3rd Workshop Energy for Sustainable Science at Research Infrastructures

29/30 OCTOBER 2015

DESY Hamburg, Germany

Organized by CERN/ERF/ESS in Cooperation with EuCARD-2,
hosted by DESY

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PREFACE BY HELMUT DOSCH

It is my great pleasure to welcome you to the workshop “Energy for Sustainable Science at Research Infrastructures”, which is jointly organized by CERN, ERF-AISBL member laboratories, ESS and in cooperation with EuCARD-2. DESY is happy to host this important workshop on its research campus in Hamburg.

Research Infrastructures (RIs) are a crucial pillar of modern knowledge societies. They allow cutting-edge research in various scientific disciplines and are home to some of the greatest scientific and technological discoveries and innovations. Apart from their substantial scientific and technological impacts, RIs have direct environmental footprints as well: operating accelerator-based facilities or high-performance computers is energy intensive and requires significant amount of electrical energy. Certainly, we have to make much more effort to find sustainable solutions in order to reduce the adverse effects on climate and environment.

The previous two workshops in Lund in 2011 and at CERN in 2013 were a big success and created the necessary awareness and the continuous and close exchange on energy related issues among research Infrastructure stakeholders. Cleary, all actors have to be mobilized and have to come together to find sustainable pathways for the European research Infrastructure landscape. It is now time to arrive at coordinated initiatives and joint programs on a European and international level to advance the implementation of sustainability measures and to devise appropriate funding schemes.

I hope that this third workshop will contribute to the important discussions and produce tangible results and recommendations also on policy-level. I would like to express my sincere gratitude to the organizers, speakers and chairs for all the efforts and I wish you a most successful and productive workshop.

Helmut Dosch
Chair of the Board of Directors at DESY

PREFACE BY FRÉDÉRICK BORDRY

The organization of the COP21 climate conference in Paris next month cannot fail to remind us how important the issue of energy is for our society. Over the last few years our research organizations have joined the debate, starting to look at what we ourselves can do to save or recover energy and thus improve our energy management.

We have already learned a lot together and I believe it is essential that we continue to share our experiences in order to improve our practices. The terms “energy efficiency” and “sustainable development” should not frighten us. On the contrary, this endeavour should be seen as a chance to improve our tools and processes and should offer us new economic, technological and social opportunities. Our scientific institutions have proven their ingenuity in the development of innovative strategies and technologies for research. And, as experts in vacuum, superconductivity and cryogenics technologies, we have at our disposal numerous tools and skills that should enable us to make progress and to develop technologies that benefit our infrastructures, as well as perhaps society and humanity too. Energy transport, storage and optimization, waste energy recovery: there are many new things for us to invent.

Although we still have some way to go, I am delighted to see that since the first workshop four years ago, many people and organizations have joined us in this now global debate, and that many organizations, including CERN, have appointed an energy coordinator.

In any case, the fact that we are all starting to come together around this topic is an encouraging sign, and I am sure that the discussions during this third workshop “Energy for Sustainable Science at Research Infrastructures” at DESY will set us on the right track for good progress in the future.

Frédérick Bordry
Director for Accelerators and Technology CERN
on behalf of the Program Committee

MOTIVATION AND OBJECTIVES

3rd Workshop on Energy for Sustainable Science at Research Infrastructures
29/30 October 2015, DESY Hamburg

Volatile energy costs, a tight budget climate and increasing environmental concerns are all inciting large-scale research facilities across the globe to devise mid- and long-term strategies for sustainable developments at their research infrastructures, including the aim for reliable, affordable and carbon-neutral energy supplies.

The workshop "Energy for Sustainable Science at Research Infrastructures" will bring together international sustainability experts, stakeholders and representatives from research facilities and future research infrastructure projects all over the world in order to identify the challenges, best practices and policies to develop and implement sustainable solutions at research infrastructures. This includes the increase of energy efficiencies, energy system optimizations, storage and savings, implementation and management issues as well as the review of challenges represented by potential future technological solutions and the tools for effective collaboration and joint projects.

This workshop is the third event in the series "Energy for Sustainable Science at Research Infrastructures" that is organized by ERF/CERN/ESS and holds biannual workshops at various places. The first workshop was held at Lund, Sweden on 13/14 October 2011, the second one at CERN on 23-25 October 2013. DESY will host the third workshop in this series in cooperation with EuCARD-2.

The themes of the workshop are related to questions of sustainability at large-scale research infrastructures and include Energy and sustainability management and strategies, policies and management at research laboratories; Energy efficiency, storage and optimization also within integrated Grid approaches; Sustainable campus management; Green IT and large-scale computer centers; novel sustainable technologies and solutions developed and/or embedded at research facilities and their possible scope as demonstrators.

Program Committee:

Frédérick Bordry, *CERN*
Roland Garoby, *ESS*
Florian Gliksohn, *ERF-AISBL*
Andreas Hoppe, *DESY*
Frank Lehner, *DESY*
Carlo Rizzuto, *CERIC-ERIC*
Wolfgang Sandner, *ELI-DC & ERF-AISBL*
Mike Seidel, *PSI*

Workshop Secretariat:

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ORGANIZING INSTITUTIONS

CERN

CERN *(www.cern.ch)*, the European Organization for Nuclear Research (Organization européenne pour la recherche nucléaire), is a European research organization that operates the largest particle physics laboratory in the world. Established in 1954, the organization is based in Geneva on the Franco–Swiss border, and has 22 member states. CERN's main function is to build and operate large-scale particle accelerators and other complex research instrumentation needed for high-energy physics research probing the fundamental structure of matter and of the universe. Numerous experiments have been constructed at CERN as a result of international collaborations. CERN is also the birthplace of the World Wide Web. The main site at Meyrin has a large computer facility containing powerful data processing facilities, primarily for experimental-data analysis; because of the need to make these facilities available to researchers elsewhere, it has historically been a major wide area networking hub.

ERF-AISBL

The Association of European-level Research Infrastructure Facilities ERF-AISBL *(www.erf-aisbl.eu)* has the not-for-profit purpose to promote the cooperation and the projects between European-level research infrastructures which are open, at international level, to external researchers. These Infrastructures include national infrastructures as well as European networks and consortia of research infrastructures. Since 2013 ERF has been recognized as an AISBL (Association Internationale Sans But Lucratif) according to the Belgian law, taking the place of the former ERF de facto association. In order to promote the cooperation and the projects between European-level research infrastructures the Association

- acts as a single voice, representing the Members with decision-makers, in particular at EU and international level;
- encourages the coordination, the development, the setting-up and the operation of high quality infrastructures, open at world level, contributing to the strength of the European Research Area, also through high level workshops and meetings;
- helps in the creation of mechanisms and best practices for an appropriate allocation of funding and resources by the European States and the EU, to ensure the best response to international users requirements and to societal challenges;
- facilitates the availability of resources (human, financial, instrumental) for high quality research infrastructures by encouraging the cooperation of the members, also through the initiation of specific joint initiatives, training courses or consortia;
- facilitates and support the collection and the access to data relevant for users, policy makers and other stakeholders;
- develops and implements specific projects of common interest, supported by the EU and/or international funding;
- supports the development of strategic planning and forward looking at national and international level.

