ESS

The European Spallation Source, to be built in Sweden, will be powered entirely by renewable energy.

Cutting science's electricity bill

Large-scale research facilities need to reduce their energy consumption and begin moving towards sustainability, says **Thomas Parker**.

Major research facilities such as accelerators and reactors each consume roughly as much electricity as a small town — hundreds of gigawatt hours (GWh) of energy per year or more (see 'Annual energy expenditure'). International and national labs use a total of roughly 3 terawatt hours per year in Europe and 4 terawatt hours (TWh) in the United States, adding up to about the energy consumption of countries such as Estonia or Ghana. This energy use is perhaps these facilities' greatest environmental impact, greater even than the radioactive waste that many produce. Radioactivity can be contained and handled safely; climate change cannot.

The European Spallation Source (ESS) — a neutron source to be built in Lund, Sweden, by 2019, for which I am the energy manager — aims to be the first sustainable such facility. We will use only renewable energy sources to power the accelerator and the lab. We will limit our energy use: so far in the design process we have reduced our energy requirements by more than 20%. And 70% of the energy that we consume will be recovered as usable heat.

Many of the specific solutions that we are adopting at the ESS rely on local conditions, including a liberalized energy market, a well-developed district heating system, a relatively cool climate and public and political support. But the project stands as proof of principle that big science can be sustainable science, and it challenges other facilities to live up to the same standards.

USE IT, DON'T LOSE IT

One area in which there is obvious room for improvement at big labs is the use of waste heat from lab equipment. Water at 40 °C can easily supply buildings with under-floor heating or thermal ventilation, if the right systems are in place. Waste heat of 75 °C can even be used to run cooling air conditioners. But most labs intentionally destroy this resource.

Conventionally, equipment ranging from accelerators to manufacturing machinery is cooled to run at 40 °C or lower. This is in part because early electronics operated best at lukewarm or cool temperatures, and in part to avoid harming aquatic life when the cooling water from hotter systems is discharged into natural systems such as rivers. This target has become so firmly entrenched that manufacturers were surprised two years ago when we began asking them if their modern equipment would work efficiently at higher temperatures. No one else had asked.

It turns out that many modern systems can work at much higher temperatures, allowing the heat to be saved for reuse, with or without conversion to electrical power, rather than being extracted by a heat pump, dissipated in expensive cooling towers, or dumped into the air or water. Sometimes this requires small modifications, such as using sturdier components, or adding adaptable cooling systems that can handle variable heat loads and deal with rare instances of overheating. At the ESS, we are working to design power systems for our accelerators and helium compressors for our cryogenics that can operate at 75–100 °C. One of the challenges is finding the room for extra sets of pipes: some parts of the facility will still need to be cooled to 40 °C for proper operation, so we need parallel cooling systems for parts that are cooled to different temperatures.

Few places recycle their heat. Instead, they burn fossil fuels to meet their heating and cooling needs. For example, CERN, the European high-energy physics laboratory near Geneva, generates waste heat at 40 °C before disposal. This could be used for heating, but its current system uses pressurized 120 °C water instead. Changing CERN's entire heating system retrospectively might be too costly, but new buildings could be designed to use the 40 °C heat. Likewise, the spallation neutron source at Oak Ridge National Laboratory in Tennessee cools its equipment to about 30 °C using a cooling tower, and then uses gas-fired boilers to heat its building, with no connection between the two systems.

Rather than dumping its leftover heat into cooling towers, the ESS will plug in to the city of Lund's district heating system, which operates a network of hot-water pipes under the entire city and a neighbouring community 20 kilometres away — showing that long distances between the producers and users of heat energy aren't necessarily a problem. We estimate that the ESS will produce about 180 GWh of heat per year, of which about half will be of a suitable temperature to go straight into the district heating system; much of the rest will be warmed electrically so that it doesn't go to waste.

A handful of facilities are taking similar steps. The ESS has a neighbouring synchrotron light facility, Max IV, currently under construction, which plans to cool some of its waste streams only to 75 °C or higher, again to feed into Lund's district heating system. On the other side of the world, a team at the TRIUMF particle accelerator at the University of British Columbia in Vancouver, Canada, is investigating whether it can use its waste heat to warm residential buildings on campus.

REDUNDANT SYSTEMS

TRIUMF demonstrates the problems that such systems can face. The plumbing and heat pumps needed can be costly. And because the surrounding communities don't need heating during summer, a lab such as TRIUMF will have to install back-up cooling devices. In Lund this won't be a problem: the district heating system is being extended, so there will always be sufficient demand for hot water to use up the ESS's waste heat. Conversely, a lab might not provide heat when the community needs it, again requiring a back-up system. If redundant systems are needed on both sides, then there are no savings in investment costs, although there may still be benefits for operating costs.

