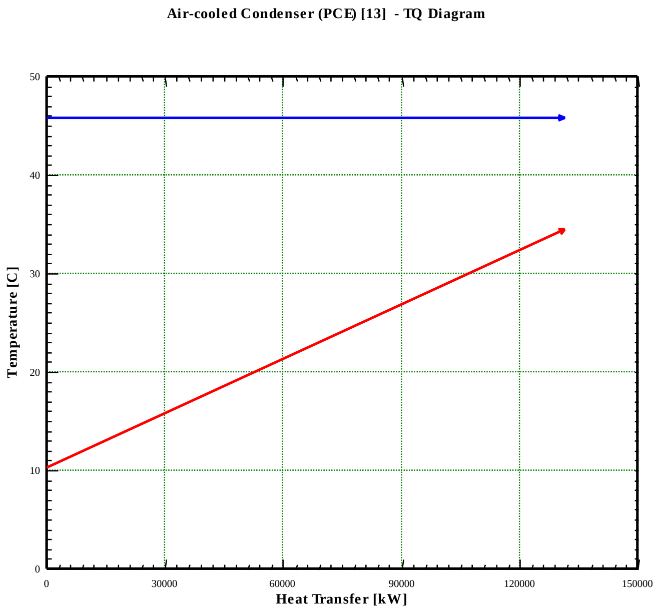
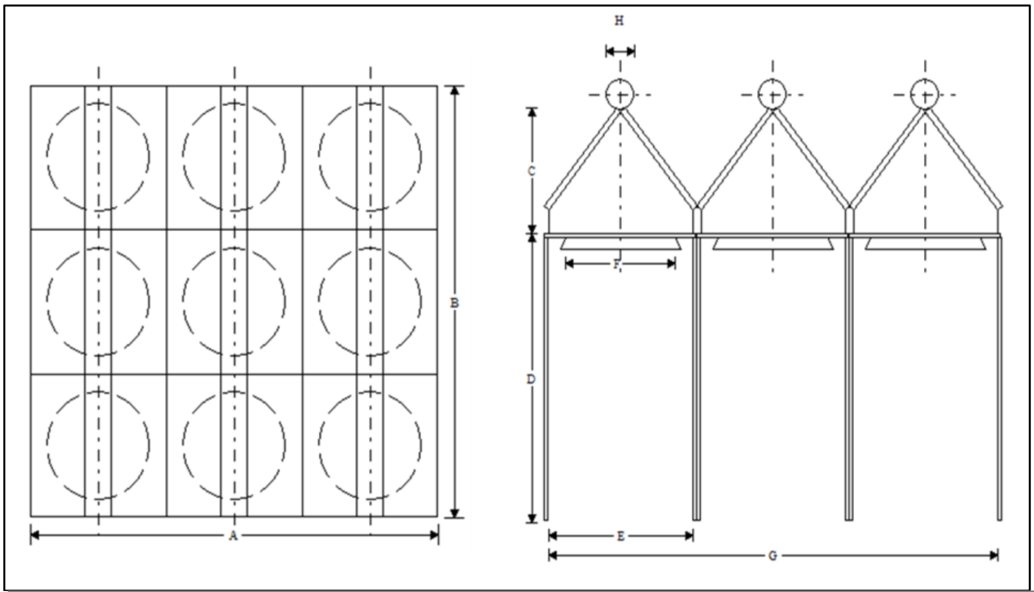


Figure 7: Temperature and Heat (TQ) diagram for the ACC solution

Note: The exhaust steam temperature in the condenser is represented by the blue line, whereas the cooling air temperature is depicted by the red line.

5.3 Physical Layout

The design of the ACC and exhaust duct is based on the boundary conditions presented in **Table 1** and a maximum exhaust steam design velocity 60 m/s in the duct. The resulting footprint of the ACC unit is shown on **Figure 8**. The footprint is approximately 34 x 34 m (1,156 m^2) with a total height of 23 m. The footprint can also have a rectangular arrangements covering a similar area and cooling units providing the equivalent cooling capacity.



A	B	C	D	E	F	G	H
33,8 m	33,8 m	8,6 m	14,7 m	11,3 m	8,7 m	33,8 m	2,3 m

Figure 8: Estimated physical layout of air cooling condensers

Note: Plan view (left) and elevation view (right).

As shown on **Figure 8**, the units are elevated by almost 15 m from ground level. This is required to allow air inflow and ensure sufficient NPSH for the condensate pumps.

ACC installation examples are presented below.

Figure 9: ACC Installation example (1)

Figure 10: ACC Installation example (2)

Figure 11: ACC Installation example (3)

5.4 Capital Investment Required

The above footprint, modelling and preliminary sizing is the basis for Ramboll's capital cost estimate. The CAPEX required for the ACC option is higher than that required for wet and hybrid cooling options.