ORGANIZING INSTITUTIONS

ESS

The European Spallation Source ESS *(www.europeanspallationsource.se)* is one of the largest science infrastructure projects being built in Europe today. ESS has the objective to be the world's leading research facility using neutrons, providing the tools for analysis that will enable the next important discoveries in nanotechnology, life science, pharmaceuticals, materials engineering, and experimental physics. It will also be the first large scale research facility that will be environmentally sustainable. Organized as a European Research Infrastructure Consortium, or ERIC, this next-generation research facility is being built through the collective global effort of hundreds of scientists and engineers from institutes and laboratories in the Member Countries throughout Europe. Located in Lund (Sweden), next to the world-leading synchrotron light source MAX IV, it will be an economic driver for all of Europe, serving up to three thousand guest researchers from universities, institutes and industry each year.
ESS construction formally began with the Groundbreaking Ceremony on September 2, 2014.
The first neutrons will be delivered by the end of the decade, with the user program to follow in 2023.

EuCARD-2

EuCARD-2 *(http://eucard2.web.cern.ch)* is an Integrating Activity Project for coordinated Research and Development on Particle Accelerators. The program is co-funded by the European Commission under the FP7 Capacities Program. The project has 40 partners, mainly research institutes, universities and accelerator laboratories from 15 European countries, including Russia. The networking activity EnEfficient (*www.psi.ch/enefficient*), is one of the 13 work packages. It aims at improving the energy efficiency of particle accelerators. EnEfficient organizes studies and workshops on selected themes, such as heat recovery, efficient RF generation, low power beam transport systems, energy storage and energy management for accelerators.

DESY

DESY *(www.desy.de)* is a national German research center and member of the Helmholtz Association. Researchers use the large-scale facilities at DESY to explore the microcosm in all its variety – from the interactions of tiny elementary particles and the behaviour of new types of nanomaterials to biomolecular processes that are essential to life. The accelerators and detectors that DESY develops and builds are unique research tools generating the world's most intense X-ray light, accelerate particles to record energies and open completely new windows onto the universe. That makes DESY not only a magnet for more than 3000 guest researchers from over 40 countries every year, but also a coveted partner for national and international cooperation.

PROGRAM

III. CERN/ERF/ESS Workshop on Energy for Sustainable Science at Research Infrastructures

Organized by CERN/ERF/ESS in cooperation with EuCARD-2 – hosted by DESY

Dates:
Thu/Fri – 29/30 October 2015
Location:
DESY Hamburg, Germany

http://erf.desy.de/energyworkshop

Format of the workshop:
· Two-day workshop with plenary and parallel sessions
· Plenary Talks are (25+5)', Parallel Talks are (20+5)'

THURSDAY, 29 OCTOBER 2015

10:00 **Welcome/Opening Session - Auditorium**
· Welcome by host, Helmut Dosch, *DESY*
· Introductions & Goals, Frédérick Bordry, *CERN*

10:30 **Plenary I – Auditorium**
Chair: Helmut Dosch, *DESY & ERF*
· Sustainable EU Research Infrastructures, Antonio Di Giulio, *DG Research & Innovation, Brussels*
· John Womersley, *STFC and Chair of ESFRI*

11:30 **Coffee Break (Foyer Auditorium)**

12:00 **Plenary II – Auditorium**
Chair: Carlo Rizzuto, *CERIC-ERIC & ERF*
· Transition to Renewable Energies – a challenge for RIs, Jutta Hanson, *TU Darmstadt*
· The Origin of Dreams, Colin Carlile, *Science Village Scandinavia*
· Energy efficient data centers – a holistic approach and best practice at LRZ, Arndt Bode, *Leibniz* Supercomputer Center LRZ/TU Munich

13:30 **Lunch (DESY Canteen)**

15:00 **Parallel Session I: Three Parallel Sessions w/ four talks each:**

Parallel Session Ia
Seminar Room 1
Energy Storage Systems (EuCARD-2 Session)

Chair: Mike Seidel, *PSI & ERF*
· Energy storage systems in research institutes
Hans-Jörg Eckoldt, *DESY*
· LIQHYSMES: a Novel Hybrid Energy Storage System
Rainer Gehring, *KIT*
· Capacitive Energy Storage for the PS Booster Synchrotron
Fulvio Boattini, *CERN*
· Development of new high slew-put and high energy-efficient power supplies for J-PARC upgrade
Yoshi Kurimoto, *KEK/J-PARC*

Parallel Session Ib
Seminar Room 4a
Energy Management/ Sustainability at RIs (the international perspective)

Chair: Andreas Hoppe, *DESY & ERF*
· Future Chinese Large Scale Facility and Sustain-ability
Yunlong Chi, *IHEP, Beijing*
· Research Sustainability Checklist for DoE Science Laboratories
Tina Kaarsberg, *DoE, USA*
· SESAME on the way to become real
Erhard Huttel, *SESAME & KIT*
· The SKA Radio Telescope: Power Intensive Research Infrastructure in Remote Regions
Adriaan Schutte, *SKA*

Parallel Session Ic
Seminar Room 4b
Energy efficiency/ recovery/optimization

Chair: Roland Garoby, *ESS*
· On the optimal operating temperature of normal-conducting electrical devices
Philippe Lebrun, *CERN*
· Towards high power klystrons with RF power conversion efficiency in the order of 90%
Igor Syratchev, *CERN*
· Heat recovery and high temperature cooling of klystron collectors
Anton Lundmark, *ESS*
· Energy Efficiency Improve ment in LLRF control for Superconducting Cavities
Rihua Zeng, *ESS*

17:15 **Coffee Break (Foyer Auditorium)**

17:45 **Plenary III – Auditorium**
Chair: Colin Carlile, *Science Village Scandinavia*
· Reports from the Parallel Sessions
· Discussions

19:30 **Dinner Buffet in DESY Canteen/Bistro**

FRIDAY, 30 OCTOBER 2015

08:30 Parallel Session II: Two Parallel Sessions w/ four talks each

Parallel Session IIa
Seminar Room 4a
Energy efficiency/recovery/optimization

Chair: Erk Jensen, *CERN*

· Energy efficient technologies for accelerators – a EuCard-2 effort
Mike Seidel, *PSI*

· Advancement and Perspectives on Compact and Low Consumption Magnet Design for Future Accelerators
Michele Modena, *CERN*

· High Efficiency Pulsed Power Converters for the ESS accelerator
Carlos A. Martins, *ESS*

· TRIUMF/UBC partnership to capture waste heat from TRIUMF for heating residential neighbourhoods
Orion Henderson, *University of British Columbia, Canada*

Parallel Session IIb
Seminar Room 4b
Energy Management (and Procurement) at RIs

Chair: Frank Lehner, *DESY & ERF*

· CERN procurement strategy
Serge Claudet, *CERN*

· Energy efficiency targets, management and actions at PSI in line with Swiss federal energy strategy 2015
David Reinhard, *PSI*

