



PROGRAM BOOKLET

ENERGY FOR SUSTAINABLE SCIENCE
AT RESEARCH INFRASTRUCTURES

SALERNO, ITALY

30 SEPTEMBER - 2 OCTOBER 2026



FOREWORD

Welcome to ESSRI 2026

Research infrastructures are entering a decade shaped by volatile energy resources, growing demand and accelerating climate pressures. Facilities that pursue exceptional scientific performance must now combine innovation with responsibility, rethinking both technological design and day-to-day operations.

For ESSRI, sustainability is a driver of scientific creativity rather than a limitation. It includes energy efficiency, circular use of materials, responsible component reuse and careful end-of-life management. Research facilities can lead by example by developing efficient technologies - including superconducting solutions - and by sharing practices that can influence the wider scientific and industrial community.

Since the first workshop at the European Spallation Source in 2011, ESSRI has brought together scientists, engineers, facility managers, policy makers and industry. Later editions at CERN, DESY, ELI-NP, PSI, Grenoble and Madrid established a continuing forum on the energy and environmental performance of large-scale research infrastructures.

ESSRI 2026 will focus on the technical, strategic and operational choices needed for truly sustainable facilities: emerging energy-efficient technologies, energy management, project practices and life-cycle assessment. Particular attention will be given to pre-doctoral researchers, whose participation is essential to the long-term sustainability of the scientific community. Salerno provides a distinctive setting for this dialogue, combining a strong academic tradition, the IRIS infrastructure for testing 1 GW superconducting power lines, and an exceptional cultural and natural heritage.

Salvatore De Pasquale and Lucio Rossi

Conference Chairs

CONFERENCE

ESSRI 2026 at a glance

The workshop connects research infrastructures, universities, laboratories, industry and policy around practical pathways to a lower-impact scientific ecosystem.

Dates	30 September - 2 October 2026
Venue	Grand Hotel Salerno, Lungomare Clemente Tafuri 1, Salerno
Main themes	Energy efficiency; sustainable facility operations; circular economy; materials and component life cycles; superconducting technologies; environmental impact
Scientific community	Scientists, engineers, infrastructure managers, policy makers, industry representatives and pre-doctoral researchers
Contact	https://conferences.phys.unisa.it/essri2026/ essri2026@unisa.it

HOST

University of Salerno – Department of Physics

The department of Physics “E. R. Caianiello” provides a strong interdisciplinary setting for ESSRI 2026. Its activities connect fundamental and applied physics with energy technologies and large-scale facilities. This environment is reinforced by IRIS, the national research infrastructure dedicated to applied superconductivity and to solutions that reduce energy use and environmental impact.

ESSRI 2026

SALERNO 30 SEPTEMBER – 2 OCTOBER 2026

THE EVENT IS ORGANIZED BY



UNIVERSITÀ DEGLI STUDI DI SALERNO



Dipartimento di
Fisica E.R. Caianiello

UNDER THE PATRONAGE OF



DIPARTIMENTO DI FISICA
"E.R. CAIANIELLO"



Istituto Nazionale di Fisica Nucleare



ORGANISATION

Committees

Conference Chairs

Salvatore De Pasquale	University of Salerno and INFN
Lucio Rossi	University of Milan and INFN

Scientific Secretary

Guerino Avallone	University of Salerno and INFN
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International Committee

Nicolas Bellegarde	CERN
Frederick Bordry	ESSRI Honorary Member, CERN Emeritus
Salvatore De Pasquale	Ex officio member
Roberto Losito	CERN representative
Juergen Neuhaus	TUM and ERF AISBL representative
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Lali Tchelidze	ESS representative
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ORGANISATION

Local organisation

Local Organising Committee

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Veronica Granata	Roma Tre University and INFN
Eugenio Nappi	INFN Bari
Lucio Rossi	University of Milan and INFN
Maria Sarno	University of Salerno and INFN

Local Technical Support

Bernardo Amoruso	University of Salerno
Carmen D'Apolito	University of Salerno and INFN
Vincenzo Di Marino	University of Salerno and INFN

SCIENTIFIC PROGRAMME

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- Maurizio Vretenar, *"Building a culture of sustainability in accelerator R&D: the role of European projects"*
- Gianluca Alimonti, *"Global Energy situation and perspectives"*
- Lucio Rossi, *"Italy's Project IRIS and its contribution to sustainability of research infrastructure"*
- Maria Marsella, *"A sustainable strategy for Einstein Telescope"*
- Paolo di Ianni, Pilade Tonini, *"The JRC Ispra energy system"*
- Marta Mirolo, *"ReMade@ARI: a new access mode for Circular Economy research to advanced characterisations"*
- Stuart Henderson, *"Nuclear Power Development in the U.S.: Commercializing the Energy Amplifier and Other Advanced Nuclear Systems"*
- Nikolaos Sapountzoglou, Nicolas Bellegarde, *"Energy Management at CERN and ISO 50001 certification"*
- Daniel Garraín, *"Assessing the Carbon Footprint in Concentrated Solar Thermal facilities"*
- Hilal Bilgin, *"Energy Management at ESS"*
- Falastine Abusaif, *"From Operational Scenarios to Lifetime Energy Costs: A Data-Driven Cross-Facility Analysis of European Accelerator Infrastructures"*
- Nikolaos Sapountzoglou, *"Update on CERN's electricity contract and experience gained from the first photovoltaic Power Purchase Agreements"*
- Maxim Titov, *"Environmental Impact and Considerations for Future Accelerator Facilities"*
- Markus Joerg, *"Review of Energy Savings in the new Light Source SLS 2.0"*
- Philippe Lebrun, *"Metrics for efficiency of high-energy particle accelerators"*
- Mario Pesce, *"Waste Heat as a Resource: Qarnot's Distributed Computing Model for Sustainable HPC"*
- L. Atzori, *"Energy Efficiency of the New Data Centre at CERN"*
- M. Statera, *"Italian projects for SC power lines for data center (SURE and ASTRA project) and other scientific infrastructures"*
- Dwayne Spiteri, *"Data-centres of the future: The RF2.0 Project at DESY"*
- Anica Araneta, *"The Sustainability Conference for Responsible Research Computing (SC4RC) 2026"*
- Luigi Serio, *"Balancing Computational Innovation and Environmental Responsibility with Sustainable AI for Research Infrastructures"*
- Y. Body, *"Update on CERN's heat recovery projects and results from the first multi-MW installation in operation"*
- Michael Pekeler, *"Industry Production of SRF for Accelerators – a High Performance yet Energy Efficient Technology"*
- Benjamin Bradu, *"Energy management in LHC cryogenics"*
- Francis Perez, *"Solid State Amplifiers efficiency developments in RF 2.0 EU Project"*
- M. Baylac, *"Progress of The Isas Project*: Innovate for Sustainable Accelerator Systems"*
- Samuele Mariotto, *"Comparison between MgB2 and REBCO for boosting energy efficiency of superferic magnets"*
- Roman Kuřátko, *"FlexRICAN: Smart Indoor Climate Control for Cleanroom Environments"*
- Esteban Coquemont, *"Who Consumes Energy? Energy Practices and Flexibility Perceptions in Research Infrastructures: A Case Study from four European Research Infrastructures"*
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- Davide Aguglia, *"Optimization tool for integrating energy storage to enable efficient renewable integration in particle accelerators"*
- Andrea Klumpp, *"PETRA IV: From cradle to cradle"*
- Enrico Cennini, *"Sustainable Procurement impacts and opportunities"*
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- Jef Bergmans, *"The iRIS (intelligent Research Infrastructure Sustainability) Horizon Europe project"*
- Anders Sunesson, *"FlexRICAN EU project overview – Turning Energy Intensive Research Infrastructure into Active Energy System Players"*
- Bryan Jones, *"Decarbonisation Initiatives at the ISIS Neutron and Muon Source"*
- Nana Kofi Twum-Duah, *"FlexRICAN: Leveraging direct and indirect energy flexibility in electro-intensive Research Infrastructures for Carbon Neutrality"*
- Frédérick Bordry, *"Synergy between scientific research infrastructure and Fusion – Is Fusion really the path forward for large-scale, sustainable energy production?"*
- Alessandro Lampasi, *"Fusion path and Italy's next tokamak DTT"*
- Jessica Catalano, *"Sustainability in Research Infrastructure: a Cost or a Benefit?"*
- A. Chiuchiolo, *"The Salerno Test Facility for GW rate Power Transmission Line"*
- A. Zoccoli, *"INFN and its contribution to sustainability of Research and Society"*
- Mark Thomson, *"Sustainability: a nuisance or an opportunity?"*

POSTER SESSION

List of Posters

- P01: Malik Muhammad Abdullah, *"Predictive Battery Control For Peak Shaving in Karlsruhe Research Accelerator"*
- P02: Francesco Baffa, *"Towards Sustainable Materials and Manufacturing for Particle Accelerator Components: An LCA-Based Approach"*
- P03: Femke Bangma, *"Waste heat recovery at Research Infrastructures"*
- P04: Wen-Shuo Chan, *"Evaluating the Performance of Integrated Energy Management at a Synchrotron Radiation Facility: A Case Study of NSRRC, Taiwan"*
- P05: D. D'Agostino, *"Two Test Facilities Supporting the Long-Term Sustainability of Superconducting Devices"*
- P06: Evangelos Matzoukas, *"Improving injection efficiency in accelerators using artificial intelligence-based optimization methods"*
- P07: Hafiz Sami Ur Rehman, *"Substrate, Doping and Buffer-Layer Engineering of PLD-Grown MoS₂ Thin Films for Hydrogen Evolution"*
- P08: Arpana Singh, *"Charge-Carrier Kinetics in Halide Perovskite Thin Films under 68 MeV Proton Irradiation: A Time-Resolved Microwave Conductivity Study over a 360-Day Post-Irradiation Window"*
- P09: S. Vaguine, *"Research with neutrons for a sustainable future"*
- P10: Séverin Valla, *"Mapping and Characterizing Electricity-Intensive Research Infrastructures across Europe"*

STUDENT PROGRAM

Student Program: List of Posters

- P11: Sana Abrar, *"Synergistic nanoadditives for high-performance and energy efficient lubrication in research infrastructures"*
- P12: D. Batia, *"Energy Saving HTS Magnets for Particle Accelerators"*
- P13: Faraz Khan, *"Sustainable MnO-MXene-PANI/PVA Nanofiber Electrodes for Advanced Energy Storage Applications in Sustainable Research Infrastructures"*
- P14: Jasmin Mandix Madsen, *"A Cradle-to-Gate LCA of Lead Shielding Units for the FCC-ee"*
- P15: M. Morriello, *"Towards Sustainable Particle Accelerators with HTS Magnets"*
- P16: Muhammad Mubashir, *"Reusable nanocomposite for advanced cooling-water treatment in large-scale research infrastructures"*
- P17: Shahzad Muhammed, *"Sustainable Ru@CuCo₂O₄/Recycled Carbon Fiber supercapacitor electrodes for energy storage in research infrastructures"*
- P18: Mariagorizia Pia Trippa, *"Towards Sustainable Smart Research Laboratories: An Energy Harvesting IoT Framework for Intelligent Lighting and HVAC Control"*

CONFERENCE VENUE

Grand Hotel Salerno

Lungomare Clemente Tafuri 1, 84127 Salerno, Italy



Welcome to Salerno

A historic and lively city on the Tyrrhenian coast of Southern Italy — an ideal place to host ESSRI 2026. Nestled between sea and hills, Salerno combines centuries of cultural heritage with a dynamic urban atmosphere and excellent connections to the wider region.

