Report on the Sixth workshop on Energy for Sustainable Science at Research Infrastructures, ESSRI

29-30 September 2022

Organized by CERN / ESS / DESY / PSI / ERF, Hosted by ESRF

JL Revol

On behalf of the International and Local Organising Committee

ESRF | The European Synchrotron

6th Workshop
Energy for Sustainable Science
at Research Infrastructures

WORKSHOP SERIES

- The 2022 workshop Energy for Sustainable Science is the 6th workshop in a series and was held at ESRF in Grenoble.
    - *First at ESS, Sweden on 13-14 October 2011,*
    - *Second at CERN, Switzerland on 23-25 October 2013,*
    - *Third at DESY, Germany on 29-30 October 2015,*
    - *Fourth at ELI-NP, Romania on 23-24 November 2017*
    - *Fifth at PSI, Switzerland on 28-29 November 2019*

- Main themes:
    - ❖ *Energy management at research infrastructures and resulting experience*
    - ❖ *Sustainability of equipment, materials and resources*
    - ❖ *Energy-efficient technologies*
    - ❖ *Energy-efficient technology research*

- *Program and organization established by an 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).*

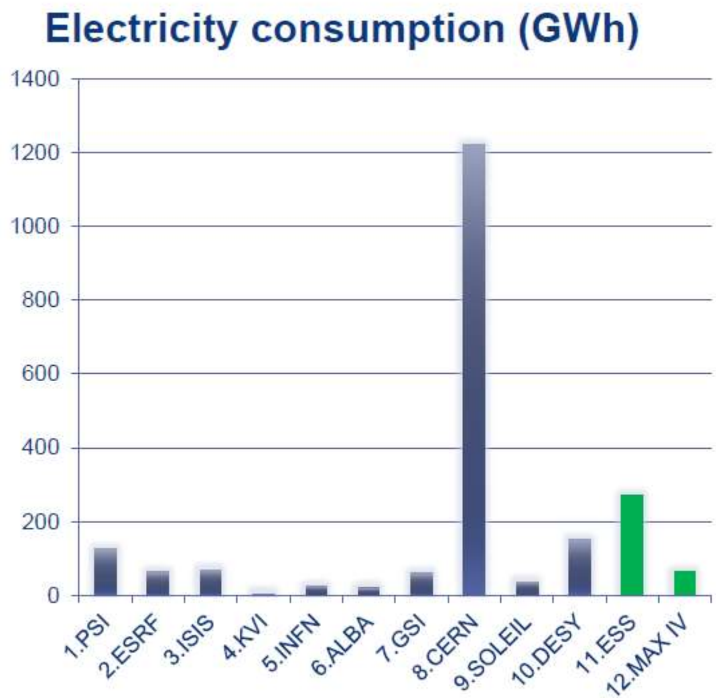
THE PROGRAM

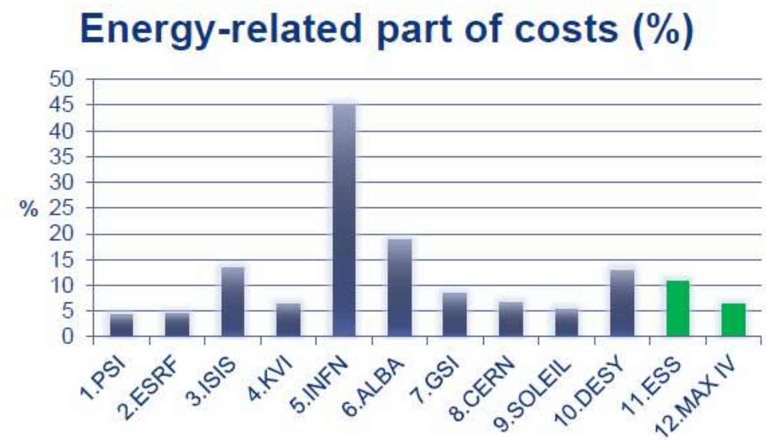
- The workshop focuses on **energy consumption, energy management and efficiency** of research infrastructures,
- but it also covers a wider context of **sustainability and societal aspects**.
- best practices of RI's are reviewed and measures to improve sustainability are proposed.
- Many contributions were dealing with energy saving measures and intelligent energy management,
- Technical topics like permanent magnets, SSA RF sources, the use of rare earth - and other critical materials, as well as sustainable live cycle management of components were also addressed.

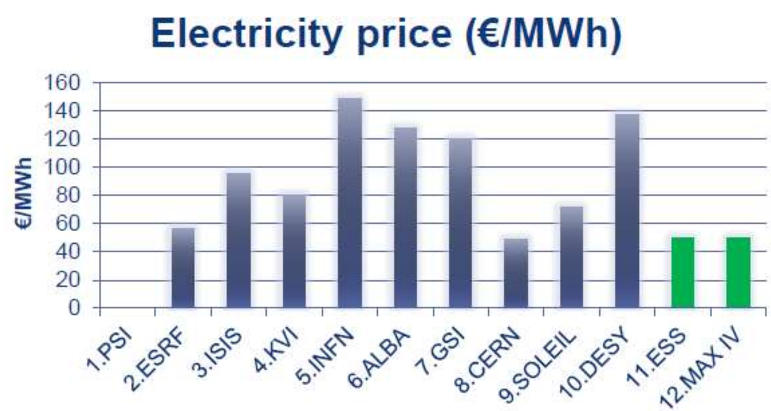
ESSRI workshop organisation was green !!

