Energy Effciency of Particle Accelerators: A Networking Effort within the EuCard2 Program

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Energy Effciency of Particle Accelerators
A Networking Effort within the EuCARD² Program

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Abstract:
EuCARD² is an Integrating Activity Project for coordinated Research and Development on Particle Accelerators, co-funded by the European Commission under the FP7 Capacities Programme. Within the network **EnEfficient** we address topics around energy efficiency of research accelerators.
The ambitious scientific research goals of modern accelerator facilities lead to high requirements in beam power and beam quality for those research accelerators. In conjunction with the users' needs the power consumption and environmental impact of the research facilities becomes a major factor in the perception of both funding agencies and the general public. In this network we combine and focus the R&D done individually at different research centers into a series of workshops.
We cover the topics "Energy recovery from cooling circuits", "Higher electronic efficiency RF power generation", "Short term energy storage systems", "Virtual power plants" and "Beam transfer channels with low power consumption". Our network activities are naturally open to external participants. With this work we will introduce our energy efficiency topics to interested participants and contributors from the whole community.

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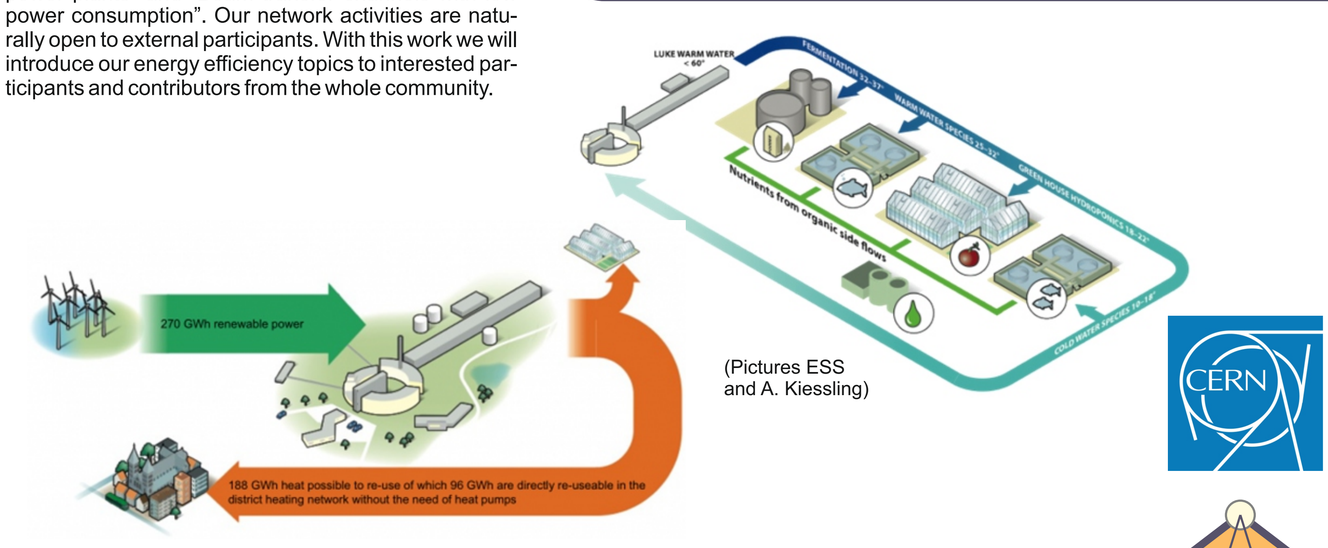
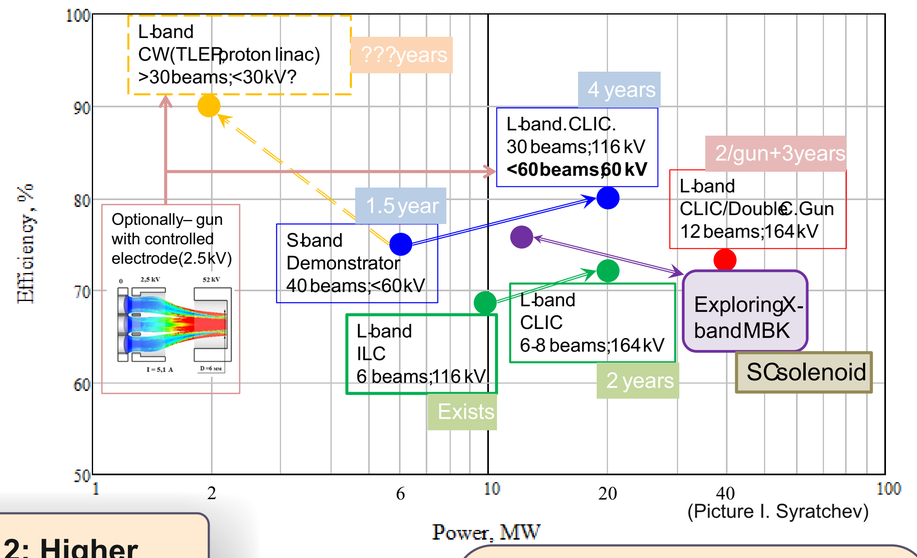
Accelerators and Power Consumption

Regarding the development of accelerator facilities two contradicting trends can be observed that lead to an increasing significance of energy efficiency. The worldwide scarcity of resources and the attempt of several countries to de-emphasize nuclear and coal-fire power production, the classical base load power production schemes, leads to economical and political pressure to limit power consumption in large facilities. On the other hand proposed next generation facilities utilize advanced technologies and provide a new quality of research opportunities, but often connected with significantly higher power consumption.
Also for other new accelerator projects energy consumption is an issue and consequently more effort should be invested in efficient technical solutions. Within the network EnEfficient we aim to support and intensify these efforts, especially in view of the new projects.