It is better to be energy efficient in the first place than to recycle: an industry rule of thumb is that electricity is about 2.5 times more valuable than high-grade heat.

Research facilities by their very nature are often pushing the limits of technology and science: cooling to temperatures near absolute zero, for example, or accelerating to near light-speed. Some of these processes are staggeringly inefficient in terms of energy use. Supercooling, for example, uses about 1,000 kWh of energy for every 1 kWh of heat energy that it removes from a system, as it fights to get to ultracold temperatures.

Many labs, including the ESS and CERN, have ongoing projects to improve the efficiency of cryogenics and accelerator power systems, to name two examples. Radio-frequency accelerator power systems have to be tuned to the right frequency for a given beamline, and while that is happening, the electrical energy needs to be diverted. Often it is used to heat water, but it would be more efficient to divert the electricity to somewhere it is needed. CERN in particular is looking into this now.

The ESS has so far managed to reduce its power requirements by 22% in the design update. Nearly two-thirds of this was achieved by using superconductivity in the accelerator power system, which eliminates losses to electrical resistance. Achieving superconductivity requires cooling the equipment to close to absolute zero, with all the inefficiencies that entails. Despite this, there is still a net efficiency gain.

The ESS will build its own renewable-energy-generating facilities to cover all its power needs. This makes the lab more sustainable and hedges against future energy-price volatility. The exact power systems have yet to be decided, although wind power seems the most economical resource in this region. Part of the plan is to have some demonstration plants on site showcasing innovative energy technologies to the public.

There is a funding problem for big facilities that tends to perpetuate energy wastage: facility budgets for initial infrastructure and for ongoing operations often come from different purses, making it hard to justify an initial investment in energy-efficient systems in exchange for long-term savings. The governing bodies of such facilities need to be aware of this issue, and remember that there is more than cash at stake.

In the United States, the national labs are obliged to reduce their emissions to 28% of 2008 levels by 2020. The plans in place to achieve this goal mostly involve increasing energy efficiency or relying on renewables — heat recycling is not mentioned in the Department of Energy's Strategic Sustainability Performance Plan. Ongoing projects include biomass heat and energy co-generation at Savannah River, and biomass steam generation at Oak Ridge.

PRACTICAL VISIONARIES

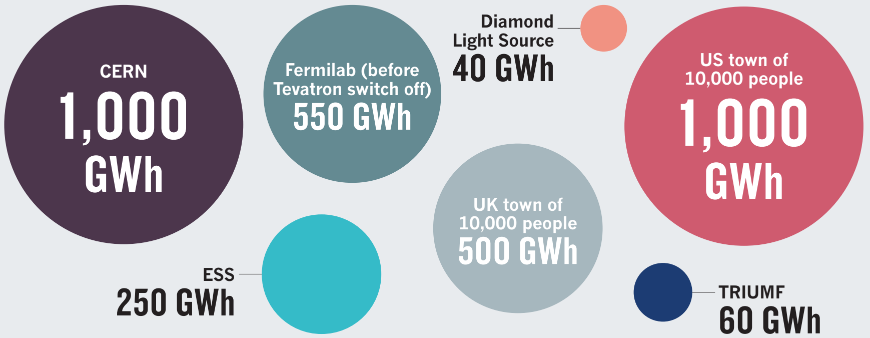
At a workshop in Lund this October on energy management for large-scale research infrastructures, initiated in part by myself and co-hosted by the ESS, CERN and the European Research Forum (the organization of national laboratories in Europe), it was clear that although many heads of national labs are in favour of greening their facilities, most are in only the earliest stages of changing operations.

Some larger projects should serve as an inspiration. The DESERTEC project, for example, promotes the construction of solar power plants and wind parks in north Africa, along with transmission lines to high-usage areas in southern Europe. As part of the programme, African nations that supplied facilities with renewable resources would also be given a say in the running of these projects. This promotes not just energy sustainability, but also intellectual sustainability in emerging economies. At our meeting, Helmut Dosch, chair of the board of directors of the German accelerator complex DESY, made an impassioned call for national labs to get involved in making this programme a reality. There is a place for both visionary leadership and practical groundwork.

As the public and its representatives become increasingly aware of the need for energy efficiency, the argument for energy-intensive research becomes weaker. Big science needs to do some housekeeping. The scientists who work at these facilities, perhaps contrary to popular perception, are people with ethical concerns about the environment. They need to translate those concerns into action. ■

ANNUAL ENERGY EXPENDITURE

Large physics facilities, such as CERN, use as much energy as a small town every year. Smaller ones, such as the European Spallation Source (ESS), also consume lots of electricity. All would benefit from going green.



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