- *Only zoom meetings of the committees*
- *No paper documents, No goodies*
- *Tramway transport, Local restaurants*

LABORATORY SURVEY: ENERGY CONSUMPTION AND ENERGY COST





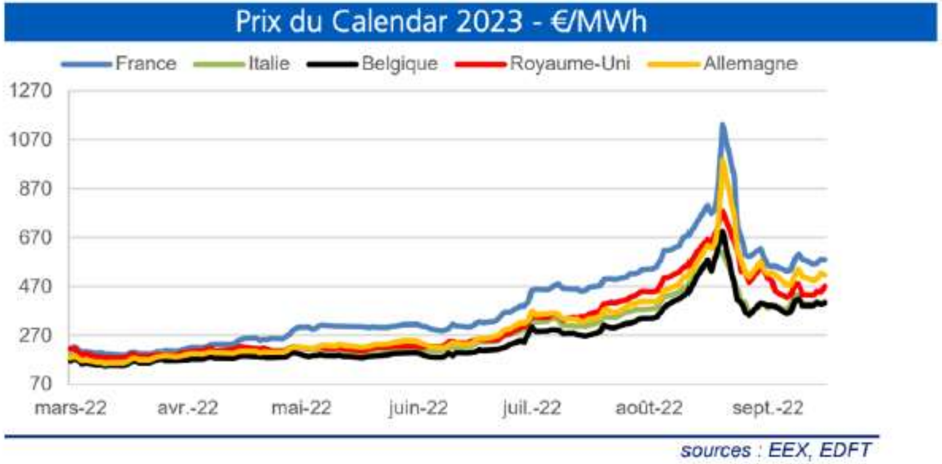


EuCARD²

Mike Seidel, 2014

RECENT TWO YEARS, EVEN MORE PRESSING CHALLENGES

- Practical experience of climate change due to record temperatures, long drought periods, forest fires, floods in many part of the world
- General inflation of energy cost due to Covid19 and the Ukraine invasion
- Unpredictable fluctuations on the energy trading exchange



SPEAKERS

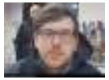
Most contributions were made by European institutions, but few speakers from Japan and the US presented as well.

ESRF AND LNCMI VISIT ON FRIDAY AFTERNOON

Presenters:

ESRF Control Room	ID32 Beamline	LNCMI	SSA RF stations
Jean-Luc	Flora	Francois	Pawel
			
			

Visit on Friday 30 September afternoon

Groupe 1 (Fastest)	**Groupe 2** (Complete)	**Groupe 3** (Fast to leave ESRF)	**Groupe 4** (Complete and fast to leave)	**Groupe 5** (No Rush)
Guide *Lee* *(Beam Dynamics)*	*Friederike* *(Diagnostics)*	*Simone* *(Beam Dynamics)*	*Lina* *(Beam Dynamics)*	*Elena* *(Diagnostics)*
				
12:35 Take away lunch *(outside if possible)*	**12:35 Take away lunch** *(outside if possible)*	**12:35 Take away lunch** *(outside if possible)*	**12:35 Take away lunch** *(outside if possible)*	**12:35 Take away lunch** *(outside if possible)*
Meeting point 12:50 *ESRF entrance hall*	*Meeting point 12:50* *ESRF entrance hall*	*Meeting point 13:10* *ESRF entrance hall*	*Meeting point 13:10* *ESRF entrance hall*	*Meeting point 13:20* *ESRF entrance hall*
12:50 *Meet + transfer CTRM*				
13:00 CTRM (20 mn + 5 mn transfer)	**12:50** *Meet + transfer To LCMI (30 mn)*	**13:10** *Meet + transfer CTRM*	**13:10** *Meet + transfer RF*	
13:25 ID32 (5mn transfer+20 mn)	13:20 **LNCMI** *(20 mn)*	13:20 CTRM (20 mn + 5 mn transfer)	13:20 SSA (5 mn transfer + 25 mn)	**13:20** *Meet + transfer To LCMI (30 mn)*
13:50 *transfer To LCMI (30 mn)*	13:50 *Back LMCI*	13:50 ID32 (5mn transfer+20 mn)	13:50 CTRM (20 mn + 5 mn transfer)	13:50 **LNCMI** *(20 mn)*
14:20 **LNCMI** *(20 mn)*	14:20 CTRM (20 mn + 5 mn transfer)	14:20 transfer To LCMI (30 mn)	14:20 ID32 (5mn transfer+20 mn)	14:20 *Back LMCI*
14:40 *Free*	14:50 ID32 (5mn transfer+20 mn)	14:50 **LNCMI** *(20 mn)*	14:50 *transfer To LCMI (30 mn)*	14:50 CTRM (20 mn + 5 mn transfer)
15:10	15:20 SSA (5 mn transfer + 25 mn)	15:20 *Free*	15:20 **LNCMI** *(20 mn)*	15:20 ID32 (5mn transfer+20 mn)
15:40	15:50 *Free to leave ESRF*	15:50	15:50 *Free*	15:50 *Free to leave ESRF*
16:10	16:20	16:20	16:20	16:20