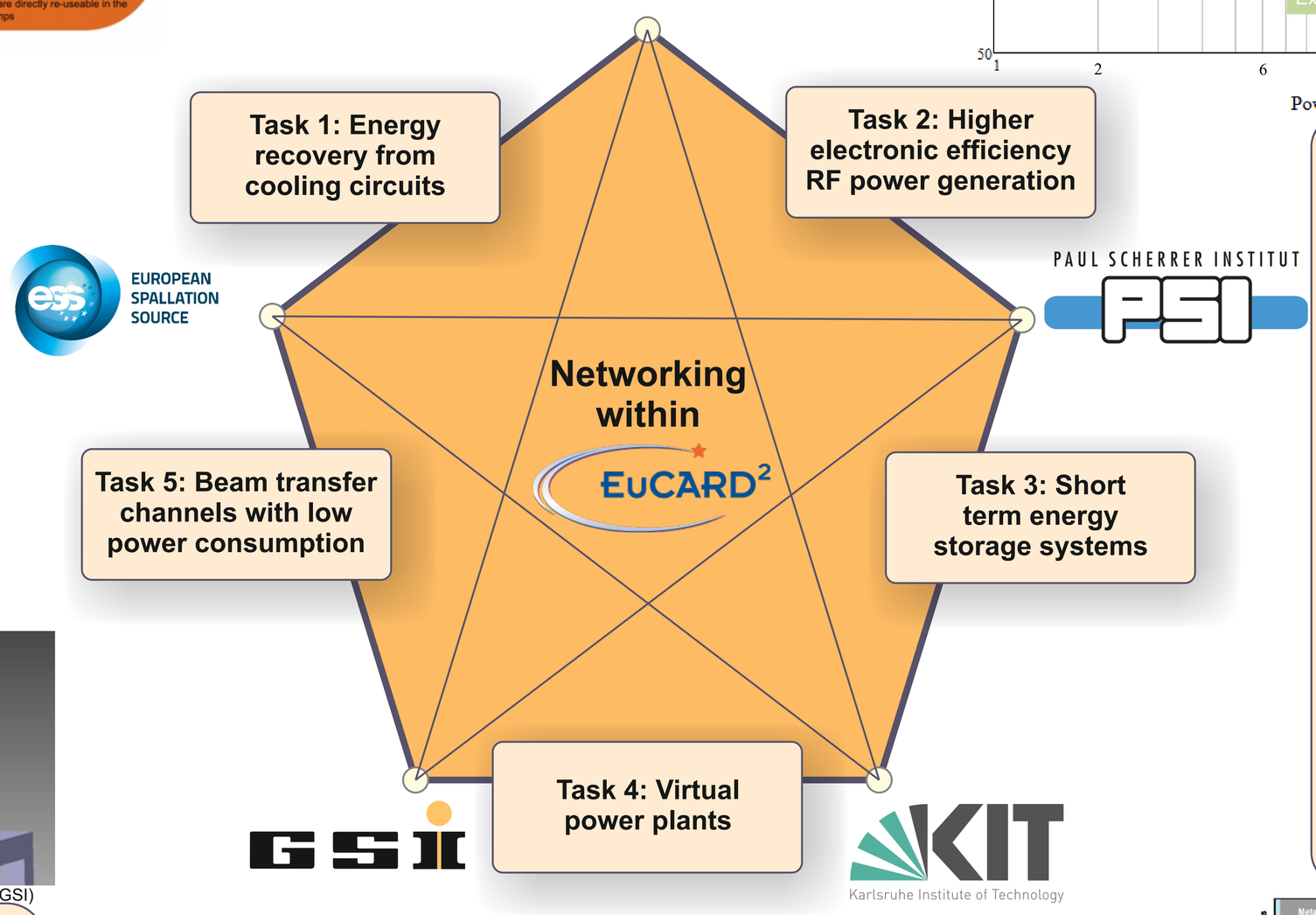
(Pictures ESS and A. Kiessling)

Strategy for high-efficency high RF power klystron development

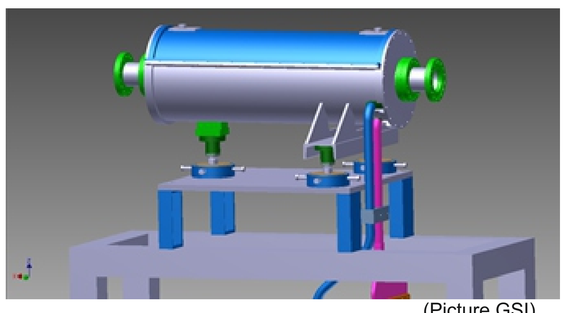


(Picture I. Syratchev)

Modern high power accelerators usually dissipate a lot of their consumed energy in cooling circuits of electronics, magnets and RF. Using the generated waste heat improves the overall efficiency and helps in reducing operation costs. Within this subtask state-of-the art methods for making use of heat are to be evaluated. Cost versus revenue scenarios are investigated. A collection of heat inventory data in all participating labs has already been conducted.