· Energy Management at DESY and a new Energy Monitoring System
Eva Leister, *DESY*

· Geothermal Use at ELI-NP
Razvan Bataiosu, *ELI-NP*

10:15 Coffee Break (Foyer Auditorium)

10:45 Plenary IV – Auditorium

Chair: Frédérick Bordry, *CERN*

· BestPath European project: Superconductivity for the European energy transition grid
Sébastian Henry, *RTE R&D-Innovation Director*

· Energy related support opportunities, Ornela De Giacomo, *CERIC-ERIC*

· Trends in the German energy sector and the impact to scientific institutions
Christian Schneider, *BTO Management Consulting AG*

· The German “Energiewende”, Dominik Schäuble, *IASS Potsdam*

12:45 Short Coffee Break (Foyer Auditorium)

13:00 Final Plenary – Auditorium

Chair: Frédérick Bordry

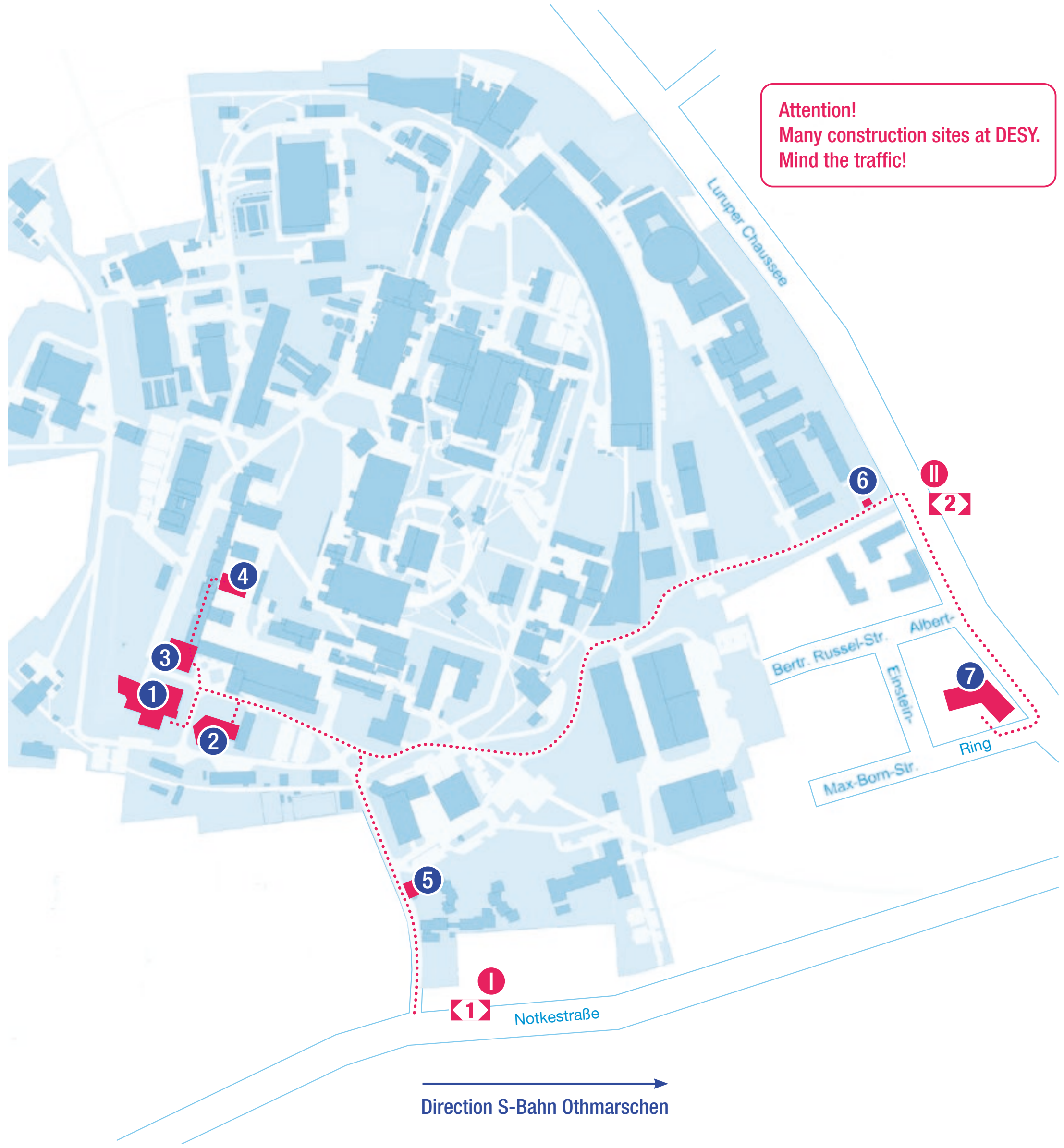
· Reports from Parallel Sessions

· Closing Talk, Wolfgang Sandner, *ELI-DC & Chair ERF-AISBL*

14:15 Working Lunch (Foyer Auditorium)

MAP OF THE CAMPUS

1 Canteen, Building 9
2 Auditorium, Building 5
3 Seminar room 1, Foyer Building 1
4 Seminar room 4a/4b, Building 1c
5 Gate lodge Notkestrasse (main gate)
6 Gate lodge, Luruper Chaussee (side gate)
7 Hotel “Mercure”, Albert-Einstein Ring 2
I Public transport (Bus No. 1, HVV)
II Public transport (Bus No. 2, HVV)
····· Walkway Mercure-Auditorium (10 minutes)



ABSTRACTS THURSDAY, 29 OCTOBER 2015

Plenary I

Sustainable EU Research Infrastructures

Dr. Antonio Di Giulio,
Head of Unit – Research Infrastructures
DG Research & Innovation
Directorate Innovation Union and European Research Area, Brussels/Belgium

The experience acquired in the build-out and operation of European RI has conducted to the identification of key requirements for their long-term sustainability. As such, governance and legal frameworks of the RI are imperative to ensure sustainability of their research effort and exploitation of the results on long time-scales.

Research infrastructures, including e-infrastructures, require long-term investments for their construction and operation, and a systematic approach to energy management will become important to the allocation of budgets. Therefore, energy may be one of the strategic factors in long-term sustainability of RI and can remain so for the future, for reasons of cost and environmental goals.

Energy management in sustainable RI throughout its lifecycle is not an easy process and not a one-time project, but requires time and should follow the never-ending circle process of four continuous steps, as squaring the circle: planning, doing, monitoring and improving.

Building up on the momentum generated by the adoption of the new Strategic Energy Technology (SET) Plan as part of the creation of the Energy Union, can bring an opportunity to promote new approaches for managing energy efficiency.

Plenary II

Transition to renewable energies – challenges for research infrastructures

J. Hanson, *TU Darmstadt*

Main goal of the energy transition is the reduction of carbon dioxide emissions.

