# iFAST 2nd Annual Meeting, April 19, 2023

Mike Seidel, PSI/EPFL

# WP11 Overview

**task 1**: **Sustainable Concepts for RIs**: networking, workshops on selected topics
deliverable: report

1) System Efficiency of Accelerator Concepts (N.Catalan Lasheras, CERN)
2) Key Technologies and Components for High Efficiency (A.Sunesson, ESS)
3) Cross Linking Accelerator R&D with Industrial Approaches (P.Spiller, GSI)
4) Ecological Concepts (D. Voelker, DESY)

**task 2**: **High Efficiency Klystron** (O.Brunner CERN, THALES, ULANC)

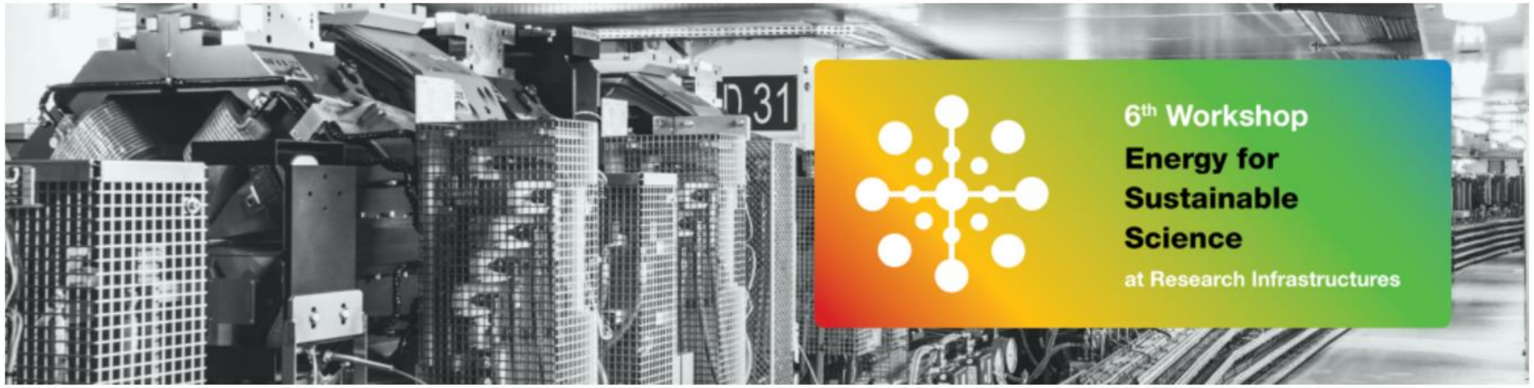
- deliverable: industrial prototype
- replacing klystrons in LHC

**task 3**: **Permanent Combined Function Magnets for Light Sources** (B.Shepherd, UKRI, DLS, KYMA, DESY)

- deliverable: magnet prototype, applicable for Diamond upgrade,PETRA-4
- several advantages of permanent magnets, not just power consumption

iFAST

# ESSRI Workshop Grenoble, Sep 29, 2022




29-30 September 2022
ESRF, Grenoble
Europe/Paris timezone

REGISTRATION OPENS 1ST MAY

Enter your search term

- Overview
- Committees
- Timetable
- Registration Instructions PLEASE READ!
- ESRF Registration Form
- Fees & Payment information

Dwindling resources together with rising energy costs and climate change are all challenges faced by the next generation of large-scale research infrastructures. Indeed, the enhanced performance of proposed new facilities often comes with anticipated increased power consumption. Sustainable developments at research infrastructures will rely on mid- and long-term strategies for reliable, affordable and carbon-neutral energy supplies.

The ESRF (European Synchrotron Radiation Facility) is pleased to host the **Sixth Workshop on Energy for Sustainable Science at Research Infrastructures** on **29th and 30th September 2022** in Grenoble, France in collaboration with:

https://indico.esrf.fr/event/2/

**Grenoble: Green Capitol of Europe, 2022**

**Session Topics**:
- energy efficient technologies
- energy management at research infrastructures
- sustainability of equipment, materials and resources
- energy management for projects

**International Organising Committee**

Carlo Bocchetta - ESS
Frederick Bordry - CERN
Serge Claudet - CERN
Andrew Harrison - ERF
Jean-Luc Revol - ESRF
Mike Seidel - PSI
Denise Voelker - DESY

# Energy for Sustainable Science, Grenoble 2022

6th workshop
101 particpants, 2-day program, 32 presentations, few remote
chair: Jean-Luc Revol (ESRF)