Founded as a Roman colony in 197 B.C., Salerno became an influential medieval center and home to the **Schola Medica Salernitana**, the first and most important medical school in Europe during the Middle Ages, where scholars from across the Mediterranean developed and shared knowledge. Today, Salerno's historic center invites visitors to explore its narrow streets, ancient churches, medieval walls, and Renaissance palaces, while the picturesque **Lungomare Trieste** promenade offers relaxing views of the Gulf of Salerno.

The city's vibrant culture is enriched by its museums, botanical gardens, theatres and lively cafés — all within walking distance of the conference venue. Salerno also serves as a perfect base for discovering **the Amalfi Coast, Pompeii, Paestum and Capri**, world-renowned destinations easily reachable for day trips. We are delighted to welcome you to Salerno for ESSRI 2026 — a setting that blends scientific tradition, Mediterranean charm, and modern hospitality, offering an inspiring backdrop for scientific exchange, networking, and collaboration.

SOCIAL PROGRAMME

Technical and cultural tour

The ESSRI 2026 social programme has been designed to combine scientific networking, cultural heritage, and the unique atmosphere of Southern Italy.

A social activity will be organized for participants interested in joining a combined technical and cultural tour in the Campania region.

The programme will start with a visit to the University of Salerno campus, one of the largest academic campuses in Italy and home to advanced research activities in physics, engineering, and energy-related technologies.

The campus tour will mainly focus on the Department of Physics and on the research facilities IRIS and THOR, offering participants the opportunity to explore advanced laboratories and infrastructures related to superconductivity, sustainability, and innovative research technologies.

Participants will depart by bus from the conference venue, the Grand Hotel Salerno, and after the campus visit the tour will continue towards the [Archaeological Park of Paestum](#).

At Paestum, participants will enjoy a guided tour of the archaeological site, internationally renowned for its exceptionally preserved ancient Greek temples and recognized as a UNESCO World Heritage Site.



The excursion will conclude with a traditional dinner at *Ristorante Nettuno*, located in front of the archaeological area, where participants will enjoy local cuisine and regional specialties in a relaxed Mediterranean atmosphere.

SCIENTIFIC PROGRAMME

Programme

Wednesday 30 September 2026

12:00	Meeting of program and organising committee
12:30	Registration Desk
14:00	Welcome and authority
14:30	Plenary Session: Setting the scenes and selected examples
16:30	Coffee break
17:00	Plenary Session: Setting the scenes and selected examples
19:30	Poster Session
20:15	Welcome reception “apericena”

Thursday 1 October 2026

8:30	Parallel Session 1: Energy management and footprints Parallel Session 2: Data Centers /AI/HPC
10:30	Coffee break
11:00	Parallel Session 1: Energy management and footprints Parallel Session 2: Data Centers /AI/HPC
12:30	Poster Session
13:15	Lunch
14:00	Parallel session 3: Energy-efficient technologies. Experiences Parallel session 4: Emerging issues and upcoming projects
16:00	Coffee break
16:30	Parallel session 3: Energy-efficient technologies. Experiences Parallel session 4: Emerging issues and upcoming projects

18:30	<i>Session discussion</i>
19:00	<i>Free time</i>
20:00	<i>Social Dinner</i>

Friday 2 October 2026

8:30	<i>Plenary Session: Future paths for energy production, transport and storage</i>
10:00	<i>Coffee break</i>
10:30	<i>Plenary Session: What we give back in terms of sustainability</i>
12:00	<i>Session discussion</i>
12:30	<i>Student Program Awards, ESSRI 2028 Preview & Closing Remarks</i>
13:00	<i>Lunch</i>
14:00	<i>Departure for visit to the University of Salerno Campus</i>
16:45	<i>Departure for visit to the Paestum Archaeological Site</i>
19:30	<i>Dinner at the Paestum Archaeological Site</i>

ABSTRACTS

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Talk Abstracts

Oral presentations



Plenary Session: Setting the scenes and selected examples



Beyond the 2°C Target (Climate Risks, Environmental Impacts, and Lessons from Recent COPs)

Where do we stand today?

Jean-Noël Thépaut¹

¹European Meteorological Society, Météo&Climat, former director of Copernicus Services at ECMWF.

Abstract

The climate of 2025–2026 provides an increasingly clear picture of a warming world. Recent observations show persistent global warming, accelerating impacts and growing exposure to extremes, with Europe experiencing particularly rapid change. This talk will take stock of the state of the global and European climate, and introduce Copernicus, the European Union's Earth Observation Programme, showing how observations, reanalysis and climate services allow us to understand where we are today and anticipate what may lie ahead.

What does moving from around 1.5°C of warming today towards 2°C—or potentially well beyond—by the end of the century actually mean for climate risks, ecosystems and societies? And, as successive COPs struggle to close the gap between ambition and action, is there still room for optimism?

While the challenges are formidable, progress matters: every fraction of a degree avoided reduces impacts. Looking at the glass as half full is not complacency—it can help turn climate anxiety into informed decisions, adaptation and action.

Keywords: *climate change, COPs, Copernicus.*

Environmental sustainability in EU policy – a science perspective

Patricia Postigo McLaughlin¹

¹European Commission, Directorate General for Research and Innovation

Abstract

The EU's Green Deal was announced in December 2019. The aim was to make the European Union climate-neutral by 2050, and this overarching objective came with a long list of legislative initiatives to cut greenhouse gas emissions, boost resource efficiency, restore nature, and transition to a clean economy.

History seemed to accelerate shortly after that announcement, when the global pandemic was declared. It did not stop there. A lot of other significant, world-changing things have happened since the pandemic.

Where does the EU's environmental ambition stand in today's rapidly shifting global landscape? And how does this affect science funding, scientific priorities, and the operation of large scientific facilities?

It will be argued that the energy transition is unstoppable, even if future climate action may be framed as a byproduct of energy security and technological independence. The incentives are now too strong. The proposal for a new EU budget maintains the percentage of funding for environmental and climate action, and this will also determine the architecture of the Framework Programme in the next financial period and the objectives of the individual sub-programmes.

Keywords: *European Union, policy, sustainability*

References

- [1] European Commission's Proposal for an EU budget 2028-2034; [Multiannual Financial Framework - European Commission](#)
- [2] Proposal for an EU regulation establishing Horizon Europe for the period 2028-2034; [EUR-Lex - 52025PC0543 - EN - EUR-Lex](#)
- [3] Proposal for a COUNCIL DECISION on establishing the Specific Programme implementing Horizon Europe - the Framework Programme for Research and Innovation for the period 2028-2034, laying down the rules for participation and dissemination under that Programme; [EUR-Lex - 52025PC0544 - EN - EUR-Lex](#)
- [4] 2026 State of the Union address [2026 State of the Union Address by the President](#)

Building a culture of sustainability in accelerator R&D: the role of European projects

Maurizio Vretenar¹

¹CERN, Geneva, Switzerland.

Abstract

Since 2004, the particle accelerator community has been engaged in a series of coordinated projects supporting accelerator R&D, funded by the European Commission under the Excellent Science – Research Infrastructures (RI) pillar of its Framework Programmes for Research and Innovation. Driven by both Commission priorities and needs of the accelerator community, these projects have progressively expanded their focus on sustainability topics, from energy efficiency to the broader environmental and economic impact of RI's. While early projects focused mainly on specific initiatives, particularly in energy efficiency, the approach has evolved towards a comprehensive integration of sustainability into accelerator R&D. This has resulted in sustainability becoming a consideration across all R&D activities, with the ambition of using European projects to foster a common culture of sustainability within the European accelerator community and help shape the next generation of particle accelerators. The talk will outline this evolution and present selected examples from the ARIES and I.FAST projects, before discussing the more pervasive integration of sustainability across all R&D activities of the new EPITA project.

Keywords: *sustainability, R&D, accelerators, research infrastructures, European Commission.*

Global Energy situation and perspectives

Gianluca Alimonti¹

¹INFN&Università degli Studi, Milano

Abstract

A global energy production and consumption overview will be given with Primary Energy showing an increase of about 70% since 1990 with fossil sources having a constant share. Electricity global production shows a more important 2,7 factor increase with renewable energy sources having a significant growth. Energy is fundamental for a society development, and it is very far from being uniformly and cleanly used on our planet: this generates pollution with several million deaths. A focus on EU energy policy is then proposed with three challenges set almost 20 years ago: Sustainability, Security of Supply, Competitiveness. The targets set to lead the path have been reached, but the challenges are still there. Meanwhile the global energy framework has and is still rapidly changing and EU finds itself in an unexpected “energy crisis”, with energy supply restrictions and costs increasing. Should EU adjust its priorities and go back to its original intentions?

Keywords: *Global Primary Energy, Energy Policy, EU Energy challenges and targets.*

Italy's Project IRIS and its contribution to sustainability of research infrastructure

Lucio Rossi^{1,2}

¹INFN – Division of Milan, LASA lab.

²University of Milan, Physics dept.

Abstract

IRIS (Innovative Research Infrastructure for Applied Superconductivity) is a distributed Italian research infrastructure, coordinated by INFN, which integrates universities, national laboratories and industry [1]. A central objective of IRIS is to exploit superconducting technologies to improve the energy efficiency and environmental sustainability of future research infrastructures. Particular emphasis is placed on high-temperature superconductors, enabling operation at 20–50 K, with reduced electrical consumption and lower dependence on liquid helium. IRIS covers the complete development chain, from materials and conductors to cables, magnets, cryogenic systems and large-scale testing. Two demonstrators exemplify this approach: ESMA, a 10 T energy-saving HTS dipole operating around 20 K, and the Green Superconducting Line, a 130 m MgB₂ power transmission line designed for 40 kA and 25 kV, corresponding to 1 GW. The latter will be tested at the Salerno facility. Beyond these technological objectives, the distributed IRIS model promotes sustainability through shared facilities, coordinated expertise, advanced training and long-term partnerships with public institutions and industry.