The most prominent measure to reach this goal is a drastic change in the electrical power system, including an intended share of renewable energies of 80 % of electrical energy consumption in 2050 in Germany. By far the largest share of installed renewable generation plants are wind power and photovoltaic plants, which both provide fluctuating power in time and located decentralized or far-away from consumers. With a traditionally inflexible demand, grid reinforcements and storage are necessary to overcome the spatial and temporal divergence of supply and demand. Networks have to become more flexible (“smart”).

The presentation will give an overview on major changes in the future network structure and network behaviour. It will be highlighted how large scale research facilities can position themselves towards this new rapidly changing electric energy environment.

Sustainable Research Centres – The Origin of Dreams

Colin Carlile, *Science Village Scandinavia, Lund & Department of Physics & Astronomy, Uppsala University.*

At the turn of the century electricity prices were fluctuating dramatically on short time scales set upon a rapidly rising curve. This had significant effects on the budgetary plans for the ILL in Grenoble where I then was, which had a knock-on effect on the scientific program. ILL possessed a 58MW nuclear reactor which had to be cooled. The emerging warm water, suitably diluted, was fed into the river.

When I left ILL in 2006 and joined the ESS team in Scandinavia an opportunity presented itself to do things differently. ESS would be built on a green-field site if Lund were the chosen site. We had to do things better, and cheaper and we realized that we could indeed do that. Sweden is an environmentally aware country and it was clear that we were expected not to bleed our warm water into the environment either via cooling towers or directly into the ground water. At that point inspiration hit in the shape of three windmills installed on our proposed site and the fact that my apartment in Lund was heated by the city’s integrated central system.

And that was how the dreams began. How many windmills would it take to power the ESS…? The end result was a practical plan for making ESS into not only the world’s most intense neutron source, but also to make it the first energy-sustainable large scale science facility. A zero carbon footprint over the whole lifetime of the facility was the goal. This goal played a significant part in winning the site decision for Lund.

Energy efficient data centers – a holistic approach and best practice at LRZ

Arndt Bode, *Chairman of the Board, Leibniz Supercomputing Center / LRZ and Technische Universität München*

Running an energy efficient data center requires energy efficient building infrastructure and computer hardware, energy aware system- and application-software and best application algorithms. It is not enough to minimize the energy consumption of each of these components individually rather one needs a complete optimization strategy: a “holistic approach”.

For running SuperMUC, a 6,8 PFLOPs supercomputer, in an energy efficient way LRZ developed such a strategy including a monitoring environment, a joint data base, analysis and control tools. First results are presented for the computer using direct warm water cooling and attempting to reuse waste heat energy.

Parallel Session Ia
Energy Storage Systems

Energy storage systems in research institutes

Hans-Jörg Eckoldt, *DESY*

In particle accelerators, energy storage components are used for different purposes. These are capacitors, inductors, battery or even flywheels. Depending on the purpose, these operate in the few ms-range like in power supply filters, in the several ms-range as in White circuits or even in the second range as installed in the CERN POPS (POwer for the PS) system. Capacitors store energy in pulsed applications as in modulators. Batteries and flywheels are installed in uninterruptible power supplies to release energy in case of a power glitch or blackout. Driving factor for the operation of these types of storage systems are either the increase of performance of operation, a reduction of mains distortions or the independence from grid related failures as glitches or power cuts.

With the energy system transformation new aims and necessity for energy storage systems appear. A need for energy storage arises e.g. due to the meteorological dependence of renewable energies. In addition, the reduction of conventional power plants decreases the ability of grid regulation. There are different possibilities of energy storage systems that could be installed in research institutes to cope with these new demands.

LIQHYSMES – a Novel Hybrid Energy Storage System

Rainer Gehring, *KIT*

Storage of electrical energy can be done in many different ways from flywheels, SMES, supercaps, electrochemical or compressed air, just to name a few. Each of those methods has advantages and disadvantages that make one method preferable for a certain application e.g. high power or large amounts of energy stored. Our approach to combine two different storage types into a hybrid system aims to use the "best of two worlds" by compensating the disadvantages of one storage type with the advantages of the other. A liquid hydrogen storage provides the high energy density and cooling for a magnetic storage which can react quickly with high power output but usually has a low amount of stored energy. The combination of electrochemical storage and SMES is discussed in this presentation.

Capacitive Energy Storage for the PS Booster Synchrotron

Fulvio Boattini, *CERN*

Among the different technologies available for energy storage, capacitors look the most dependable one. In particular polypropylene film capacitors are well known for their robustness and their self-healing characteristics that allow continuing operation even in case of a temporary overload.

A new power converter system for the PS Booster Synchrotron is under realization at CERN in the frame of the upgrade required by the LIU project (LHC Injectors Upgrade) to allow operation with increased particle energy. The PS Booster Synchrotron operates in cyclical mode with one pulse every 2.4 s. The pulsating mode of operation allows using a capacitive energy storage system to decouple the power of the load from that taken from the AC network.

The design of such system is based on the experience acquired with the operation of the POPS converter (POwer for PS Synchrotron) since 2011, where a huge capacitor bank is used as energy storage mean. The talk gives an overview of the CERN projects where the capacitive storage is applied and illustrates the experience acquired in the robust design of these capacitors.

Development of new high slew-put and high energy-efficient power supplies for J-Parc upgrade

Yoshinori Kurimoto, *J-PARC*

In J-PARC Main Ring (MR), the upgrade toward megawatt beam intensity is scheduled. To achieve a megawatt beam, we need to increase the repetition rate of the accelerator from 0.42 Hz to about 1 Hz. In this case, the total power variation in main grid is up to 100 MVA. This is because the magnets in MR should be driven much faster in 1 Hz operation.

However, such power variation is not allowed by the electricity company. Therefore, we are planning to replace the current power supply of the magnets in MR for the new one with large capacitor energy storage. The capacitors used for such application must survive after 108 cycles of charging and discharging, which corresponds to 10 years operation. We have developed the capacitors whose lifetimes are longer than 10 years with a manufacturer. In this talk, we will present about not only the capacitors but also the power supply under development.

Parallel Session Ib
Energy Management/Sustainability

Future Chinese Large Scientific Facility and Sustainability

Yunlong Chi, *IHEP Beijing*

As a main possible research direction for both high energy physics and accelerator facility, the circular electron positron collider (CEPC) was proposed 3 years ago in China. The extra large scale of the CEPC means not only the size and the budget of the machine, but the power consumption of the whole facility. China is a large country with less energy resources compared to most developed countries. Sustainability becomes more and more important in the development of China, especially as one of the most critical issues to be considered in the future large scientific facilities. In this talk, the Chinese policy on energy resources and development is reviewed and the way on how to save the power consumption is investigated.

