Annex I: Comparison of the processes at Facility with the BREF for Industrial cooling systems (published December 2001).

1. A horizontal approach to defining BAT for cooling systems

Aspect of BAT	BAT	Status at Installation
Introduction	Before summarising the BAT conclusions in this chapter, a short explanation is given on how the horizontal character of this BREF should be interpreted. In a horizontal approach it is assumed that the environmental aspects of the applied techniques and the associated reduction measures can be assessed and that generic BAT can be identified that are independent of the industrial processes in which techniques are applied. Industrial cooling systems are an integrated part of the industrial process to be cooled. The cooling systems within the scope of this document are used in many of the industrial sectors under the scope of IPPC. Consequently, the variety of applications, techniques and operational practices is enormous. Additionally, the thermodynamic character of the process leads to further variations in performance and consequently in the environmental effects. Due to this large variation, comparisons between techniques leading to general conclusions on BAT are difficult. The identification of a general preventive approach is considered to be possible, based on practical experience with reduction of emissions from cooling systems.	

Aspect of BAT	BAT	Status at Installation
	In this preventive approach or, primary BAT-approach, attention is firstly given to the process to be cooled. The design and the construction of the cooling system are an essential second step, in particular for new installations. Finally, changes of equipment and the way in which the cooling system should be operated will address new installations, but are particularly important in existing systems, where technological options are considerably limited and cost-intensive. Careful evaluations must be performed case by case.	
Integrated heat management **Industrial cooling = Heat management**	Cooling of industrial processes can be considered as heat management and is part of the total energy management within a plant. The amount and level of heat to be dissipated requires a certain level of cooling systems performance. This performance level will in turn affect the system configuration, design and operation and consequently the cooling systems' environmental performance (direct impact). Reversibly, the cooling performance will also affect the overall efficiency of the industrial process (indirect impact). Both impacts, direct and indirect, need to be balanced, taking into account all variables. Every change in the cooling system has to be considered against the consequences it may have for this balance. This concept can be used as a starting point to formulate the first principle of BAT for cooling systems. BAT for all installations is an integrated approach to reduce the environmental impact of industrial cooling systems	The CCGT condenser and other auxiliaries cooling demands are met via once-through water cooling using seawater as the heat transfer fluid as detailed in section C.02.02.01. This technology shall enhance the efficiency of the CCGT. There are mainly two alternative cooling systems configurations widely used in power plants: · Dry air cooling system: This system includes air cooled condensers for main condenser cooling demand and fin-fan coolers for auxiliary cooling. No cooling water is required minimizing environmental impact; however the power output and efficiency of the power plant will decrease due to higher vacuum levels. A considerably larger plan plot area and will be required. The capital expenditure as well as O&M costs will sharply increase with the dry cooling system. · Evaporative cooling: This cooling concept is used in wet or hybrid cooling tower. The water requirement is about 40 to 60 times lower than the amount of water required by once-through cooling system. In some areas, visible

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	maintaining the balance between both the direct and indirect impacts. In other words, the effect of an emission reduction has to be balanced against the potential change in the overall energy efficiency. There is currently no minimum ratio in terms of the environmental benefits and the possible loss in overall energy efficiency that can be used as a benchmark to arrive at techniques that can be considered BAT. Nevertheless, this concept can be used to compare alternatives (Chapter 3.2 and Annex II).	plumes can be generated in cooling towers arising visual impact concerns. Plumes can be abated with more sophisticated hybrid cooling towers. A larger plan plot area will be required for cooling tower systems in any case. CAPEX and well as O&M costs are typically higher for this Alternative.
Integrated heat management **Reduction of the level of heat discharge by optimization of internal/external heat reuse**	A preventive approach should start with the industrial process requiring heat dissipation and aim to reduce the need for heat discharge in the first place. In fact, discharge of heat is wasting energy and as such not BAT. Reuse of heat within the process should always be a first step in the evaluation of cooling needs. Process-integrated energy measures are outside the scope of this document, but reference is made to other BAT Reference Documents drafted in the framework of IPPC describing options for energy measures. In a greenfield situation, assessment of the required heat capacity can only be BAT if it is the outcome of maximum use of the internal and external available and applicable options for reuse of excess heat. In an existing installation, optimizing internal and external reuse and reducing the amount and level of heat to be discharged must also precede any change to the potential capacity of the applied cooling system. Increasing the	Noted Heat is dissipated to the environment when its exergy content is such that it’s not justifiable to recover further energy. The only heat dissipation in the new installations takes place in the CCGT condensers. Steam coming out from the steam turbine at low pressure and temperature is condensed and this latent heat is rejected into the seawater. Recovering this heat is unjustifiable because the exergy content is very low, further expansion of the steam in the steam turbine is unpractical given the moisture content of this steam. This is common practice in steam cycles.