6. WET COOLING TOWER

6.1 Configuration

With a wet cooling tower exhaust steam is condensed in a once-through surface condenser placed beneath the turbine. Pumps below the condenser lift the condensate back to the deaerator for boiler supply. A height difference between condenser and pumps is required to ensure the necessary NPSH, thereby minimizing cavitation risk. The minimum height difference depends on the condensate pump NPSH requirement. Ramboll estimates that the steam turbine needs to be placed 15 to 20 meters above the condensate pumps.

Wet towers cool hot water from the once-through condenser, primarily through evaporative heat transfer.

Water in the cooling circuit is treated to prevent microorganism growth that can cause legionnaires disease. This may include filtering to remove particles to prevent scaling and fouling, and the addition of chlorine to prevent microorganism growth. A continuous blow down of water from the cooling tower is also performed to keep concentrations of salts and minerals below acceptable levels.

Chlorine in the water circuit could cause undesirable effects by leaving the cooling tower as particulate emissions with off-gas, potentially causing/accelerating corrosion of building surfaces and structures. Therefore, cooling towers are usually placed away from the plant and buildings. More expensive sanitising agents such as bromine and hydrogen peroxide are available. These can mitigate the disadvantages of chlorine use.

Figure 12 shows a conceptual flow diagram of the cooling tower option. The cooling tower includes a sump, and circulation pump installation, as well as the once-through condenser under the turbine.

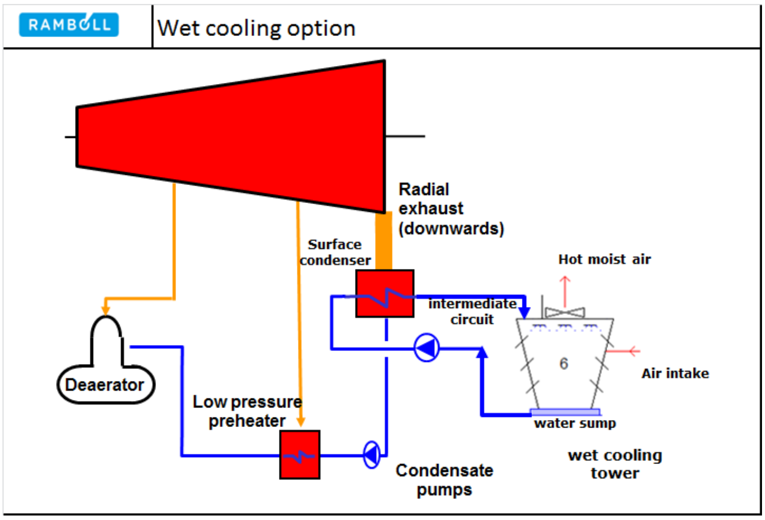


Figure 12: Process setup of the cooling tower option

Cooling tower installation examples are presented below.

Figure 13: Wet cooling tower installation example (1)

Figure 14: Wet cooling tower installation example (2)

The working principle of the cooling tower is depicted by arrows in **Figure 15**. Water from the condenser is sprayed through nozzles onto the side of the cooling tower. Air fans located on top of the cooling tower draw atmospheric air through the water mist. Air becomes saturated with water leading to an evaporative cooling effect. Evaporated water losses are replaced by fresh water (make up water). The sump of cooling water in the bottom of the cooling tower is slowly discharged to flush away the build-up of salts (blow down). The rate of blowdown is highly dependent on the quality of make-up water.

Fresh water consumption is estimated as 1.7 to 2.3 m^3 per tonne of waste processed. Water use is dependent on make-up water quality, blow down needs, ambient temperature and relative humidity.

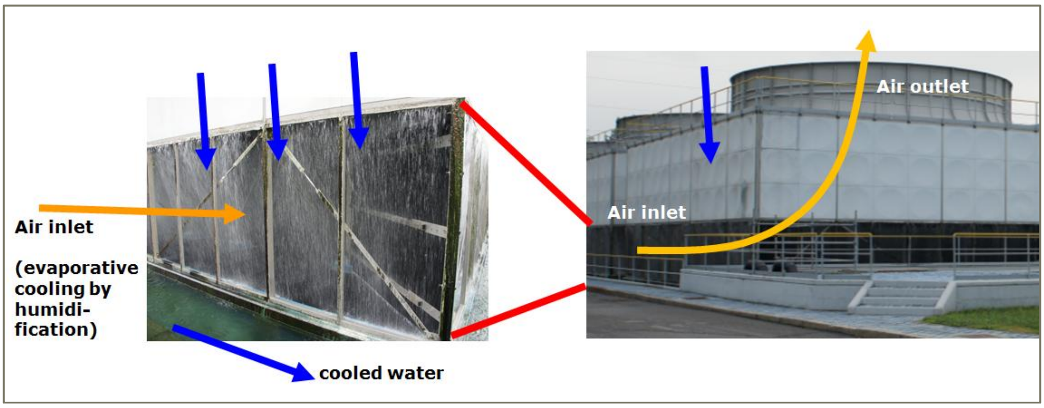


Figure 15: Pictures and principles of cooling tower

6.2 Thermodynamic Modelling Results

The thermodynamic modelling results for the cooling tower option are shown in **Figure 16**. The water circulation pump and air fans consumes a total of 0.70 MWe. This is given by a design temperature lift on the water side of 15 °C. The total water consumption of the system is estimated to be 176 t/h. This corresponds to 2.0 m^3/tonne of waste processed, thus equating to an estimated annual water consumption of 1.4 million m^3. This is similar to the annual quantity of water consumed by the current Edmonton facility.

