CSPBankability Project Report

# Draft for an Appendix I
# Water Demand, Quality and Supply

# to the
# SolarPACES Guideline for
# Bankable STE Yield Assessment

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# I. Water demand and quality

CSP plants as well as all other thermal power plants using heat transfer fluids (water/steam, organic media, synthetic oil etc.) use water in various qualities and quantities.

A water balance diagram shall be developed for the specific necessities of the project showing a preliminary flow scheme that will be further elaborated throughout the project development towards a chart showing all the incoming water ressources with the respective process data such as massflow, temperatures, pressures etc. as well as the process flow including all consumers and deposits.

## I.1. Raw water

Depending on the local conditions, the in-coming at the power plant (raw water) can either be seawater (if the plant is located near the shore side) or water from other surface water ressources such as river, lake, wells and other recervoirs. The raw water has to be treated in order to remove organic content and solids to achieve a constantly high level of quality as input for the further processing. This treatment and processing can be realized either within the plant or in an external plant as a base for the further treatment to feed the various demands and cosumers.

Raw water is the basis for different purposes such as:

- Process water (e.g. cooling water, fire fighting etc.)
- Softened water / demineralized water
- Potable water
- Service water
- etc.

Waste water and eluates deriving from treatment processes have to be handled within the CSP plant and disposed in compliance with international and local regulations.

## I.2. Process water

### I.2.1.Cooling water

Basically, the power plant has two different cooling cycles with different thermodynamic demands. The main cooling water cycle enables the steam/water cycle of the power plant to change its phase from exhaust steam (after steam turbine) to condensate (start of heat exchange sequence). Another smaller cooling cycle does serve the auxiliary as well as ancilliary processes as a heat sink, i.e. for cooling of turbine oil circuits.

#### I.2.1.1. Main cooling water

The main cooling water supplies cooling media from a source and/or reservoir with – redundant main cooling water pumps (e.g. 2x100% or 3x50%) for the exhaust steam condenser of the steam turbine to enable the phase change from exhaust steam to condensate. The water demand is calculated from the heat balance diagram (HBD) of the steam/water cycle which can be reflected with the basic equation:

$$\dot{Q}_{Cond} = c_{water} * \dot{m}_{water} * (T_{cond,in} - T_{cond,out}) \tag{I.1}$$

With

| | |
|---|---|
| $\dot{Q}_{Cond}$ | Thermal load of the condenser |
| $c_{water}$ | Mean heat capacity of the cooling water |
| $\dot{m}_{water}$ | Cooling water mass flow |
| $T_{cond,in}$ | Cooling water temperature at condenser inlet |
| $T_{cond,out}$ | Cooling water temperature at condenser outlet |

Main cooling can be performed with one of the following three different condenser types:

- Once-through cooling with river or sea water
- Wet cooling tower
- Air-cooled condenser (ACC)

Once-through cooling requires large quantities of water. So far no CSP plant has been realized with river water once-through cooling. This is due to the fact, that at typical CSP sites generally no rivers are available. Also so far, no CSP plant has been built near to the coast. Possible reasons are:

- High land costs near the coast
- Reduced DNI resource due to haze from the sea
- High corrosion potential of the ambient conditions near the coast

Wet cooling is the most frequently used technology for condenser cooling. The water demand of this technology depends mainly on the humidity of the ambient air and the salinity of the water source for the make-up water.

The cooling effect in a wet cooling tower is realized by two physical principles:

- Evaporation of droplets
- Sensible heat increase of the air flowing through the cooling tower

Basically, there are two different types of wet cooling towers:

- In case of the natural flow cooling tower, the air flow is realized by the natural physical properties of the air itself, thus requiring high structures with chimney effects. The local wet bulb temperature will indicate the capacity of the cooling tower. This type requires rather high thermal capacities and is more common in conventional fossil-fired power plants with capacities of more than 400 $MW_e$.
- The second type is the forced-draft cooling tower requiring mechanical equipment such as fans/blowers to induce the air flow. Also the local dry bulb temperature will accordingly indicate the capacity of this cooling concept. This type of cooling tower is mostly used in CSP plants - if water resources are suitable.