Research Sustainability Checklist for Department of Energy Science Laboratories

Tina Kaarsberg, *Department of Energy DoE, USA*

The speaker – a high energy physicist turned energy efficiency expert – is on assignment to DOE's Office of High Energy Physics within its Office of Science. Tina Kaarsberg, a federal employee with more than 20 years working at DOE's Office of Energy Efficiency and Renewable Energy, has worked to identify steps DOE Office of Science National Laboratories could take to increase energy efficiency and other sustainability. Dr. Kaarsberg will summarize successes and new efforts at the laboratories including:

- New and planned onsite and renewable installations:
  - Brookhaven National Laboratory's (BNL) 31.5 megawatt photovoltaic (PV) array since 2011, has avoided emissions of 31,000 metric tons of greenhouse gas (GHG) per year
  - Argonne National Laboratory's 5.8 megawatt-electric Combined Heat & Power (CHP) plant is projected to reduce annual GHG emissions by 35,000 metric tons starting in 2016. BNL is exploring a CHP installation as well
  - Lawrence Livermore and Lawrence Berkeley National Laboratories' 3 MW PV array will come online in 2016.
- Fermi National Accelerator Laboratory (Fermilab) has won the Energy Star data center award in each of the last four years with measures including hot and cold aisles, no cabling under raised floors, air conditioner return ducting to hot air layer, and matching air conditioning to temperature sensors.
- DOE facilities operate six of the top 50 most efficient supercomputers in the world.
- Fermilab's PIP-II accelerator upgrade includes a highly energy-efficient RF source (magnetron) and accelerator (high Q superconducting RF cavities). Behavioral changes resulted in a 52 percent reduction in leakage of Sulfur hexafluoride (SF6) across the DOE complex since FY 2008.

Dr. Kaarsberg will propose a lab sustainability checklist including:

- Is there an energy/finance/policy analytic team with broad data (including longitudinal data) and management access to identify opportunities and document successes?
- Does the Lab have a complete, multi-year baseline of energy use in its buildings and is it working to meet DOE High Performance Sustainable Buildings (HPSB) requirements?
- Has efficient (CHP) and or renewable onsite been actively considered (using the latest cost information)?
- Has the lab reached out to potential community and financial partners on large sustainability projects?
- Have accelerator (or other high energy science mission-related electricity use) efficiency improve ments been actively considered in planning for scientific upgrades?
- Has energy recycling (e.g. with accelerator cooling water) been actively considered – especially during

scientific and /or infrastructure upgrades?
· Have behavioral change initiatives been actively considered/implemented?

This list is a work in progress and is intended to help each lab consider the full spectrum of cost-effective energy efficiency opportunities in diverse areas such as buildings, onsite energy, computing, efficiency increases in energy-using research equipment, water infrastructure, and behavior changes. Different approaches across the DOE lab complex will be discussed including case studies based on the above examples.

SESAME on the way to become real
Erhard Huttel, *SESAME and KIT*

SESAME is a 2.5 GeV Synchrotron Radiation Source under construction in Jordan. It is the first international research center in the Middle East, member states are Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. As injector for the storage-ring the 20 MeV Microtron and the 800 MeV booster synchrotron of the former BESSY I is used. The Booster is in operation since 2014. The components for the storage-ring are in delivery phase. Installation is foreseen till mid-2016, commissioning end-2016. Coming in operation the high power consumption (RF (500 kW), Magnets (500 kW), Cooling (500 kW), AC (300 kW)) is one of the challenges for SESAME, to keep the operation cost low, despite the high power cost in Jordan of 0.3 euro/kWh. The installation of solar power is foreseen to cover at least part of the peak-load.

The SKA Radio Telescope: Power Intensive Research Infrastructure in Remote Regions
Adriaan Schutte, *SKA*

The Square Kilometre Array (SKA) project is an international effort to build the world's largest radio observatory, with a final combined telescope collecting area of over a square kilometre. To avoid radio interference, the telescope receptors will be built in remote regions of Western Australia and South Africa.

The SKA instruments will consume a significant amount of power, both at the remote sites and at supercomputing centres in the closest major cities. For SKA Phase 1 the power consumption is manageable, but for Phase 2 the power consumption is a major challenge that will drive the system design.

The supply of power to the remote sites is also hindered by lack of existing power infrastructure, geographically distributed antenna arrays and semi-desert environments. These aspects present unique challenges to the SKA project.

The SKA Organization is addressing these challenges through a three-tiered approach, consisting of (1) management of sub-system power consumption by means of a formal budgeting process during the design phases, (2) active investigation of alternative and renewable power sources that simultaneously decrease emissions and power tariffs and (3) implementation of low-cost reticulation methods, taking into account the nature of the loads and the environment.

Parallel Session Ic
Energy efficiency/recovery/optimization

On the optimal operating temperature of normal-conducting electrical devices
Philippe Lebrun & Davide Tommasini,
CERN, Geneva (Switzerland)

Colliding elementary particles at high energy and high luminosity requires large beam intensity and accelerating voltage, thus leading to large beam power up to the MW range. With the relatively low grid-to-beam efficiency of today's particle accelerators, this entails high overall power consumption, reaching hundreds of MW for the largest machines, and may thus constitute a technical, economical and societal limitation to their further development. While the generalized use of superconducting magnets and acceleration cavities helps kerb the power demand, many electrical components of accelerator systems remain normal-conducting and hence subject to Joule dissipation. Since the development of high-temperature electrical insulators, attempts were made to recover and valorise waste heat by raising the operating temperature of the normal-conducting electrical devices. We discuss the issue of optimal operating temperature from different engineering points of view pertaining to thermodynamics, heat transfer and reliability of operation.

Towards high power klystrons with RF power conversion efficiency in the order of 90%.
Igor Syratchev, *CERN*

The increase in efficiency of RF power generation for future large accelerators is considered a high priority issue. The vast majority of existing commercial high power RF klystrons operates in the electronic efficiency range between 40% and 55%. Only a few klystrons available on the market are capable of operating with 65% efficiency or above. Recently the new electron bunching technique was invented, which (yet in simulations) allows to increase the RF power production efficiency up to 90% and even above. The new High Efficiency International Klystron Activity (HEIKA) was established to facilitate the development of this new technology. The progress and status of various projects within HEIKA will be presented.

Heat recovery and high temperature cooling of klystron collectors
Anton Lundmark and John Jurns,
ESS, Lund, Sweden

The European Spallation Source (ESS) aims at being the world's first sustainable research facility. One of the major challenges to accomplish this will be the facility's energy consumption and related costs. ESS's Responsible, Renewable, Recyclable energy concept is the primary tool for realizing this goal. ESS is thus committed to recycle the surplus energy from its operations. The surplus energy consists of hot water that is a result of the cooling process in the facility.

In order to optimize heat recovery efficiency, the cooling system is planned to operate at three temperature levels: 10 °C, 25 °C and 50 °C, where the high-temperature waste heat can be transferred and recycled directly into the local district heating system.

One important part in this energy concept is cooling the klystrons at high temperature. Klystrons are RF amplifiers that convert electrical energy from the grid to RF power needed to accelerate the proton beam. However, this process is not ideal and up to 40% of the power fed into the klystron is dissipated as heat in the collector. ESS plans to make use of these losses!