Keywords: *Applied Superconductivity, Superconducting Magnets, Particle Accelerators, Power Transmission Lines.*

References

- [1] Lucio Rossi, *et al.*, “IRIS—The Innovative Research Infrastructure on Applied Superconductivity in Italy”, *EPJ Research Infrastructures*, (2026) 10:17, <https://doi.org/10.1007/s41781-026-00174-7>

A sustainable strategy for Einstein Telescope

Maria Marsella¹ with ET-PP WP9 and ARUP team

¹Dipartimento di Ingegneria Civile, Edile e Ambientale, Università di Roma La Sapienza, Roma

Abstract

The Einstein Telescope (ET) has the potential to become Europe's premier next-generation gravitational wave observatory, while setting a new benchmark for sustainable research infrastructure. Building on the foundational principles for environmental impact and carbon mitigation strategy, it is relevant to establish the strategic backbone for implementation. This outlines the vision, core pillars, and actions required to embed sustainability across the entire project lifecycle. Specifically, it envisions ET as a low-carbon, climate-resilient, and nature-positive infrastructure that fosters positive local community outcomes without compromising scientific excellence or long-term operational performance. Developed during the ET Preparatory Phase (ET-PP projects) and prior to final site selection, the analysis done is intentionally site-agnostic. It serves as a vital bridge between the evidence base established in previous deliverables and the future choices that will shape ET's design, procurement, construction, operation, and eventual decommissioning. This implementation strategy integrates the environmental assessment framework with the whole-life carbon management approach. Together, these studies identify key sustainability topics, performance indicators (KPIs), and mitigation strategies to guide future decisions while remaining strictly neutral regarding candidate sites and configurations. A strategy functions as a practical guide for the future development phases of ET. In the short term, it will inform the site selection process; in the long term, it will guide lifecycle design and management decisions. The sustainability vision, implementation principles, KPIs, and methodological frameworks established in this stage must be used collectively to guide development and demonstrate alignment with ET's environmental ambitions, considering that sustainability must be deeply embedded into all levels of decision-making.

Keywords: *Gravitational wave observatory, nature-positive infrastructure, performance indicators*

The JRC Ispra energy system

Paolo di Ianni¹, Pilade Tonini²

¹, ²Joint Research Centre - European Commission – Ispra Site

Abstract

The Joint Research Centre (JRC) at Ispra hosts one of the European Commission's most complex research infrastructures and requires a highly reliable, efficient and sustainable energy system. Over the past five years the site has achieved a 35 % reduction in primary energy consumption, driven by a systematic plan of energy efficiency measures implementation, and the integration of renewable generation. The same period has seen a 60 % decrease in CO₂ emissions, reflecting both the energy-efficiency gains and the gradual shift towards low-carbon energies.

The campus JRC Ispra site produces most of the electricity, heating and cooling required for its daily operation and owns and manages its own high-voltage grid and tele district heating network; redundancy and the security of energy supply are therefore key requisites for uninterrupted research activity.

A central element of the campus' resilience strategy is the recently commissioned trigeneration plant, which supplies electricity, heating and cooling. Although the plant is a strategic, long-term asset that ensures highly efficient energy production for the whole site, the system is fully integrated with the internal micro-grid, district heating network, and battery and thermal-energy storage facilities, allowing uninterrupted power supply during the ongoing global energy crisis and enhancing the site's autonomy. The JRC Ispra energy system now exemplifies a forward-looking model of energy continuity, resilience and environmental stewardship, supporting high-level scientific activities while aligning with the EU's decarbonization objectives.

Keywords: *Energy strategy, Trigeneration, Multi-source system, Emissions*

ReMade@ARI: a new access mode for Circular Economy research to advanced characterisations

Marta Mirolo¹

¹ESRF – The European Synchrotron.

Abstract

With the scope of encouraging new scientific fields to access advanced characterization, the ReMade@ARI project focused on research groups working in Circular Economy to discover different analytical tools. [1] Within the project, academic and industrial users are accompanied by Junior Scientists, experts in the different offered techniques in the ReMade@ARI project, to tailor the proposal, design the experiments and analyse data. Thanks to that, new user groups could approach advanced characterization, such as synchrotrons and neutron facilities, or exotic techniques, such as positron annihilation spectroscopy.

Scientific examples cross multiple stage in the production chain: valorisation of waste to produce battery materials, reduction of critical raw materials (CRMs) in batteries and their life extension, recycling of electronics to recover pure CRMs.

Keywords: *Circular Economy, Synchrotron.*

References

- [1] <https://remade-project.eu/>

Nuclear Power Development in the U.S.: Commercializing the Energy Amplifier and Other Advanced Nuclear Systems

Stuart Henderson¹

¹Subcritical Systems Inc., 8602 Lava Hill Rd., Austin TX, 78744

Abstract

Subcritical Systems Inc. (SSI), based in Austin, TX, is developing and commercializing accelerator-driven subcritical Energy Amplifier (EA) fission systems [1] for electrical power production. Because the EA operates deeply subcritical, it falls outside the licensing framework governing critical power reactors, offering a path to faster deployment and lower cost. The same systems are well suited to transmuting long-lived isotopes in spent nuclear fuel, easing the burden on long-term geologic storage. This work is unfolding against a backdrop of rising U.S. power demand driven by data-center growth, which — together with federal incentives and expanded support for public-private partnerships — is helping drive a broader nuclear renaissance in the U.S.

Keywords: *Accelerator driven systems, subcritical fission.*

References

- [1] C. Rubbia, *et al.*, "An Energy Amplifier for Cleaner and Inexhaustible Nuclear Energy Production Driven by a Particle Beam Accelerator," CERN Report CERN/AT/93-47(ET), Geneva, 1993.

Parallel Session 1: Energy management and footprints



Energy Management at CERN and ISO 50001 certification

Nikolaos Sapountzoglou¹, Nicolas Bellegarde¹

¹HSE Department, CERN, 1211 Geneva 23 - Switzerland

Abstract

CERN operates one of the world's largest scientific research infrastructures, with an annual average energy consumption of 1.3 TWh and electricity as its predominant energy vector. To manage such a high consumption demand, CERN has established a comprehensive Energy Management System, integrating governance, planning, monitoring, forecasting and continuous improvement across the accelerator complex, technical infrastructure and support facilities. The system relies on a dedicated management team, an Energy Management Panel and digital tools for performance monitoring. Certification to ISO 50001 in February 2023 provides an internationally recognised framework combining measurable performance indicators, external verification and structured improvement cycles. CERN's energy policy is built around three key objectives: minimizing the energy required for operations, improving energy efficiency and recovering waste heat. Concrete actions include optimization of accelerator and infrastructure operation, energy performance indicator tracking for major facilities, high-efficiency data centres, large-scale waste heat recovery projects and renewable electricity procurement through long-term solar power purchase agreements. Together, these initiatives support CERN's sustainability objectives while preserving its scientific mission.

Keywords: *energy management, energy efficiency, ISO 50001, particle accelerators, CERN*

Assessing the Carbon Footprint in Concentrated Solar Thermal facilities

Daniel Garraín¹

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Abstract

Life Cycle Sustainability Assessment provides a comprehensive framework for evaluating the environmental, economic, and social impacts of infrastructures throughout their life cycle. Within this framework, Life Cycle Assessment (LCA) and Carbon Footprint (CF) identify environmental hotspots and support the development of low-carbon technologies. Their integration with Multiregional Input–Output analysis and Social-LCA further enables the assessment of global supply-chain impacts and associated socio-economic effects, providing a broader perspective for sustainable investment and policy decisions.

The Horizon Europe SOLARIZE project (<https://solarize-project.eu/>) aims to improve the sustainability and efficiency of Concentrated Solar Technology (CST) Research Infrastructures (RIs). Within this context, this presentation describes the ongoing development of a common framework for assessing the CF of EU-SOLARIS ERIC, the European Research Infrastructure for Concentrated Solar Power and Solar Thermal Energy. The framework seeks to provide a harmonised approach for CST facilities while exploring its potential transferability to other European RIs.

Keywords: *Life Cycle Assessment, Carbon Footprint, Concentrated Solar Technology.*

Energy Management at ESS

Hilal Bilgin¹, Lali Tchelidze¹, Olle Lagerblad¹, and Björn Eldvall¹

¹European Spallation Source ERIC (ESS), Lund, Sweden.

Abstract

ESS will be the world's most powerful accelerator-based neutron source and is expected to be operational in 2028. As ESS moves from commissioning towards operations, energy management becomes an increasingly important part of operational planning.

When in operation, ESS consumes a significant amount of electricity and generates significant volumes of excess heat, which is recovered and supplied to the local district heating network. From an early stage, ESS has taken energy management into account to minimize costs and reduce the environmental impact and has committed to an energy strategy that consists of three pillars: Responsible, Renewable, Recyclable.

This presentation provides an overview of the current energy setup and strategy at ESS, including energy consumption and demand trends, key dependencies, and operational challenges. It will also highlight ongoing work around cooling solutions and their potential impact on energy use, system capacity, and operational flexibility. By bringing these topics together, the presentation aims to provide a broad view of how the energy management approach is evolving at ESS as the facility transitions towards regular operations.

Keywords: *Energy management.*

From Operational Scenarios to Lifetime Energy Costs: A Data-Driven Cross-Facility Analysis of European Accelerator Infrastructures

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Abstract

Particle accelerators are among the most energy-intensive research infrastructures, making energy performance and long-term operating costs increasingly important considerations in facility operation, upgrades, and future planning. Within the Horizon Europe project Research Facility 2.0 (RF2.0), a harmonized framework has been developed to investigate energy consumption and energy-cost drivers across multiple European accelerator facilities. The study combines subsystem-level energy characterization, analysis of operational and environmental parameters, data-driven power modelling, and long-term scenario-based energy-cost assessment. The methodology is applied to ALBA, BESSY II, CERN, KARA, and MAX IV accelerators, covering facilities with different scales, technologies, and operational strategies.

The work examines the contribution of major accelerator subsystems to overall energy demand, the influence of operational scenarios on power consumption, and the evolution of energy costs over facility lifetimes under different electricity-market assumptions. Particular attention is given to the development of transferable modelling and forecasting approaches that support energy-aware operation and strategic planning of research infrastructures. The presented work provides a common basis for sustainability assessment across current and future accelerator facilities.

Keywords: *Energy management, lifetime energy-cost assessment, operational scenarios, accelerator facilities.*

Update on CERN's electricity contract and experience gained from the first photovoltaic Power Purchase Agreements

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Abstract

Power purchase agreements (PPAs) have become one of the principal instruments for renewable electricity procurement in Europe [1], yet their integration into large research infrastructures remains undocumented. Three off-site physical solar PPAs signed by CERN in 2024 total 89 MWp (128 GWh/year) over 15 years, covering 10% of annual consumption under full operation and 25% during shutdowns [2]. A survey of the French energy regulator identified 116 contracts covering 2.2 GW of capacity of which 81% was photovoltaic with a total mean duration of 19 years against 13 across Europe [3]. The aggregation types off-site delivery requires, their cost and their interplay with the electricity contract types determine which risks the offtaker retains [4]. Long-term hedging, bundled guarantees of origin and additionality in financing new capacity constitute the value proposition; among the challenges, midday overproduction resold on the wholesale market, amplified in low-consumption shutdown years and negative spot prices predominate. Deteriorating capture prices therefore reweight that proposition towards certificates and additionality [5], [6], with solar–wind coupling, storage-integrated structures and 24/7 hourly matching as potential mitigation [7].