- 4 places to see
- 5 groups with a dedicated expert guide
- Different duration and starting time to allow some of you to leave earlier
- Write your name on the dedicated boards
- Maximum 20 persons / group
- Wear mask during the visit
- Take good shoes and coat for the transfers

PARTICIPANTS

Close to 100 participants coming mostly from Europe,
a few participants following the workshop remotely

ESSRI WORKSHOP PROGRAM

	Plenary Session (Thursday morning)
09:30	Climate change is accelerating. We need to move much faster – M. Jarraud, World Meteorological Organization
10:00	Energy Transition: towards a complex cyber-physical system of systems – L. Saludjian, RTE
11:15	Electrical Flexibility Market – B. Remenyi & C. Gaunand, Energy Pool
11:45	Energy management at Stanford University – L. Bleveans, Stanford University
12:15	ERLs and Sustainability – A. Hutton, Jefferson Lab

	Plenary Session (Friday morning)
08:30	Summary: Energy efficient technologies – D. Voelker, DESY
08:45	Summary: How will projects deal with energy and sustainability? – M. Eshraqi, ESS
09:00	Summary: Energy management at research infrastructures – JL. Revol, ESRF
09:15	Summary: Energy management at research infrastructures and materials – S. Claudet, CERN
09:30	Summary: Energy management for the Future Circular Collider (FCC) – JP. Burnet, European Organisation for Nuclear Research
10:00	Efforts to save Energy consumption in KEK accelerator facilities – T. Koseki, KEK
10:50	Advanced energy concepts and energy efficiency – HJ. Eckoldt, DESY
11:20	Transmutation of Nuclear Waste with Accelerator-driven Systems – M. Bourquin, Genova University
11:50	EBS: A New Light for Science - first scientific highlights – M. Krisch, ESRF
12:20	Closing remarks and next workshop – JL. Revol, ESRF & JM. Perez, CIEMAT
13:30	Facility tours: ESRF, LNCMI

	Parallel Session (Thursday afternoon) Energy efficient technologies	Parallel Session (Thursday afternoon) Energy management at research infrastructures
14:00	Challenges of a megawatt CW class solid state power amplifier for the SPS at CERN – E. Montesinos, CERN	An overview of the status of energy sustainability at the European Spallation Source (ESS) – M. Eshraqi, ESS
14:25	Progress with permanent magnets and return on experience – J. Chavanne, ESRF	Energy optimisations implemented at accelerators and infrastructures at PSI – D. Reinhard, PSI
14.50	Free Air cooling solution for the Data Centers – L. Roy, CERN	Energy management at High Magnetic Field Facilities – F. Debray, CNRS Grenoble
15:15	Energy management University Darmstadt – C. Ripp	ESRF EBS energy management – C. Nevo, ESRF
	Parallel Session (Thursday afternoon) How will projects deal with energy and sustainability	Parallel Session (Thursday afternoon) Energy management at research infrastructures and materials
16:00	Sustainability at Fermilab and the PIP-II Project – T. Price, Fermi National Accelerator Laboratory	A big science facility as a living-lab for energy transition: the LNCMI use case – F. Wurtz, G2ELAB-CNRS-UGA
16:25	Sustainability studies for Linear Colliders – S. Stapnes, CERN	ISO 50001 Energy management – N. Bellegarde / S. Claudet, CERN
16.50	Investigating energy futures: The KITTEN test facility for sustainable research infrastructures – G. De Carne, KIT	Water, reduction in consumption and treatment of effluents from cooling towers – S. Deleval, CERN
17:15	Sustainable accelerator R&D in the UK – B. Shepherd	Rare earth and Life cycle management – D. Voelker, DESY
17.40		Superconducting alternative magnets – L. Rossi, INFN

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	Plen
08:30	Sumr
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Organisation of this report:

1) The context
2) New initiatives in large research centres
3) Sustainably for new projects
4) Energy saving technologies
5) Energy management at research infrastructure
6) Other topics
7) Conclusion and outlook

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		gement at High Magnetic Field Debray, CNRS Grenoble
		nergy management – RF
		on (Thursday afternoon) gement at research s and materials
		facility as a living-lab for energy LNCMI use case – ELAB-CNRS-UGA
		nergy management – / S. Claudet, CERN
	research infrastructures – G. De Carne, KIT	tion in consumption and treatment om cooling towers – S. Deleval, CERN
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PLENARY SESSION: OPENING TALK ON CLIMATE CHANGE

The first plenary sessions contained topics of general interest or applicability to a broader range of research infrastructures.

A general presentation on climate evolution

- M.Jarraud: Climate change is moving fast. We need to move faster!