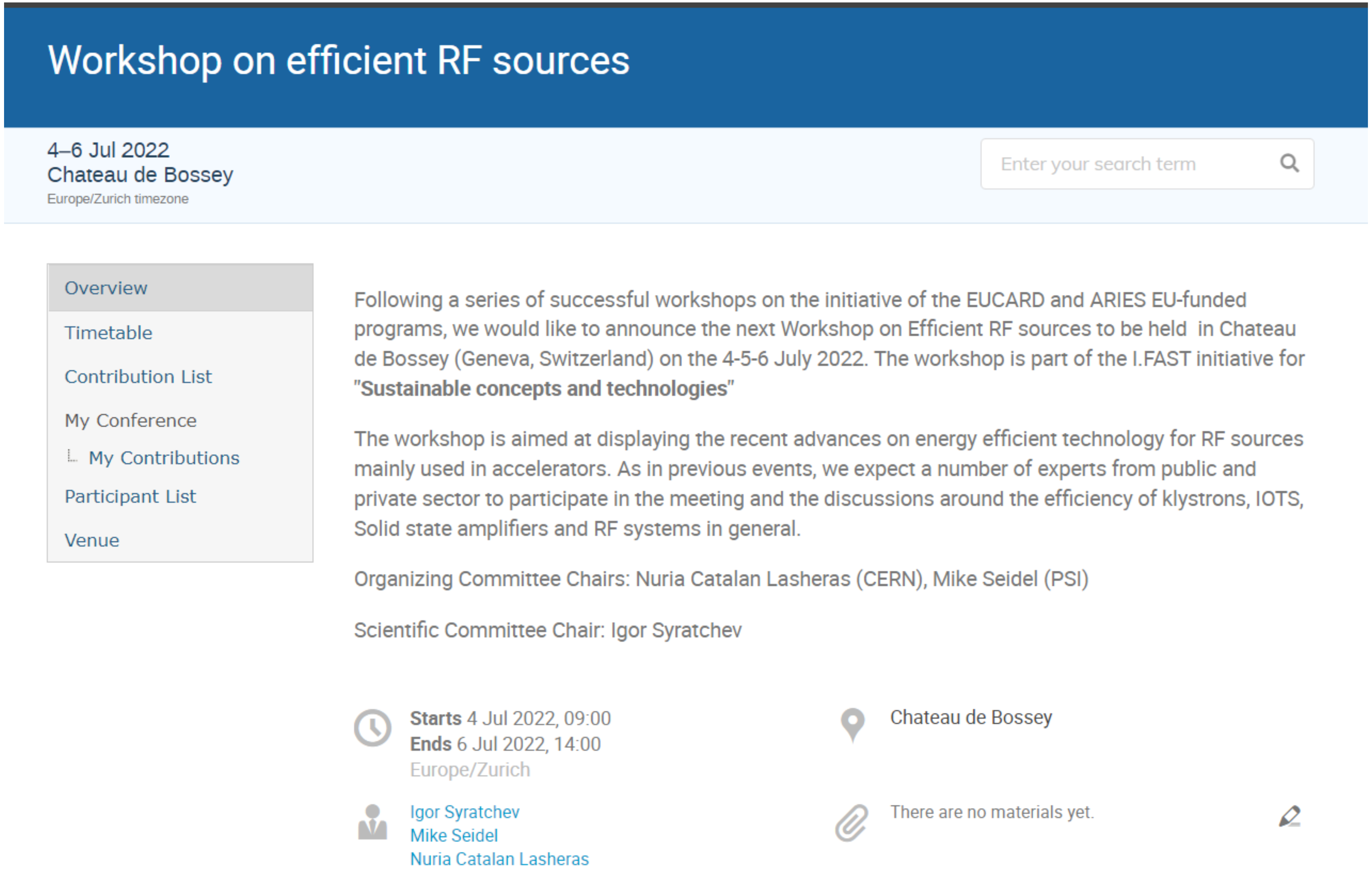

next ESSRI workshop ca 9/2024, CIEMAT Madrid
chairmanship & organization: J.Perez et al.
support by I.FAST WP11

**First day …**

| | | | | |
|---|---|---|---|---|
| 09:00 | **Welcome** | *Francesco Sette* | *Auditorium, ESRF, Grenoble* | 09:00 - 09:10 |
| | **Workshop Introduction** | *Frederick Bordry* | *Auditorium, ESRF, Grenoble* | 09:10 - 09:20 |
| | **Practical Information** | *Jean-Luc Revol* | *Auditorium, ESRF, Grenoble* | 09:20 - 09:30 |
| | **Climate change is accelerating. We need to move much faster** | *Michel Jarraud* | *Auditorium, ESRF, Grenoble* | 09:30 - 10:00 |
| 10:00 | **Energy Transition: towards a complex cyber-physical system of systems** | *Lucas Saludjian* | *Auditorium, ESRF, Grenoble* | 10:00 - 10:30 |
| | **Coffee break & Photo** | | *Entrance Hall, ESRF Central Building* | 10:30 - 11:15 |
| 11:00 | **Electrical Flexibility Market** | *Bernadette Remenyi et al.* | *Auditorium, ESRF, Grenoble* | 11:15 - 11:45 |
| | **Energy management at Stanford University** | *Lincoln Bleveans* | *Auditorium, ESRF, Grenoble* | 11:45 - 12:15 |
| 12:00 | **ERLs and Sustainability** | *Andrew Hutton* | *Auditorium, ESRF, Grenoble* | 12:15 - 12:45 |
| | **Lunch** | | *Site Restaurant* | 12:45 - 14:00 |
| 13:00 | | | | |
| 14:00 | **Challenges of a megawatt CW class solid state power am.** | *Eric Montesinos* | | |
| | **An overview of the status of energy sustainability at the .** | *Mamad Eshraqi* | | |
| | **Progress with permanent magnets and return on experien** | *Joel Chavanne* | | |
| | **Energy optimisations implemented at accelerators and ir** | *David Reinhard* | | |
| 15:00 | **Free Air Cooling solution for the Data Centers** | *Laurent Roy* | | |
| | **Energy management at High Magnetic Field Facilities** | *François Debray* | | |
| | **Energy management University Darmstadt** | *Christopher Ripp* | | |
| | **ESRF EBS energy management** | *Christian Nevo* | *Auditorium, ESRF* | 15:15 - 15:40 |
| | **Coffee break** | | | |
| | **Coffee break** | | | |

## WP11, 1.1: N.Catalan-Lasheras

- RF efficiency in operational and planned accelerators
- High efficiency klystrons
- Industrial partners contribution
- Magnetrons, IOTs, tetrodes
- Solid State Amplifiers


# Workshop on efficient RF sources

4–6 Jul 2022
Chateau de Bossey
Europe/Zurich timezone

Enter your search term

- Overview
- Timetable
- Contribution List
- My Conference
  - My Contributions
- Participant List
- Venue

Following a series of successful workshops on the initiative of the EUCARD and ARIES EU-funded programs, we would like to announce the next Workshop on Efficient RF sources to be held in Chateau de Bossey (Geneva, Switzerland) on the 4-5-6 July 2022. The workshop is part of the I.FAST initiative for "**Sustainable concepts and technologies**"

The workshop is aimed at displaying the recent advances on energy efficient technology for RF sources mainly used in accelerators. As in previous events, we expect a number of experts from public and private sector to participate in the meeting and the discussions around the efficiency of klystrons, IOTS, Solid state amplifiers and RF systems in general.

Organizing Committee Chairs: Nuria Catalan Lasheras (CERN), Mike Seidel (PSI)