Keywords: *power purchase agreements, electricity markets, renewable energy sources, energy aggregation, electricity contracts, risk management*

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Environmental Impact and Considerations for Future Accelerator Facilities

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Abstract

The Large Particle Physics Laboratory Directors Group (LDG), which coordinates the development of HEP accelerators in Europe, established a Sustainability Panel in 2024 with the mandate to develop guidelines and a minimum set of key indicators for the sustainability assessment of future accelerators. While focused on accelerator projects, the proposed framework is also relevant to existing and future research infrastructures. The Panel's findings and recommendations have been submitted as input to the process for the 2026 Update of the European Strategy for Particle Physics.

With its renewed mandate for 2026-2028, and building on previous work, the Panel is committed to analyzing best practices in the construction and operation of sustainable accelerator-based research infrastructures, including their potential for improvement and associated cost-benefit aspects. This talk highlights Panel's activities, invites feedback from the wider community, and summarizes future strategic developments.

Keywords: *Sustainable Research Infrastructures, Accelerator Sustainability.*

Review of Energy Savings in the new Light Source SLS 2.0

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Abstract

The Swiss Light Source (SLS) was fully upgraded from the third- to the fourth-generation design between 2023 and 2024, with complete storage ring replacement within the existing building. Electron energy increased from 2.4 to 2.7 GeV, enabling a 35-fold increase in brilliance and significantly improved beam emittance characteristics. Thanks to the coordinated technical innovations, energy consumption of the upgraded SLS 2.0 facility has been reduced by approximately 35 % compared with the former SLS. Key innovations include permanent-magnet bending magnets and solid-state RF amplifiers replacing klystrons, providing both direct reductions in power consumption and improved beam stability. The comprehensive technical infrastructure upgrade, including optimized thermal management, enhanced cooling systems, and heat recovery, contributed substantial additional efficiency gains while improving temperature stability and operational reliability.

Keywords: *Synchrotrons, Sustainability, Power Saving, Energy Efficiency*

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Parallel Session 2: Data Centres/AI/HPC



Metrics for efficiency of high-energy particle accelerators

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Abstract

Among the largest scientific instruments built by man, high-energy particle accelerators and colliders are large and powerful electromagnetic machines and thus large electricity consumers. Their efficiency is therefore a major issue, influencing their environmental impact, capital and operational expenditure, and conditioning their financial affordability and societal acceptance. This characteristic is shared with data centres, for which the Power Usage Efficiency (PUE) metric was devised. We analyse sources of inefficiency of high-energy accelerators and propose more refined metrics, beyond PUE, for measuring the efficiency of their power and energy usage in relation with their scientific goals. This is illustrated by applying these metrics to the proposals for future particle colliders submitted in the recent update exercise of the European Strategy in Particle Physics, in comparison with existing or past projects.

Waste Heat as a Resource: Qarnot's Distributed Computing Model for Sustainable HPC

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Abstract

Qarnot operates high-performance computing (HPC) infrastructure built around a single design principle: computing heat is not a byproduct to be discarded, but a resource to be reused. Rather than concentrating servers in large data centers, Qarnot distributes its compute nodes directly into buildings — district heating centers, swimming pools — where the heat generated by CPU/GPU workloads is captured and redirected to meet local heating needs, replacing conventional gas or electric heating [1]. This approach provides a solution both to the growing carbon footprint of the cloud and to the current difficulty in securing the megawatts required to set up new data centers.

This talk presents an overview of Qarnot's architecture and operating model, the engineering trade-offs involved in decentralizing compute while maintaining HPC-grade reliability and performance, and the measured impact on energy reuse and carbon footprint compared to traditional data centers (Water Usage Effectiveness, Energy Reuse Effectiveness, avoided emissions).

The presentation aims to share Qarnot's experience operating energy-integrated, distributed computing at scale, as input to broader discussions on facility-level and community-level heat reuse strategies.

Keywords: *data center, high-performance computing, heat reuse, distributed computing.*

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Energy Efficiency of the New Data Centre at CERN

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Abstract

The Prévessin Data Centre (PDC) is the new CERN computing facility, in operation since February 2024, built to absorb the increase in computing capacity required by the HL-LHC. Procured as a turn-key solution including ten years of operation and maintenance, it will grow from 4 MW to 12 MW in three phases, across six IT rooms of 2 MW each. Energy efficiency drove the design: UPS coverage is deliberately restricted, chiller-less cooling, controlled inlet temperature in IT rooms and PUE target defined contractually. Up to 4 MW of thermal energy is recovered to heat the offices located on the CERN Prévessin site. This contribution presents the data centre design, the PUE, WUE and heat- recovery figures measured during the first years of operation, and the lessons learned.

Keywords: CERN, data centre, energy efficiency, PUE, WUE, heat recovery, HL-LHC computing.

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Italian projects for SC power lines for data center (SURE and ASTRA project) and other scientific infrastructures

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Abstract

The rapid growth of artificial intelligence and high-performance computing is driving unprecedented energy demand in data centers, creating a strong need for efficient and sustainable power distribution solutions. Superconducting power transmission offers a promising approach by combining near-zero electrical losses with high current density and compact system integration.

This contribution presents the Italian projects SURE (Superconducting Reliability & Efficiency) and ASTRA (Applied Superconductivity for Technology and Research Advancement), which address complementary aspects of superconducting power technologies. SURE, focuses on the demonstration of MgB₂ superconducting power lines for data center applications through a real-scale installation at the INFN National Laboratories of Frascati, investigating reliability, efficiency, cryogenic integration, and environmental benefits. ASTRA strengthens the national research infrastructure for applied superconductivity by developing advanced test facilities, cryogenic platforms, and high-field HTS magnet systems, providing a unique environment for the validation of superconducting technologies for energy and scientific applications.

The paper discusses the current status of both projects, their technical objectives, and the opportunities they create for future superconducting power networks, energy-efficient data centers, and large-scale scientific infrastructures.

Keywords: *Superconducting Power Transmission, Data Centers, MgB₂ Power Links, Cryogenic Systems, Research Infrastructures*

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Data-centres of the future: The RF2.0 Project at DESY

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Abstract

Computing forms a fundamental pillar of modern research. Efforts to minimise correlated CO₂ emissions of research infrastructures therefore need to include plans for sustainable computing models, and research into novel operations of data centres need to be conducted. The team on the Horizon EU RF2.0 project at DESY investigated how their data centre operates and tested a variety of operational policies to manage the environmental impact of a data centre within the larger research ecosystem. A simulation of the data-centre ORACLE-D (Optimised Resource Analysis and Carbon Legacy Estimator for Data centres) designed to test policies faster than real time and some of the discussed saving schemes were trialled during an energy saving program at the data centre during the summer of 2025 where an estimated 3500 kWh of energy was saved. The culmination of DESY's involvement in the RF2.0 project is the building of the POC CET (Proof Of Concept Cluster for Emissions Tracking) mini-cluster; a demonstrator showcasing a future of computing centres where computing policies are autonomously implemented, in possible response to external stimuli like grid cleanliness, or price fluctuations.

Keywords: *sustainable computing, data centres, simulation.*

The Sustainability Conference for Responsible Research Computing (SC4RC) 2026

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Abstract

We give an overview of the first instance of the Sustainability Conference for Responsible Research Computing (SC4RC). This conference took place from 4th-8th May at CERN, with the aim of creating a space where knowledge on environmentally sustainable research computing could be shared across different disciplines, and progress could be coordinated through networks created during the conference. We will share the outcomes and lessons learned.

Keywords: *environment, sustainability, computing, data, machine learning*

Balancing Computational Innovation and Environmental Responsibility with Sustainable AI for Research Infrastructures

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Abstract

High-performance scientific facilities demand ever-more sophisticated computational tools to design, operate, and maintain them efficiently. At the same time, the accelerating energy and resource footprint of artificial intelligence (AI) presents a fundamental challenge for sustainability: unchecked growth in model sizes, data-center compute, and AI workload energy demand risks significantly undermining gains achieved through hardware and operational decarbonization.

Empirical analyses show that AI-related computing and data centers already represent a significant and rapidly expanding share of energy consumption and environmental impact in the digital ecosystem, with implications for electricity, water, and carbon footprints [1].

We discuss emerging approaches for resource-aware AI development, including model efficiency, decentralized learning, and algorithmic choices that explicitly account for energy and emissions constraints.

Finally, we present a concrete implementation of sustainable AI principles at CERN [2] to illustrate how federated learning and distributed inference can reduce data movement, enable collaborative model development, and support environmentally responsible AI deployment in large research infrastructures [3] that can be integrated into future scientific facilities to ensure that digital innovation reinforces, rather than overwhelms, long-term sustainability objective.

Keywords: *AI, federated learning, sustainability, decentralized computing.*

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Parallel Session 3: Energy-efficient technologies. Experiences



Update on CERN's heat recovery projects and results from the first multi-MW installation in operation

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Abstract

CERN's Large Hadron Collider releases large amounts of heat to the atmosphere through its accelerator cooling systems. Following a 2017 energy review that identified this waste heat as a valuable resource, CERN partnered with local authorities in Ferney-Voltaire, France, to recover heat from cooling towers at Point 8 and feed it into a new urban district-heating network. The network was inaugurated in December 2025 and became operational in January 2026, marking CERN's first multi-MW heat-recovery installation in real operation. It can currently supply up to 10 MW and could deliver around 20 GWh per year, heating the equivalent of several thousand homes while avoiding thousands of tonnes of CO₂ emissions annually. This presentation covers the project's history, technical implementation, and first operational results from Point 8. Two related projects are also briefly touched on: an ongoing effort to recover heat from Point 1 cooling towers for CERN's own Meyrin site, and the Prévessin Data Centre heat-recovery project, which is the subject of a dedicated presentation at this event.

Keywords: *Heat recovery, CERN*

Industry Production of SRF for Accelerators – a High Performance yet Energy Efficient Technology

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Abstract

Industrial Production of superconducting radio-frequency cavities and cryomodules in industry for worldwide particle accelerators has become standard within the last two decades. The benefit of superconducting RF technology in view of energy saving is briefly described. We report on the production capabilities which are today available in European industry. Experience gained through past projects is described and an outlook for future industrial production for large scale scientific projects like FCC or IFMIF-DONES is given.

Keywords: *Superconducting RF, Sustainability*

Energy management in LHC cryogenics

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Abstract

LHC (large Hadron Collider) cryogenics is the main electrical energy consumer of CERN with about 40 MW installed and 280 GWh consumed each year (25 % of CERN). The cryogenic team was used to implement energy-efficiency measures for the cryogenic systems across the full project lifecycle, especially for the LHC particle accelerator. First, at the design phase, static heat loads are minimized and cryogenic loads are intercepted at the highest possible temperature. Then, during tendering, cryoplant contracts include a bonus/malus mechanism tied to energy efficiency, in line with ISO 50001 of CERN. Finally, in operation, the annual schedule is organized to group high- and low-load periods for efficient system reconfiguration, and electrical consumption is forecast and monitored regularly to optimize the refrigeration power to the accelerator heat load demand. Moreover, since this year, waste heat from LHC cryogenics is partially recovered to supplement external heating systems to the nearby city.