No one, no country can do it alone.
A multilateral approach is essential

We have very little time left. We must take decisions and act quickly

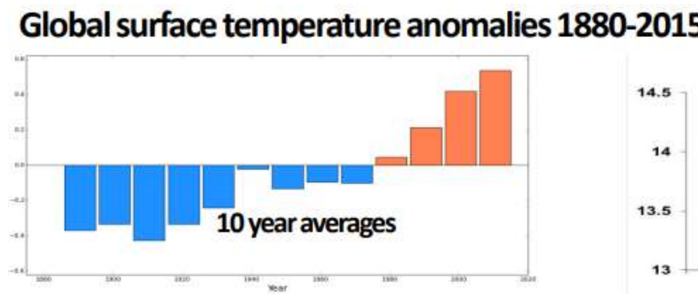
We may be the first (and last) generation to be able to do it

- We are facing a unique situation
- Our planet is unique: « no plan B, because no planet B » (Ban Ki-moon)
- A fundamental principle: global solidarity. Failure to cooperate will ensure failure (for humanity, not for the planet)
- Our differences are minuscule compared to the collective interest of mankind
- Medium and long term consideration must prevail on national, local or even personal short term interests

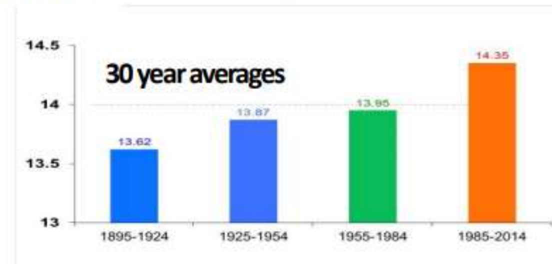
Some current worrying political and social trends

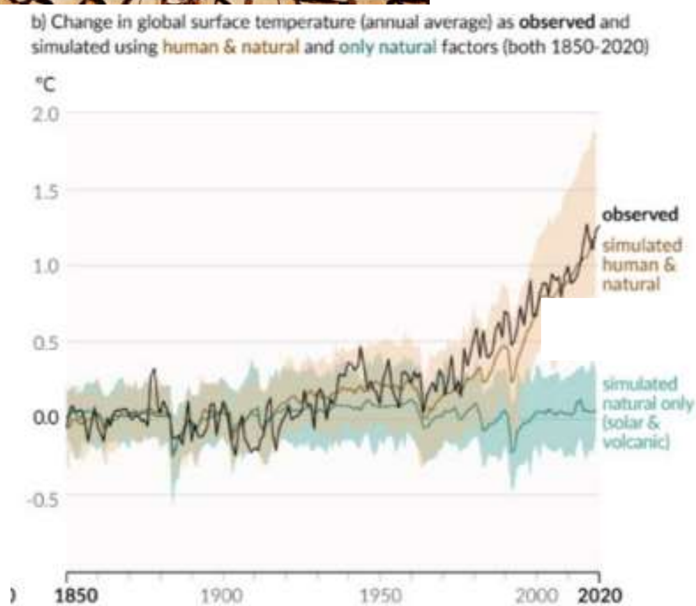
- In many countries, resurgence or strengthening of nationalistic trends
- Favoring short term national interests, rather than medium or long term global ones
- Tendency to blame "others"
- Increased individualism
- Weakening of global solidarity
- Refusal to accept (or even to listen to) different opinions
- Trends reinforced by social medias
- More and more difficult for individuals, and even top decision makers, to distinguish real from fake news

PLENARY SESSION: OPENING TALK ON CLIMATE CHANGE



climate system is clear”

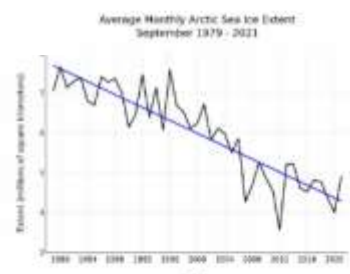




Human influence has warmed the climate at a rate that is unprecedented in at least the last years

Arctic sea ice

Trend 1979–2021
-13% per decade

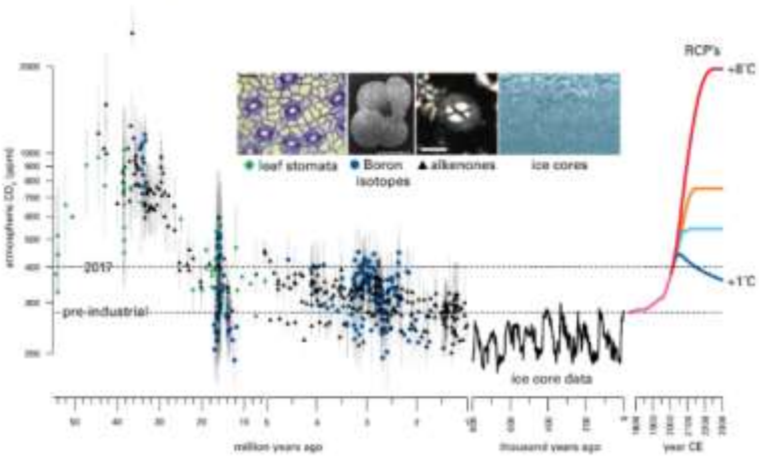


Arctic ice extent (Sept 2022)