Scientific Committee Chair: Igor Syratchev

**Starts** 4 Jul 2022, 09:00
**Ends** 6 Jul 2022, 14:00
Europe/Zurich

Chateau de Bossey

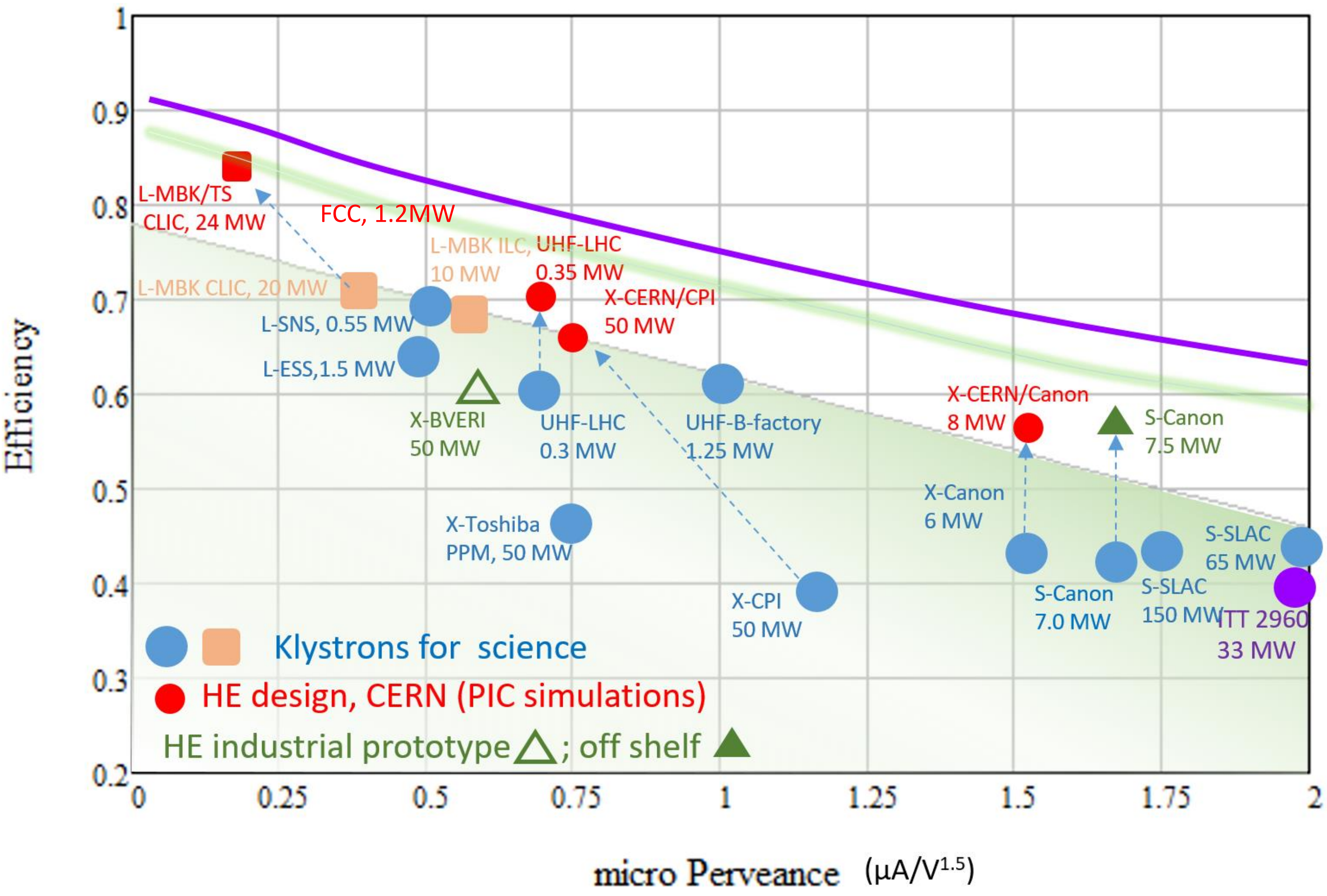
Igor Syratchev
Mike Seidel
Nuria Catalan Lasheras

There are no materials yet.

https://indico.cern.ch/event/1138197/

**I.Syratchev, High efficiency klystron technologies**

Efficiency performance of the selected commercial klystrons and the new HE klystrons.

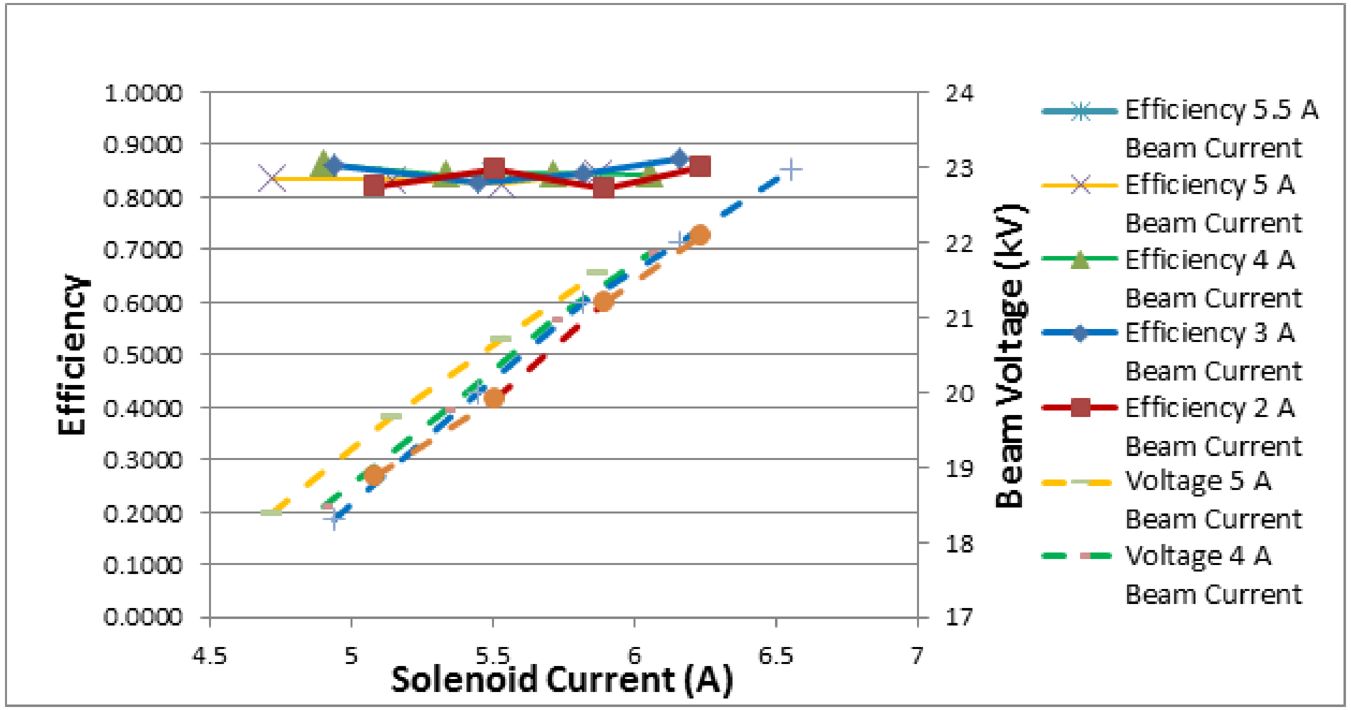



klystron talks, Tu

| | |
|---|---|
| 09:00 | **HE klystrons technologies**<br>*Chateau de Bossey* |
| | **Review of computer codes for the klystrons design**<br>*Chateau de Bossey* |
| 10:00 | **FCC HE TS klystron development**<br>*Chateau de Bossey* |
| | **Coffee Break**<br>*Chateau de Bossey* |
| 11:00 | **CSM HE LHC klystron. THALES**<br>*Chateau de Bossey* |
| | **50 MW Xband HE klystron program. CPI**<br>*Chateau de Bossey* |
| 12:00 | **CEPC high efficiency klystron status**<br>*Chateau de Bossey* |
| | **X-band HE klystron development. Canon Electron Tubes & Devices**<br>*Chateau de Bossey* |

