Responsible, Renewable, Recyclable. An Energy Management Strategy for the European Spallation Source

Parker, Thomas

2010

30 April 2010

Responsible, Renewable, Recyclable

An Energy Management Strategy for the European Spallation Source

Final Report

Energimyndigheten projekt 31093-1
Vinnova Dnr 2008-03141
Vetenskapsrådet

Contacts
Thomas Parker, thomas.parker@esss.se, tel. 046-2226701
Energy Manager, European Spallation Source
Vetenskapsrådet, Johan Holmberg, johan.holmberg@vr.se
Energimyndigheten, Mattias Blomberg, tel. 016-544 22 52,
Vinnova, Kaj Klarin, tel 08-473 3170 kaj.klarin@vinnova.se

Abstract: Energimyndigheten, Vetenskapsrådet and Vinnova have supported the ESS Scandinavia Secretariat with 3 MSEK to explore sustainable energy solutions. The result has been that even greater resources have been contributed by cooperating industry. The work is still in early stages of progress, but preliminary calculations indicate that the savings for the ESS might amount to four times the initial funding and save 160 000 tons of CO_2 emissions annually.

Kort sammanfattning: Energimyndigheten, Vetenskapsrådet och Vinnova har stött ESS Skandinavien Sekretariatet med 3 Mkr för att undersöka hållbara energi - lösningar. Resultatet har blivit att ännu större resurser har bidragits från samarbetande industri. Arbetet är fortfarande i ett tidigt skede av utvecklingen, men preliminära beräkningar visar att besparingarna för ESS kan uppgå till fyra gånger den ursprungliga finansieringen och spara 160 000 ton CO_2 utsläpp per år.

Summary

The goal of the project was to develop a strategy for energy management for the European Spallation Source and thus strengthen Sweden's candidacy for hosting the facility. The project has been a great success in that:

1. A proactive energy strategy was developed and presented.
2. The site for ESS has been determined to be Lund.
3. The Energy Strategy was accepted by the ESS Steering Committee.

The designated method of developing the proposed strategy was to hire an Energy Manager and an Energy Engineer. Both have been in post now for over a year.

The strategy is based on three energy goals:

1. Reduction of expected energy use by 20% compared with original design.
2. Using 100% renewable source of energy.
3. Recycling 60% of the energy used as heat.

According to the formulated strategy, these objectives will be met by careful energy planning and management, investment in a wind farm for electricity generation equivalent to projected use, and the recovery of waste heat for district heating.

With the specifications used when the decision was made to locate the European Spallation Source in Lund, the plant was calculated to use 300 GWh of electricity per year over 40 years of operating time. Fulfilment of all the targets above through the implementation of the strategy would have the effect of:

1. Saving 60 GWh of electricity per year for 40 years.
2. Recycling 144 GWh of heat per year for 40 years.
3. Increasing profitability by 13 million € a year.

A snowball effect of the strategy work can also be seen in that the Lunds Energi group and E. ON Sweden today contribute at least two full-time professional positions to work towards implementing the strategy. This will be a major effort, requiring surmounting challenges such as seasonal storage of surplus heat, systems and technology for temperature regulation, design and process optimisation in order to realise savings and target temperatures as well as optimisation of the internal process simultaneously with the local energy system. To meet these challenges will require both research and development. As a direct result of working to overcome these challenges, a vision emerged of a centre for research, development and demonstration of energy - even before the ESS facility itself is complete.

One further goal will be achieved through this strategy – ESS will become a model for large scale scientific facilites in the future. Already high visibility is being achieved through invitations to give seminars abroad and through articles in international journals.

Sammanfattning

Syftet med projektet var att ta fram en strategi för energiledning på European Spallation Source och på så vis stärka Sveriges kandidatur som värld för anläggningen. Projektet har varit en stor framgång i det att:

1. En offensiv energistrategi togs fram och presenterades.
2. Platsen för ESS har bestämts till Lund.
3. Energistrategin fastställdes av ESS Steering Committee och kommer därmed verkställas.

Den utpekade metoden att utveckla strategin var att anställa en ”Energy Manager” och en ”Energy Engineer”. Så har också skett.
Strategin baseras på tre energimål:

1. Minska energianvändningen med 20% jämfört med ursprunglig design.
2. Använd 100% förnyelsebar energi.
3. Återvinn 60% av den använda energin som värme.