Keywords: *cryogenics, particle accelerator, LHC.*

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Solid State Amplifiers efficiency developments in RF 2.0 EU Project

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Abstract

The aim of the EU project Research Facility 2.0 (<https://rf20.eu/>) is to develop and validate novel solutions for components and systems, that allow transforming particle accelerators into more sustainable and energy efficient research infrastructures. One of the tasks was dedicated to the improvement of the operation's efficiency of Solid-State Amplifiers (SSA) for accelerators, i.e. how to make the SSA work in the most efficient way under any operation condition of the accelerator. Two projects were launched, one with the company Cryoelectra at the RF frequency of 500MHz, and another with the company COMMTIA, at 1.5GHz. In this presentation, the design and development, together with the results of the two projects, tested under simulated real conditions operation at the labs of HZB and ALBA, will be presented.

Keywords: *Solid State Amplifiers, RF efficiency.*

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Progress of The Isas Project*: Innovate for Sustainable Accelerator Systems

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Abstract

Particle accelerators are essential instruments not only for fundamental research but also for advancing healthcare, high-tech developments or safety. They must now meet the challenge of energy sustainability. Among the solutions developed to minimize energy consumption, the project *Innovate for Sustainable Accelerator Systems* (iSAS) focuses on energy-efficient superconducting radiofrequency (SRF) accelerating systems. This European-funded project (HORIZON-INFRA-2023-TECH-01-01) will develop, prototype and validate SRF technologies enabling accelerators to achieve the same or improved performance while significantly reducing their energy consumption [1]. iSAS is devoted to improve the energy efficiency of:

- RF power: use of ferro-electric fast reactive tuners (FE-FRT) and optimized low level RF (LLRF) system
- cryogenics: development of coatings of Nb₃Sn on Cu cavities for operation at 4.5 K and optimized fundamental and high order modes (HOM) couplers to reduce the cryogenic load,
- beam: re-use of the beam energy with energy-recovery linacs.

The project envisages to integrate these new accelerator technologies into the design of a more sustainable LINAC cryomodule, into existing research facilities and into industrial solutions. The progress report will be presented two years after the project's launch [2].

Keywords: *iSAS, SRF, FE-FRT, LLRF, ERL, Nb₃Sn on Cu, HOM couplers.*

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Comparison between MgB_2 and REBCO for boosting energy efficiency of superferric magnets

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Abstract

Large accelerator facilities for protons and heavy-ions generally rely on normal-conducting magnets generating significant energy losses due to joule heating. A promising strategy to improve their sustainability is the replacement of resistive coils with magnesium diboride or high-temperature superconductors, while preserving the existing iron yoke, thus reducing operational costs and energy consumption without compromising magnet performance.

In this framework, the Energy Saving Accelerator and Beam Line Magnets (ESABLiM) project aims to develop superconducting magnets for such accelerator facilities like the Centro Nazionale di Adroterapia Oncologica and the Paul Scherrer Institute [1,2]. The project focuses on reducing power losses in the superconducting coil and improving the cryogenic systems efficiency using both MgB_2 and REBCO technologies working at temperatures above 20 K.

This contribution compares superferric dipoles with equivalent resistive configurations using a semi-analytical design framework coupled to finite-element electromagnetic optimization. Mechanical and thermal designs are scaled to minimize power consumption and heat loads. A detailed analysis of capital and operational costs identifies the conditions under which superconducting solutions become economically advantageous, highlighting their potential for more efficient and sustainable accelerator infrastructures.

Keywords: MgB_2 , REBCO, sustainability, superconducting magnets.

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FlexRICAN: Smart Indoor Climate Control for Cleanroom Environments

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Abstract

Research Infrastructures require highly stable indoor conditions to ensure the reliable operation of cleanrooms, laser laboratories and other highly controlled environments. At the same time, they face increasing pressure to reduce energy consumption and adapt to changing climate conditions. Within the FlexRICAN project, an open methodology for HVAC optimisation has been implemented and tested at the ELI Beamlines facility, based on reusable BMS program blocks, climate observations and projections, interoperable control logic, and AI-assisted engineering tools.

The work responds to a practical limitation of many proprietary Building Management Systems: their control logic is difficult to reuse, validate or extend, and therefore restricts long-term optimisation and integration with scientific equipment. The proposed approach creates a transparent and interoperable control layer in which mathematical models, engineering knowledge and operational data can be combined across HVAC subsystems into a unified energy management framework. This openness is not presented as an alternative to artificial intelligence, but as an enabling condition for the future deployment of AI-driven optimisation, which is difficult to achieve in closed modular automation environments.

The presentation focuses on implementation experience at the ELI Beamlines facility, including lessons learned from cleanroom environmental control, evaluation of existing assets under current and future climatic conditions, observed benefits for energy efficiency and operational resilience, and the organisational requirements for wider deployment. It also outlines the next steps towards deeper integration of HVAC control with scientific equipment and future AI-supported decision-making in research infrastructure operations.

Keywords: *Research Infrastructures, HVAC optimisation, Building Management Systems (BMS), Artificial Intelligence (AI), Energy efficiency, Climate resilience*

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Who Consumes Energy? Energy Practices and Flexibility Perceptions in Research Infrastructures: A Case Study from four European Research Infrastructures

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Abstract

Universities and electricity-intensive Research Infrastructures (RIs) have a role to play in the energy transition, notably by acting as drivers and setting an example [1]. In this context, four European RIs are investigating the reduction of greenhouse gas emissions through energy flexibility, that is, the ability of infrastructure to adapt its consumption in response to an external signal [2]. These four facilities were studied through a socio-technical analysis combining the consumption profiles of the RIs with semi-structured interviews with the RIs' staff.

Consumption patterns allow us to identify two archetypes. The first has stable consumption, whilst the second has marked consumption peaks. The interviews highlighted a difference in the perception of flexibility between these two archetypes. Indirect flexibility – that is, flexibility linked to social consumption practices – seems to be much less prominent in the ‘continuous consumption’ archetype.

This paper aims to demonstrate that these findings stem from various social practices of consumption and the embodiment of consumption.

Keywords: *Sociotechnical System, Energy Flexibility, Energy practices.*

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Parallel Session 4: Emerging issues and upcoming projects



Optimization tool for integrating energy storage to enable efficient renewable integration in particle accelerators

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Abstract

The Future Circular Collider (FCC) is a 91 km-long particle collider under study as a potential successor to the LHC. Its scale and power requirements call for a careful assessment of renewable energy integration and the identification of technically and economically sustainable solutions.

A global optimization approach combining capital and operational expenditures (CAPEX and OPEX) is proposed to investigate the trade-offs between investments enabling increased use of renewable energy and operational costs over the FCC lifetime. A key challenge is the intermittent nature of renewable generation. Energy Storage Systems (ESS) can provide the flexibility required to better match accelerator demand with renewable energy availability and to exploit favourable energy procurement conditions.

The talk presents the developed optimization framework and software tool for evaluating different renewable energy and storage scenarios for the FCC. Preliminary studies are presented considering battery and hydrogen-based energy storage solutions.

Keywords: *Accelerator sustainability, Renewable energy, Batteries, Hydrogen.*

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PETRA IV: From cradle to cradle

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Abstract

DESY has had a dedicated staff unit for sustainability since 2019. Taking a broad approach to sustainability, we have already made great progress. The use of renewable electricity and sustainable waste heat utilisation, as well as promoting diversity, are just a few of the things DESY have already achieved or are well underway with.

The new flagship project, PETRA IV, presents new challenges and opportunities for developing and implementing sustainability within the scientific community.

The broad approach to sustainability adopted by DESY will also be continued in PIV. A key focus is the careful use of resources. To achieve this, we must consider the entire life cycle.

While reporting, KPIs and measures against climate change are important, sustainability must also be considered beyond simply counting CO₂. In this talk, I will outline the PIV project's sustainability strategy and present some examples.

Sustainable Procurement impacts and opportunities

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Abstract

The *CERN's strategy and main objectives for the period 2026–2030* has been recently published, the aim D of CERN organizational excellence highlights the commitment to embed *Sustainability in all that CERN does*. Procurement practices should translate this strategy into actions to strengthen supply-chain risk management in a changing external environment. Moreover, quality ESG data should support sustainability reporting.

Building on CERN's Environmentally Responsible Procurement approach, the CERN Sustainable Procurement (CSP) project aims to progressively integrate ESG risks and opportunities throughout pre-procurement, procurement and supplier management. This includes identifying high-impact procurement areas, improving supply-chain data, embedding proportionate sustainability requirements and strengthening supplier engagement.

The presentation will explore how procurement can move beyond impact identification and compliance towards collaboration and value creation. Attention will be given to supplier engagement as a source of expertise, data and innovation, using energy management and optimization as a practical example. Engaging mature suppliers while developing less-mature but willing suppliers can help identify efficiency opportunities, improve carbon and energy data, strengthen resilience and progressively reduce supply-chain impacts.

Keywords: *Sustainable Procurement, Supply Chain Risk Management.*

HTS4SRI: An EU-Funded Project for Sustainable and Energy-Efficient High-Temperature Superconducting Magnets for the Future of European Research Infrastructures

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Abstract

Large-scale research infrastructures are among the most energy-intensive scientific facilities, with accelerator magnets contributing significantly to their electrical power consumption and environmental footprint. Advances in REBCO high-temperature superconductors (HTS), cryogen-free cooling, and sustainable manufacturing are enabling accelerator magnets operating at higher temperatures with improved energy efficiency. HTS4SRI, funded under the EU call HORIZON-INFRA-2025-01-TECH-01, brings together eight European research organizations and industrial partners to develop sustainable HTS magnet technologies for future research infrastructures. The project integrates conductor development, sustainable magnet engineering and manufacturing, cryogenic and powering optimization, and life-cycle assessment. Its research is demonstrated through three complementary prototypes: a large-aperture HTS final-focusing coil, a 4 T beam-line dipole, and a combined-function magnet, developed respectively in the context of the GSI SIS18 heavy-ion synchrotron [1], PSI TATTOOS project [2], and CERN FCC-ee [3]. These demonstrators address key scientific and engineering challenges while targeting energy savings of up to 50% and reduced carbon emissions. This paper presents HTS4SRI's objectives, organization, technological results, and expected impact.

