Factsheet

9 Mar. 2009

Solar thermal cooling

Through use of thermal-driven coolers, solar heat can be used for cooling. In fact, a large part of the existing thermal cooling systems worldwide is driven by solar heat.
Solar thermal cooling is very adequate for hot areas, because temperature variation is positively correlated with solar radiation.

The main components of solar thermal cooling systems are:

1. thermal-driven cooling unit;
2. solar collector.

Alternative systems can be based on electric solar panels in combination with traditional cooling. Lambert and Beyene (2007) have shown that such systems will only be feasible with "exorbitant electric pricing".

Thermal-driven cooling unit

The cooling unit generally is a sorption chiller (using absorption, adsorption or desiccant cooling principle). The efficiency of those chillers (cooling power relative to heat use) varies from 0.5 (single-effect systems under sub-optimal conditions) to 1.2 (double-effect system, optimal conditions).

Solar collectors

Table 1 gives an overview of efficiency and costs of modern solar collectors (for "house-owner scales"; for large-scale applications some discount is expected).
Heat production by solar panels will depend on:

- solar panel type
- collector or setpoint temperature (closely related with the chosen thermal chiller system)
- actual solar radiation (influenced by solar angle and weather conditions).
- hot-water buffer size and isolation.

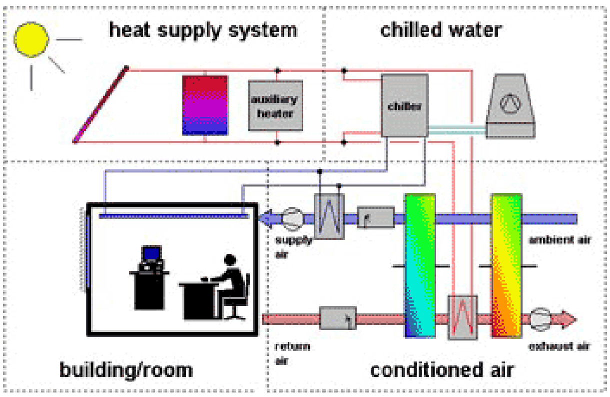

Figure 1. Solar thermal cooling system (figure: www.californiasolarcenter.org)

Efficiency and net solar conversion (W/m^2) for photovoltaic modules and thermal collectors: flat panel, evacuated flat panel (EFP), and compound parabolic concentrator (CPC)

Type of solar collector	Efficiency expression	Efficiency η at specified conditions[a]	Net conversion (W/m^2) at specified conditions[a]	Cost per m^2[c]	Installed cost per Net kW elec. or thermal
Photovoltaic (PV), single crystal or poly-crystalline, not thin film	0.15	0.15	123	\$616–\$740	\$5500–\$6500[b]
[7]Flat Panel: single-glazed ($\tau_S = 0.86$), black paint ($\alpha_S/\varepsilon_{IR} = 0.96/0.96$)	$0.83–8.6(T_{coll} - \overline{T}_a)/q_S$	0 @ max. $T_{coll} = 111$ °C	0	\$175	Cannot reach T_{coll}
[7]Flat Panel: double-glazed ($\tau_S = 0.79$), black paint ($\alpha_S/\varepsilon_{IR} = 0.96/0.96$)	$0.76–4.9(T_{coll} - \overline{T}_a)/q_S$	0 @ max. $T_{coll} = 160$ °C	0	\$200	Cannot reach T_{coll}
[7]Flat Panel: single-glazed ($\tau_S = 0.89$), solar-selective ($\alpha_S/\varepsilon_{IR} = 0.90/0.20$)	$0.80–3.8(T_{coll} - \overline{T}_a)/q_S$	0.162	133	\$200	\$1500
[6]Flat Panel: double-glazed ($\tau_S = 0.79$), solar-selective ($\alpha_S/\varepsilon_{IR} = 0.95/0.15$)	$0.75–3.4(T_{coll} - \overline{T}_a)/q_S$	0.179	147	\$225	\$1530
Evacuated Flat Panel (EFP): etched single-glazed ($\tau_S = 0.95$), solar-selective ($\alpha_S/\varepsilon_{IR} = 0.92/0.10$)	$0.874–1.754(T_{coll} - \overline{T}_a)/q_S$	0.580	477	\$250	\$524
Compound Parabolic Concentrator (CPC): CR = 10, etched single-glazed ($\tau_S = 0.95$), solar-selective ($\alpha_S/\varepsilon_{IR} = 0.92/0.10$)	$0.613–0.381(T_{coll} - \overline{T}_a)/q_S$	0.549	451	\$375	\$831

