Renewable Cooling

Factsheet

9 Mar. 2009

Seawater cooling

Seawater Air Conditioning (SWAC) systems use the cold water from the deep ocean (and in some cases a deep lake) to cool buildings. It can largely reduce the power consumed by air conditioning (AC) systems. In various situations it has proven cost-effective. Seawater cooling is also applied for cooling industrial processes; many examples exist of power stations cooled with seawater.

SWAC components

- Cold seawater. Although the temperature of surface seawater does not deviate very much from ambient temperatures, substantial lower temperatures exist at large depths. This is due to global water circulations in the oceans: driven by density cold water from the poles flows at large depths to warmer areas. Simultaneously, the water at the ocean surface layer flows back to the poles. Roughly, the ocean water temperature at various depths is as follows:

700m	below 7℃
1000m	below 5℃
2000m	below 3℃

- Sea water supply system: pipes for cold water in take and for returning heated water. These pipes are made out of seawater-resistant material, like polyethylene. Furthermore, the pipe design should resist the hydrodynamic impact. Adequate filters are needed to prevent accumulation of solid particles in the system.
- Heat exchanger (“cooling station”). This brings over the cold to a closed water system. Titanium heat exchangers are used for this, because titanium combines resistance to salty water with high heat conductivity.
- Chilled water distribution net (heat-isolated pipes).
- Cooling system: mostly the chilled water is cool enough for direct cooling application.

In some situations, the cooling capacity is insufficient. Then an auxiliary chiller can be used to supplement the cooling supplied by the sea water.

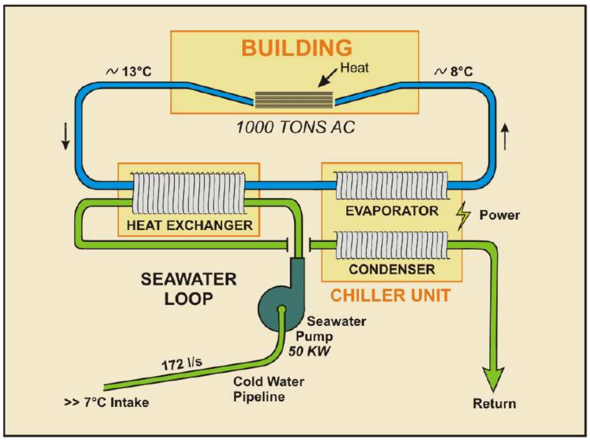
Pre-requirements for SWAC

- availability of cold water in the vicinity
- high cooling demand

Practical examples

SWAC have been realised in amongst others:

- Toronto: a 5 km long pipe draws cold water (4℃) from Ontario Lake. This system meets up to 40% of the city’s cooling need. The cooling water is also used for drinking water purposes.
- Cornell University utilises a comparable system for cooling the campus and school (using water from the Cayuga Lake).
- Stockholm: Here, sea water is used. The system has two water inlets: one at sea level and another at a depth of 20m.



Scheme for a SWAC including an auxiliary chiller unit. (Source: Bellinger, 2006).

  - The deep inlet is used for cooling water. 80% (280GWh) of the district cooling in Stockholm comes from seawater.
  - The inlet at sea level is used for heating. In 2006 16% (1600GWh) of the heating for Stockholm is supplied by seawater.
- Hawaï: a 1m diameter pipe is used for 15MW cooling power (with intake depth at 800m) (Ryzin and Leraand, 1992).
- Other seawater cooling systems have been realised or are considered in Halifax, Tahiti, Curacao, Korea, Malta, the Cape Verde Islands, Haiti and Mauritius.

In many of these project Hawaii based Makaï Ocean Engineering is involved.

Energetic feasibility

SWAC systems only need energy for pumping water; generally this is below 10 to 20% of the energy needed for traditional cooling.
For large building and hotels in tropical and subtropical climates, air conditioning represents the major energy demand. As a rule-of-thumb, a typical hotel room requires approximately 3.5kW of air conditioning with an energy requirement of 0.9 kW. A conventional system utilizes about 900 kw/1000 tons but a similar sized A/C system using seawater requires only pumping power in the order of 40-80 kw/1000 tons, representing a 90% electrical saving over the chiller power requirement.