# Lawrence Ives, Calabazas Creek Research, High Efficiency RF Source Development

Efficiency varied between 81% and 87%, depending on parameters




A 100 kW 1300 MHz **magnetron** with 10% duty

collaboration with Fermilab

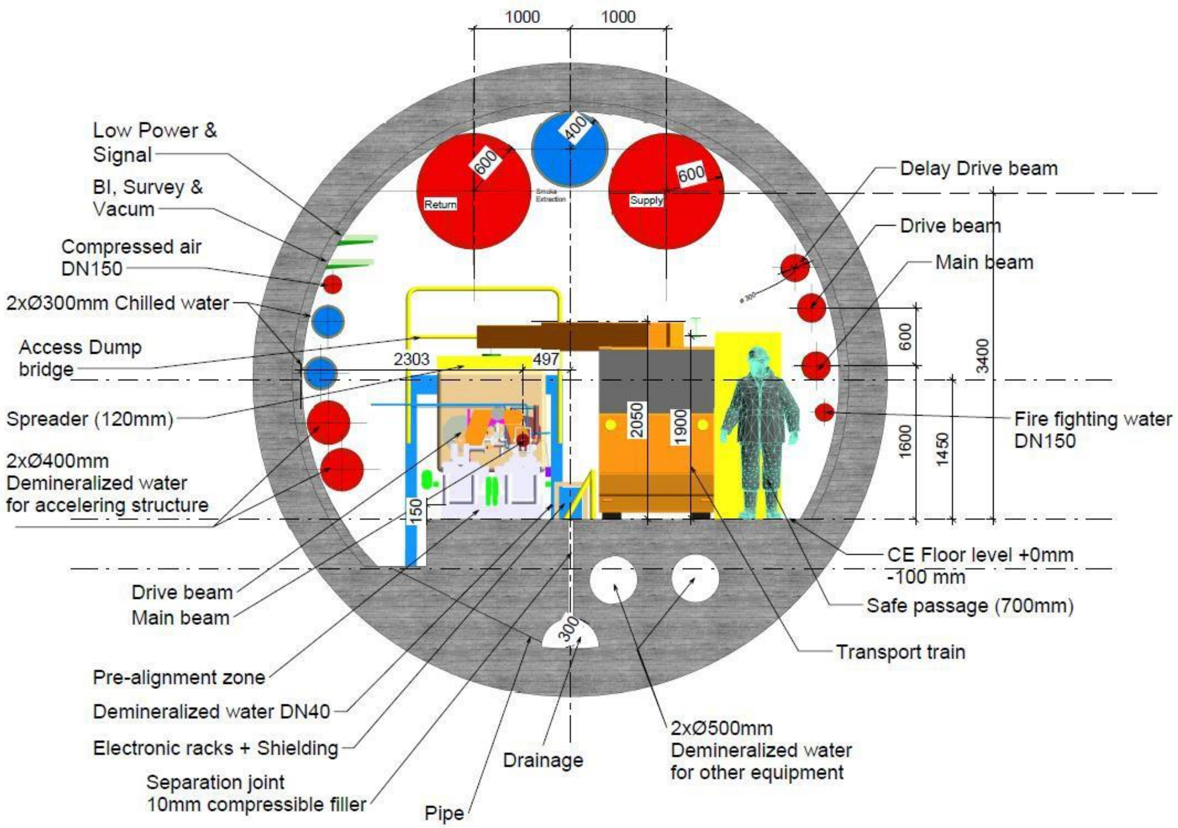
[related: I.FAST Innovation Funds project: D.Dancilos, Crossed Field Amplifier, presented on Fri]

# A.Grudiev, on CLIC optimizations Comparison of wall plug to beam efficiencies

→ impressive example of efficiency optimization of a complex collider system
main measures: new low (R/Q) damping ring resonators, drive beam klystron & modulator improvement

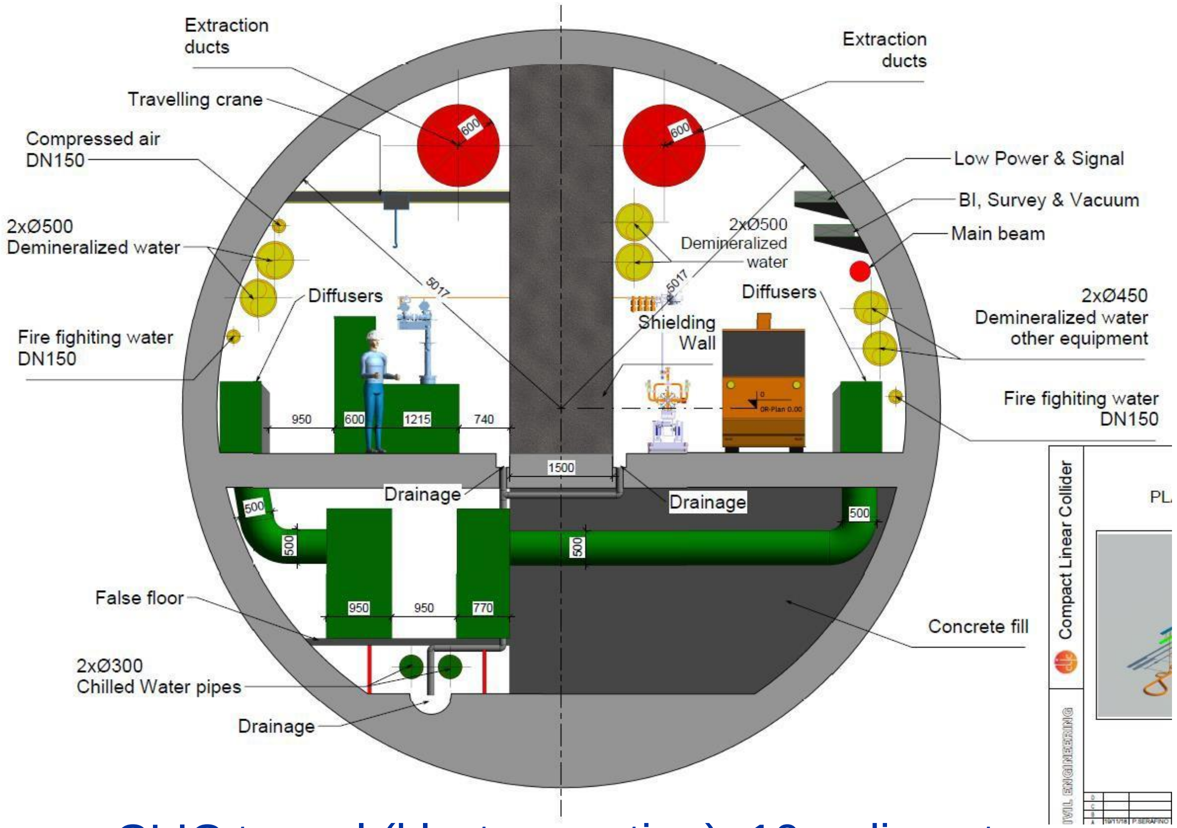
| | **PIP baseline** | **New DR** | **New TS MBK** |
|---|---|---|---|
| DB klystron efficiency [%] | 70 | 70 | 82 |
| DB modulator pulse efficiency [%] | 86 | 86 | 94 |
| **DB complex Wall plug to DB efficiency [%]** | **31.8** | **31.8** | **37.6** |
| DR wall plug to MB efficiency [%] | 7.9 | 56.7 | 56.7 |
| **CLIC Wall plug to MB efficiency [%]** | **3.3** | **4.8** | **5.2** |