[a] $T_{coll} = 170$ °C, $\overline{T}_a = 32$ °C, $\overline{K}_T = 0.60$, $\theta \approx 0°$, $\beta = 20°$, $\rho_{surr} = 0.2$, $q_S = 822$ W/m^2.
[b] Cost of additional PV needed for HVAC added onto 3 kW array for non-HVAC usage.
[c] Equals retail price plus estimated installation cost of \$50/m^2.

Table 1. Solar collectors indicative costs and efficiency (Lambert and Beyene, 2007)

Estimate of costs and benefits

Below, the costs and benefits for cooling offices during summer season is analysed.

Situation:

- average daily solar radiation (average summer day according to data from www.helioclim.net for Amsterdam): 4.8 kWh/m^2 (per horizontal area unit);
- average solar radiation power between sun rise and sun set (16¼ hour) on average summer day: 293W/m2;
- maximum solar radiation during average day 460W/m^2 (estimate);

System considered:

- solar panel (estimations based on table 1)
  - o type: vacuum tube collector (EFP in table 1)
  - o installed costs per m^2 €200;
  - o oriented towards south;
  - o setpoint temperature 85℃;
  - o average conversion on summer days 170W/m^2;
  - o maximum conversion on summer days 330W/m^2.
- sorption cooling process:
  - o adsorption cooling;
  - o COP 0.7;
  - o investment costs 100 to 300 € per kW cooling capacity (for a system with 3000 resp. 300 kW cooling capacity).

According to current standards, 30W cooling capacity is needed per m^3 office room. Thus, for cooling a unit of 5000m^2 offices (with height say 4m) total cooling capacity of 600kW would be needed.

Based on the above system considerations follows (estimations):

- average solar panel heat production 850kW;
- solar collector area 5000m^2;
- investment costs solar panels k€1000;
- investments costs adsorption cooler k€200.

Total investments (excluding heat buffer) about k€1200.

For reference: investments for a traditional cooling system would be a few hundreds thousands euros. Annual energy use: 80MWh (for 16¼ hours per day on the summer days; 5 days per week; averagely 50% of 600kW cooling, with COP 4). With electricity price of €0.10/kWh, the annual energy costs would be k€8.

Conclusion

Straightforward implementation of solar thermal cooling in the Netherlands is not financially feasible.
Feasibility can be improved by using the collected heat of the solar panels also during the cold seasons (for instance for heating purposes).

Sources and further info

Lambert, M.A. and A. Beyene: Thermo-economic analysis of solar powered adsorption heat pump. *Appl. Thermal Engineering* 27, pp. 1593-1611 (2007).

TNO and Deerns: *Keuzewijzer voor koelinstallaties in de utiliteitsbouw*. Rijswijk, Netherlands (2007).

Contact: *Jan Broeze*, AFSG Wageningen UR, phone +31.317.480147, e-mail jan.broeze@wur.nl
Sietze van der Sluis, TNO, Phone +31.88.8662206 email Sietze.vanderSluis@tno.nl

This renewable cooling research is executed with practical input by NVKL and financial support by the Dutch Ministry of Economic Affairs; program *Energie Onderzoek Subsidie: lange termijn (EOS-LT)*.