Renewable Energy for the Paranal Observatory

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The operation of observatories at remote sites presents significant demands for electrical energy. The use of renewable energy may become the solution to cope with the ever-rising prices for electrical energy produced from fossil fuels. There is not only a purely commercial aspect, but also the carbon footprint of observatory activities has to be considered. As a first step on the way to a "greener" Paranal Observatory, we propose the installation of a solar cooling system for the cooling of the telescope enclosures, using the abundant insolation that is freely available in the north of Chile. Further into the future, feasible options for photovoltaic and wind energy could supply the needs of the Paranal Observatory in a sustainable manner.

The location of the Paranal Observatory in the Atacama Desert has, apart from its remoteness, two other important advantages: the clear night-time sky in northern Chile provides astronomers with more than 320 clear nights per year; the clear day-time sky also provides abundant sunshine. But 20 years ago, when oil was still cheap, little thought was given to the fact that the situation for economic provision of energy to the observatory could one day change. It is increasingly difficult for the Paranal operations budget to accommodate the growing financial demand for electrical energy production. The increasing energy costs cannot be predicted in an easy way for the near future and depend heavily on exchange rates, oil prices and the global economy.

Between 2003 and 2010, electricity prices in Chile rose on average by 6.8% per year, according to statistics from the Organization for Economic Co-operation and Development (OECD[1]). The renewable energy share in Chile was 49% in 2009[2] with, however, a downward trend anticipated in the coming years as coal-fired power plant projects, presently under discussion, begin to be realised. Confronted with these facts, the Observatory started to look into possible solutions to control its energy costs. One obvious option is the production and use of renewable energies.

There are however some caveats and boundary conditions that have to be taken into account:
- Paranal is operating in "island mode" and has no connection to the Chilean power grid.
- Solar energy cannot easily be stored, either as electrical or thermal energy.
- Wind energy is highly intermittent and requires a full back-up by conventional energy generators.
- Any solution adopted for Paranal should be compatible with the European Extremely Large Telescope (E-ELT) project which is planned to be built on the nearby Cerro Armazones peak, and not pose any precedents or dependencies for this new project.
- The proposed investment should be reasonable and the time for return on investment should be as short as possible.

Paranal power consumption has remained stable over the past few years, despite the addition of the VISTA survey telescope and the VLT Survey Telescope (VST). In the telescope area, the four unit telescopes (UTs), the VLT Interferometer (VLTI) and the VST consume 67% of the total power of approximately 1200 kW. A breakdown of the power use across the Observatory is shown in Figure 1.

Beyond purely economic considerations, the long-term impact of observatory operations on global climate and environmental sustainability should also be addressed. The carbon footprint of the Observatory is, at 22 000 metric tonnes of CO_2 per year (see Figure 2), at a level that is hardly sustainable. (The cost to offset the entire CO_2 emission of the Paranal Observatory would be in the range of €500 000 per year [at €23 per tonne of CO_2]). The CO_2 emission of the Observatory translates into approximately 46 tonnes of CO_2 per peer-reviewed VLT science paper per year, which itself is equivalent to the yearly CO_2 footprint of ten people at the current world average. The main contributor to the CO_2 footprint is the electricity generation by liquefied petroleum gas (LPG, consisting of butane/propane). A reduction in the number of international and domestic flights, i.e. by eliminating visitor mode observations, would only reduce the footprint by some 10%, but would have an undesired

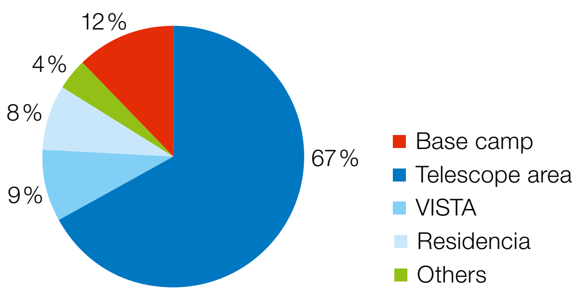

Figure 1. The breakdown of average electrical power distribution between the various elements of the Paranal Observatory (100% = 1200 kW).

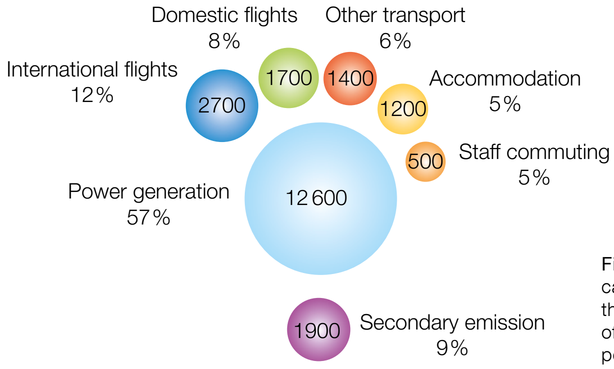

Figure 2. The breakdown of the carbon footprint for the operation of the Paranal Observatory in terms of tonnes of CO_2 equivalent and by percent.

impact on the operational model of Paranal. Connection to the Chilean grid would also not improve the carbon footprint much, once coal dominates the energy mix in Chile. This demonstrates that a real reduction of the CO_2 emission can only be achieved if electricity is generated from *renewable* sources.