The European Synchrotron | ESRF

PLENARY SESSION: OPENING TALK ON CLIMATE CHANGE

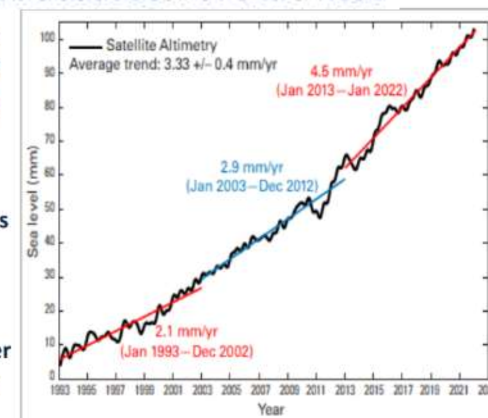
CO_2 over last 55 million years



Sea level rise

Oceans absorb about 93% of extra heat

- 1901-1990: 1.9 mm/yr
- 2003-2012: 2.9 mm/yr
- 2013-2022: 4.5 mm/yr
- Causes:
  - thermal expansion
  - Melting of land glaciers
  - Others
- Impacts:
  - Coastal erosion
  - Intrusion of salted water
  - Impact of storm surges and tsunamis
  - ...



Two presentations giving a comprehensive description of the French electrical distribution network and revealed how important it is to ensure flexibility as well as economy at the laboratory level.

- Lucas Saludjian (RTE): (R)Evolution of the electrical system and its challenges.;

Outline

1. European Electrical System & RTE
2. (R)evolution of power systems
3. Stability issues
4. New control architecture
5. Towards 2050

European electricity today

36 interconnected countries (43 TSOs)
- Security of the power system in real time
- Economic optimization
- Security of supply

5 synchronous zones
- Scandinavia
- United Kingdom
- Ireland
- Continental Europe
- Baltic countries

Installed capacity : **~1140 GW**
Consumption : **~3,600 TWh/year**
Peak Load : **~500 GW**
Physical exchanges : **~425 TWh/year**
Population : **500 Million +**

RTE: French Transmission System Operator
SO & TO: system operation, grid maintenance, grid access, grid development

PLENARY SESSION: ELECTRICAL SYSTEM

(R)Evolution of power systems

A huge increase of the system complexity !

Renewable energies with characteristics such as almost no marginal costs with power electronics interfaces, **more intermittent generation, dispersed in distribution grids**, which are out of phase with the dominant sources of electricity today. RES are **less predictable & less observable**

Decrease of inertia in the system involves **faster dynamics** but **emerging solutions** on **storage.**

Need to coordinate a large population of devices/agents with partial autonomy

Future impacts of **electric mobility** ?

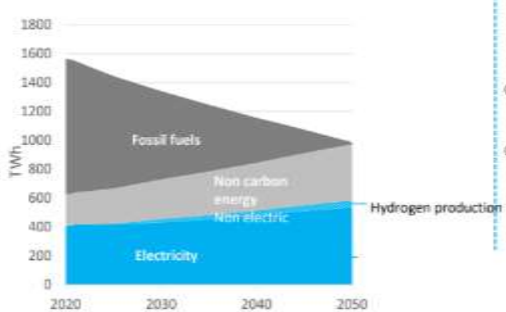
New societal exceptions and **low public acceptance of new infrastructures**

An **increasing number of stakeholders** – economic & technical – x 1000 – **prosumers** promoting autarchy ! NIMBY & BANANA effects

There is a urgent need to rethink both **economics and dynamics of power systems**. Patches to adapt marginally the historical design are perhaps not a good approach even if the migration path is a critical issue.

Evolution of Energy Consumption in France and share of electricity

French National Low Carbon Strategy



- **-40% in Energy final consumption**
- **+ 35% for Electricity**

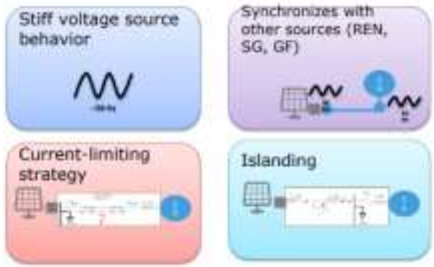
Today various type of generators and loads to manage

Stability issues

Inertia

Grid Forming & Synchronization

- What if, there is no signal to lock on



Grid Forming !