ESS has decided to cool the klystron collectors with the 50 °C cooling circuit. However, there is only limited experience cooling klystron collectors at this temperature. Therefore, ESS has designed a cooling system that allows for flexibility and reduced risks. By doing this ESS can safely gain experience during commissioning and early stages of operation by cooling the klystron collectors at lower temperatures, but have the ability in the future to increase heat recovery even further by gradually increasing the temperature at which the klystron collectors are cooled.

Since a lot of heat is dissipated into the RF loads during beam-off operation ESS has also planned to install the RF loads on the high temperature circuit. With this configuration heat can be recovered during a wide range of operating modes. However, this requires new designs of RF loads with potential risks.

Energy Efficiency Improvement in LLRF control for Superconducting Cavities
Rihua Zeng, Anders J Johansson,
Carlos A. Martins, *ESS, Lund, Sweden*

Significant Energy Efficiency improvement in LLRF control becomes possible at ESS, with great benefit from advantages in digital technology revolution, progress in high performance hardware, and remarkable achievement in accelerator community on high precision RF measurement and innovative automatic control for superconducting cavities.

RF power overhead – the difference between the maximum RF amplifier output and the power delivered to the beam – is the main factor to consider for energy efficiency increasing. Sufficient overhead more than 30% is traditionally considered necessary to maintain a constant cavity field in the presence of perturbations and errors. Extensive studies at ESS indicate that this number could be dramatically reduced to 10%, by overcoming main difficulties in beam commissioning with a variety of beam modes and operation close to power amplifier saturation area. Advanced technologies in modern high performance hardware make these solutions possible, with great flexibility in configuration and short time in implementation.

RF filling time – the time needed for RF power to feed into cavity and build up required gradient before beam injection – is another important factor when considering energy efficiency increasing.
In traditional accelerator, adequate time up to 100µs is typically required as well for feedback loop to reach a stable state. The time for RF filling and feedback stabilizing could be effectively reduced under innovative cavity control and operation algorithm, which is based on progress in high precision measurement of basic cavity RF parameter, thereby holistically understanding of cavity RF system. Up to 5% energy efficiency increasing can be foreseen if RF filling time is well adjusted.

Power overhead reduction and RF filling time shortening bring also opportunities to optimize the high voltage supplied on power amplifiers, which would increase overall efficiency in modulator system.

ABSTRACTS FRIDAY, 30 OCTOBER 2015

Parallel Session IIa
Energy efficiency/recovery/optimization

Energy efficient technologies for accelerators – a EuCard-2 effort
Mike Seidel, *PSI*

New particle accelerator based research facilities tend to be much more productive, but often in coincidence with higher energy consumption.
On the other hand scarcities of resources and climate change impose the requirement for minimizing all energy consumption. For the public acceptance of particle accelerator projects it is thus very important to optimize them for best utilization of electrical energy and to show these efforts to funding bodies and to the public. Within the European accelerator development program Eucard-2 we organize a network EnEfficient that aims at improving the energy efficiency of accelerators.
In this presentation I review the activities in this network, discuss the typical power flow in accelerator facilities and give examples for developments of efficient accelerator systems, such as magnets, RF generation, heat recovery and energy management.

Advancement and Perspectives on Compact and Low Consumption Magnet Design for Future Accelerators
Michele Modena, *CERN*

Accelerators are good examples of large scale research infrastructure concerned by energy saving aspects. For about half a century, the aspect of energy consumption was not considered as one of the most critical in the power & cost evaluation phase of the magnet systems for new accelerators. Today situation is quite different and any project approved or under study, has to show an attentive and comprehensive evaluation on this aspect.
The talk will address the actual status on magnet design toward low consumption, covering mainly “iron dominated” magnet design working at constant field, fast cycled and pulsed regime. It will take advantage from the outcome and conclusions of a dedicated workshop on this subject hold at CERN on November 2014. The talk will cover past experience, status and perspectives at the most important European Laboratories, for major accelerator projects under construction and for some of the future accelerator projects today under worldwide based R&D studies.

High Efficiency Pulsed Power Converters for the ESS accelerator
Carlos A. Martins, Max Collins, Goran Göransson,
ESS, Lund, Sweden
Roberto Visintini, Davide Castronovo, Alessandro Fabris, *Elettra Synchrotrone, Trieste, Italy*

In high power linear accelerators with a beam duty-cycle below 20%, the choice between DC or pulsed power converters is worth considering from the efficiency point of view.

In the case of ESS, where the beam duty-cycle is less than 5% and the RF power stations require a huge electrical power, it is obvious that the power converters for the RF amplifiers (modulators) have to be pulsed. The efficiency of such modulators is very dependent on their topology. Indeed, depending on the pulse rise time, the number of power conversion stages and the power electronics structure, power losses can easily vary by a factor of two.

In the context of the ESS project, the development has therefore been launched of a modulator prototype using a new topology that, besides other advantages, provides an efficiency on the upper side of the currently available spectrum. A brief description of this topology will be given together with a comparative analysis of its efficiency with respect to other alternatives.

Another important subject, in terms of efficiency, is the choice between pulsed or DC magnets. Both possibilities have been studied and compared for the ESS accelerator quadrupole magnets. The main advantage of pulsed over DC systems is the important saving on water cooling capacity (about 620 liters/min), both for the magnets and power supplies, with the corresponding improvement in the accelerator reliability/availability due to avoidance of water leaks in the tunnel. Furthermore, the electrical power consumption of pulsed systems is 90% lower than DC ones, corresponding in the case of the ESS accelerator to about 300kW. This 2% improvement of the accelerator global electrical efficiency is obtained with a pulsed system that is estimated to be 5% more costly to build and install. Considering only the above stated savings on electrical power consumption, the cost difference payback time will be of approximately 3 years.

This contribution will describe the result of a pre-feasibility assessment and pre-dimensioning of the pulsed magnets and related pulsed converters using an innovative power electronics topology.

UBC Neighbourhood – TRIUMF/UBC partnership to capture waste heat from TRIUMF for heating residential neighbourhoods

Orion Henderson, *Director, Energy Planning and Innovation, University of British Columbia Vancouver, BC, CANADA V6T 1Z4, orion.henderson@ubc.ca*

Since 2011 TRIUMF and UBC have been working together with the objective of making use of the waste heat resulting from TRIUMF accelerators. TRIUMF is an important part of the local community and supplying the waste heat from research makes sense for all concerned. UBC has set aggressive GHG reduction targets for its academic campus and residential neighbourhoods and needs alternative sources of energy in order to achieve these targets.
Following 4 years of planning and negotiation a partnership between TRIUMF, UBC and Corix Utilities has resulted in the regulatory approval for a district energy system to provide thermal energy for space heating and domestic hot water for all future residential developments on campus (1.1 million square meters) and excess energy will help UBC's Academic campus achieve its GHG reduction targets.

Construction of this $85 M District Energy system started in March 2015 and its build out will follow that of neighbourhood development. The system has a renewable energy target of 60%. This target will be achieved in 2024, once neighbourhood development has reached a critical point and the economies of scale make the connection with the TRIUMF cooling system possible.