Aspect of BAT	BAT	Status at Installation
	efficiency of an existing cooling system by improving systems operation must be evaluated against an increase of efficiency by technological measures through retrofit or technological change. In general and for large existing cooling systems, the improvement of the systems operation is considered to be more cost effective than the application of new or improved technology and can therefore be regarded as BAT.	
Integrated heat management **Cooling system and process requirements**	Once the level and amount of waste heat generated by the process is established and no further reduction of waste heat can be achieved, an initial selection of a cooling system can be made in the light of the process requirements discussed in Chapter 1. Every process has its unique combination of requirements, where the level of control of the process, process reliability and safety play an important role. This makes it almost impossible at this stage to make a first characterisation of BAT, but the following conclusions can be drawn with respect to a number of process characteristics. The application of the ambient temperature levels is based on the experiences in Europe in applying cooling systems under different climatic conditions. Generally, dry bulb temperatures do not justify cooling away low level waste, heat and water-cooling is preferred. But in areas with low average dry bulb temperatures dry air-cooling is applied to cool down to lower process temperatures (after options for reuse have been explored). Water-cooling, if sufficient water is available, can then dissipate the residual amount of	Noted The cooling capacity shall be higher than 10 MWth. Once-through technology is considered BAT as per part 2 of this document. The other alternatives are not feasible in this projects due to the following reasons: 1) Wet cooling technology such as cooling towers require a big footprint which is not available on site. The cooling capacity of this alternative shall be lower than the once-through. This will have a direct impact on the efficiency of the power plant. Cooling towers will have higher visual impact and plumes. 2) Dry cooling technology such as air cooled condensers is not feasible for this project due to the lack of available space on site as it requires even bigger footprint than cooling towers. The dry bulb temperature in Malta is very high throughout the year which makes this alternative the least recommended

Aspect of BAT	BAT	Status at Installation
	waste heat. Hazardous process substances, which involve a high environmental risk to the aquatic environment in case of leakage, should be cooled by means of indirect cooling systems to prevent an uncontrollable situation. The selection of a cooling configuration should be based on a comparison between the different feasible alternatives within all requirements of the process. Process requirements are for example control of chemical reactions, reliability of process performance and maintenance of required safety levels. The aim is to minimise the indirect impact of the selected alternative. For each alternative the environmental performances can be best compared if expressed in direct and indirect use of energy (kWe) per unit of energy discharged (kWth). Another way to compare configurations is to express the change in direct energy use (kWe) of the cooling system and the change in production level of the process in tonnes, both per unit of energy discharged (kWth). A change in cooling technology to reduce the environmental impact can only be considered BAT if the efficiency of cooling is maintained at the same level or, even better, at an increased level. See Figure 1.	and will have the highest impact on efficiency. It's estimated that the impact in the power plant efficiency can be circa 2.5% reduction. 3) The existing ENEMALTA water intake infrastructure will be re-used in the project. This simplifies and reduces the environmental impact during construction.
Integrated heat management	The site-imposed limits apply particularly to new installations, where a cooling system must still be selected.	Noted

Aspect of BAT	BAT	Status at Installation
Cooling system and site requirements	If the required heat discharge capacity is known it may influence the selection of an appropriate site. For temperature-sensitive processes it is BAT to select the site with the required availability of cooling water. For many reasons new installations are not always erected on a site that is preferred from a cooling technology point of view, whereas for both new and existing installations the site characteristics are clear once the site is known. The most important thermodynamic characteristic of a site is its annual climatic pattern described by the dry and wet bulb temperatures. Other characteristics identified are space, water availability to cool and to discharge and the surrounding sensitive areas (urban and industrial). With respect to groundwater, it can be BAT to apply a dry cooling system following the principle to minimise the use of groundwater, particularly in those areas where depletion of aquifers cannot be ruled out. In Figure 2, BAT examples are shown that have been identified for a few site characteristics.	For coastal sites for cooling applications with a cooling capacity demand of >10MWth Once-through technology is BAT as per figure 2. Delimara site is a coastal site with very limited space available. Mean weather data is included below: · Mean dry bulb temperature: 24degC · Mean sea water temperature: 21degC · Mean relative humidity (%): 65% The cooling duty required shall be higher than 10 MWth. Once-through technology is considered BAT as per table 4.2 of this document.
Application of BAT in industrial cooling systems	In Chapter 1 the outline of a preventive approach is presented showing how a step-by-step evaluation of all constraints can lead to what may be called "Best available cooling technique". Within the framework of this approach, Chapter 1 and Chapter 3 and the associated Annexes discuss the factors and offer techniques involved in the identification of potential BAT for the major cooling	Noted O&M procedures shall be in place to preserve the effectiveness of the cooling system, avoiding the necessity of additional seawater or impacting on the efficiency. Fouling of the main CCGT condenser shall be prevented by the dosing of biocides and mechanical cleaning. These shall be

Aspect of BAT	BAT	Status at Installation
	configurations using water and/or air. The optimization of a cooling system to reduce its environmental impact is a complex exercise and not an exact mathematical comparison. In other words, combining techniques selected from the BAT-tables does not lead to a BAT cooling system. The final BAT solution will be a site-specific solution. However, it is believed that, based on experience in industry, conclusions can be drawn on BAT, in quantified terms where possible. In Chapter 3 options for reducing emissions into the environment have been presented based on the information submitted by the TWG. For each environmental issue and for each relevant cooling configuration an attempt has been made to identify a general approach and arrive at BAT. Some techniques are described in more detail in the Annexes. Emphasis is clearly on the water-related problems with a focus on reduction of the application of biocides and blacklisted substances. The proposed techniques are applied techniques. They have proven to be effective, although quantification is difficult and they may create unrealistic expectations. It can be assumed that all measures proposed as BAT, and which are not entirely dependant on the local situation, can be considered for new systems. With respect to existing installations, care must be taken as the assessment is more difficult where options are limited and depend on a multitude of (process) factors. There do not seem to be many obstacles to implementation of operational measures	dosed intermittently depending on the seawater temperature. Entrainment of aquatic organisms is reduced by the filtering and screening systems of the exiting seawater intake. The level of dissipated heat shall be low (around 29degC) as per Table 4.1. The cooling medium shall be seawater. Delimara site is a coastal site with very limited space available. Mean weather data is included below: · Mean dry bulb temperature: 24degC · Mean sea water temperature: 21degC · Mean relative humidity (%): 65% The cooling duty required shall be higher than 10 MWth. Once-through technology is considered BAT as per table 4.2 of this document.