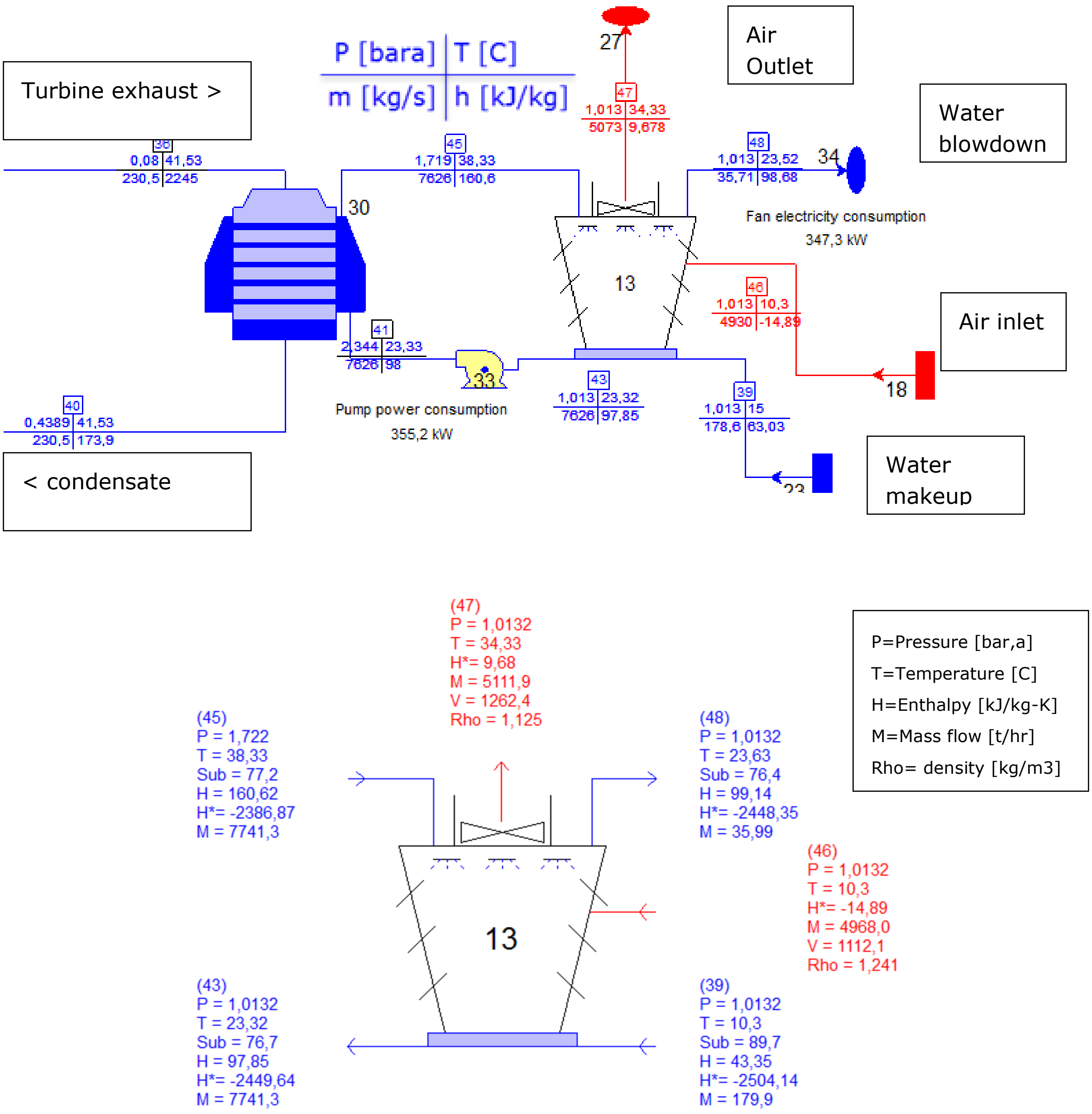


Figure 16: Thermodynamic modelling results for the cooling tower option

Note: Component 30 is the shell and tube condenser, component 13 is the cooling tower, 33 is the cooling tower circulation pump.

Figure 17 shows the temperature change with heat transfer (temperature versus heat reject curve (TQ diagram)). This figure illustrates that 135 MWth of heat is transferred from the water circuit by means of heating the incoming air and by means of saturating the air (evaporation).