# B.List et al: CLIC $CO_2$ Footp.-Tunnel Cross Sections




CLIC tunnel (drive beam option), 5.6m diameter

My estimate: 12.4m$^2$ concrete
-> 31t/m concrete




CLIC tunnel (klystron option), 10m diameter

My estimate: 44.8m$^2$ concrete
-> 112t/m concrete

# B.List et al: CLIC $CO_2$ Footp.- Summary

Tunnel (per 2.01m module):

- 12 t CO2-eq for two-beam
- 42t CO2-eq for klystron

Accelerator (T0 module)

- 5 t CO2-eq for two-beam

A lot of things missing:

- Transport, fabrication, installation stages
- Tunnel infrastructure (heating/ventilation, cooling pipes, cable trays)
- Magnet cables, power supplies
- Magnets for T1-T4 modules

**Conclusion so far:**

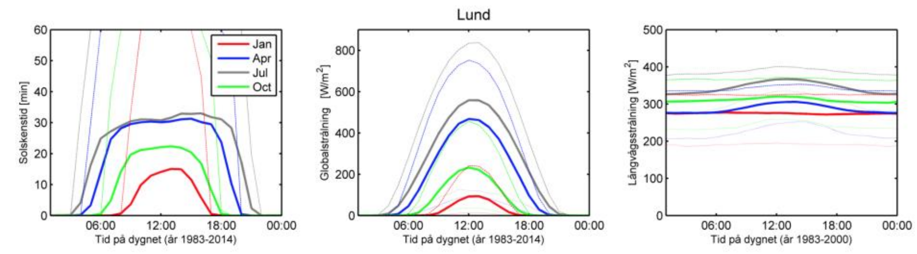
- **Civil engineering (tunnel) is dominant source of CO2**
- **Accelerator non-negligible, even in absence of large magnets**
- **Accelerator supports are more important that RF structures**

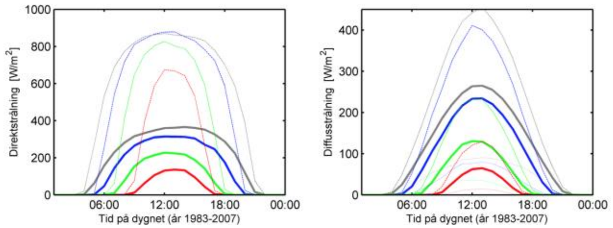
# ESS Topics, Anders Sunesson

- Sustainability in accelerator operation:
  - PV installation to supplement the grid – considerable savings possible
  - More efficient DC/DC converter to directly power equipment (in fact, most electronics is powered by DC!), for example to 1.1 kV voltage, which would allow direct powering of HV modulators with higher efficiency
- Improved power converters in general using active frontends – less need for compensation for flicker etc
- Workshop 2023 moved to 2024. Suggested focus Efficient Power converters and solar power generation optimization
- ESS co-applicant to HORIZON 2023 program FlexRICAN geared towards sustainability and flexibility in how you power facilities

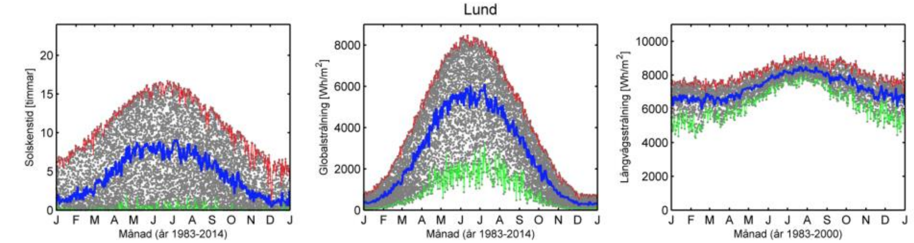
# Solar cells powering the neutron source

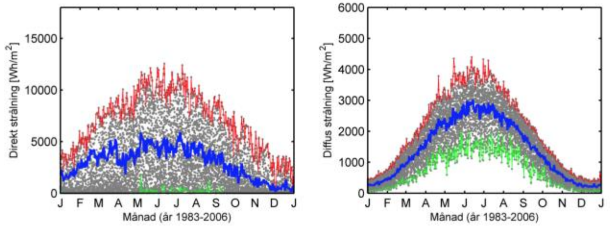
- Panels are 1.1 x 1.75 m, each rated at 410 W
  - With ~34k panels the installed capacity is ~14 MW, total cost (incl VAT): 154 MSEK