Enligt den framtagna strategin, ska målen uppfyllas genom en noggrann energiplanering, investering i en vindkraftpark för motsvarande elproduktion, och återvinning av spillvärme till Lunds Energis fjärrvärmenät.
Med den utformning som användes när beslutet fattades att förlägga European Spallation Source till Sverige och Lund beräknades anläggningen använda 300 GWh elenergi per år under 40 års drifttid. Uppfyllelse av alla mål genom förverkligande av strategin skulle därför få effekten att:

1. Spara 60 GWh el per år i 40 år.
2. Återvinna 144 GWh värme per år i 40 år.
3. Minskade koldioxidutsläpp med 165 000 ton per år i 40 år.
4. Förbättrad lönsamhet med 13 miljoner euro om året.

En snöbollseffekt av strategiarbetet kan också märkas i att Lunds Energikoncernen AB och E.On Sverige AB idag bidrar med motsvarande minst två heltidstjänster till arbetet med att förverkliga strategin. Detta kommer att vara ett omfattande arbete och kräva lösningar på frågor som säsongslagring av överskottsvärme, system och teknik för temperaturhållning, design och processoptimering för att realisera besparingar och måltemperaturer samt optimering av den interna processen samtidigt med det lokala energisystemet. För att klara dessa utmaningar kommer det att krävas både forskning och utveckling. Som ett direkt resultat av arbetet att möta dessa utmaningar har fötts en vision om ett centrum för forskning, utveckling och demonstration på energiområdet – innan ens ESS anläggningen är klar.

Ett ytterligare mål kommer att uppnås genom denna strategi – ESS kommer att bilda modell för storskaliga vetanskapligsanläggningar i framtiden. Projektet har redan fått stort genomslag genom inbjudningar till seminarier i utlandet och artiklar i vetenskapliga tidskrifter.

1. Background: A Strategic Meeting

Following a discussion on December 11, 2007 between the Heads of Vinnova, Vetenskapsrådet, Energimyndigheten and the ESS Scandinavia project at the Vetenskapsrådet offices in Stockholm, a project was proposed to develop a compre - hensive Energy Strategy for the European Spallation Source. This was to be of suffi - cient scope and quality to contribute to the selection of Lund as the site of the future ESS. The benefits of success for the environment and a sustainable society would be profound, as the project would ensure that the Energy Strategy that was developed indeed was comprehensive, and winning the site decision would ensure a commit - ment to follow the strategy laid out. It was proposed that a project cost of 3 MSEK would be shared equally between these two funding agencies together with Vinnova.

On the evening of May 28, 2009, in Brussels, an informal vote among nations committed to the ESS project was taken and showed an overwhelming support for Lund as the future site of ESS. Since then, fourteen nations, including the former site contenders Spain and Hungary, have signed agreements and formed a Steering Committee to oversee the development of the European Spallation Source. At the first meeting of the Steering Committee, on October 23, 2009, representatives of 13 European governments considered and approved a proposal entitled "Environmental Strategy", which detailed the conclusions and recommendations of the Energy Strategy project. The results of the work have been given the name Sustainable Energy Solutions.

2. Resources: The Snowball Effect

The project envisiaged the employment of an Energy Manager and an Energy Engineer, both of whom have been recruited. In addition, preliminary investigations in the project showed an opportunity to make use of resources in local energy companies, a resource which is now being put into full use. Four energy companies, varying from local to international players, have signed cooperation agreements with the ESS Secretariat and are contributing substantially, involving around 20 of their experts, corresponding to 5-8 full time engineers.

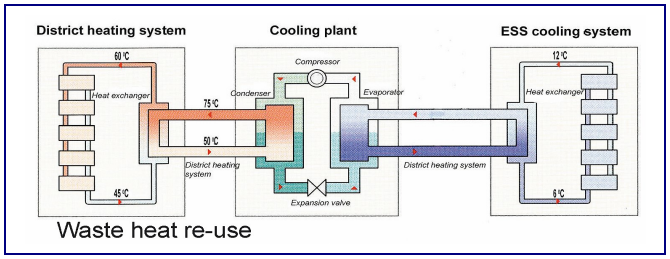
A cooperation agreement with the Spallation Neutron Source, at the Oak Ridge National Laboratory in Tennessee, has allowed full access to that facility and relevant operational data in order to quantify its energy inventory and apply this to the ESS. This has been very useful for modelling the future European Spallation Source and its associated energy and temperature flows.