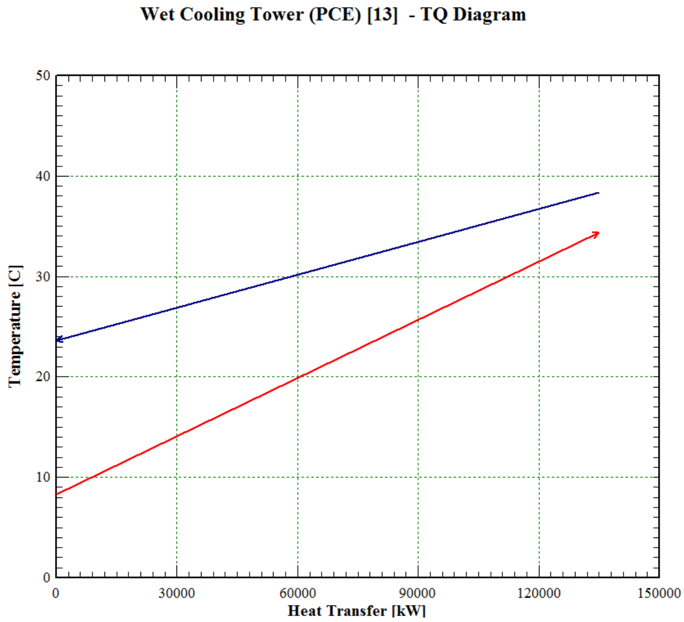


Figure 17: Temperature (T) Heat transfer (Q) diagram for the cooling tower

Note: The blue line represents the temperature of the water flow and the red line represents the temperature of the air flow drawn through the cooling tower. The air temperature shown is the wet bulb temperature.

Figure 18 is a psychrometric chart showing the state of airflow. The incoming air is modelled at 10.3 °C and with a relative humidity of (RH) 77.1 %, resulting in a wet bulb temperature (adiabatic saturation temperature) of 8.3 °C. The air leaving the cooling tower is heated to 34 °C and relative humidity of 100 % (E). When this saturated air leaves the cooling tower, it will mix with the ambient air, following the mixing line E – A, and its temperature will rapidly drop to match the surrounding temperatures, causing the evaporated water to condense, thus resulting in a visible plume.

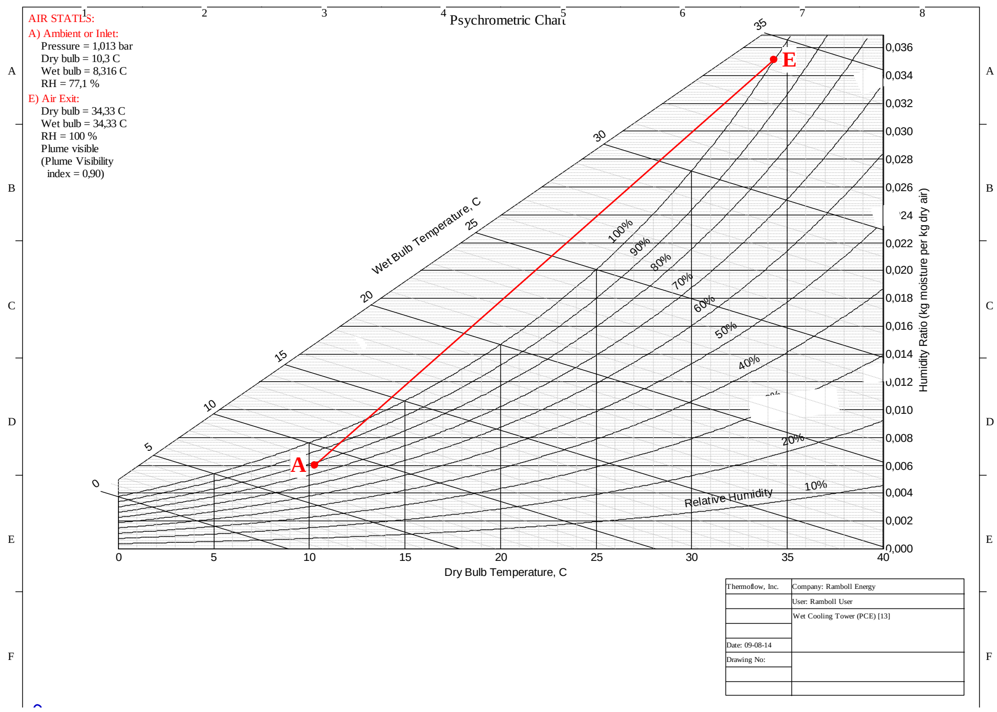
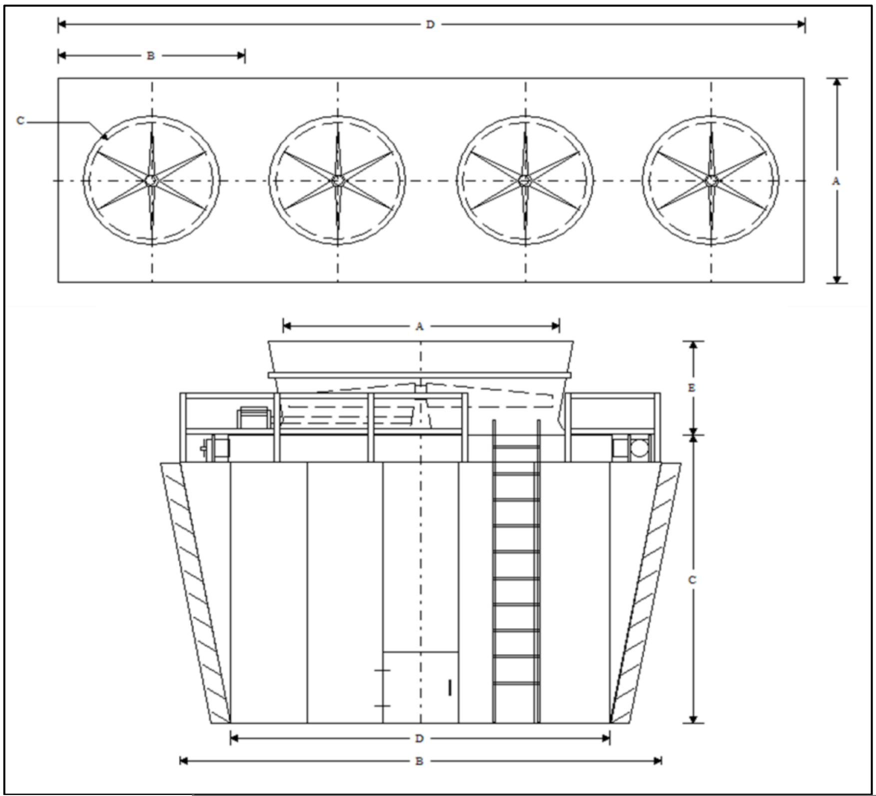