Both types of cooling tower will face constant losses of the flowing water, $\dot{m}_{cooling\ water}$ during operation of the cooling towers which basically derive from

- evaporation losses up to 1.2% of the full water flow (depending on cycles)
- drift losses up to 0.02% of the full water flow
- flushing losses up to 1.0% to maintain the circulating water quality depending on the cycles given by the local water quality (up to 10 cycles if using appropriate material for the construction)

The ACC uses air as intermediate cooling medium, thus working at a higher temperature profile which in turn implies a higher condenser pressure and consequently higher thermal losses. A massive air flow is induced by horizontally arranged electrically driven air fans with a rather high auxiliary electrical consumption.
A small amount of washing water (service water is applicable here) will be necessary to keep the heat exchanging surfaces clean from dust and impurities (mostly depending on the local soiling rates).

An ACC is the most suitable way of condenser cooling at sites with scarce water resources. However, the ACC is more expensive than the other two cooling technologies due to comparatively

- higher purchase price of the of equipment
- higher axiliary electrical consumption of the cooling fans and
- lower efficiency of power block

#### I.2.1.2. Auxiliary cooling water

The auxiliary cooling water supplies cooling media with -redundant- auxiliary cooling water pumps (e.g. 2x100%) feeding a -redundant- heat exchanger (e.g. 2x100%). This heat exchanger shall preferably be of shell and tube type if a water-cooled condenser is available. Alternatively a plate type heat exchanger may be considered. However, the cleaning of this equipment has to taken into account. The heat exchanger will feed an intermediate “closed cooling cycle water (CCCW)” to feed the various auxiliaries and anchiliary systems of the CSP plant such as:

- Lube oil cooler(s)
- Compressed air generation
- Heating, ventilation and air conditioning (HVAC)
- etc.

The water demand is calculated from the requirements of the various consumers (e.g. temperature level, mass flow, temperature differences etc.) and is subject to further basic/detailed project-specific engineering.

#### I.2.1.3. Closed cooling cycle water

The closed cooling cycle uses specially treated demineralized water for the various consumers of the plant. The system shall be filled with demineralised water/condensate and the additives for the treatment shall be injected manually. Losses due to drainage and/or leakage need to be recovered. These losses are comparatively rather low and thus can be neglected.

### I.2.2.Fire fighting water

The above mentioned raw water source and/or reservoir is also an essential basis for the fire fighting system of the CSP plant. The lower section of the raw water recervoir (if flat bottom tank) can be used as fire fighting water basin to feed the fire fighting pumps accordingly, whereas the upper section of the reservoir can feed the further water treatment. The volume of this revervoir has to designed following internationally recognized codes and standards (such as NFPA 850) and consequently agreed with the local fire brigade.
The diesel and electrically driven fire fighting pumps as well as the jockey pumps and the buffer vessel are fed by the storage tank. The fire fighting equipment shall be placed inside an enclosure with adequate access for testing, operation and maintenance. The pumps will feed the main fire network (preferably arranged in the underground).

Following the recommendations of associated international standards, most of the CSP plants have no ring system installed within the solar field, however this topic has to be discussed and agreed with the local authorities.

### I.2.3.Mirror cleaning water

The mirrors of the solar collectors require frequent washing in order to maintain a high reflectivity and thereby to ensure a high productivity of the solar field. Basically, the water demand for mirror washing is determined by the soiling conditions at the plant site, which are described in more detail in Appendix N.

Based on the soiling characteristics and the set target average solar field cleanliness to be maintained, a cleaning strategy is developed. To obtain the average cleanliness of the solar field, spot reflectivity measurements are being carried out with adequate reflectometers and a sound distribution of the measurement points in the solar field.
In order to estimate the expected the mirror cleaning water demand, a rough calculation can be performed taking the following factors into consideration:

- Total solar field mirror surface ($m^2$)
- Specific water consumption of cleaning technique (liters/$m^2$)
- Number of cleaning sessions per year
- etc.

The specific water consumption of the cleaning vehicles is a performance parameter given by the supplier. For example, the specific cleaning water consumption in case of vehicles for parabolic trough collectors amounts to approx. 0.4 liters/$m^2$ for one cleaning session.