Alternatives

Looking at all the known technical options and discarding those that are not suitable for the Observatory — either due to its mountain location, or for other reasons — there remain basically only three alternatives for energy generation from renewable sources:

- solar thermal energy, harvested either by concentrating or flat collectors;
- solar electricity, by means of photovoltaic panels in staring or tracking mode;
- wind energy, with windmills on a nearby mountain ridge, avoiding increased turbulence at the observing site.

Solar thermal energy is the easiest option of all, as it uses known, simple and cheap technology that has been available for many decades. Using concentrating collectors, processing of heat up to 600 °C can be achieved to drive Stirling engines or Rankine cycle turbines, while flat collectors can deliver hot media just below the boiling point of water- or glycol-based coolants.

Photovoltaic (PV) energy is a modern technology, but ripe for industrial use, and it has been proved that it can be competitive in terms of reliability and cost and is almost maintenance free. Crystalline solar cells now reach efficiencies in the range of 20%, while thin-film cells are just about crossing the 15% level. The costs for PV have now almost reached the magic barrier of 1 €/W, which is considered to be the price where PV becomes economically feasible. Manufacturers of PV technology now guarantee a service life of more than 20 years.

Wind energy on the other hand is attractive from the point of view of simplicity, but has some drawbacks, such as intermittency, that could have a more serious effect at Paranal compared to PV, for example. Wind turbines cannot be installed in the immediate vicinity of the Observatory due to the long turbulence tail they cause. Siting them further away would result in higher installation costs. Estimates show that two wind turbines of the 800 kW class would cover ~ 40% of the Observatory's energy demand.

With the possibility of getting a connection to the Chilean power grid sometime in the near future, both PV *and* wind are highly attractive solutions for the future and should be kept on the alternative energy agenda of Paranal. Under conservative assumptions, up to 50% of the energy demand could be covered using these three technologies.

Expanding on these ideas, business models like BOO (Build-Own-Operate) or DFBO (Design-Finance-Build-Operate) could be considered as well, also in the context of the E-ELT. Due to their intrinsic modularity, PV fields and wind turbines can be added with little effort and at will to an existing system and cope with growing demand and increasing energy costs. The higher energy costs rise, the sooner alternative solutions become economically interesting and the shorter the return time on investment is. This fact should not be left out of the discussion. During 2010 and 2011, we looked into possible solutions to, at least partially, provide the Observatory with renewable energy and explored one idea that would in fact be in line with the considerations listed above: a solar cooling system for the VLT telescope enclosures.

The cooling of the VLT enclosures

Paranal uses three chillers that produce cooled media for the cooling of all the electronic equipment, the scientific instruments, the buildings and the enclosures of the VLT. These chillers operate almost continuously, as the demand for cooling during the night at 660 kWth (thermal) is only about 30% lower than during the day. This extra demand of around 300 kWth during the day is only used for air conditioning the VLT enclosures.

During the day, there is an almost perfect correlation between cooling demand and availability of solar energy. With an adsorption or absorption system, this thermal energy can be transformed into cooling energy and supply the air-conditioning systems in the telescope enclosures. The load of at least one chiller could be taken over and approximately 150 kW of electrical power could be saved. This would correspond to 15% of the generated power and about 5% of the energy, translating into savings of the order of € 150 000 per year at *present* energy prices. This solution is simple and does not imply very sophisticated technology. Several solar cooling plants are already operating in southern Europe and the Middle East and compare in terms of reliability to conventional

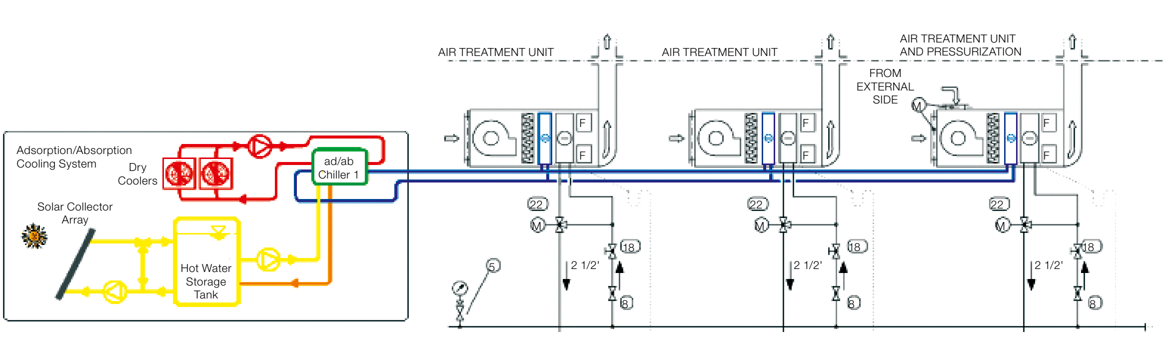

Figure 3. A solar-powered cooling circuit for one Unit Telescope is shown. See text for explanation of the various elements. The solar circuit is shown in yellow; ab(d)sorption cooler in green; dry cooler (red); cooled media delivery (blue) for three air-handling units at the telescopes (only one shown).