Keywords: HTS, Energy efficiency, Sustainability, Radiation Hard, Cryogenic power supply, Life Cycle Assessment, Research infrastructure

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The iRIS (intelligent Research Infrastructure Sustainability) Horizon Europe project

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Abstract

iRIS positions Research Infrastructures as testbeds and innovation engines for the green and digital transitions [1]. Motivated by the Future Circular Collider [2] and the Einstein Telescope [3], this project aims at demonstrating AI-powered environmental technologies and sustainability-by-design across the infrastructure lifecycle. Its relevance extends beyond fundamental-science RIs: AI approaches [4,5] for particle accelerator design and optimisation can improve resource efficiency in industrial plants. AI-powered real-time materials characterisation and separation can accelerate circular construction and recycling. The soil reconstitution pilots advance land restoration and ecosystem service recovery. These technological demonstrations are integrated with a harmonised socio-economic sustainability appraisal combining lifecycle and cost-benefit approaches to support evidence-based investment decisions [2,3,6]. Outreach, training and open tools strengthen European skills, industrial uptake and societal trust. By federating the European Commission's Joint Research Centre and integrating with the RAISE efforts towards AI driven infrastructures for science, iRIS ensures that European sustainability concepts, indicators and policy frameworks are integrated from the outset, enhancing replicability, relevance of policy feedback to the EC, and establishing a European reference model for sustainable design and operation of research infrastructures.

Keywords: *Research Infrastructures, Sustainability-by-Design, Artificial Intelligence, Energy and Resource Efficiency, Circular Economy, Materials Reuse and Characterisation, Soil Reconstitution, Land Restoration, Lifecycle Assessment, Socio-economic Impact Assessment, Sustainable Science*

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FlexRICAN EU project overview – Turning Energy Intensive Research Infrastructure into Active Energy System Players

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Abstract

Large Research Infrastructures (RIs) require substantial amounts of electricity and water for cooling, thereby generating waste heat. In the FlexRICAN project [1], energy and water usage are considered from the flexibility perspective. We study how this can improve sustainability, transforming RIs into active players in the European energy landscape.

FlexRICAN members include a neutron spallation source (ESS in Sweden), two high-magnetic field laboratories (HFML-FELIX in the Netherlands and LNCMI/CNRS in France), three high-power light sources (ELI in the Czech Republic, Hungary and Romania) and two industry partners (Alfa-Laval, Sweden and Energy Pool, France).

FlexRICAN explores how both direct (automated) and indirect (through RI users) flexibility can optimise the usage of energy and at RIs and how this is implemented at the various member RI sites.

The presentation will outline achievements (reported in the midterm report [2]), including digital tools to model the performance of PV installations and battery arrays at any given RI, tools to assess the carbon load reduction based on energy mix per RI, tools to plan building systems, including so-called digital twins, waste heat handling and recovery.

Keywords: *Large Research Infrastructures, Sustainability, Waste Heat Recovery, Energy Resilience*

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Decarbonisation Initiatives at the ISIS Neutron and Muon Source

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Abstract

ISIS is a world-leading centre for research in the physical and life sciences, located at the Rutherford Appleton Laboratory, UK. Each year it hosts >3000 researchers from academia and industry to conduct around 1200 experiments across a diverse scientific programme. ISIS is driven by an 800 MeV proton accelerator, with a considerable energy consumption of ~60 GWh per year and a carbon footprint of 11,000 tonnes CO₂e per year. In this presentation, we will report on a range of recent and upcoming initiatives to reduce energy demand and/or reduce the facility's carbon footprint. On the demand reduction side, we have upgraded the tetrode valves on the fundamental and second harmonic RF systems [1] to reduce energy consumption. In the future, we will replace the decay channel muon solenoid [2] with a much more efficient unit. On the supply side, a large part of the roof area at the lab is covered with solar panels, and in the future, we are planning to have a direct wire to a proposed large solar farm nearby.

Keywords: *Research Infrastructures, Renewable Energy and energy efficiency management in Scientific Research.*

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FlexRICAN: Leveraging direct and indirect energy flexibility in electro-intensive Research Infrastructures for Carbon Neutrality

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Abstract

Research Infrastructures (RIs) like industrial facilities are increasingly expected to provide energy flexibility services to power systems, often via technology-centered approaches (i.e., direct energy flexibility). As complex socio-technical systems, RIs can leverage social mechanisms for indirect energy flexibility mobilization. In this study, we investigate the dimensioning of both direct (solar PV and batteries) and indirect flexibility mechanisms (e.g., experiment rescheduling [1]) using a Mixed-Integer Linear Programming (MILP) based framework [2], [3]. The study focuses on the French research infrastructure, LNCMI – characterized by high demand peaks coupled with significant randomness linked to experiments. The objective of this optimization is the carbon footprint reduction of the LNCMI over the lifetime of the dimensioned solar PV system. The analysis first considers the French grid's carbon intensity, then extends to Czech, Dutch, and Hungarian grids in the context of the Infra-Tech Flexrican project. By introducing optimal experiment scheduling, we evaluate the interplay between direct and indirect flexibilities and their combined impact on carbon reduction. The results provide a decision-support framework for RIs to align experimental performance, operational constraints, and carbon output minimization, offering a transferable methodology for assessing energy flexibility strategies in energy-intensive RIs.

Keywords: *Decarbonization, Energy flexibility, Research infrastructures.*

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Plenary Session: Future paths for energy production, transport and storage



Synergy between scientific research infrastructure and Fusion

Is Fusion really the path forward for large-scale, sustainable energy production?

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Abstract

Fusion energy has long been pursued within publicly funded research infrastructures, culminating in ITER and complemented by JET, W7-X and major programmes in the United States, China, Japan, Korea and elsewhere. This presentation explores the deep technological synergies between fusion facilities and major research infrastructures such as CERN, CEA, CIEMAT, INFN, PSI, KIT and IPP, including common challenges in superconducting magnets, vacuum, cryogenics, RF systems, tritium, materials and large-scale project management. The career of Robert Aymar, who led the launch of ITER before becoming Director-General of CERN, provides a striking illustration of these links.

Building on these synergies, the presentation addresses a more fundamental question: is fusion really a viable pathway to sustainable large-scale electricity production? Five decades of research have resolved major physics challenges, but critical issues remain, notably tritium self-sufficiency, materials, component lifetime, supply chains and nuclear licensing. The rapid emergence of private companies and investment is shifting fusion from physics-driven research towards engineering and industrial development. This transition brings opportunities but also risks of overpromising commercial fusion on unrealistic timescales.

Keywords: *Fusion energy; Sustainable power production; Tritium fuel cycle; Research infrastructures synergies; Public-Private Partnership.*

Fusion path and Italy's next tokamak DTT

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Abstract

Nuclear fusion can provide safe and sustainable energy.

The Divertor Tokamak Test (DTT) facility, under construction at the ENEA Center in Frascati, Italy, is a crucial milestone in the international roadmap toward commercial fusion energy. DTT is designed as a flexible testbed to investigate alternative solutions for the extraction of the heat generated by fusion processes under reactor-relevant conditions.

The project is reaching more than 80% of construction commitments, in particular for the 43000 m³ Torus Hall, to start operations in early 2030s.

All primary components have already been delivered on site or are in production phase. The delivery of the first superconducting coils is expected for the beginning of 2028, to be tested at currents up to 43 kA in a new cryogenic facility. A satellite facility for development of remote handling systems is under installation at University of Naples. Two new underground lines at 150 kV with related infrastructures will be connected to supply up to 300 MVA to DTT. This power is sufficient to operate all the DTT systems thanks to significant support from energy storage.

Keywords: *nuclear fusion, superconductivity.*

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Plenary Session: What we give back in terms of sustainability



Sustainability in Research Infrastructure: a Cost or a Benefit?

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Abstract

This talk discusses whether sustainability in research infrastructures should be viewed as an additional cost or as a long-term economic benefit. Large-scale facilities such as particle accelerators are highly energy-intensive, making energy efficiency a central engineering and financial challenge. Using a cost-benefit analysis framework and the Future Circular Collider (FCC) feasibility study as a case example, the presentation highlights how sustainability-driven design choices—such as improved cryogenic efficiency, advanced RF technologies, and waste heat recovery—can significantly reduce operational costs over the lifetime of a facility. In addition, sustainability-oriented R&D generates wider economic benefits through knowledge transfer, industrial collaboration, and technological spillovers. The presentation argues that embedding sustainability as a core design objective not only improves the economic performance of research infrastructures but also strengthens their societal legitimacy and long-term viability.

Keywords: *Research infrastructures, Sustainability, Cost-benefit analysis, Energy efficiency, Technological spillovers*

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The Salerno Test Facility for GW rate Power Transmission Line

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Abstract

The Test Facility for Large Magnets and Superconducting Lines (TFML) operated by the National Institute for Nuclear Physics (INFN) in collaboration with the Department of Physics of the University of Salerno, is a state-of-the-art laboratory dedicated to the development and testing of superconducting technologies, with a particular focus on large-scale magnets and power transmission lines.

Within the IRIS (Innovative Research Infrastructure on Applied Superconductivity) program, a new test facility has been realized to reproduce realistic operating conditions for testing a 130 m-long MgB₂-based superconducting cable, capable of carrying up to 40 kA at 25 kV, corresponding to a nominal power of up to 1 GW, operating at 20 K with helium gas.

This contribution presents the Salerno facility as a full-scale testbed for assessing the performance and sustainability potential of superconducting power transmission lines, highlighting the importance of considering the complete integrated setup including cryogenics, power supplies, mechanical and electrical interfaces and auxiliary equipment.

Keywords: *Test Facility, Superconducting cable*

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Poster Abstracts

Poster contributions



Predictive Battery Control For Peak Shaving in Karlsruhe Research Accelerator

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Abstract

This work proposes an energy management system by integrating photovoltaic (PV) forecasting with model predictive control (MPC) for battery energy storage system operation. Using real data from a 500 kW PV and 1.7 MWh BESS system, a Long Short-Term Memory (LSTM) machine learning model based probabilistic forecast was developed and applied in a receding-horizon control framework. Results show that forecast-based MPC reduced the annual peak demand by 8.6%, while rule-based control showed no reduction. Economic benefits were also higher for MPC, achieving up to 1.56% net revenue. However, forecast uncertainty increased battery usage, indicating a trade-off between performance and ageing. The study highlights the importance of improved forecasting data and local measurements for maximizing system efficiency.

Keywords: *Battery energy storage system, model predictive control, machine learning, photovoltaic plant, particle accelerator.*

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Towards Sustainable Materials and Manufacturing for Particle Accelerator Components: An LCA-Based Approach

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Abstract

A structured approach has been initiated at CERN to assess the environmental impact of research and engineering activities. Within such scope, a specific campaign – focusing on materials and manufacturing processes for mechanical equipment – has been launched by the authors.

Materials selection plays a critical role in determining the overall environmental footprint of technical components, especially when considering specialized materials or non-standard material conditions frequently required in high-energy physics applications.

In parallel, the impact of manufacturing processes is being investigated through the systematic collection of data to support Life Cycle Assessment (LCA) studies. Building on this effort, the development of a digital tool is being explored, aimed at supporting decision-making in the selection of manufacturing routes for components produced within CERN workshops.

This work presents the initial steps made, towards integrating sustainability considerations into design and production of mechanical equipment in a research environment, while highlighting key challenges, opportunities, and future directions.