Figure 18: Psychrometric chart for the air flowing into the cooling tower

Note: Point 'A' is the initial state, point 'E' shows the final state just as the air flow exits the cooling tower.

6.3 Physical Layout

The footprint of a wet cooling tower system is estimated as 429 m^2. This is smaller than that of an ACC due to higher specific heat of water evaporation. The approximate layout of the cooling tower is presented in **Figure 19**.



	A	B	C	D	E
Plan view	10,9 m	9,7 m	6,4 m	38,6 m	-
Elevation view	6,4 m	10,9 m	7,1 m	8,5 m	2,3 m

Figure 19: Estimated wet cooling tower layout. Plan view (top) and elevation view (bottom)

As discussed above, a shell and tube type condenser is installed at the turbine steam outlet. The condenser heat transfer area requirement is approximately 5,000 m^2. This will be achieved with condenser dimensions equating to 11.2 x 3.4 x 5.7 m (L x W x H).

6.4 Capital Investment Required

The above footprint, modelling and preliminary sizing is the basis for Ramboll's capital cost estimate. The CAPEX required for the wet cooling tower option is both lower than that required for ACC and hybrid cooling options.

7. HYBRID COOLING TOWER

7.1 Configuration

A hybrid cooling tower is a wet cooling tower with a dry section. The purpose of this solution is to limit plume visibility. The wet part produces a flow of saturated air, just as the pure wet cooling tower. The dry section produces a heated, dry air flow. These two streams are then mixed and, if well designed, the mixture is dry enough to avoid a visible plume under typical weather conditions.

The performance and issues of the hybrid cooling tower are generally the same as those described above for the wet cooling tower. The hybrid cooling tower is connected as per a wet cooling tower via a once-through water condenser as shown in **Figure 12**.

Air flow in a hybrid tower is significantly higher than that in a wet cooling tower. This is because the dry section needs more air to dissipate the same amount of energy. Thus hybrid tower fans and footprint is larger than those of a wet cooling tower. Power consumption of the hybrid tower fans is higher than that of the wet cooling tower. Water consumption is slightly lower than the simple wet tower because some heat is dissipated in the dry section without evaporation.

Hybrid towers can be designed to limit plume formation to restricted conditions. If plume formation is to be eliminated at lower temperatures, the dry section, and thus footprint, cost and electricity consumption will be larger/higher. In the following section the hybrid tower is designed to eliminate plumes down to freezing point (0 °C).

7.2 Thermodynamic Modelling Results

In the following the dry section is sized to supply 14 % of the cooling needs to eliminate plumes down to the freezing point at a relative humidity of 77.1%.