For the purpose of safe and efficient mirror cleaning, specially designed vehicles are used for the cleaning of parabolic trough collectors and heliostats with a high degree of automization. In case of primary reflectors of Linear Fresnel Reflectors (LFR), cleaning robots are applied which wipe the flat mirror surfaces with reduced water usage. It should be taken into account that the number of cleaning vehicles to be supplied for a project needs to be carefully assessed since any underestimation leads to unexpected additional costs due to purchasing of further vehicles once the plant is operational.

In terms of maintainability, adequate access shall be ensured between the solar collectors for maneuverability of the cleaning vehicles.

With regards to the water quality required, the cleaning water shall be at least of softened water quality to avoid deposits on the mirrors. Demineralized water is comparatively more expensive wherefore the need of this water type for cleaning purposes shall be analyzed and clarified.

## I.3. Softened and demineralized water

The steam/water cycle of the CSP plant as well as any steam power plant has certain losses that have to be compensated by demineralized water; preferably injected into the hot well of the main condenser of the steam turbine. The losses mainly derive from:

- Flashing of steam generators to maintain a specific condensate quality

- Spillages during start-up (low and high-pressure flushing)
- Constant blow down of vessels to maintain the condensate quality
- Condensate polishing
- Leakages etc.

The losses can be assumed in the range of approx. 0.5 - 1.2% of the steam/water cycle mass flow.

The demineralization plant which generates the demineralized water from the raw water is usually located at the plant site. Its capacity is usually twice as high as needed during regular operation. Due to this oversizing the plant can continue to operate even if the demineralized water consumption is increased due to some leakage which is not harmful for the continued operation of the plant.

The salinity of the demineralized water shall be 0.1 ppm or lower. The salinity is measured indirectly via the conductivity. For low salinities the relation between conductivity and salinity is approx. 1 ppm = 2 $\mu$S/cm.

## I.4. Potable water and service water

The plant should be equipped with a separate potable water system. On the basis of produced demineralized water, through further treatment potable water should be generated in accordance with local and international standards. The system basically consists of a storage tank, the associated water treatment facility and necessary distribution systems to supply various consumers.
As a rule of thumb, the consumption of the potable water for personnel reasons can be assumed in the range of 50-100l/person per day. However, this figure can vary depending on local custom and practice.

For the common purpose of washing, cleaning and flushing of various equipment and civil structures of the project,a service water system is required.

## I.5. Water consumption and cost

The table below shows indicatively some consumption figures for the already introduced main consumers in relation to the total steam/water cycle mass flow.

Table I-1: Typical water consumption of main consumers for a CSP plant

| | low | high |
|---|---|---|
| ***Cooling tower evaporation losses*** | 0.5% of cooling water cycle | 1.2% of cooling water cycle |
| ***Cooling tower flashing losses*** | 0.5% of cooling water cycle | 1.0% of cooling water cycle |

| | | |
|---|---|---|
| ***Demin water losses*** | 0.5% of steam/water cycle | 1.2% of steam/water cycle |
| ***Potable water consumption*** | 0.05 m$^3$/person*day | 0.1 m$^3$/person*day |

It should be taken into account, that the above given data is for reference and initial estimates only as the water consumption strongly varies depending on the project-specifics.

The specic cost (€/m$^3$ water) shows a broad range depending on the available raw water quality. Moreover, it can be stated that local influences have a high impact on the prices. As an example, in the Middle East, countries having water pipelines show remarkably low water prices whereas countries with water scarcety and poor water network infrastructure suffer very high costs due to e.g. truck transport. The range does vary from 1€/m$^3$ up to more than 5€/m$^3$ depending also on the supply method and proximity to sources and infrastructure.

## I.6. Waste water, eluates and waste

For all the liquid and solid waste that derive from the operation and maintenance of the CSP plant, a waste water treatment system is required. All effluents and eluates have to be treated in a professional way to meet the local and/or international rules and regulations.

For sewages originating from operation and maintenance as well ass personnel areas, isolated applications may be considered in the form of septic tanks to be disposed by professional and authorized 3rd party companies.