Aspect of BAT	BAT	Status at Installation
	in existing cooling systems, unless the technological design limits the number of options for modification. In Figure 3 to Figure 11, techniques are presented that are considered BAT, following on from the primary BAT-approach for: • increasing the overall energy efficiency, • reduction of use of water and of cooling water additives, • reduction of emissions to air and water, • reduction of noise, • reduction of entrainment of aquatic organisms and • reduction of biological risks. No clear BAT has been identified on the reduction of waste or techniques to handle waste avoiding environmental problems, such as contamination of soil and water, or air in the case of incineration. For each environmental issue the consequences for other media of the application of a reduction technique have been identified. Generally speaking every change made to a cooling system must be carefully balanced against the associated effects and in this sense the optimisation of industrial cooling is a cross-media issue. For some measures BAT-values have been identified. However, addressing the application of different cooling techniques in a multitude of varying process conditions does not allow for clear associated levels. In those cases a	

Aspect of BAT	BAT	Status at Installation
	qualitative description is given. For new cooling installations it is BAT to start identifying reduction measures in the design phase, applying equipment with low energy requiring requirement and by choosing the appropriate material for equipment in contact with the process substance and/or the cooling water. In this sense the following quotation is exemplary: “in practice… attention to design, layout and maintenance of the cooling water system has a relatively low priority compared to the environmental consequences of a poorly designed and/or operated cooling water system. Since little attention is paid to design factors, treatments often have to make up for bad design, and therefore need to be chosen in such a way that they minimize risks of fouling. Few changes of this attitude are to be expected as long as there is a low level of awareness of the long-term costs of operating and maintaining poorly designed CWS” [tm005, Van Donk and Jenner, 1996]. If dry air cooling systems are the preferred option, measures are primarily related to reduction of direct energy consumption and noise emissions and the optimization of size with respect to the required cooling surface. For existing installations, technological measures can be BAT under certain circumstances. Generally, a change in technology is cost-intensive where overall efficiency must be maintained. Cost evaluation should then compare investment costs of the change versus the change in	

Aspect of BAT	BAT	Status at Installation
	operational costs and validate the reduction effect versus other environmental consequences. For example, it would need a comparison between the environmental effect of recirculating the cooling water - requiring the application of biocidal water treatment - against a once-through system without biocides, but a large heat emission to the aquatic environment. In the case of pre-assembled off-the-peg cooling towers, a change in technology seems feasible both technically and economically. No comparable data have been submitted that can support this, but supplier experience is that it is relatively easy to change small size cooling towers, for example, from a closed recirculating wet to a closed recirculating hybrid or wet/dry configuration. This would not need major process modifications or construction work. For large custom-designed towers that are erected on-site, technological changes are not easy to make. A different technology generally means a completely new cooling tower. For existing wet cooling systems, where the focus is largely on environmental measures to reduce water use and to emissions of chemicals to the surface water, BAT has not so much technological but rather an operational character. Monitoring, operation and maintenance are the key issues here.	

Figure 1:

Table 4.1: Examples of process requirements and BAT

Process characteristics	Criteria	Primary BAT approach	Remark	Reference
Level of dissipated heat high (> 60°C)	Reduce use of water and chemicals and improve overall energy efficiency	(Pre-) cooling with dry air	Energy efficiency and size of cooling system are limiting factors	Section 1.1/1.3
Level of dissipated heat medium (25-60°C)	Improve overall energy efficiency	Not evident	Site-specific	Section 1.1/1.3
Level of dissipated heat low (<25°C)	Improve overall energy efficiency	Water cooling	Site selection	Section 1.1/1.3
Low and medium heat level and capacity	Optimum overall energy efficiency with water saving and visible plume reduction	Wet and hybrid cooling system	Dry cooling less suitable due to required space and loss of overall energy efficiency	Section 1.4
Hazardous substances to be cooled involving high environmental risk	Reduction of risk of leakage	Indirect cooling system	Accept an increase in approach	Section 1.4 and Annex VI

Figure 2:

Table 4.2: Examples of site characteristics and BAT

Characteristics of site	Criteria	Primary BAT approach	Remarks	Reference
Climate	Required design temperature	Assess variation in wet and dry bulb T	With high dry bulb T dry air cooling generally has lower Energy efficiency	Section 1.4.3
Space	Restricted surface on-site	(Pre-assembled) Roof type constructions	Limits to size and weight of the cooling system	Section 1.4.2
Surface water availability	Restricted availability	Recirculating systems	Wet, dry or hybrid feasible	Section 2.3 and 3.3
Sensitivity of receiving water body for thermal loads	Meet capacity to accommodate thermal load	- Optimise level of heat reuse - Use recirculating systems - Site selection (new cooling system)		Section 1.1
Restricted availability of groundwater	Minimisation of groundwater use	Air cooling if no adequate alternative water source is available	Accept energy penalty	Section 3.3
Coastal area	Large capacity > 10 MW_{th}	Once-through systems	Avoid mixing of local thermal plume near intake point, e.g. by deep water extraction below mixing zone using temperature stratification	Section 1.2.1 / Section 3.2 /Annex XI.3
Specific site requirements	In case of obligation forplume reduction and reduced tower height	Apply hybrid cooling system	Accept energy penalty	Ch.2