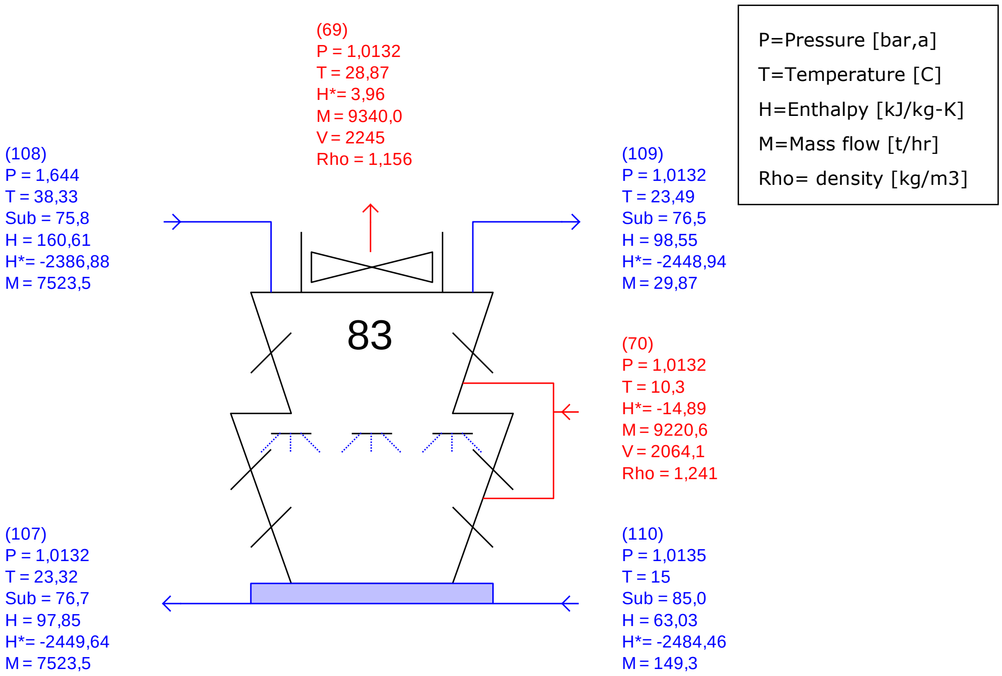


Figure 20: Thermodynamic modelling results for the hybrid cooling tower option

The ability of the plant to eliminate plumes can be evaluated in psychrometric charts. **Figure 21** and **Figure 22** respectively show the psychrometric charts for the hybrid cooling tower at ambient temperatures of 10.3 °C and 0 °C. The line A - D follows the ambient air passing through the dry section and W indicates the wet air after the wet section. E indicates the resulting exiting mixture from the dry (D) and wet (W) sections. When mixed air (E) exits the tower it will be mix further with the ambient air, following the mixing line E - A. Since this line does not reach above 100 % saturation, there will be no visible plume. This can be compared with the psychrometric chart for the wet cooling tower (**Figure 18**), where E - A passes well above 100 % saturation indicating that there will be a visible plume.

With 14 % cooling provided by the dry section the hybrid solution water consumption will be approximately 14 % lower than the wet tower solution. Therefore, an estimated water requirement of 149 t/h. Water consumption will be less during cooler ambient conditions because the dry section will be able provide more cooling.

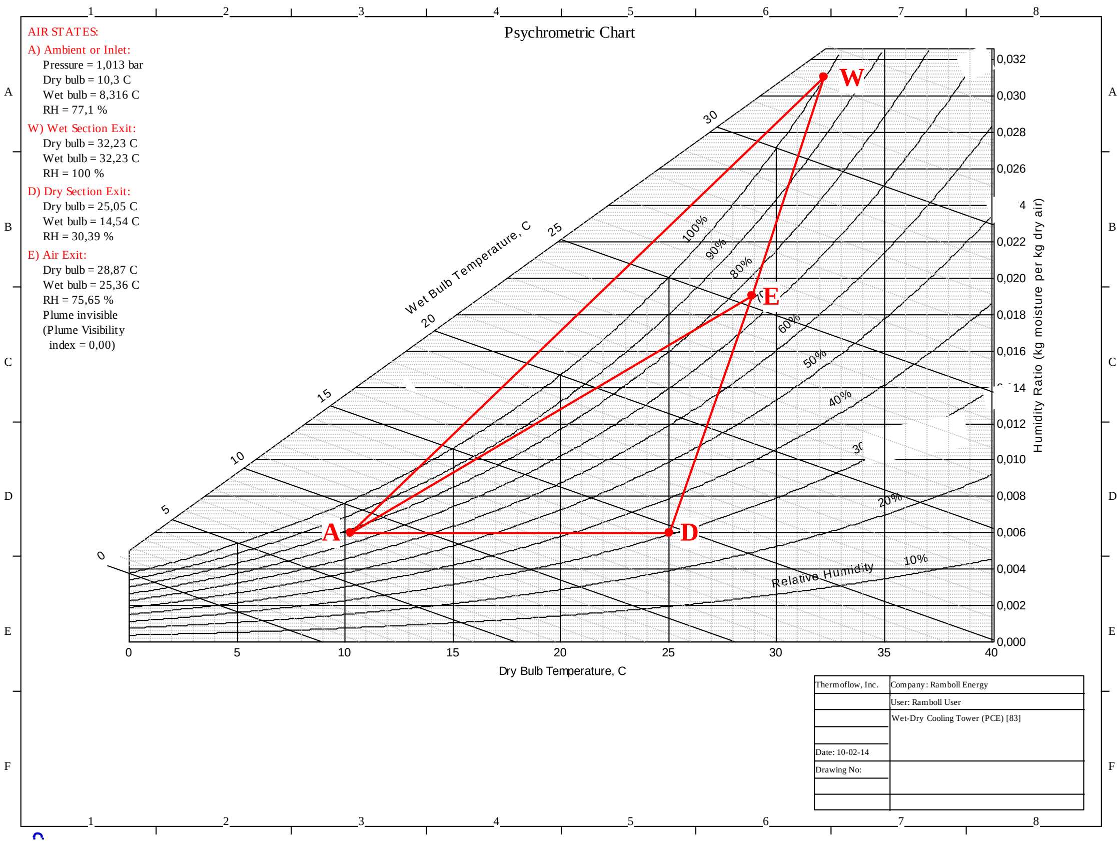


Figure 21: Psychrometric chart for the air flow in the hybrid cooling tower at 10.3 °C ambient temperature