3. Project Results: Progress and Processes

The basis for the Sustainable Energy Strategy for ESS in Lund includes:

- An energy culture supported by careful monitoring,
- An environmental and energy management system,
- Three demanding energy goals, that are:
    - 20% reduction of energy,
    - 100% renewable energy use, and
    - 60% of energy used recycled.

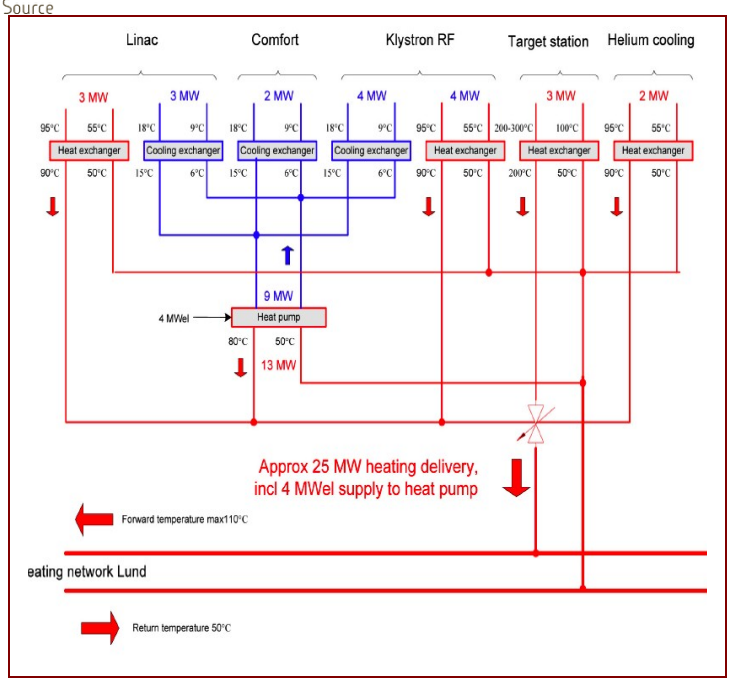
The figure below shows the principle of heat recovery to the district heating system. In this case heat pumps are used to augment temperatures for each system. This can be very efficient if the temperatures difference between the systems is not to high. It would be even more efficient if the heat pump were made unnecessary by channelling hotter water to top up the temperature. In all cases, the systems will be closed loop and separated by heat exchangers.



Waste heat re-use

The energy goals present a number of challenges and processes are in place to meet each of these. Significant gains in energy efficiency can be made with careful design of heating and cooling systems, as well as the buildings themselves. Because of the dominating energy consumption of the accelerator systems, however, energy efficiency gains must also be realized within these and this has been a major focus in these efforts.

Efficiency in connection with the recycling of excess heat requires careful attention to temperature, as well as to energy flows. This is being addressed by constructing an energy and temperature flow chart for the planned facility, to be presented in its initial form in June 2010. Based on this flow chart, preparations for strategic design decisions can be made, such as the number and temperature of the various cooling loops. This will also be an important input into feasibility studies for energy recycling options, most importantly to the district heating system. The diagram below shows an example of a flow chart, based on earlier information.



During the year, it is clear that the heat produced at ESS will, during some seasons, exceed the total need within the local district heating system. To achieve the goal for energy recycling, a seasonal storage system will therefore be necessary, either on site or elsewhere in Lund. Two alternatives are being explored. The first alternative is to convert Lunds Energi's established geothermal plant for use as a storage aquifer. The other option would be drilled storage on site, similar in type but on a much larger scale to the systems that are in operation at the nearby Lund University chemistry centre, the astronomy department and the languages and literature centre.

During the process of the project, it became clear that the technology choices for capture and recovery of waste heat are entirely dependent on temperature. Initial models showing energy flows only, therefore needed to be complemented. This process is underway. Interim findings indicate that appropriate temperatures for district heating should be achievable. In this case, the use of the excess heat as district heating will almost certainly be the most attractive alternative. Lunds Energi, the owner and operator of the local district heating network, has been working closely with ESS for the entire project and has devoted a qualified and diverse team of experts and managers to the effort of developing a mutually beneficial system. Although there are no agreements that stipulate a commitment for either side to supply or receive the heat, the level of effort indicates a clear commitment. Moreover, a liberalisation of district heating systems nationally is expected in future regulation, allowing third party access to distribution networks. This would strengthen the position of ESS by allowing sale of excess heat on an open market.