2. Reduction of energy consumption

Aspect of BAT	BAT	Status at Installation
General	It is BAT in the design phase of a cooling system: • To reduce resistance to water and airflow • To apply high efficiency/low energy equipment • To reduce the amount of energy demanding equipment (Annex XI.8.1) • To apply optimised cooling water treatment in once-through systems and wet cooling towers to keep surfaces clean and avoid scaling, fouling and corrosion. For each individual case a combination of the above-mentioned factors should lead to the lowest attainable energy consumption to operate a cooling system. Concerning BAT a number of techniques/approaches have been identified.	Noted 1) Resistance to water is minimized by using bid diameters in water pipelines and by minimizing the amount of bends in the system. 2) Cooling water treatment shall be applied to keep heat exchanger surface free of scale and reduce system resistance and so pumping power demand. 3) The main cooling water pumps shall be driven by a variable speed driver. The speed of the pump shall be adapted to the water demand optimizing the energy consumed in the pumping of seawater and so optimizing the global efficiency.
Identified reduction techniques within the BAT-approach	In an integrated approach to cooling an industrial process, both the direct and indirect use of energy are taken into account. In terms of the overall energy efficiency of an installation, the use of once-through systems is BAT, in particular for processes requiring large cooling capacities (e.g. > 10 MWth). In the case of rivers and/or estuaries once-through can be acceptable if also: § extension of heat plume in the surface water leaves passage for fish migration; § cooling water intake is designed aiming at reduced fish entrainment;	Note Once-through seawater technology (BAT) shall be adopted for this project

Aspect of BAT	BAT	Status at Installation
	§ heat load does not interfere with other users of receiving surface water. For power stations, if once-through is not possible, natural draught wet cooling towers are most energy-efficient than other cooling configurations, but application can be restricted because of the visual impact of their overall height. See Figure 3.	

Figure 3:

Table 4.3: BAT for increasing overall energy efficiency

Relevance	Criterion	Primary BAT approach	Remarks	Reference
Large cooling capacity	Overall energy efficiency	Select site for once-through option	See text above table	Section 3.2
All systems	Overall energy efficiency	Apply option for variable operation	Identify required cooling range	Section 1.4
All systems	Variable operation	Modulation of air/ water flow	Avoid instability cavitation in system (corrosion and erosion)	
All wet systems	Clean circuit/ exchanger surfaces	Optimised water treatment and pipe surface treatment	Requires adequate monitoring	Section 3.4
Once-through systems	Maintain cooling efficiency	Avoid recirculation of warm water plume in rivers and minimise it in estuaries and on marine sites		Annex XII
All cooling towers	Reduce specific energy consumption	Apply pumping heads and fans with reduced energy consumption		

3. Reduction of water requirements

Aspect of BAT	BAT	Status at Installation
General	For new systems the following statements can be made: • In the light of the overall energy balance, cooling with water is most efficient; • For new installations a site should be selected for the availability of sufficient quantities of (surface) water in the case of large cooling water demand; • The cooling demand should be reduced by optimising heat reuse; • For new installations a site should be selected for the availability of an adequate receiving water, particularly in case of large cooling water discharges; • Where water availability is limited, a technology should be chosen that enables different modes of operation requiring less water for achieving the required cooling capacity at all times; • In all cases recirculating cooling is an option, but this needs careful balancing with other factors, such as the required water conditioning and a lower overall Energy efficiency. For existing water cooling systems, increasing heat reuse and improving operation of the system can reduce the required amount of cooling water. In the case of rivers with limited availability of surface water, a change from a once-through system to recirculating cooling systems is a technological option and may be considered BAT.	Noted Cooling with seawater is considered. Water availability is high for the proposed project. Waste heat is reused within the CCGT steam cycle so long as the waste heat streams contain considerable exergy to be recovered. Table 4.4 applies for wet cooling options and Dry cooling options which are not considered in this project

Aspect of BAT	BAT	Status at Installation
	For power stations with large cooling capacities, this is generally considered as a cost-intensive exercise requiring a new construction. Space requirements must be taken into account.	
Identified reduction techniques within the BAT-approach	See Figure 4. Application of dry air-cooling has been suggested on a number of occasions. If the overall Energy efficiency is taken into account, dry air-cooling is less attractive than wet cooling. With this the dry technology is not disqualified. For shorter lifetime periods it was calculated that the differences in costs between dry and wet become less than for longer lifetime periods. When costs for water and water treatment are taken into account, differences also become smaller. Dry cooling can be recommended in certain circumstances and for precooling at higher temperature levels, where excessive water would be needed.	Dry cooling is not considered for the proposed project.