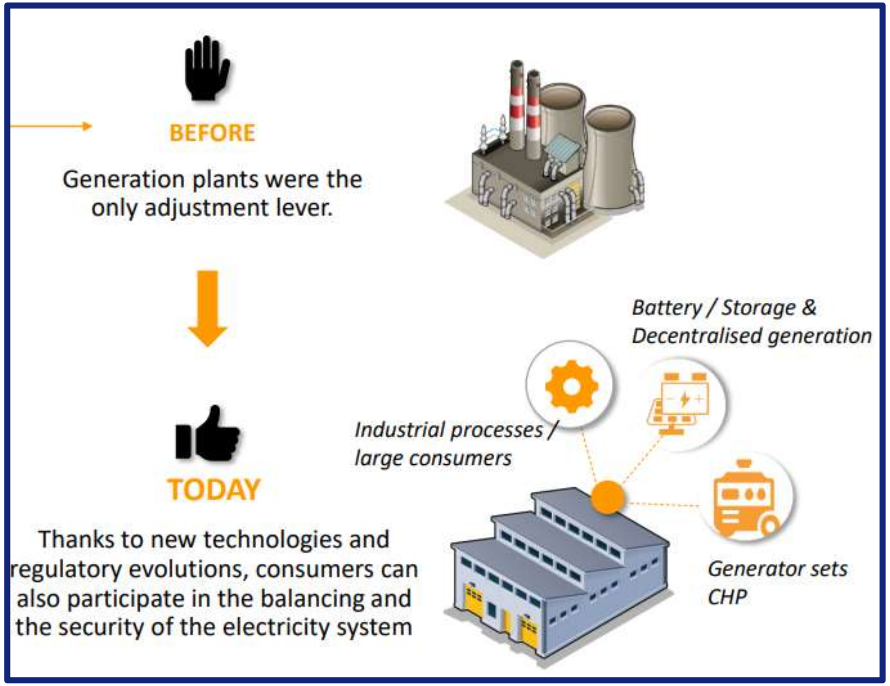
Different scenarios presented aiming for renewable energy .. including also nuclear plants (old and new)

- **Flexibilities are deeply needed beyond 2035**

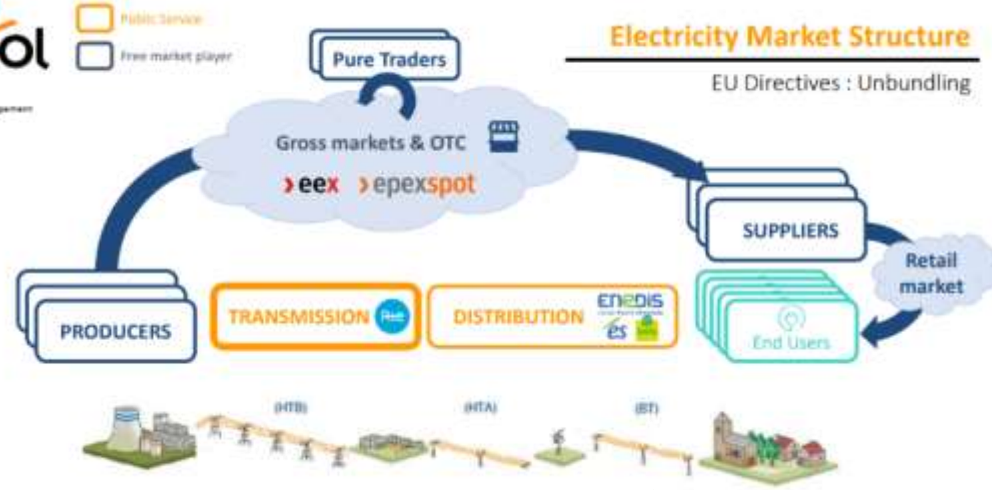
PLENARY SESSION: FLEXIBILITY

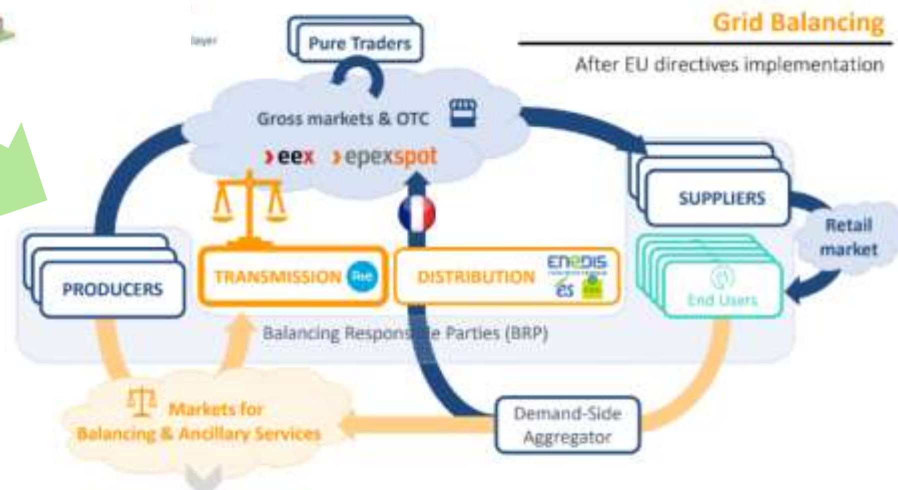
- Bernadette REMENYI: Introduction to Demand Side Flexibility