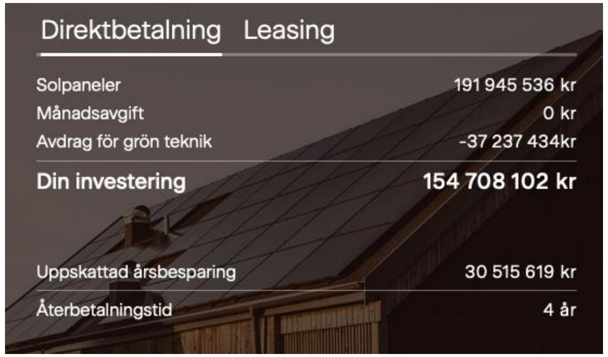




Daily variations

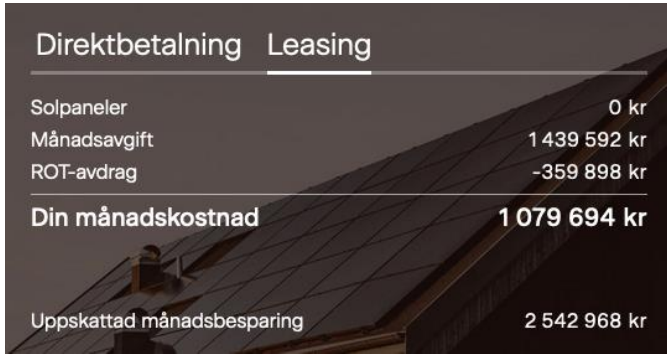



Annual variations



| Direktbetalning | Leasing |
| --- | --- |
| Solpaneler | 191 945 536 kr |
| Månadsavgift | 0 kr |
| Avdrag för grön teknik | -37 237 434kr |
| **Din investering** | **154 708 102 kr** |
| Uppskattad årsbesparing | 30 515 619 kr |
| Återbetalningstid | 4 år |



| Direktbetalning | Leasing |
| --- | --- |
| Solpaneler | 0 kr |
| Månadsavgift | 1 439 592 kr |
| ROT-avdrag | -359 898 kr |
| **Din månadskostnad** | **1 079 694 kr** |
| Uppskattad månadsbesparing | 2 542 968 kr |

https://www.smhi.se/kunskapsbanken/meteorologi/stralning/solstralning-i-sverige-1.89984

iFAST

6.–8. Feb. 2023
Hamburg
Europe/Berlin Zeitzone

# Critical Materials and Life Cycle Management: The Example of Rare Earths – curse or blessing?

## DESY Hamburg, Denise Völker, Andrea Klumpp et al
## → see highlight talk by Denise

- Übersicht
- Zeitplan
- Anmeldung
- Information
- Participant list
- Impressions of the work shop

**Orga**

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andrea.klumpp@desy.de

Life Cycle Assessments get more and more in the focus in industry and also in science. iFAST presents a platform for discussing and finding solutions in these topics.
In our workshop we want to focus on the Life Cycle Management using the example of Rare Earths Elements (REE), the key material in permanent magnets used in a variety of fields like accelerator, turbines, hard drives and many more.

On the workshop we will discuss the following points:

- Life cycle management
  Consider entire life cycle of technical component using critical materials:
  construction – operation – deconstruction
- Mining and processing of REE
  a socio-ecological approach – energy savings versus destructive mining and processing
- Using permanent magnets
  Examples of the use of permanent magnets and its Pro and Con
- Certification for mining and processing of REE
  How to force more sustainable thinking in the production of REE
- Recycling of permanent magnets
  New processes for the re-use and recycling of permanent magnets
- Alternatives for permanent magnets with REE
  New magnetic materials as well as improved electromagnets

Science, industry, politics and NGO in cooperation can forces to tackle the problem – we can develop solutions together.

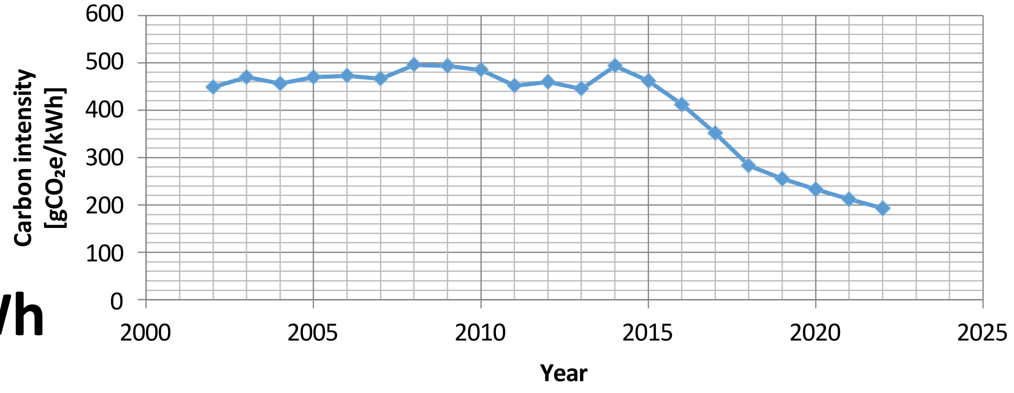
**Topics**:

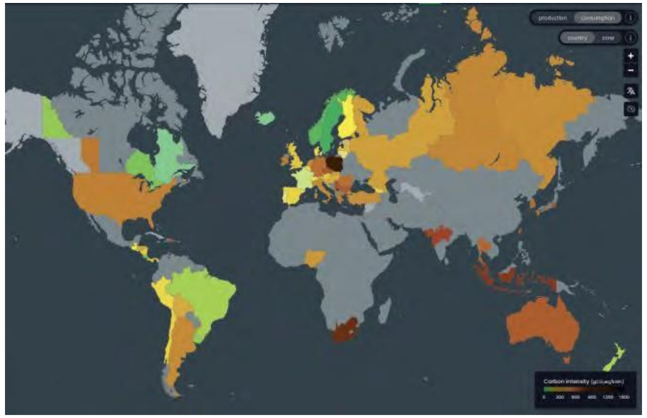
- rare earths: benefits and issues
- assessing carbon footprint, env. impact, societal impact …
- supply chains and certification
- recycling

https://indico.desy.de/event/35655/

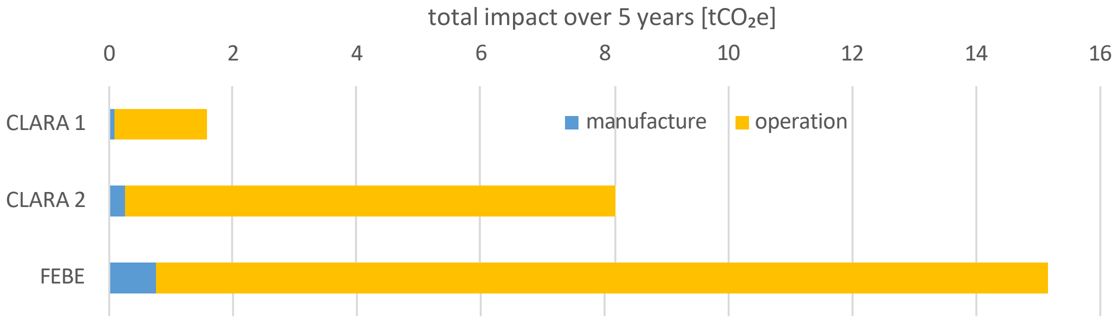
# B.Shepherd (STFC): Three quadr. type electro- vs. permanent magnet comparison