Keywords: *Sustainability in High-Energy Physics, Life Cycle Thinking, Sustainable Manufacturing for Materials and Processes.*

Waste heat recovery at Research Infrastructures

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Abstract

Heat is often seen as waste, but can be a valuable side product of scientific experiments. In this poster we show how ESS and HFML-FELIX recover heat using completely different strategies.

The ESS will be the most powerful neutron source and is expected to be operational in 2028. The RI will consume up to 26 MW electrical power at steady state operations (at 2MW Beam on Target). All recovered heat is upgraded to the right temperature using heat pumps, and then continuously provided to the district heating system of Lund, Sweden, and will be providing around 10,000 households of heat at steady state operations (2MW BoT).

HFML-FELIX generates high magnetic fields using up to 22MW of electric power, with consumption fluctuating rapidly (0–22MW within 15 minutes). All power consumption is converted to heat. Since 2002, HFML-FELIX supplies waste heat at 20°C to the Radboud University campus through a heat exchanger connected to an aquifer thermal energy storage system. We demonstrate that despite the high intermittency and the relatively low temperatures, waste heat recovery is possible and can be valuable.

Keywords: *heat recovery, district heating*

Evaluating the Performance of Integrated Energy Management at a Synchrotron Radiation Facility: A Case Study of NSRRC, Taiwan

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Abstract

Accelerator and utility systems consume substantial electricity in synchrotron light source radiation facilities, making energy efficiency essential for sustainable operation. This study evaluates integrated energy management measures implemented at the National Synchrotron Radiation Research Center (NSRRC), including chiller plant load dispatch, booster injection optimization, accelerator waste heat recovery, and renewable energy deployment. A baseline regression model was developed using 2019 electricity consumption, weather, and accelerator operating hours, corresponding to the year NSRRC obtained ISO 50001 certification. Adjusted baseline consumption for 2020–2025 was calculated using annual weather and operating conditions and compared with actual consumption to quantify energy savings. Environmental compliance in accelerator and beamline areas was also evaluated.

In 2025, electricity consumption was 9.2% below the adjusted baseline, corresponding to annual savings of approximately 6.7 GWh, while temperature and relative humidity compliance remained above 95%. In addition, a 1.2 MWp solar photovoltaic system generates approximately 1.4 GWh annually, excluding this contribution from the reported savings. These results demonstrate that integrated energy management can significantly reduce electricity consumption without compromising environmental control. Future work will investigate deep-learning-based HVAC optimization, permanent-magnet replacement of accelerator electromagnets, and radio-frequency system upgrades.

Keywords: *Synchrotron light source, Integrated energy management, Energy baseline modelling.*

Two Test Facilities Supporting the Long-Term Sustainability of Superconducting Devices

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Abstract

The Italian National Institute for Nuclear Physics (INFN) is spending lot of efforts in technological activities based on superconductivity with an outlook on the sustainability of the future research programs. The new Test Facility for Large Superconducting Magnets and Superconducting Line at the Physics Department of the University of Salerno (Italy), consisting in two buildings, is currently devoted to the test and commissioning of superconducting devices, such as superconducting magnets for synchrotrons, and power transmission line for future green power grids. The former facility is committed in the Site Acceptance Tests (SAT) of quadrupole doublets modules (QDM) for the SIS100 accelerator, part of the FAIR facility under construction. On the other hand, a new facility is under construction under the PNRR_IRIS project, targeting the application of superconductivity to the Green Transition and aiming at fostering the technology of superconducting power transmission lines based on MgB₂ cables. Both facilities will be presented with an outlook on future commitments in the test of sustainable superconducting magnets and power transmission cables.

Keywords: *superconducting magnets, superconducting power transmission lines*

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Improving injection efficiency in accelerators using artificial intelligence-based optimization methods

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Abstract

Optimizing the injection line from the microtron to the booster is essential for achieving stable and efficient operation of the Karlsruhe Research Accelerator (KARA) storage ring at KIT. This study presents a real-time application of Bayesian optimization during accelerator operation [1]. The optimization framework integrates live measurements of beam current fluctuations, injection quality, microtron power consumption, and the stability of the beam repetition rate, an important parameter that depends strongly on the transport conditions in the microtron-to-booster transfer line. Improved stability in this region increases the injection rate at low energy, enabling a faster and more consistent booster fill-up and supporting a higher effective repetition rate for downstream operation. Initial results indicate promising trends toward improved transport efficiency, increased repetition-rate stability, and more energy-aware operation. This work is part of the RF2.0 project, funded by the Horizon Europe program, which aims to advance sustainable, intelligent accelerator technologies [2].

Keywords: Bayesian optimization, microtron, booster, KARA, injection line, efficiency.

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Substrate, Doping and Buffer-Layer Engineering of PLD-Grown MoS₂ Thin Films for Hydrogen Evolution

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Abstract

Molybdenum disulfide (MoS₂) is a cost-effective alternative to platinum-group catalysts for the hydrogen evolution reaction (HER), yet its performance strongly depends on the interfacial environment established during growth. We present a systematic study of pulsed-laser-deposited (PLD) MoS₂ thin films in which the local polymorphism (1T/2H ratio), strain and electrocatalytic activity are tuned through three complementary strategies: substrate selection (Al₂O₃, SrTiO₃, SiC)[1-2], transition-metal doping (Co,Mn)[2-4] and buffer-layer insertion (Au, V₂O₃, Cr₄Te₅) on sapphire (Al₂O₃). Combining X-ray diffraction, Raman spectroscopy, near ambient pressure photo electron spectroscopy (NAP-XPS), in situ/operando soft X-ray absorption spectroscopy, transmission electron microscopy (TEM), linear sweep voltammetry (LSV) and electrochemical impedance spectroscopy (EIS), we show that interfacial charge transfer and stabilization of the metastable 1T phase are the key parameters governing hydrogen evolution reaction (HER) kinetics and change in electrochemically active surface area. Al₂O₃-supported films and V₂O₅ buffer layers yield the lowest overpotentials and Tafel slopes, while Co doping promotes water dissociation via Co–OH bond formation. These results establish substrate and interface engineering as effective strategies for optimizing earth-abundant MoS₂ electrocatalysts for sustainable hydrogen production.

Keywords: Pulsed-laser-deposited (PLD), Hydrogen evolution reaction (HER), near ambient pressure x-ray photoelectron spectroscopy (NAP-XPS), Transmission electron microscopy (TEM), X-ray absorption spectroscopy (XAS), Linear sweep voltammetry (LSV), Electrochemical impedance spectroscopy (EIS)

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Charge-Carrier Kinetics in Halide Perovskite Thin Films under 68 MeV Proton Irradiation: A Time-Resolved Microwave Conductivity Study over a 360-Day Post-Irradiation Window

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Abstract

Halide perovskites are increasingly considered for radiation-tolerant optoelectronic applications; however, most reported hardness assessments rely on a single pre- or post-irradiation comparison, leaving the temporal evolution of radiation-induced defects largely unresolved. [1,2]. Here, contactless time-resolved microwave conductivity (TRMC) [3] is used to track the free-carrier decay kinetics of four bandgap-engineered, surface-passivated, and non-passivated triple-cation perovskite films following 68 MeV proton irradiation (fluence 2×10^{12} p cm⁻²), with irradiated and non-irradiated samples re-measured in parallel at four time points spanning a 360-day post-irradiation window. The extracted peak photoconductance and decay-time metrics show no consistent sign or systematic temporal trend attributable to the irradiation itself across any sample, indicating that radiation-induced trap states do not show a clear tendency to change and do not dominate the carrier kinetics in the investigated films. This radiation response is markedly weaker and less systematic than the directionally consistent ambient-storage evolution independently observed on the same films over the same period, implicating background aging processes, rather than proton-induced damage, as the primary driver of long-term charge-carrier kinetics changes in this material system. These results inform how radiation-tolerant materials should be qualified and stored for sustainable, long-lifetime research-infrastructure instrumentation.

Keywords: halide perovskites, proton irradiation, radiation hardness, time-resolved microwave conductivity, charge-carrier dynamics, ambient stability.

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Research with neutrons for a sustainable future

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Abstract

The Research Neutron Source Heinz Maier-Leibnitz (FRM II) is a world-class research infrastructure in Germany providing neutrons for scientific experiments. More than thirty instruments, operated in the framework of the MLZ, are available to the international community for cutting-edge neutron research. Projects advancing sustainable technologies are of utmost relevance to MLZ. To highlight the applications of neutrons in such projects, we present here four exemplary directions for research and technological development at our research facility:

- 1) Neutron grating interferometry at the instrument ANTARES enables the visualization of magnetic flux in rotors of electric motors and allows to study novel approaches of magnetic flux guidance to significantly increase efficiency.
- 2) Non-destructive operando analysis of rechargeable batteries at the neutron diffractometers SPODI and STRESS-SPEC sheds light on critical processes in battery materials, suggesting ways for their optimization.
- 3) Nuclear transmutation doping of silicon single crystals produces n-doped Si with highly homogeneous resistivity, supporting sustainable solutions, e.g. in the transport sector.
- 4) Operando small-angle neutron scattering studies on reverse-osmosis membranes at the KWS-3 / KWS-1 instruments help improve membrane performance in water desalination.

Keywords: FRM II, neutron scattering, neutron imaging, non-destructive analysis, batteries, Si-doping, membranes, electromotors.

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Mapping and Characterizing Electricity-Intensive Research Infrastructures across Europe

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Abstract

The energy transition requires a clearer picture of how much electricity major European Research Infrastructures (RIs) actually consume. Yet this field remains largely undocumented: no formal definition of "electricity-intensive" RI exists, and no current database — MERIL [1], ESFRI [2] -includes any energy-related criterion. Building on the European project FlexRICAN (Horizon Europe), which develops energy flexibility strategies for RIs, we address this gap by proposing an operational definition: an electricity-intensive RI is a scientific facility whose annual electricity consumption exceeds an empirically calibrated threshold and is predominantly driven by its scientific activity. On this basis, we establish a ten-category typology (photon sources, neutron sources, supercomputers, high-field magnets, high-power lasers, fusion facilities, etc.) and carry out a systematic census using European institutional networks (LEAPS [3], LENS [4], EuroHPC [5], EUROfusion [6], Laserlab-Europe [7], etc.), covering both pan-European and national facilities. This yields a preliminary inventory of over one hundred electricity-intensive RIs across fifteen European countries. Initial data reveal a spectrum spanning several orders of magnitude — from a few GWh/year to 1,290 GWh/year for CERN [8] — and confirm the scale of the documentation gap. Systematic data collection is now underway.