Figure 4:

Table 4.4: BAT for reduction of water requirements

Relevance	Criterion	Primary BAT approach	Remarks	Ref.
All wet cooling systems	Reduction of need for cooling	Optimisation of heat reuse		Ch.1
	Reduction of use of limited sources	Use of groundwater is not BAT	Site-specific in particular for existing systems	Ch.2
	Reduction of water use	Apply recirculating systems	Different demand on water conditioning	Ch.2/3.3
	Reduction of water use, where obligation for plume reduction and reduced tower height	Apply hybrid cooling system	Accept energy penalty	Ch.2.6/ 3.3.1.2
	Where water (make-up water) is not available during (part of) process period or very limited (drought-stricken areas)	Apply dry cooling	Accept energy penalty	Section 3.2 and 3.3 Annex XII.6
All recirculating wet and wet/dry cooling systems	Reduction of water use	Optimization of cycles of concentration	Increased demand on conditioning of water, such as use of softened make-up water	Section 3.2 and section XI

4. Reduction of entrainment of organisms

Aspect of BAT	BAT	Status at Installation
General	The adaptation of water intake devices to lower the entrainment of fish and other organisms is highly complex and site-specific. Changes to an existing water intake are possible but costly. From the applied or tested fish protection or repulsive technologies, no particular techniques can yet be identified as BAT. The local situation will determine which fish protection or repulsive technique will be BAT. Some general applied strategies in design and position of the intake can be considered as BAT, but these are particularly valid for new systems. On the application of sieves it should be noted that costs of disposal of the resulting organic waste collected from the sieves can be considerable.	The existing seawater intake will be used for the expansion project. Seawater screens are already in place in the existing seawater intake as repulsive technique (BAT)
Identified reduction techniques within the BAT-approach	See Figure 5.	The existing seawater intake will be used for the expansion project. The seawater intake design is not part of the project scope.

Figure 5:

Table 4.5: BAT for reduction of entrainment

Relevance	Criterion	Primary BAT approach	Remarks	Ref.
All once-through systems or cooling systems with intakes of surface water	Appropriate position and design of intake and selection of protection technique	Analysis of the biotope in surface water source	Also critical areas, such as spawning grounds, migration areas and fish nurseries	Section 3.3.3 and Annex XII.3.3
	Construction of intake channels	Optimise water velocities in intake channels to limit sedimentation; watch for seasonal occurrence of macrofouling		Section 3.3.3

5. Reduction of emissions to water

Aspect of BAT	BAT	Status at Installation
General BAT approach to reduce heat emissions	Whether heat emissions into the surface water will have an environmental impact strongly depends on the local conditions. Such site conditions have been described, but do not lead to a conclusion on BAT in general terms. Where, in practice, limits to heat discharge were applicable, the solution was to change from once-through technology to open recirculating cooling (open wet cooling tower). From the available information, and considering all possible aspects, care must be taken in concluding that this can be qualified as BAT. It would need to balance the penalty increase in overall energy efficiency of applying a wet cooling tower (Chapter 3.2) against the effect of reduced environmental impact of reduced heat discharge. In a fully integrated assessment at the level of a river catchment, this could for example include the raised overall efficiency levels of other processes using the same, but now colder, water source, which becomes available because there is no longer a large warm water discharge into it. Where the measures generally aim at reducing the ΔT of the discharged cooling water, a few conclusions on BAT can be drawn. Pre-cooling (Annex XII) has been applied for large power plants where the specific situation requires this, e.g. to avoid raised temperature of the intake water. Discharges will have to be limited with reference to the constraints of the requirements of Directive 78/659/EEC for	The seawater temperature increase shall be limited to 8 degC in compliance with 78/659/EEC.

Aspect of BAT	BAT	Status at Installation
	fresh water sources. The criteria are summarised in BREF Table 3.6. Reference is made to a provision in Article 11 of this directive regarding derogation of the requirements in certain circumstances.	
General BAT approach to reduce chemical emissions to water	Prevention and control of chemical emissions resulting from cooling systems have received the most attention in Member States' policies and industry. Next to heat discharge they are still considered to be the most important issue in cooling. Referring to the statement that 80% of the environmental impact is decided on the design table, measures should be taken in the design phase of wet cooling system using the following order of approach: o identify process conditions (pressure, T, corrosiveness of substance), o identify chemical characteristics of cooling water source, o select the appropriate material for heat exchanger combining both process conditions and cooling water characteristics, o select the appropriate material for other parts of the cooling system, o identify operational requirements of the cooling system, o select feasible cooling water treatment (chemical composition) using less hazardous chemicals or chemicals that have lower potential for impact on	Chlorine dioxide shall be used as biocide (BAT). This is the same biocide used currently on site. Dosing quantities will not increase as a result of the expansion project. The Delimara4 CCGT condenser tubes are made of titanium which is highly resistance to corrosive environment and suitable for seawater applications. The dosing of the CCGT CW water shall be through the existing dosing system, currently utilised by the other facilities on the site, it is monitored prior to discharge to ensure the appropriate amount of dosing is being carried out. The CCGT CW pumps, both main and auxiliary, are specifically designed to meet the operations requirements of the new plant so as to operate efficiently at the normal operating conditions of the plant. Blowdown water and clean drains from boilers typically have low concentrations of total dissolved solids, no suspended particles and a pH of around 9. This effluent is treated in the neutralization system before discharge. The pH shall be adjusted by dosing NaOH (base) or HCl (acid) The discharge pH shall be kept within 7 and 8.5 as per local regulations. The pH shall be monitored prior to discharge. Water which could have been potentially contaminated with

Aspect of BAT	BAT	Status at Installation
	the environment (Section 3.4.5, Annex VI and VIII) o apply the biocide selection scheme (Chapter 3, Figure 3.2) and o optimise dosage regime by monitoring of cooling water and systems conditions. This approach intends to reduce the need for cooling water treatment in the first place. For existing systems technological changes or changes to the equipment are difficult and generally cost-intensive. Focus should be on the operation of the systems using monitoring linked to optimized dosage. A few examples of techniques with good performances have been identified. They are generally applicable for certain categories of systems, they are considered cost effective and do not need large changes to the cooling installation. After reducing the sensitivity of the cooling system to fouling and corrosion, treatment may still be needed to maintain an efficient heat exchange. Selecting cooling water additives less harmful to the aquatic environment and to applying them in the most efficient way is then the next step. With respect to the selection of chemicals, it has been concluded that a ranking of treatments and the chemicals of which they are composed is difficult if not impossible to carry out in a general way and would be unlikely to lead to BAT conclusions. Due to the large variation in conditions and treatments only a site-by-site assessment will lead to the	oil shall be routed to the oil interceptor before discharge. The cooling water system for the FSU boilers, which are required to operate only during STS and disconnection events, utilise an Impressed Current Anti Fouling (ICAF) system for the marine/biological growth prevention system. No chemicals will be used to treat this water. For further details refer to section B2.2.1.