Using TRIUMF's waste heat, the district energy system will be able to achieve a 50% reduction in neighbourhood GHG emissions.

Parallel Session IIb
Energy Management (and Procurement) at RIs

CERN Procurement Strategy

Serge Claudet, Energy coordinator for CERN accelerators and technology

To comply with European regulation, all large energy consumers still benefiting from the special regulated tariff system will have to purchase electricity on the open market from 1st January 2016. With energy consumption above 1 TWh per year, this required change was considered for CERN a major change in energy procurement with potential risks and constraints for the approved physics program.

The context and the procurement strategy considering quality and flexibility will be presented. The status of energy procurement will be briefly described, together with the goals and intended mechanism to manage energy presently under implementation.

This change is now seen as an opportunity, with a great potential towards rational and efficient use of energy for CERN.

Energy efficiency targets, management and actions at PSI in line with Swiss federal energy strategy 2015

David Reinhard, *PSI*

One of the main points of the Swiss Federal Energy Strategy is the realisation of energy efficiency potentials. The Paul Scherrer Institute with its accelerator facilities is a significant consumer of electricity and is considered a large consumer, for which legal obligations to undertake measures apply. Furthermore, the Swiss Federal Office of Energy SFOE has defined specific energy efficiency targets. Increasing our efficiency includes both more intensive use and reduction of energy consumption. Implementing both categories will allow to substantially increase the efficiency of our research institute.

Management of efficiency increase starts with the energy guideline our direction has put in force at PSI. The energy guideline allocates operation of facilities to aim for high efficiency in operation and refurbishment and it especially obligates to seek a high efficiency at the design of new facilities, laboratories and buildings. All energy saving measures that amortize during the live time have to be considered. The implementation of the energy guideline to all divisions of the institute is delegated to a steering committee which is supported by two work groups. Typical examples will show representative specific energy optimization measures, realised and planned at PSI. These examples will show the wide range of measures PSI has taken and planned for the coming years.

Energy Management at DESY and a new Energy Monitoring System

Eva Leister, *DESY*

As a national research laboratory in Germany, DESY operates for more than 50 years as a large-scale research facility for physical and life sciences, which is very energy intensive, mainly due to the large accelerator complex. In the recent years several projects have been launched to generally enhance energy efficiency and to improve waste heat recovery on the campus. One important aspect for a successful sustainable energy concept is the detailed knowledge of all energy sub-consumptions at different facilities, labs and buildings on the campus. For this purpose a large energy survey was started to collect all available counters and their consumers and to investigate how the data can be standardized, centrally stored and analyzed. Furthermore, a concept for detailed, automated metering was created.

Geothermal Use at ELI-NP

Razvan Bataiosu, *ELI-NP*

Use of Renewable Energy is receiving considerable attention from officials world-wide. The issue of world pollution has been widely discussed over the years and steps towards reducing the amount of human harmful actions on the environment have been taken. European directive 20-20-20 is an example of goals to be reached by 2020 (reduction in CO_2 emissions compared to 1990 levels, 20% of the energy, on the basis of consumption, coming from renewables and a 20% increase in energy efficiency). Shallow geothermal energy is one of the renewable energies that can be used in order to achieve an important reduction of CO_2 emissions. This paper describes the HVAC system used for the ELI-NP (Extreme Light Infrastructure Nuclear Physics) project, the cost benefits and the pollution reduction in comparison to a classical HVAC system. The total heating power needed is over 3 MW while the cooling power needed exceeds 5 MW. To provide this power, over 130 geothermal heat pumps and 1080 boreholes have been used, thus being the largest project of its kind in Europe and the second largest in the World.

Plenary IV

BestPath European project: Supraconductivity for the European energy transition grid

Sebastien Henry, *RTE R&D-Innovation Director*

Within the next 20 years, superconducting power cables could offer significant power transmission solutions for densely populated, high load areas. These future transmission power systems will need to transfer from 2 to 20 GW of power over distances of a few hundreds of km from remote wind farms to the final distribution centres. In this application, long superconducting cables could carry very high currents, from 5 –10 kA, without resistive losses, achieving very high power levels in combination with high voltages up to 400 kV.

With nearly 40 leading organizations from research, industry, utilities, and transmission systems operators, the BestPaths project aims to develop novel network technologies to increase the pan-European transmission network capacity and electricity system flexibility. While several demonstrations have been launched for AC networks, this project is investigating the suitability of MgB2 technology as a component of a DC grid by operating a prototype with a very high power transmission level.

Energy related support opportunities
Ornela de Giacomo, *CERIC-ERIC*

The European Union has set in the Europe 2020 strategy, ambitious objectives on climate/energy to be reached by 2020. The strategy is supported at EU and national levels with concrete actions. At EU level, several financial instruments have been mobilized (e.g. rural development, structural funds, R&D framework program, TENs, EIB) as part of a consistent funding strategy, that pulls together EU and national public and private funding. These instruments are intended to support different kind of initiatives, according to the expected outcome. Large Research infrastructures are in most cases high energy consumers. For this reason, they can help further develop and demonstrate methods and techniques for the sustainable use of energy, becoming key players for addressing energy challenges and contributing to the achievement of the targets set by Europe 2020. In this framework, the presentation will give an outlook on some of the financial instruments potentially available for Research Infrastructures in projects supporting a resource efficient Europe.

The German "Energiewende"
Dr. Dominik Schäuble, *deputy group leader, Plattform Energiewende, Institute for Advanced Sustainability Studies (IASS) Potsdam*

Germany aims for a complete transformation of its energy system. This transformation is known as the German Energiewende with its three pillars: nuclear phase-out, expansion of renewable energies and reduction of energy demand. Major reasons for the Energiewende are climate change mitigation, the preservation and improvement of security of energy supply and economic competitiveness through predictable and competitive energy prices and a strong green economy. For the implementation of the Energiewende long term targets and the renewable energy act have been crucial. As a result power generation from renewables has reached a share of about 30% in 2014 and costs for solar PV and wind energy have decreased strongly. With the deployment of renewables, electricity wholesale market prices have been decreasing, power generation has become more decentralized and new actors have emerged in power generation.
It is remarkable and unique that almost half of the renewable capacity was at least partially owned by citizens and cooperatives in 2012. However, there are still considerable challenges, e.g. the slow decrease of greenhouse gas emissions from the power sector due to high generation from coal, the insufficient transformation dynamics in heating and transport and the deficient pace of electricity grid development. This talk will provide an overview on the German Energiewende highlighting accomplishments and challenges with an emphasis on political and economic aspects.

USEFUL INFORMATION

DESY Campus

The third CERN/ERF/ESS workshop "Energy for Sustainable Science at Research Infrastructures" will take place at the site of DESY *(http://www.desy.de)* located in the west of Hamburg. DESY has two entrances: a main entrance located at Notkestrasse and a side entrance at Luruper Chaussee. The main entrance is open all day and night. The side entrance is open for motorists from Monday until Friday, 06:00 to 19:00, and closed on weekends. It is open for pedestrians and cyclists at all times. The gate keepers at the DESY entrances will provide you with a map of the DESY campus. The DESY campus is signposted to point you to the right buildings.