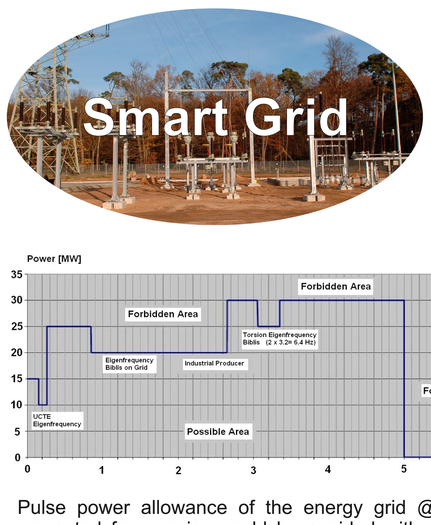


One of the main power consumers in accelerators is the RF. At a recent EnEff workshop, 44 international experts were discussing new ideas of how better RF systems could be conceived and built. It should be noted that high efficiency in RF power conversion not only reduces the power consumption and thus running cost, but also reduces the power lost as heat and the carbon footprint. The power and cooling installations become smaller as well. Klystrons reach efficiencies of up to 65% today. Revolutionary new ideas implying "core oscillations" and the "BAC method" (bunch–align–collect) make the 90% efficiency range appear reachable.



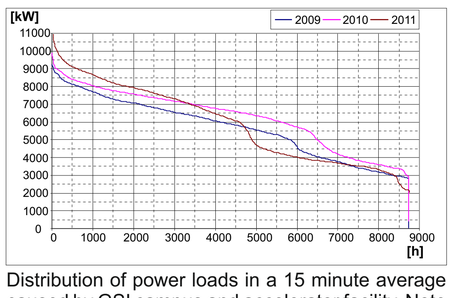
(Picture GSI)

Focusing and beam transport systems for high energy beams requires quadrupole lenses with rather strong magnetic fields. A novel type of quadrupole lens is characterized by its iron free magnetic core in which one single conductor is wounded four times along the beam pipe. This arrangement creates the desired magnetic quadrupolar field for beam focusing. The special feature of such lenses is their low inductance which enables a short pulsed operation.
The design of the lens, developed at GSI, has to consider transient effects due to the fast current variation. Special technical solutions have been developed for the connector and the conductors. The overall design has to withstand the large Lorentz force which may reach values of up to 64 tons per meter.
The energy efficiency of such lenses may be significantly improved at operation in a resonant electrical circuit.

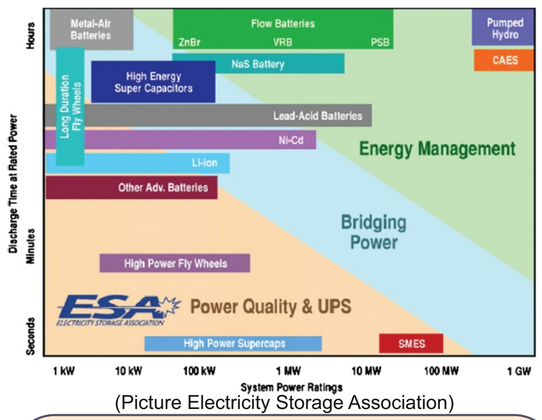


(Pictures/Graphs GSI and G. Otto, A. Zschau)

Pulse power allowance of the energy grid @GSI. The unwanted frequencies could be avoided with short term power storage devices (Task 3).



Distribution of power loads in a 15 minute average caused by GSI campus and accelerator facility. Note the difference in load from 5000 h to 6500 h due to different operation times of the accelerator



(Picture Electricity Storage Association)

Electrical energy storage on time scales of seconds up to around a minute can contribute to the safe and efficient operation of accelerators. Short interruptions of the grid can already lead to unwanted beam aborts. During the often long recovery time the full grid power is needed leading to inefficiency.
Energy storage at accelerators is even more important for pulsed operation of high power klystrons or ramped magnets. The negative feedback of a strongly fluctuating high power load on the electricity grid can be avoided by a short-term storage device.

The overall high energy consumption of accelerator research facilities suggests to use them for energy grid stabilizing.
Instead of increasing the energy production in times of high demand it is as effective to reduce the overall power consumption. The scheduled winter shut down at CERN is an example for this procedure on a long term basis.
If a facility identifies enough power consumers which can be switched off on short notice, ideally without impact to the facility's routine operation, they can form a virtual power plant. For identification of power using devices which are possible candidates to be part of a virtual power plant the power consumption of the entire facility has to be analyzed. A survey of the electrical energy use of the present GSI accelerator complex and science campus has been done.

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