- Power usage at nominal operating point
  - CLARA 1: **385 W**
  - CLARA 2: **2.01 kW**
  - FEBE: **3.72 kW**
- UK electricity carbon intensity 2022: **193 $gCO_2e$ / kWh** (and improving every year!)
  - Highly dependent on fuel mix:
    Sweden 21g; France 102g; USA 432g; Germany 481g; Switzerland 153g
    (source: Electricity Maps)



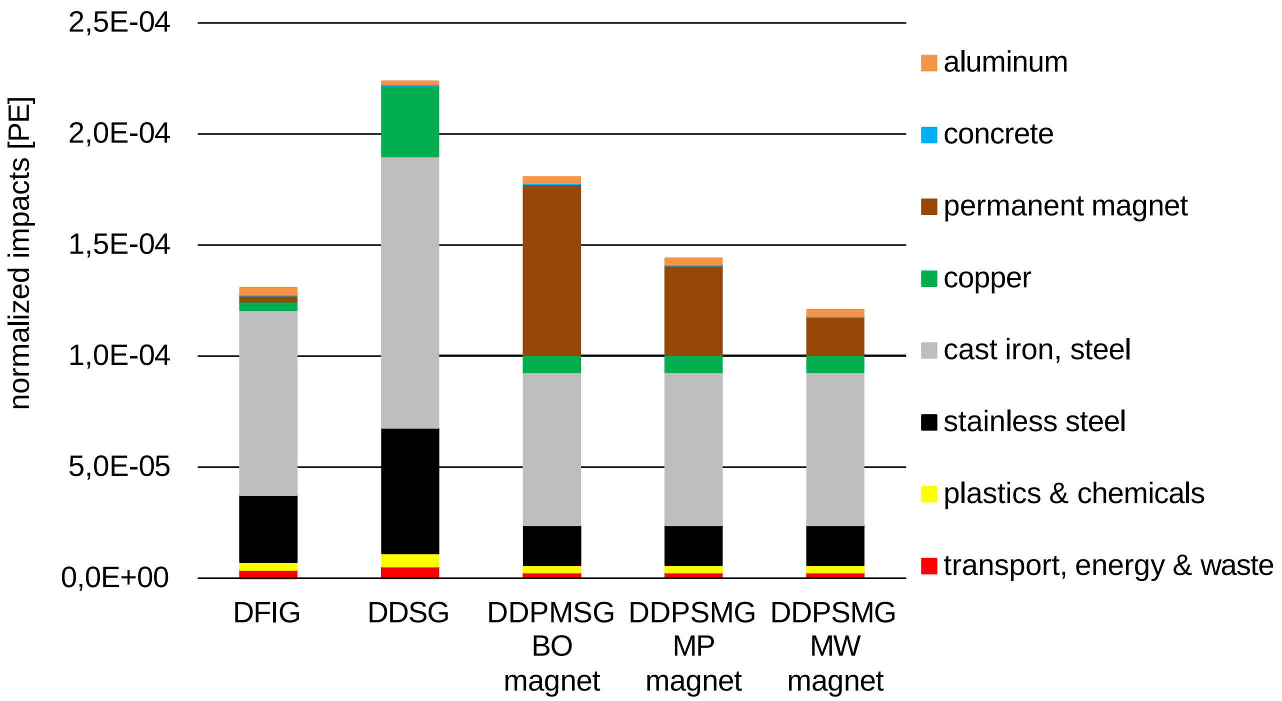



- Assume operated for 5 years, 250 days per year, 16 hours per day
- Total impact of operation *(note: cooling not included)*
  - CLARA 1: **1.49 $tCO_2e$**
  - CLARA 2: **7.76 $tCO_2e$**
  - FEBE: **14.4 $tCO_2e$**
- Much greater than manufacture impact



# Petra Zapp (IEK-STE), excerpt: Comparison of Wind Generator Types

## Influence of RE origin (ore type, mining location, specific site conditions) on environmental impacts per 1 kWh electricity generated by 3 MW wind power plant




DFIG: doubly-fed induction generator
DDSG: direct driven synchronous generator

DDPMSG: electrically excited and direct drive permanent magnet synchronous generator

- Electricity generation by DDPMSG with permanent magnet produced from Chinese RE (Bayan Obo) has higher normalized environmental impacts compared to
  - U.S. Mountain Pass (→ 20%)
  - Mt. Weld (Aus) (→ 33%)
- Electricity generation by Australian DDPMSG is 8% better than by DFIG

A. Schreiber, J. Marx and P. Zapp: **Comparative life cycle assessment of electricity generation by different wind turbine types;** Journal of Cleaner Production ***2019*** Vol. 233 Pages 561-572

# GSI: Energy Efficiency – Topics
## P.Spiller, J.Stadlmann et al

1. Energy Saving HTS Magnet
2. KI based Power Grid Monitoring
3. Sensor Based Power Monitoring
4. Watchdog for Accelerator Devices
5. Development of a HTS Nuclotron Cable
6. FAIR Energy Consumption Forecast
7. Cooling Water Flow Control
8. Energy Efficient Design of SIS100 Cooling System
9. Energy Efficient beam Transport by High Current Pulsed Magnets

# EU IFAST Workshop - Accelerator meets Industry

iFAST Innovation Fostering in Accelerator Science and Technology -

P.Spiller, J.Stadlmann et al, GSI

„Superconductivity for Sustainable Energy Systems and Particle Accelerators“
@ GSI, Darmstadt, Germany