Note: Point 'A' is the initial state, point 'W' is the state of air leaving the wet part, 'D' is the state of air leaving the dry part. Point 'E' shows the state of the mixed air after final state just as the air flow exits the cooling tower.

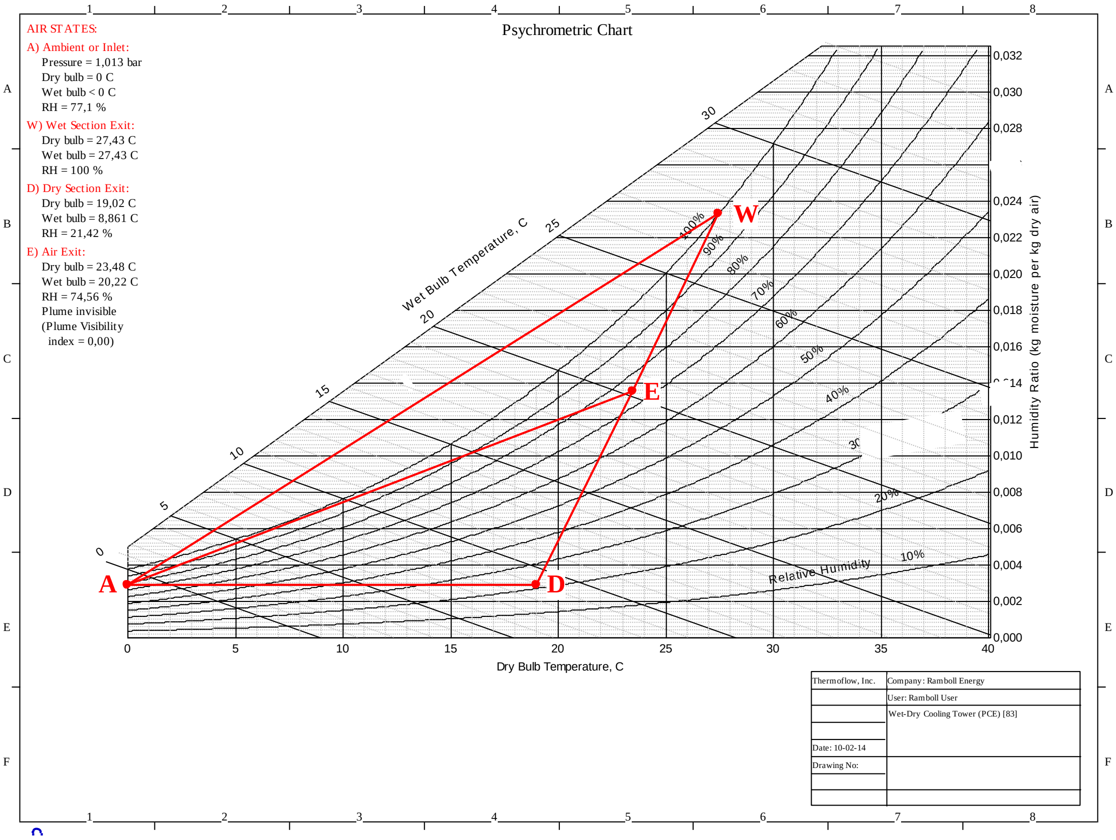
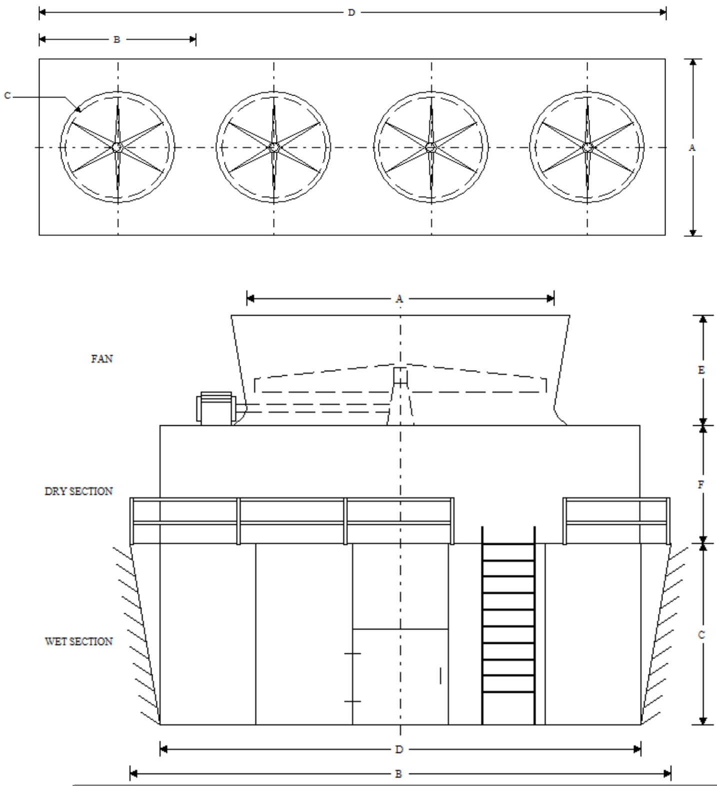