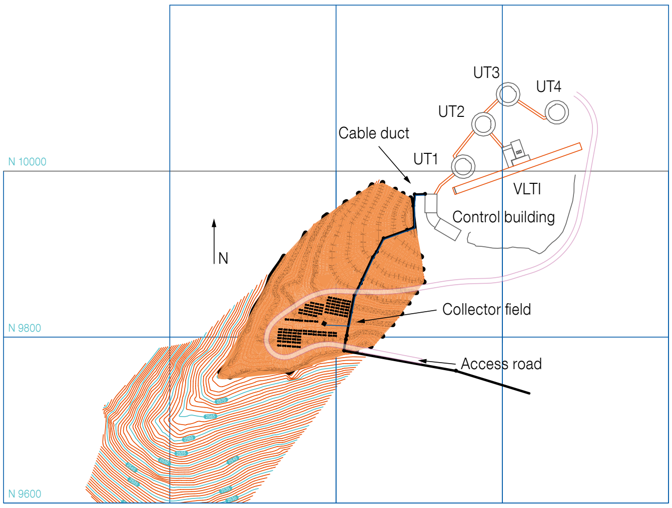

Figure 4. Proposed location of the solar array collector field at the Paranal Observatory; the connection to the telescope enclosures is shown.

plants with electrical compressor chillers. The temperature that an absorption cooler can deliver does not however reach the low levels that are required by the technical equipment in the telescopes (3–5 °C). There are two possible ways to implement this system on Paranal.

One solution would supply the cooled media directly to the air-handling units located on the outside of the VLT enclosures. Figure 3 shows the diagram of the system: hot water from the solar panels (yellow) acts as a thermal compressor in the absorption chiller[3] (green) and evaporates the water from a water / lithium bromide solution. The water is then condensed by means of the dry cooler loop (red) and absorbed back again into the lithium bromide. The cold water (blue), produced in the absorption process, then feeds the air-handling units (black) of the telescope enclosures. The other possible solution would be to use the solar energy circuit to pre-cool the return flow from the cooling system and feed this pre-cooled water to the electrical chillers to further lower its temperature to the desired level. It has not yet been decided which of the two solutions will finally be chosen. A detailed engineering study is required to explore these options.

A collecting area of approximately 1500 square metres is required for the solar collectors, which would require an area of 2000 square metres of land. A suitable place has been identified in the vicinity of the present satellite antenna (see Figure 4).

The absorption machine would be placed in a container nearby and the piping would be routed through existing ducts to the control building and the telescopes.

Other energy savings

Beyond the large-scale projects for the implementation of renewable energies, energy saving also has to be addressed. The awareness of the Observatory staff with respect to energy saving is growing and together with technical solutions, can reduce the waste of energy. Many proposals have been made, but they are sometimes difficult to put into practice.

On the larger scale, pumps may be switched off if they are not in use or idling, recirculation pumps and fans could be upgraded with variable speed control. Capacitor banks for the compensation of reactive power are currently being installed on the low voltage grid and will save of the order of €100 000 in LPG per year. The hot water for the Paranal Residencia is already heated with the exhaust gas from the gas turbine, but this system could be expanded also to the container camp and later be upgraded to a solar heating system. Waste water treatment and recycling is another example where costs and resources could be saved.

On the smaller scale there are all the desktop computers, screens and printers that could either be switched off or put into hibernation, lights in corridors and telescope tunnels could be motion controlled and office equipment could either be switched off completely or put into hibernation, etc. There are many opportunities to tackle the energy issue also from the side of savings and we will continue to address them over the coming years.

Outlook

Unfortunately, when the VLT project was conceived in the early nineties, renewable energy concepts were not on the agenda. To refurbish the Paranal Observatory now with renewables would be expensive and only partially lead to an ideal solution. Compromises have to be made and the heritage from sustainability not designed-in right from the beginning will always remain. Nevertheless rising energy prices will force us to go this route and the solar cooling project is just at the beginning of the green path that the Paranal Observatory is willing to take! Astronomy is one of the oldest sciences and perhaps could be considered as one of the purest. We should try to avoid contributing to the pollution of the atmosphere of our planet, and make use of the abundant energy that the nuclear fusion reactor at the centre of our Solar System is producing for free.…

Acknowledgements

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References

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Links

[1] OECD: http://www.oecd-ilibrary.org/economics/country-statistical-profile-chile_20752288-table-chl
[2] International Energy Agency: http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=CL
[3] Absorption Chillers: http://www.solair-project.eu/143.0.html