For renewable energy production, a recent expert study commissioned for ESS

shows profitability for investments in wind power on-shore in Sweden or offshore in Germany. Such projects are currently being explored with partners in the energy industry. ESS has an agreement with Vattenfall Vindkraft AB to explore projects to develop a wind power plant with sufficient production to cover the annual demand of the ESS facility, currently projected to be close to 300 GWh. Additionally, wind power developments are also being discussed within the framework of the broader cooperation agreement with E.On Sverige AB.

A special study commissioned from Vattenfall Power Consultants (attached) shows profitability, under current conditions for wind power on shore in Sweden and off shore in Germany, if possible locations are limited to those within partner countries only. Acquiring an appropriate site for wind power development may prove to be the most challenging step of the development. Another challenge, currently in focus, is securing full financing for ESS for the wind power project. This is a clear requirement from the ESS Steering Committee.

The ESS site itself is not sufficient for wind power instalments adequate for the power needs of the facility, although the working goal is to build as much on-site power generation as possible.

Regardless of the site of the future wind power production, or other renewable production form, a direct coupling between the power production and the ESS is not technically or economically feasible. Some sort of energy balancing will be necessary. Such contracts are well known in the Nordic electricity market, and can be obtained with ease and reasonable cost from several providers. This aspect in itself brings considerable advantage to the operational budget of ESS, in that fluctuations in energy costs are factored out.

4. Expected Outcomes: Economy and Ecology

Economic calculations of the Sustainable Energy Solutions show that the annual savings and revenue may amount to five million euro per year from improved energy efficiency and revenue from waste heat, compared to a conventional facility. Additionally, partner energy companies have estimated the value of the renewable energy investment as eight million euro per year in reduced electricity costs, after the financial costs have been deducted. At the same time, CO_2 emissions will be reduced by 160 000 tons per year. Apart from the electricity production, the sustainable energy solution is actually calculated to requre a lower total investment than the conventional alternative, mainly due to avoiding both cooling towers and boilers.

5. Continued Research: Science for Science

Realising the Sustainable Energy Solutions for the European Spallation Source will still require significant research and development efforts. The involved disciplines will be centred on energy technology and energy systems, but also involve such diverse areas as geology and management. Technologically, the greatest challenge is certainly the energy efficiency of the accelerator and related systems. A 200 MSEK laboratory effort is currently being planned in Uppsala to address this. On a lesser, but nonetheless substantial scale is the development of seasonal heat storage in Lund to encompass 50-100 GWh of heat. The basis for the energy solutions must be an energy flow map. Methods, analysis and models to work with energy and temperature flows will have to be developed as the project progresses. Finally, an Environmental and Energy Management system appropriate for a Big Science project such as the ESS must be explored, adapted and developed. Currently, discussions are underway for 3 masters projects and 4 doctoral projects within the ESS energy solutions.

Here is an opportunity for Swedish science to occupy a new space in the forefront of Big Science. Already, the sustainability efforts at the ESS have created interest in places like Darmstadt, Washington and Vancouver. A "Greening of Accelerators" group is starting to form. Based on work at ESS, a position at the forefront of Green Big Science is within reach.

There are also attainable benefits for Swedish industry and municipalities. A successful model for recycling waste heat could be applicable all across Sweden. Interesting and aspects that can be generalised include both the design of a complex process to minimise energy use and maximise recycling, and the system for seasonal storage.

It is our sincere hope that the strategic partnership formed in this explorative project may be applied to the development of these opportunities.

Thomas Parker, thomas.parker@esss.se, tel. 046-2226701
Energy Manager, European Spallation Source

Attachments: Reports produced in the project
Sydtotal: Energy use in buildings and processes at ESS.pdf
Vattenfall Power Consultants: Wind Power supply - Financial impact report.doc
Parker: Strategy Document for Steering Committee (SC Agenda item 9.2.doc)
Parker: Strategy Document for ESS Board (Secretariat Board April 14 2010 Agenda item 7.doc)
Parker: Interim Project Report (ESSS Energy Management May 2009.doc)
Andersson: Electrical Diagrams (The electricity supply of ESS.pdf)