Energy Pool
Smart Energy Management



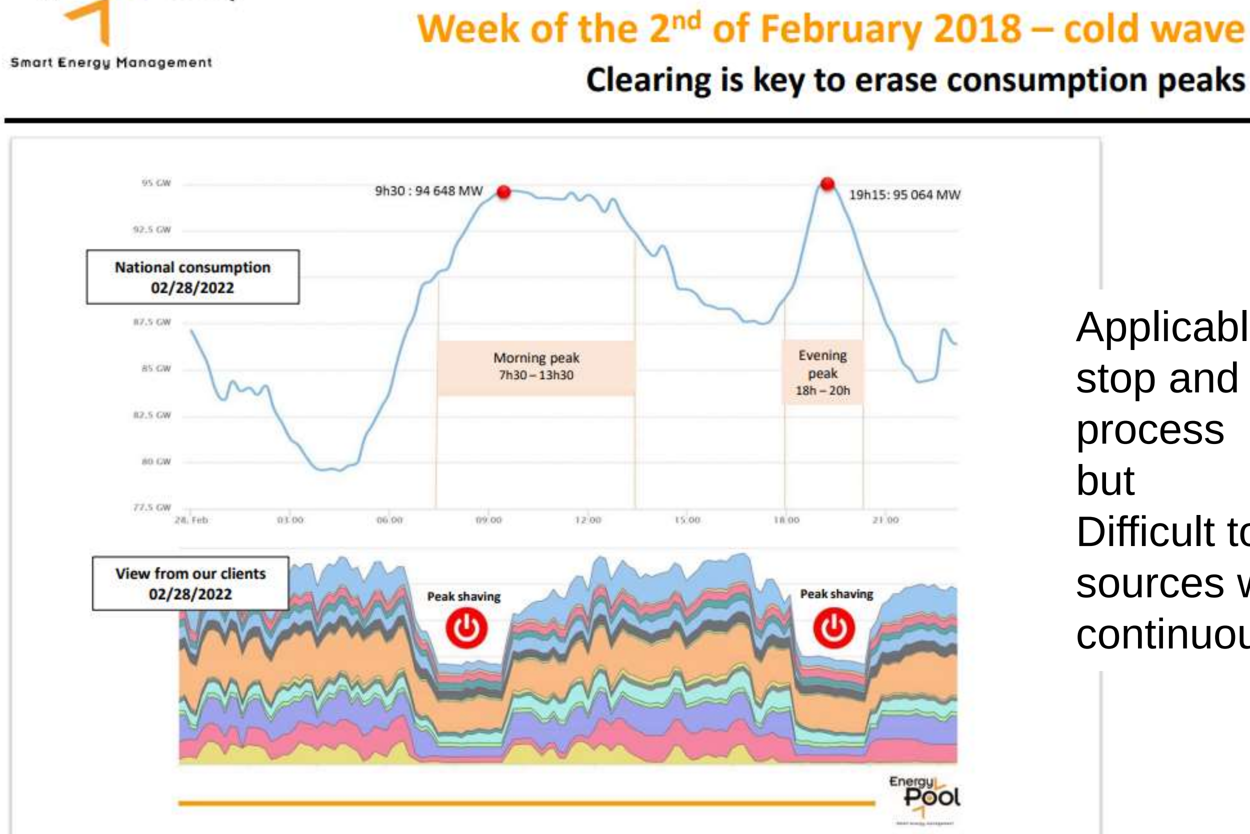
PLENARY SESSION: FLEXIBILITY





After EU directives implementation

➔ New actors : aggregators



Applicable to actors who can stop and restart easily their process
but
Difficult to apply to light sources which have a continuous delivery process

NEW INITIATIVES IN LARGE RESEARCH CENTRES

We heard how large research centres like Stanford University (Lincoln Bleveans), KIT (Giovanni De Carne) or Darmstadt university (Christopher Ripp) are launching new initiatives to save and monitor energy consumption and to study alternative ideas in a real set-up.

Making Energy Sustainability Innovation Real
(Lincoln Bleveans)

Goal: reach 0% carbon emissions on campus

- Use the opportunity of the end of life of some infrastructures to renew and transform it, New heath recovery system
- Transition to 100 percent renewable electricity using solar cells and energy storage

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Investigating energy futures: The KITTEN test facility for sustainable research infrastructures

(Giovanni De Carne)

Karlsruhe Institute of Technology

A joint venture between the accelerator **KARA** and the test-field **Energy Lab 2.0** to improve the energy use and power quality in large research infrastructures.

The KITTEN Approach

Need to work on 4 different levels

- **Physics / Component level:** new materials and components targeting an efficiency increase
- **Energy / Component level:** integration and optimal operations of sustainable low carbon technologies (e.g., energy storage, renewables)
- **Physics / System level:** improve the efficiency operations in large research facilities using AI
- **Energy / System level:** increase the sustainability of large research facilities in the electrical system

Development of the KITTEN Lab, bringing together the knowledge and laboratories of the accelerator KARA and the energy research infrastructure Energy Lab 2.0.

- Real Time data transmission between the two labs (10kHz)
- Development of a real time Digital Twin of the KARA accelerator
- Once the Digital Twin is ready, new energy technologies with the Power Hardware in the Loop approach will be proceeded to test experimentally before to be installed at KARA.

