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Conclusion and recommendations

The study has shown that for the pilot-project in Guaratinguetá the following appropriate and cost-effective solar cooling technology can be applied:

- A closed chilled water cycle system with an integrated (Yazaki WFC-SC10) 35 kW (10 TR) single-effect LiBr-H2O Absorption Chiller and a wet-cooling tower.

- The cold distribution inside the auditorium by four fan coil units. A cooling ceiling is not suitable because it brings nit the sufficient cooling capacity into the building.

- A collector array of 80 m² with Bosch Bruderus Logasol SKN 3.0 (Flat-Plate) has the best performance-cost relation.

- As back-up system should a conventional electrically driven compression split air-conditioning system applied, because heating up the water with gas for driving the single-effect absorption chiller causes six times higher operation cost. Consequently, a thermal gas back-up can not be recommended due to the gas prices in the necessary consumption range and as well due to the negative CO2 balance.

Therewith the congruence between solar gain and cooling demand is good, thus less collector surface is necessary and the investment cost decreases, it's important to clarify in advance which indoor set point temperatures are applicable for the cooling demand calculation. According the Brazilian thermal comfort standard (PNB-10) is 24°C indoor temperature by 29°C ambient temperature well sufficient. With an indoor set temperature of 24°C, the cooling load can be reduced in contrast to an indoor temperature of 20°C for more than half.

It was noted that it is important to verify before dimensioning of a solar cooling system, or generally of a conventional air-conditioning system, too, which cooling demand is really necessary and how it can be reduced through alternative ways, such as, shading measures, (night-) cooling with outside air, building insulation or decreasing (lighting etc.) the internal load.

Through the case study was the economic feasibility of the specified solar-assisted air-conditioning checked and compared with a conventional electrically driven compression split air-conditioning system. It turned out, that the low operation cost can compensate the higher investment cost within the solar cooling system life time of minimum 20 years.

In Guaratinguetá this happens after 12 years with a "tropicalizated" system in which the components are provided individually mostly by the Brazilian market, and after about 16 years by an application of a complete solar "kit" from SolarNext AG, Germany (without solar collectors). In Minas Gerais would yield payback times of 8 and 11 years since there is the price of electricity 60% higher than in Guaratinguetá.

Consequently, solar assisted air-conditioning can compete with Split-Air conditioning system, but only under the following conditions:

- No minor electricity prices than in Guaratinguetá (0,38R$/kWh)

- Cooling demand only during daytime thus application for offices, universities or schools etc. Cinemas are not recommendable.

- Efficient pumps and fans applied

- Financial support for the acquisition through low-interest credits or direct investment grant.

Finally, it must be mentioned that the payback periods are very high for privately-owned buildings. On the other side private companies e.g. hotels could use this technology to do “eco-facade/green marketing”. Solar air-conditioning is a renewable energy technology with an enormous marketing potential. It makes the Sun generate chilled water.

By the demonstration project validation could be made against the simulation data by checking actually measured data. A solar cooling pilot project could fill many of the existent knowledge gaps, confirm the technical and economical feasibility and perhaps become a precursor for a general implementation.

A Pilot-Project is the first step to disseminate this for Brazil "new" environmental friendly technology. It must be made sure that quality of planning and installation has a high level to ensure to later reliability of the system. A market barrier of the implementation is not only the high investment cost, as well, a lack of knowledge. Therefore it's important to realize the first project in cooperation with experienced firms. Hereby a know-how transfer to Brazilian companies who pretends to deal with solar cooling is elementary. As well, a simple pre-design software tool for Brazil must be introduced, thus local companies can dimension their systems. This program should also consider the economic feasibility by the individual local energy prices.

Last but not least, a recommendation regarding "solar cooling" integration in high buildings. In Tropical Cities sufficient roof area for providing a whole skyscraper with solar air-conditioning is often not given. Through a rough estimation can be said that only for two stores enough roof space exists. Hence it is recommendable to use an electrically driven compression central chiller to cover the latent cooling loads and use a solar cooling system in side-stream to cover the highest cooling loads during the day. Thus extra capacity generated by the sun occurs only when the load is the greatest, and the energy source to drive it has no recurring cost.

The energy source is somewhat coincident with the greatest load, providing a sensible means of Peak Shaving, keeping the electric chillers in their most efficient mode during the hottest period of the day. And if the solar collectors are placed on the roof, they will provide a reduced cooling load by shading the roof [3].

The next figure shows clearly that that most efficient mode of an electric chiller lies between 25% and 75% of full load. If the chiller runs at full load it will waste more energy kW per Tons of Refrigeration.

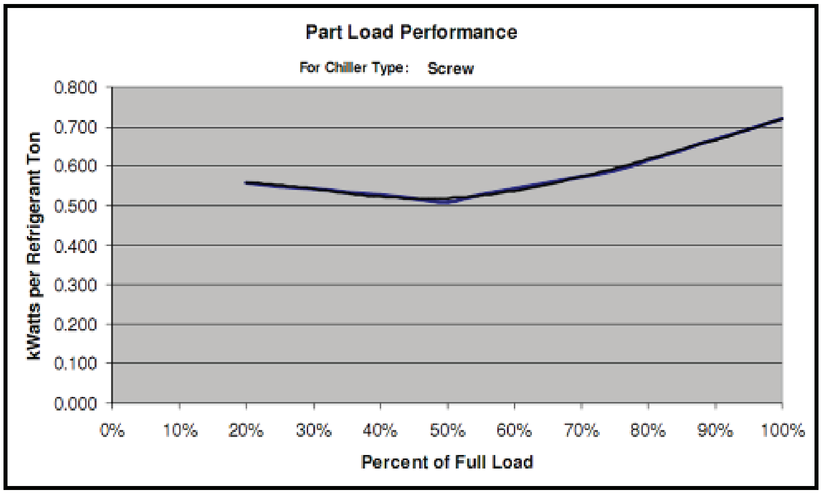

Figure 4.1 - Typical electric driven screw chiller power curve [3].

Brazil receives solar energy in the order of 10^13 MWh per year, which is about 50.000 times the country's annual consumption of electricity. But, despite of this optimum solar radiation condition, as yet only a small part of this energy is used. The most electrical energy is generated by large-scale central hydropower plants, whose sustainability is doubtful. The power supply is through the centrality of power generation very interference-prone, which had showed the recently black-out from 10. November 2009. As well, a lot of energy is wasted due to long way energy transmission for example from Itaipu to São Paulo.

In future the Brazilian government intends to secure the country's electricity supply by more nuclear power and fossil-fuelled thermal power stations.

Energy efficiency measures like solar cooling implementation can contribute to less electric energy consumption. Certainly, it does not solve the country's energy problem, but if the whole country cooling demand would be supplied by solar cooling systems more or less one large-scale power plant could be avoided.

Solar cooling technology is a way to provide building air-conditioning by using local regenerative sun energy. The main advantage is that the cooling load and solar gain occurs at the same time, an at least at seasonal level, which is by other regenerative energies often not the case. From central power plants used primary energy can be saved and CO_2 emissions can be minimized. Through a solar cooling pilot Project in Guaratinguetá 8,3 tons CO_2 could be saved per year and it could open the way for a general application of this environmental technology in Brazil.