Keywords: *research infrastructure, large-scale facilities, electricity-intensive, electricity consumption, census, energy flexibility, FlexRICAN, Horizon Europe.*

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Student Program Abstracts

The ESSRI 2026 Student Program



Synergistic nanoadditives for high-performance and energy-efficient lubrication in research infrastructures

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Abstract

Research infrastructures rely on high-precision mechanical systems, including pumps, compressors, bearings, positioning devices, and scientific instrumentation, whose reliability is strongly affected by friction and wear [1,2]. Advanced lubrication strategies can therefore contribute to improving operational efficiency, durability, and maintenance of critical equipment. In this work, a lubricant formulation incorporating a MoS₂-based complex and TiO₂ nanoparticles as functional nanoadditives is proposed for demanding tribological applications. MoS₂ provides low-shear layered structures capable of promoting the formation of protective tribofilms at sliding interfaces, thereby reducing direct contact between surface asperities [3]. TiO₂ nanoparticles are introduced to further enhance surface protection and potentially promote synergistic tribochemical effects under boundary lubrication conditions [4,5]. The combined system is designed to improve friction reduction, wear resistance, and lubricant performance under variable operating conditions. This nano-enabled lubrication approach provides a promising strategy for the development of high-performance lubricants potentially applicable to mechanical components and precision equipment within research infrastructures, where reduced friction, extended component lifetime, operational reliability, and lower maintenance requirements are essential for ensuring continuous and efficient operation.

Keywords: MoS₂; TiO₂ nanoparticles; Nanolubricants; Tribology; Friction and wear; Research infrastructures; Predictive maintenance.

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Energy Saving HTS Magnets for Particle Accelerators

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Abstract

Next-generation particle accelerators demand innovative technologies able to meet the performance and sustainability requirements of particle physics and applied science, while ensuring high efficiency and reduced costs for industrial applications. High-Temperature Superconductors (HTS), particularly REBCO tapes operating at 20 K via dry conduction cooling, are the most promising technology to drastically reduce the energy footprint and operational costs of research infrastructures. Within the EPITA WP8 project framework, we present the conceptual and electromagnetic design of an energy-saving HTS split-coil magnet. Targeting a 10 T central field, a 150–200 mm inner bore, and a 20 K operating temperature, this system places itself well beyond the operational state of the art, as no existing facility combines these three parameters simultaneously. We address the open engineering challenges, multiphysics modeling, and material selection needed for high magnetic stresses and dry cooling. The Split Coil will serve as a shared experimental platform and technology driver for future colliders (FCC, Muon Collider), while generating validated numerical tools and engineering guidelines. Beyond particle physics, these solutions directly apply to medical imaging, nuclear fusion, and sustainable energy infrastructures.

Keywords: *High-Temperature Superconductors, REBCO Split-Coil, Energy Sustainability, Conduction Cooling, Accelerator Magnets.*

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Sustainable MnO-MXene-PANI/PVA Nanofiber Electrodes for Advanced Energy Storage Applications in Sustainable Research Infrastructures

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Abstract

The increasing energy demand of modern research infrastructures requires sustainable and efficient energy-storage technologies capable of supporting renewable energy integration and reliable power- management systems. In this study, MnO-MXene-PANI/PVA composite nanofibers were fabricated and evaluated as advanced electrode materials for supercapacitor applications. A sustainable materials approach was adopted by recovering MnO particles from spent alkaline batteries and integrating them with multilayered MXene nanosheets to construct MnO-MXene composite structures. The optimized composite was incorporated into PANI/PVA blended nanofibers through electrospinning, generating conductive electrode architectures with enhanced charge-storage capability. The characterization was done using FTIR, SEM, EDX, and TGA, while electrochemical performance was evaluated through CV, GCD, and EIS analyses. The developed nanofibers exhibited uniform morphology and homogeneous distribution of active components, enabling efficient charge transfer. The electrode achieved a Faradaic capacitance of 395 F g^{-1} at 2 A g^{-1} , with energy and power densities of 30 Wh kg^{-1} and 25 W kg^{-1} , respectively, demonstrating competitive performance compared with reported MnO, MXene, and polymer-based electrodes. These findings highlight the potential of recycled MnO-MXene nanofibers as sustainable electrode materials for next-generation supercapacitor systems supporting energy-efficient research infrastructures.

Keywords: MXene, Manganese oxide, nanofibers, electrospinning, supercapacitor, recycled

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A Cradle-to-Gate LCA of Lead Shielding Units for the FCC-ee

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Abstract

The Future Circular Collider (FCC-ee), a proposed 91 km electron-positron collider, requires roughly 13,000 shielding units to attenuate synchrotron radiation scattered inside the arc dipole magnets. Lead has traditionally been used for this application due to its high density, low cost, and strong attenuation properties. However, lead is classified as hazardous and toxic, conflicting with CERN's 2030 environmental goals. Five candidate materials (lead PB970R, W-Ni-Cu alloy, copper 10500, 316L SS, and high-density concrete) were evaluated against mechanical constraints and environmental indicators using Ansys Granta EcoAudit. Lead proved most favourable, owing to its density, low cost, and recyclability, leaving the manufacturing route as the remaining open design choice. Beyond material comparison, this work presents a cradle-to-gate life cycle assessment, using OpenLCA and the EF 3.1 method, comparing two suppliers with different manufacturing routes for the same functional unit; casting-and-milling (UK) and casting-rolling-cutting-milling (Germany). Preliminary results show the second route carries a ~20% higher carbon footprint per unit, driven primarily by higher electricity demand and the German grid mix, highlighting manufacturing route and location as an additional sustainability lever.

Keywords: *life cycle assessment, radiation shielding materials, manufacturing, lead recycling.*

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Towards Sustainable Particle Accelerators with HTS Magnets

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Abstract

The development of next-generation particle accelerators requires superconducting magnet technologies that combine high magnetic performance, energy efficiency, and reduced operating costs. High-Temperature Superconductors (HTS), particularly REBCO coated conductors operated at 20 K through conduction cooling, offer a promising solution for high-field magnets with reduced cryogenic requirements and improved sustainability. Within the EPITA WP8 project, we present the conceptual and electromagnetic design of a REBCO-based cos-theta magnet targeting a 10 T central field, a 50 mm aperture, and a 20 K operating temperature. The design investigates the potential of HTS technology to reduce the energy footprint of future research infrastructures, while addressing key challenges related to coil geometry, conductor arrangement, field quality, screening currents, and electromagnetic forces. Multiphysics numerical models are developed to characterize magnet performance and optimize the coil configuration while maintaining a mechanically robust and technologically feasible design. The proposed concept provides a pathway towards more sustainable accelerator facilities by combining high-field performance with reduced energy demand and cryogenic requirements, contributing to the development of high-field superconducting technologies for next-generation research infrastructures.

Keywords: *High-Temperature Superconductors, Energy Sustainability, REBCO cos-theta magnet, Conduction Cooling, Accelerator Magnets.*

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Reusable nanocomposite for advanced cooling-water treatment in large-scale research infrastructures

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Abstract

Large-scale research infrastructures require substantial volumes of water for cooling and technological operations, making efficient water purification and recirculation essential for reducing freshwater consumption and wastewater discharge [1-4]. In this context, advanced adsorbent materials could provide an additional polishing step for removing residual organic contaminants before water reuse. Among the investigated nanocomposite systems, MoS₂/ZrO₂ was selected and evaluated using methylene blue as a model organic pollutant. Structural, morphological, and surface characterization confirmed the successful formation of the heterostructured material and the synergistic interaction between MoS₂ and ZrO₂. The composite achieved nearly complete pollutant removal within 1 h at pH 9 and retained more than 92% of its adsorption performance after four consecutive reuse cycles. Density functional theory calculations supported the experimental results, revealing enhanced interfacial charge transfer and stronger adsorbate–surface interactions. These findings demonstrate the potential of MoS₂/ZrO₂ as a reusable adsorbent for integration into advanced water-treatment and recycling systems of large research infrastructures, particularly as a polishing stage prior to water recirculation, supporting closed-loop water management and reduced environmental impact.

Keywords: *nanocomposite; water recycling; research infrastructures; cooling water; adsorption; organic contaminants; water treatment; closed-loop water management; DFT.*

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Sustainable Ru@CuCo₂O₄/Recycled Carbon Fiber supercapacitor electrodes for energy storage in research infrastructures

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Abstract

Research infrastructures increasingly rely on autonomous monitoring systems, sensor networks, and scientific instrumentation requiring reliable, rapid, and sustainable energy storage solutions. In this context, high-performance supercapacitors are attractive due to their high power density and long cycling life [1,2]. Here, recycled carbon fibers (RCFs) were valorized as lightweight conductive supports for a hybrid CuCo₂O₄/Ru electrode [3–4]. RCFs were functionalized by NH₄OH/H₂O₂ treatment and decorated with spinel CuCo₂O₄ nanoparticles via a solvothermal route. The resulting CuCo₂O₄@f_RCF hybrid was subsequently modified with 1 wt.% Ru. Morphological analysis revealed a homogeneous distribution of Cu, Co, O, and Ru over the carbon fibers. XRD confirmed the cubic spinel CuCo₂O₄ phase with an average crystallite size of ~12 nm, while FT-IR further supported its formation. Electrochemical performance was investigated in alkaline electrolytes containing K₃[Fe(CN)₆] as a redox-active additive. This approach combines RCFs waste valorization with advanced electrode design, offering a sustainable route toward lightweight supercapacitor devices potentially suitable for power buffering and short-term energy storage in research infrastructure monitoring and sensing systems.

Keywords: Recycled carbon fibers; CuCo₂O₄; Ruthenium; Supercapacitors; Sustainable energy storage; Research infrastructures; Circular economy.

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This research was supported by the "Horizon Europe" program, funded by the European Union (AEROSOFT spa, project leader. Project n. F/310328/01-05/X56– MARiS – Materiali compositi Avanzati ottenuti dal Riciclo di materiali di Sfrido (o Scarto) - Advanced composite Materials obtained from the Recycling of Scrap materials (or waste)).

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Towards Sustainable Smart Research Laboratories: An Energy Harvesting IoT Framework for Intelligent Lighting and HVAC Control

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Abstract

The increasing energy demand of research infrastructures calls for innovative solutions for environmental monitoring and energy consumption optimization. This work proposes an energy management framework for Smart Research Laboratories that integrates an eco-friendly, self-powered IoT node based on energy harvesting techniques with decision-making algorithms for the intelligent control of lighting and HVAC systems [1]. The proposed methodology relies on the development of a simplified digital model of a research laboratory, from which synthetic datasets are generated to represent different operational scenarios. The model realistically reproduces laboratory occupancy, scientific equipment operation, and the temporal evolution of key environmental parameters, defining dynamic trends and critical thresholds for temperature, CO₂ concentration, and illuminance. Based on these scenarios, two energy optimization strategies are implemented: **(i)** an intelligent lighting system based on daylight harvesting, which dynamically adjusts LED dimming according to the available natural daylight; and **(ii)** an HVAC control strategy that modulates heating, ventilation, and air conditioning according to environmental conditions and laboratory occupancy estimated from CO₂ concentration. The proposed framework contributes to the development of more sustainable and energy-efficient research laboratories.

Keywords: *environmental monitoring; energy efficiency; sustainability.*

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