Aspect of BAT	BAT	Status at Installation
	appropriate solution. Such an assessment and its constituent parts could represent an approach that can be considered BAT. This approach is offered in this BREF and consists of a tool that can assist in a first ranking of selected chemicals and of an approach to assess biocides, linking the requirements of the cooling system to requirements of the receiving aquatic ecosystem (Annex VIII). The approach aims at minimising the impact of cooling water additives and, in particular, biocides. The Biocidal Products Directive 98/8/EC (BPD) and the Water Framework Directive (WFD) form the key building blocks for this approach. It is essential to use PEC and PNEC values for the different substances, where the PEC/PNEC ratio could function as a yardstick for BAT determination. On the application of specific substances, much experience has been obtained in once-through systems with chlorine-derived components (in particular hypochlorite, chloramine) and chlorine/bromine combinations, as well as with the application of reduced concentration levels. The same applies to the use of biocides for conditioning of recirculating systems. Treatments for these systems are often multisubstances. It is clear that some components or substances can be identified as not BAT or should not be applied at all. A general approach to select the appropriate biocide will include local aspects, such as the water quality	

Aspect of BAT	BAT	Status at Installation
	objectives of the receiving surface water.	
Identified reduction techniques within the BAT-approach **Prevention by design and maintenance**	See Figure 6.	Seawater velocity intake shall be higher than 1.8 m/s to avoid biological deposition. (BAT) The condenser shall be made of low corrosive alloys suitable for corrosive environments. (BAT) The condenser is to be in two halves, each with separate water boxes, and with the possibility of cleaning one half while the other half is still in service (Mechanical cleaning BAT).
Identified reduction techniques within the BAT-approach **Control by optimised cooling water treatment**	See Figure 7.	Chlorination doses shall be reduced in winter months and increase in summer months depending on ambient temperature. This is the current technique used by ENEMALTA. This is out of the scope of the project

Figure 6:

Table 4.6: BAT for reduction of emissions to water by design and maintenance techniques

Relevance	Criterion	Primary BAT approach	Remarks	Reference
All wet cooling systems	Apply less corrosion-sensitive material	Analysis of corrosiveness of process substance as well as of cooling water to select the right material		Ch.3.4
	Reduction of fouling and corrosion	Design cooling system to avoid stagnant zones		Annex XI.3.3.2.1
Shell&tube heat exchanger	Design to facilitate cleaning	Cooling water flow inside tube and heavy fouling medium on tube side	Depending on design, process T and pressure	Annex III.1
Condensers of power plants	Reduce corrosion-sensitiveness	Application of Ti in condensers using seawater or brackish water		Annex XII
	Reduce corrosion-sensitiveness	Application of low corrosion alloys (Stainless Steel with high pitting index or Copper Nickel)	Change to low corrosion alloys can affect formation of pathogens	Annex XII.5.1

	Mechanical cleaning	Use of automated cleaning systems with foam balls or brushes	In addition mechanical cleaning and high water pressure may be necessary	Annex XII.5.1
Condensers and heat exchangers	Reduce deposition (fouling) in condensers	Water velocity > 1.8 m/s for new equipment and 1.5 m/s in case of tube bundle retrofit	Depending on corrosion sensitivity of material, water quality and surface treatment	Annex XII.5.1
	Reduce deposition (fouling) in heat exchangers	Water velocity > 0.8 m/s	Depending on corrosion sensitivity of material, water quality and surface treatment	Annex XII.3.2
	Avoid clogging	Use debris filters to protect the heat exchangers where clogging is a risk		Annex XII

Table 4.6 (continued): BAT for reduction of emissions to water by design and maintenance techniques

Relevance	Criterion	Primary BAT approach	Remarks	Reference
Once-through cooling system	Reduce corrosion-sensitiveness	Apply carbon steel in cooling water systems if corrosion allowance can be met	Not for brackish water	Annex IV.1
	Reduce corrosion-sensitiveness	Apply reinforced glass fibre plastics, coated reinforced concrete or coated carbon steel in case of underground conduits		Annex IV.2
	Reduce corrosion-sensitiveness	Apply Ti for tubes of shell&tube heat exchanger in highly corrosive environment orhigh quality stainless steel with similar performance	Ti not in reducing environment, optimised biofouling control may be necessary	Annex IV.2
Open wet cooling towers	Reduce fouling in salt water condition	Apply fill that is open low fouling with high load support		Annex IV.4
	Avoid hazardous substances due to anti-fouling treatment	CCA treatment of wooden parts or TBTO containing paints is not BAT		Section 3.4 Annex IV.4
Natural draught wet cooling towers	Reduce anti-fouling treatment	Apply fill under consideration of local water quality (e.g. high solid content, scale)		Annex XII.8.3

Figure 7:

Table 4.7: BAT for reduction of emissions to water by optimised cooling water treatment

Relevance	Criterion	Primary BAT approach	Remarks	Reference
All wet systems	Reduce additive application	Monitoring and control of cooling water chemistry		Section 3.4 and Annex XI.7.3
	Use of less hazardous chemicals	It is <u>not BAT</u> to use • chromium compounds • mercury compounds • organometallic compounds (e.g. organotin compounds) • mercaptobenzothiazole • shock treatment with biocidal substances other than chlorine, bromine, ozone and H_2O_2		Section 3.4/ Annex VI
Once-through cooling system and open wet cooling towers	Target biocide dosage	To monitor macrofouling for optimising biocide dosage		Annex XI.3.3.1.1
	Limit application of biocides	With sea water temperature below 10-12°C no use of biocides	In some areas winter treatment may be needed (harbours)	Annex V

Once-through cooling system	Reduction of FO emission	Use of variation of residence times and water velocities with an associated FO or FRO-level of 0.1 mg/l at the outlet	Not applicable for condensers	Ch.3.4 Annex XI.3.3.2
	Emissions of free (residual) oxidant	FO or FRO ≤ 0.2 mg/l at the outlet for continuous chlorination of sea water	Daily (24h) average value	Annex XI.3.3.2
	Emissions of free (residual) oxidant	FO or FRO ≤ 0.2 mg/l at the outlet for intermittent and shock chlorination of sea water	Daily (24h) average value	Annex XI.3.3.2
	Emissions of free (residual) oxidant	FO or FRO ≤ 0.5 mg/l at the outlet for intermittent and shock chlorination of sea water	Hourly average value within one day used for process control requirements	Annex XI.3.3.2
	Reduce amount of OX-forming compounds in fresh water	Continuous chlorinating in fresh water is not BAT		Ch.3.4 Annex XII

Table 4.7 continued: BAT for reduction of emissions to water by optimised cooling water treatment

Relevance	Criterion	Primary BAT approach	Remarks	Reference
Open wet cooling towers	Reduce amount of hypochlorite	Operate at $7 \leq pH \leq 9$ of the cooling water		Annex XI
	Reduce amount of biocide and reduce blowdown	Application of side-stream biofiltration is BAT		Annex XI.3.1.1
	Reduce emission of fast hydrolyzing biocides	Close blowdown temporarily after dosage		Section 3.4
	Application of ozone	Treatment levels of ≤ 0.1 mg O_3/l	Assessment of total cost against the application of other biocides	Annex XI.3.4.1

6. Reduction of emissions to air

Aspect of BAT	BAT	Status at Installation
General approach	Comparatively, air emissions from cooling towers have not been given much attention, except for the effects of plume formation. From some reported data it is concluded that levels are generally low but that these emissions should not be neglected. Lowering concentration levels in the circulating cooling water will obviously affect the potential emission of substances in the plume. Some general recommendations can be made which have a BAT-character.	The project will not include cooling towers
Identified reduction techniques within the BAT-approach	Avoid. See Figure 8.	Not applicable as cooling towers are not foreseen in this project.

Figure 8:

Table 4.8: BAT for reduction of emissions to air

Relevance	Criterion	Primary BAT approach	Remarks	Reference
All wet cooling towers	Avoid plume reaching ground level	Plume emission at sufficient height and with a minimum discharge air velocity at the tower outlet		Chapter 3.5.3
All wet cooling towers	Avoid plume formation	Application of hybrid technique or other plume suppressing techniques such as reheating of air	Need local assessment (urban areas, traffic)	Chapter 3.5.3
All wet cooling towers	Use of less hazardous material	Use of asbestos, or wood preserved with CCA (or similar) or TBTO is <u>not BAT</u>		Chapter 3.8.3
All wet cooling towers	Avoid affecting indoor air quality	Design and positioning of tower outlet to avoid risk of air intake by air conditioning systems	Is expected to be less important for large natural draught CT with considerable height	Section 3.5
All wet cooling towers	Reduction of drift loss	Apply drift eliminators with a loss <0.01% of total recirculating flow	Low resistance to airflow to be maintained	Section 3.5 and XI.5.1

7. Reduction of noise emissions

Aspect of BAT	BAT	Status at Installation
General	Noise emissions have local impact. Noise emissions of cooling installations are part of the total noise emissions from the site. A number of primary and secondary measures have been identified that can be applied to reduce noise emissions where necessary. The primary measures change the sound power level of the source, where the secondary measures reduce the emitted noise level. The secondary measures in particular will lead to pressure loss, which has to be compensated by extra energy input, which reduces overall energy efficiency of the cooling system. The ultimate choice for a noise abatement technique will be an individual matter, as will the resulting associated performance level. The following measures and minimum reduction levels are considered as BAT.	Unlike in Wet or dry cooling systems where multiple noise emission sources are present, the seawater pumps are the only source of noise in the once-through cooling seawater system. Their design shall comply with EU regulations (85dB(A) at 1m distance). This is accomplished by a proprietary noise cancelling system from the pump manufacturer.
Identified reduction techniques within the BAT-approach	See Figure 9.	