Workshop Venues & Catering

The workshop plenary talks will be held in the main DESY auditorium (building 05). The parallel sessions are held in seminar room 1 and seminar rooms 4a and 4b located in building 1b. All rooms are equipped with beamer, PC and other technical equipment. Coffee during the breaks will be served in the foyer of the auditorium. Lunch will be taken in the DESY canteen. At the registration we will provide you with lunch vouchers. The workshop dinner on Thursday, 29 October, starts at 19:30 and will take place in the DESY canteen.

There will be WLAN available to the workshop participants. Please connect to DESY-Energy requiring you to fill out a Web form on our portal server and register your mobile device (e.g. notebook). For participants, whose home institutes are participating in the project eduroam, we offer also this wireless guest network connection. For registered user this is a quick and easy way to obtain a secure access to the Internet without any further registration.

How to get to DESY

From the Mercure Hotel you can walk to the DESY campus within 10 minutes. We offer a DESY shuttle from the Hotel Mercure to DESY on
· Thursday, 29 October 2015 at 9:30
· Friday, 30 October 2015 at 8:00
For the other hotels you should take the bus (Metro Bus 1 or Metro Bus 2). Please see the attached map of the surrounding of DESY on page 26.

Registration

The workshop registration is free. DESY covers coffee breaks, lunch and the workshop dinner. The workshop secretariat and the registration desk will open on 29 October 2015 starting from 09:00 in the foyer of the main auditorium. The desk remains open throughout the workshop and will be also your main contact point where you can get help at any time:

CERN/ERF/ESS Workshop on "Energy for Sustainable Science at Research Infrastructures"
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Sightseeing in Hamburg

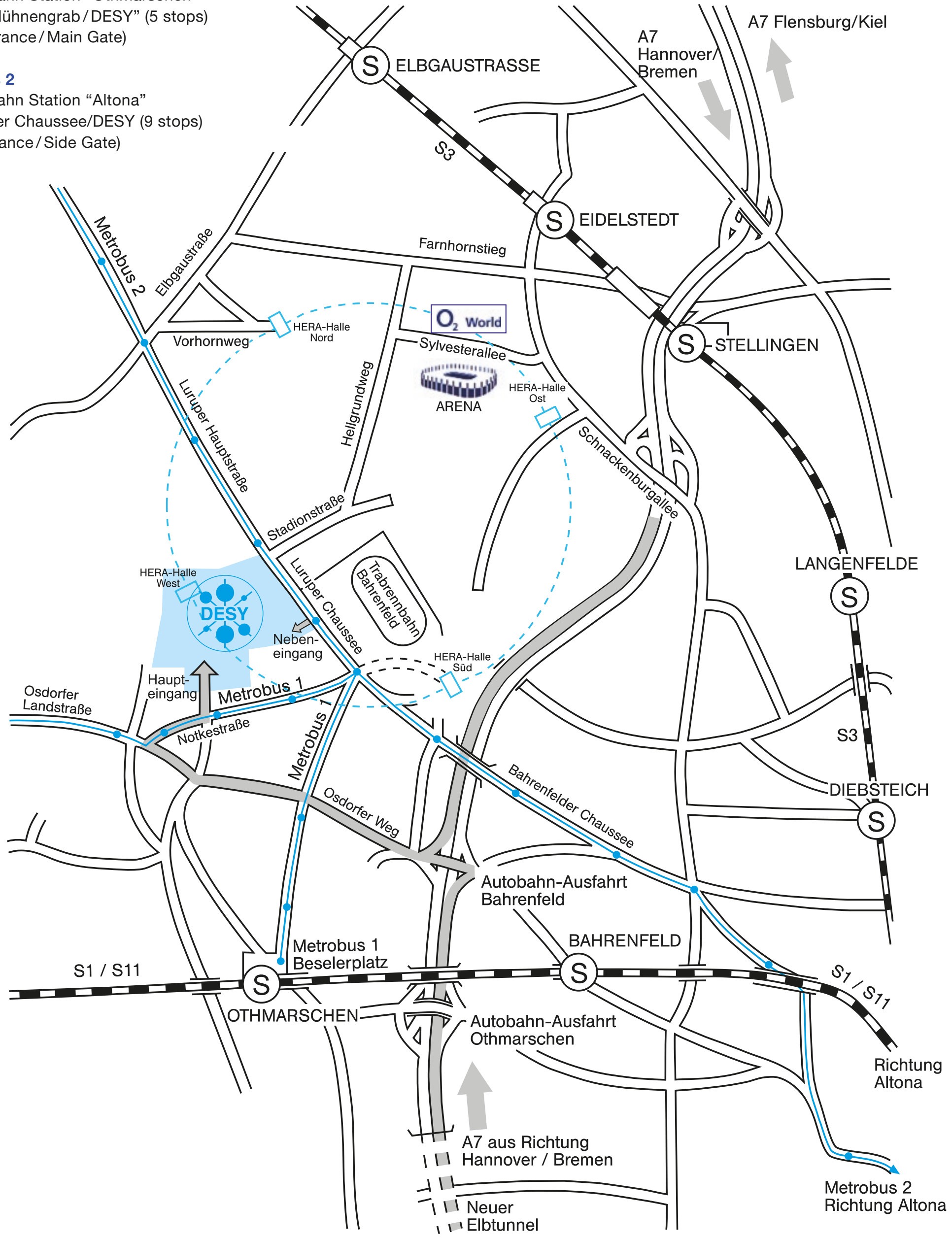
With its flair and its maritime charms Hamburg counts amongst the most beautiful cities in Germany. The "Gateway to World" – as the seaport on the Elbe river is also frequently called – offers pure city life with unique shopping, culture but also nature experiences.

Informations about sightseeing spots are available on the Hamburg Tourismus website (*http://english.hamburg.de*).

MAP OF THE SURROUNDING OF DESY

Metrobus 1
From S-Bahn Station "Othmarschen"
to "Zum Hühnengrab / DESY" (5 stops)
(Main Entrance / Main Gate)

Metrobus 2
From S-Bahn Station "Altona"
to "Luruper Chaussee/DESY (9 stops)
(Side Entrance / Side Gate)



Herausgeber:
Deutsches Elektronen-Synchrotron DESY
Ein Forschungszentrum der Helmholtz-Gemeinschaft

Art Direction and Layout:
Georg Schmalstieg
www.gsbrand.de

3rd Workshop
Energy for Sustainable Science
at Research Infrastructures

III. CERN/ERF/ESS Workshop
on Energy for Sustainable Science
at Research Infrastructures

Organized by CERN/ERF/ESS
in cooperation with EuCARD-2, hosted by DESY

Thu/Fri – 29/30 October 2015
DESY Hamburg, Germany

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