Figure 22: Psychrometric chart for the air flow in the hybrid cooling tower at 0 °C ambient temperature

Note: Point 'A' is the initial state, point 'W' is the state of air leaving the wet part, 'D' is the state of air leaving the dry part. Point 'E' shows the state of the mixed air after final state just as the air flow exits the cooling tower.

7.3 Physical layout

The footprint of a hybrid cooling tower system is estimated as 807 m^2. This is larger than the wet cooling tower, but still much smaller than that of an ACC. The approximate layout of the cooling tower is presented in **Figure 23**.



	A	B	C	D	E	F
Plan view	15,4 m	13,1 m	8,7 m	52,4 m	-	-
Elevation view	8,7 m	15,4 m	5,2 m	13,7 m	3,1 m	3,3 m

Figure 23: Estimated wet cooling tower layout. Plan view (top) and elevation view (bottom)

The turbine condenser will be identical to that of the wet cooling tower.

7.4 Capital Investment Required

The above sizing, modelling and preliminary sizing is the basis for Ramboll's capital cost estimate. The CAPEX required for the hybrid cooling tower option is higher than the wet cooling tower option, but lower than the ACC option.

8. PERFORMANCE COMPARISON

The lower turbine exhaust pressure with wet and hybrid cooling towers yields higher power production than with the ACC solution. There are also minor differences in auxiliary power consumption between the cooling technology options. This has been factored into the comparisons below.

The main performance figures for the options are summarised in **Table 2**.

These performance figures are based on the average ambient conditions, variations across the year are not considered in this comparison.

Figures based on design @ 10.3°C ambient temperature	ACC option	Wet option	Hybrid option	Unit
Net power difference (MWe)	(base)	+ 0.70	+0.43	MWe
Water consumption (m^3/h)	-	176	149	m^3/h
Waste water discharge (m^3/h)	-	35	30	m^3/h

Table 2: Performance of ACC and wet cooling tower

9. CONCLUSION

The following sets out comparisons for the cooling technology options considered:

	Air Cooled Condensers (ACC)	Wet Cooling Tower	Hybrid Cooling Tower
Relative cost of cooling technology option	Highest	Lowest	Middle
Turbine back pressure	100 mbara	80 mbara	80 mbara
Net power gain over ACC cooling	-	700 kWe	430 kWe
Estimated footprint	1,156 m^2	422 m^2	807 m^2
Plume visibility	None	Normally visible	None down to 0°C ambient conditions
Approximate water consumption (figures calculated at 10.3°C ambient, 77% humidity)	-	2.0 m^3/t_{waste} (range: ~ 1.7 to 2.3 m^3/t, mainly dependant on ambient temperature)	1.7 m^3/t_{waste} (with 14% dry cooling)

The assessment of cooling plant options for the ERF site can be summarised as follows:

- The ACC system would typically induce a turbine back pressure of 100 mbara at an ambient design temperature of 10.3 °C. A wet or hybrid cooling tower solution will enable a back pressure of approximately 80 mbara. This effect leads to approximately 700 kWe of additional power production by the wet or hybrid tower options.

- The wet cooling solution has the smallest plant footprint (approximately 50% of the ACC option).

- Wet cooling towers are high water consumers and will produce visible plumes. Water vapour plume is often perceived as pollutant containing smoke.

- Wet cooling towers can sometimes result in water settlement/condensation outside of the site boundary and will be taken into consideration in planning and permit applications. The water used for wet cooling is treated with chlorine to prevent microbial growth and evaporated water can accelerate corrosion of plant structures and buildings. More expensive sanitising agents such as bromine and hydrogen peroxide are available. These can mitigate the disadvantages of chlorine use.

- Hybrid cooling towers can provide the same cooling as wet cooling towers without the visible plume and use less water. Disadvantages relative to wet cooling are higher power consumption (+260 kW), larger footprint (+90 %) and higher investment costs. The hybrid system is still more cost effective and yields more net power than the ACC system.

- Month-by-month analysis of cooling options, taking expected variations in ambient conditions into account, will not change the conclusion because the ACC will have a lower output than design power output in hotter months. This is not compensated by a higher power output in the colder months. Therefore, a month-by-month analysis is likely to further disadvantage the ACC in terms of financial viability. This analysis needs to be undertaken at the detailed design phase for sizing purposes.