Figure 9:

Table 4.9: BAT for the reduction of noise emissions

Cooling system	Criterion	Primary BAT approach	Associated reduction levels	Ref.
Natural draught cooling towers	Reduce noise of cascading water at air inlet	Different techniques available	≥ 5 dB(A)	Section 3.6
	Reduce noise emission around tower base	E.g application of earth barrier or noise attenuating wall	< 10 dB(A)	Section 3.6
Mechanical draught cooling towers	Reduction of fan noise	Apply low noise fan with characteristics, e.g.: - larger diameter fans; - Reduced tip speed (≲ 40 m/s)	< 5 dB(A)	Section 3.6 Section 3.6
	Optimised diffuser design	Sufficient height or installation of sound attenuators	Variable	Section 3.6
	Noise reduction	Apply attenuation measures to inlet and outlet	≥ 15 dB(A)	Section 3.6

8. Reduction of risk of leakage

Aspect of BAT	BAT	Status at Installation
General approach	To reduce the risk of leakage, attention must be paid to the design of the heat exchanger, the hazardousness of the process substances and the cooling configuration. The following general measures to reduce the occurrence of leakages can be applied: • select material for equipment of wet cooling systems according to the applied water quality; • operate the system according to its design, • if cooling water treatment is needed, select the right cooling water treatment programme, • monitor leakage in cooling water discharge in recirculating wet cooling systems by analysing the blowdown.	Seawater ingress into the once-through condenser shall be prevented and monitored with automatic response (BAT). According to table 4.10, this will be rated with a process safety score of VCI≥9. If the pressure in the condenser increases rapidly, immediate measures shall be taken as follow: 1) If a predefined high pressure value (H1) is reached the second evacuation pump is started 2) If a predefined high high pressure value (H2) is reached a DCS alarm is actuated and the Steam turbine is tripped. 3) If none of these prevent the rise in pressure in the shell side of the condenser, the rupture disks will burst to protect the equipment. Small leaks are also detected by monitoring the conductivity of the condensate water. The condenser and auxiliary cooling heat exchanger shall be designed so that the temperature difference will be lower than 50degC.(BAT) Temperature of water in the cooling water side shall be lower than 60 degC. (BAT)
Identified reduction	See Figure 10.	Please refer to “General Approach” section above

Aspect of BAT techniques within the BAT-approach	BAT	Status at Installation

Figure 10:

Table 4.10: BAT to reduce the risk of leakage

Relevance[1)]	Criterion	Primary BAT approach	Remarks	Reference
All heat exchangers	Avoid small cracks	ΔT over heat exchanger of $\leq 50^oC$	Technical solution for higher ΔT on case-by-case basis	Annex III
Shell&tube heat exchanger	Operate within design limits	Monitor process operation		Annex III.1
	Strength of tube/tube plate construction	Apply welding technology	Welding not always applicable	Annex III.3
Equipment	Reduce corrosion	T of metal on cooling water side < 60ºC	Temp. affects inhibition of corrosion	Annex IV.1
	VCI score of 5-8	Direct system $P_{cooling\ water} > P_{process}$ and monitoring	Immediate measures in case of leakage	Annex VII
	VCI score of 5-8	Direct system $P_{cooling\ water} = P_{process}$ and automatic analytical monitoring	Immediate measures in case of leakage	Annex VII
	VCI score of ≥ 9	Direct system $P_{cooling\ water} > P_{process}$ and automatic analytical monitoring	Immediate measures in case of leakage	Annex VII

Once-through cooling systems	VCI score of ≥ 9	Direct system with heat exchanger of highly anticorrosive material/ automatic analytical monitoring	Automatic measures in case of leakage	Annex VII
	VCI score of ≥ 9	Change technology - indirect cooling - recirculating cooling - air cooling		Annex VII
	Cooling of dangerous substances	Always monitoring of cooling water		Annex VII
	Apply preventive maintenance	Inspection by means of eddy current	Other non-destructive inspection techniques are available	
Recirculating cooling systems	Cooling of dangerous substances	Constant monitoring of blowdown		
1) Table not applicable for condensers				

9. Reduction of biological risk

Aspect of BAT	BAT	Status at Installation
General approach	To reduce the biological risk due to cooling systems operation, it is important to control temperature, maintain the system on a regular basis and avoid scale and corrosion. All measures are more or less within the good maintenance practice that would apply to a recirculating wet cooling system in general. The more critical moments are start-up periods, where systems' operation is not optimal, and standstill for repair or maintenance. For new towers consideration must be given to design and position with respect to surrounding sensitive objects, such as hospitals, schools and accommodation for elderly people.	Biological growth shall be controlled and prevented by mechanical and chemical cleaning (BAT). Temperature and pressure drop across the condenser will be monitor to detect fouling. Stagnated areas within the heat exchangers shall be prevented to avoid fouling. The seawater speed shall be kept higher than 1.8m/s (BAT) to prevent biological growth. Sun Light will not reach the cooling water heat exchanger side. (BAT)
Identified reduction techniques within the BAT-approach	See Figure 11.	The cooling system is once-through, table 4.11 is not applicable. Measures for reducing biological growth are outlined above.

Figure 11:

Table 4.11: BAT to reduce biological growth

Cooling system	Criterion	Primary BAT approach	Remarks	Reference
All wet recirculating cooling systems	Reduce algae formation	Reduce light energy reaching the cooling water		Section 3.7.3
	Reduce biological growth	Avoid stagnant zones (design) and apply optimized chemical treatment		
	Cleaning after outbreak	A combination of mechanical and chemical cleaning		Section 3.7.3
	Control of pathogens	Periodic monitoring of pathogens in the cooling systems		Section 3.7.3
Open wet cooling towers	Reduce risk of infection	Operators should wear nose and mouth protection (P3-mask) when entering a wet cooling tower	If spraying equipment is on or when high-pressure cleaning	Section 3.7.3