The Curacao project (built in 2008):

The pipeline will reach 6 kilometres out into the sea, … down to a depth of 850 meters, fetching up seawater at a temperature of 6℃ at half cubic meter per second. The SWAC system operates with a *temperature differential (ΔT) between the water it takes in and the water it lets out of about 7℃, and the return water will go into the sea again at 100 meters depth to avoid any substantial environmental impact. (source: OTEC news, www.otecnews.org)*

The cooling cooling capacity of this system will be about 10MW.

Financial feasibility

Like most sustainable energy concepts, investment costs of SWAC are relatively high, with relatively low operational costs.

The investment costs depend on:

- Required water flow rate (determining the diameter of pipes, sizes of the heat exchangers and pumping capacity. The flow rates are dependent on:
  - o application/peak cooling load
  - o sea water temperature
- Length of the pipes:
  - o offshore distance to cold water below, say, 5℃
  - o length of the onshore distribution system
- Specific measures needed for protecting the pipes.
- Percentage use of the cooling system

Because of the economy of scale, a SWAC system is most appropriate for supplying multiple buildings or hotels in a coastal area. Since normal water is used for the cold distribution, mostly existing building can be easily converted to SWAC by simply bypassing existing chillers.

Ryzin and Leraand (1992) give the following evaluation of payback periods:

… We studied the feasibility of seawater air conditioning for three sites on Curacao. with air conditioning loads ranging from 2 to 7.5 MW (corresponds to cooling of 540 to 2,100 hotel rooms). The length of the seawater intake pipelines ringed between 1.6 to 3.6 km depending on the site and the seawater intake temperature.

The capital cost--including pipeline, heat exchangers, and chilled water distribution system was on the order of $2 to $5 million. The payback period for these systems ranged between 5 and 6 years for feasible sites and 9 to 17 years for the site with the smallest air conditioning loading.

This payback is based on the cost of supplying existing buildings. If new construction only is considered (without chillers), the payback is considerably better.

Makai Ocean Engineering has also completed some preliminary analyses for Guam in the Tumon Bay area where there is a high density of hotel rooms. This preliminary analysis indicates that 10,000 hotel rooms could be air conditioned with cold seawater and that the capital payback period for installing such a system would be approximately 5 to 6 years.

Investment costs for the Curacao project mentioned above amounted approximately M€15-20. With an electricity prize of €0.10 per kWh, the annual electricity cost saving will be about M€3. Thus, the pay-back period will be about 6 to 8 years.

Suitability for the Netherlands

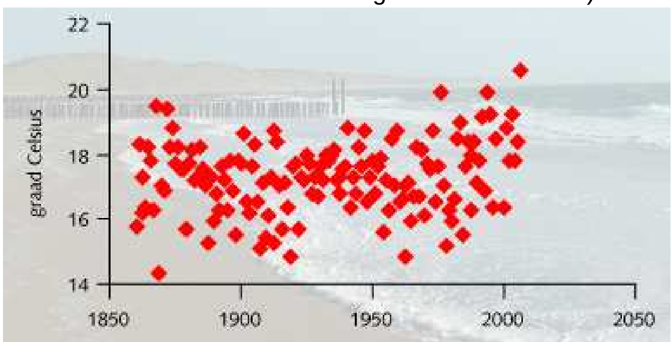
This technology could also be used in the Netherlands. In fact, the technology is used sometimes for cooling with lakewater:

- some buildings along the south axis of Amsterdam are being cooled with water from the "Nieuwe Meer" (developed in 2006),
- the Atlas Arena complex (also in the south of Amsterdam) will be cooled with water from the Ouderkerkerplas (starting in 2009),
- Sauna Fort Bronsbergen in Zutphen uses cold water from the Bronsbergen lake.

These examples all use water from lakes that resulted from sand winning, because those lakes are relatively deep (over 15m). Water at that depth is relatively cold (below 8℃). A large number of this kind of lakes ex ist in the Netherlands.

A typical lake has an area of 1km^2, with an average depth of 15m. The heat capacity of such a lake is about 63TJ/℃. Thus, per degree temperature increase allo wed per year (heating up will gradually decrease), 63TJ cooling per year can be provided by the lake, which is 2.0MW averagely.

Conditions for cooling with seawater, however, are less favourable than the examples mentioned before, because very cold water is not available: the North Sea does not have a thermocline (the depth of the North Sea between the Netherlands and England is about 40m).



Average sea water temperature near Den Helder, The Netherlands (source: Rijkswaterstaat, through www.trendsinwater.nl)

Sources

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