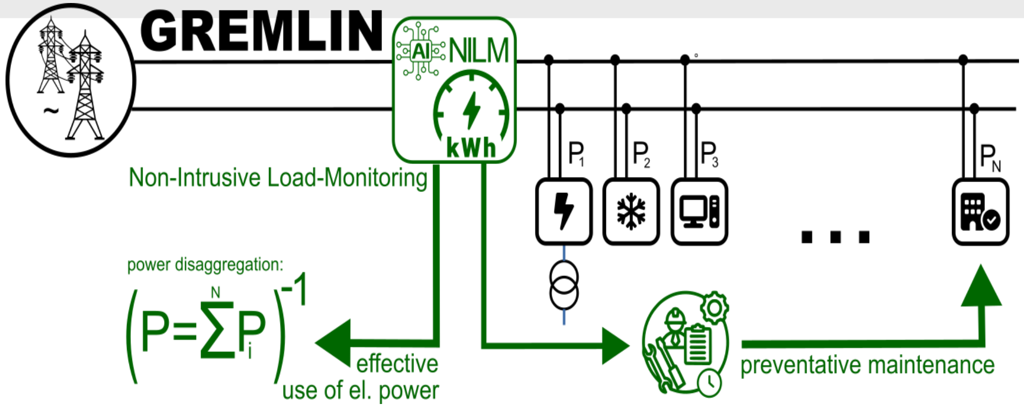
Date: October 19th-20th, 2023

Common workshop with the European Association of Superconducting Industry „Connectus - **CONsortium of European Companies Determined To Use Superconductivity”**

**Scope: Energy efficient superconducting accelerator components and energy systems. Application/dual use of s.c. accelerator technologies in energy systems. Collaboration of research and industry. New superconductor technologies and applications. Minimization of AC loss and heat load. Higher coolant temperatures.**

Indico registration soon published

# NON-INTRUSIVE LOAD MONITORING

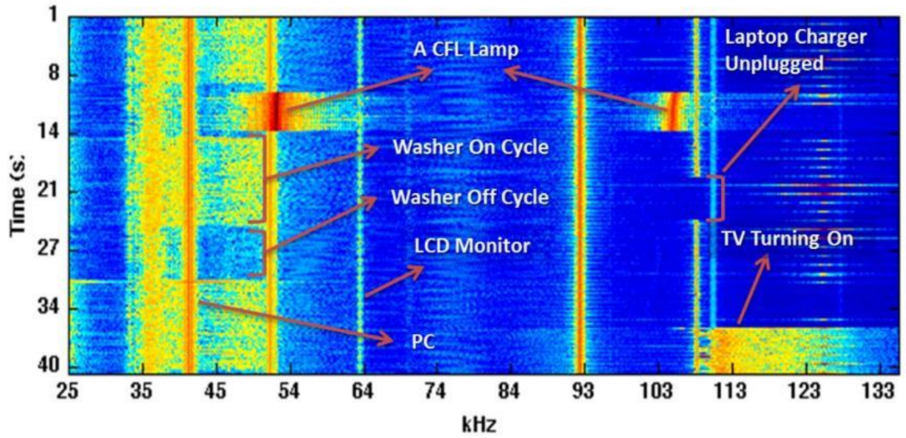



- AI-based classification of facility's effective energy consumption at the device level without the need for direct instrumentation of each device (N.B. "big brother" of domestic smart-meters)
  - N.B. identification via unique electromagnetic interference (EMI) emissions devices generate on the network

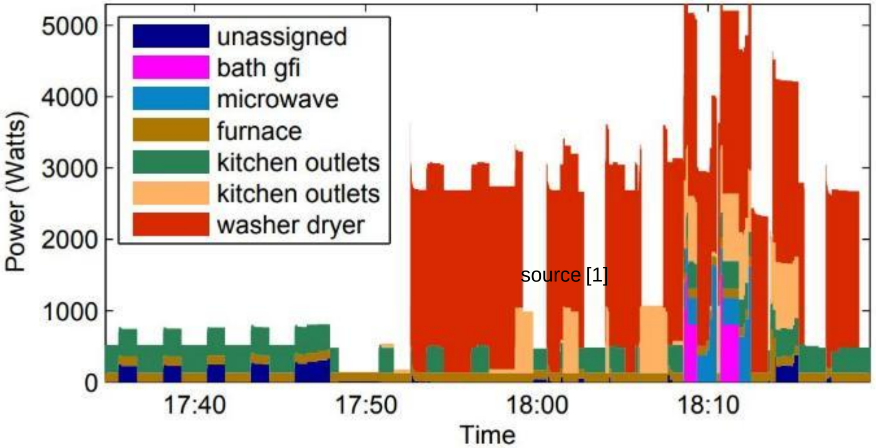
Opportunities:

- monitor effective energy use on a sub-component level
  → detect unused or unnecessarily powered devices
- identify malfunctioning, degrading, or inefficient equipment
  → schedule preventative maintenance or mitigation measures.

EMI Device Fingerprints




Extended Domestic Application beyond FAIR:




[1] Sidhant Gupta, "ElectriSense: Single-Point Sensing using EMI for Electrical Event Detection and Classification [..]", PhD thesis, U-Washington, 2014

# Appendix: Milestones & Deliverables

Schedule of relevant Milestones

| Milestone number[18] | Milestone title | Lead beneficiary | Due Date (in months) | Means of verification | |
|---|---|---|---|---|---|
| MS50 | Workshop on energy for sustainable science at research infrastructures, at ESRF | 41 - PSI | 6 | Web site (task 11.1) | **September 2022, done** |
| MS51 | Workshop on efficient RF sources | 1 - CERN | 13 | Web site (task 11.1) | **July 2022, done** |
| MS52 | Workshop on efficient magnet- and RF power supplies | 2 - ESS | 22 | Web site (task 11.1) | Delayed to 2024 |
| MS53 | Workshop on sustainable materials and lifecycle management for accelerators | 12 - DESY | 18 | Web site (task 11.1) | **February 2023, done** |
| MS54 | Workshop on industrial approaches for sustainable accelerators | 13 - GSI | 42 | Web site (task 11.1) | December 2023 (HTS topic) |
| MS55 | Design review | 1 - CERN | 12 | Web site (task 11.2) | **June 2022, done** |
| MS56 | Magnets constructed and tested | 25 - KYMA | 25 | Magnetic measurements completed (task 11.3) | July 2023 |

| Deliverables related to WP11 | |
|---|---|
| **D11.1:** Sustainable Accelerators Report.<br>*Report on strategies to improve sustainability and reduce environmental impact of accelerators.* | M45 |
| **D11.2:** Klystron prototype completed and validated.<br>*Report on the construction of the klystron prototype and on the test results.* | M36 |
| **D11.3:** Prototype adjustable PM quadrupole and combined function magnets.<br>*Two prototype PM-based magnets one quadrupole and one combined-function magnet designed, built and measured.* | M28 |

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