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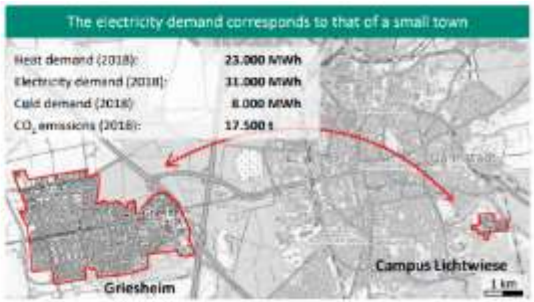


Electricity demand of the campus

The campus has its own generation and distribution

Interdisciplinary Research Project „EnEff:Stadt Campus Lichtwiese II“

(Christopher Ripp)

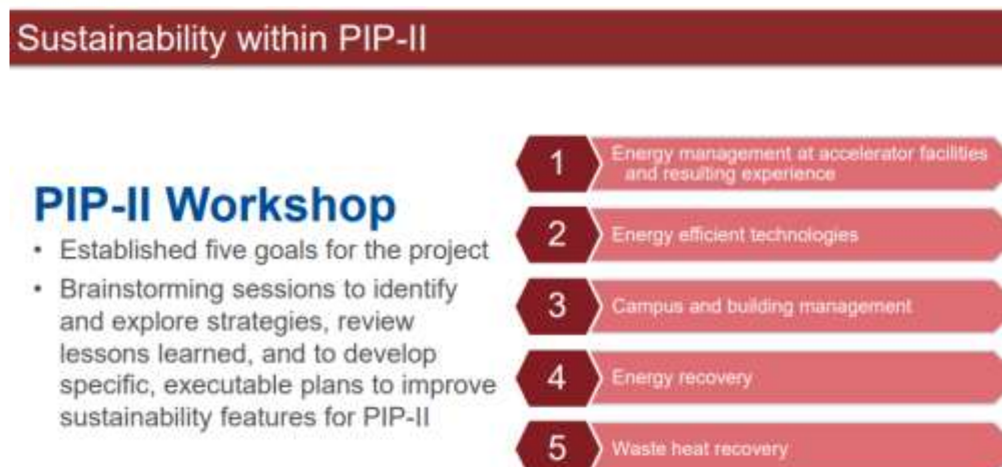
- Energy monitoring
- Implementation of a digital twin of a multi-energy system
- Modern and interactive data access (web base energy platform)
- Decrease energy consumption, cost and Co2 emission

SUSTAINABLY FOR NEW PROJECTS

New projects like PIP-II (Tiffany Price), ESS (Mamad Eshraqi), Petra IV (Denise Voelker), or the Linear collider (Steinar Stapnes) are implementing policies focused on energy efficiency and sustainability.

There will be no future large-scale project without an energy management component, an incentive for energy efficiency and energy recovery among the major objectives
(F Bordry in the introduction)

PIP-II is the world's highest energy and power CW proton linac, and the first U.S. accelerator to be built with major international contributions



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AN OVERVIEW OF THE STATUS OF ENERGY SUSTAINABILITY AT THE ESS (Mamad Eshraqi)

- Review of the consumption of each part of ESS
- Review of the cryogenics system and consumption savings with distribution at 4K and a use at 2K, But also heat recovery from compressors
- Technical review of the accelerator and the optimization for energy consumption reduction Optimization of the full Linac design to reduce energy consumption

- Review of the energy saving at target using optimization and pulse shaping

- Review of the energy saving at the neutron chopper system using magnetic bearing and motor (side product of the increase lifetime and reduction of maintenance).
- Certify the office building using Breeam *Building Research Establishment Environmental Assessment Method.*
- Looking to solar cells powering the neutron source 19000 panels for a capacity of 7.6 MW

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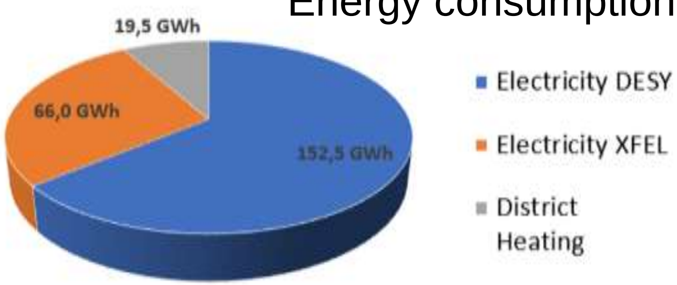
Advanced energy concepts and energy efficiency (Hans-Jorg Eckoldt)

Energy consumption at DESY



Campus-wide activities focus on CO_2 reduction

Electrical power:

from 2023 on 100 % Renewable

55.000 tons CO_2 less per year (compared to 2019)

Business trips:

1/3 less travel in total , short trips only by train, Flights compensated

Heating:

currently comes from a coal plant nearby

already use waste heat from the cryogenic hall

DESY has an energy monitoring system to track consumption

Sustainability at DESY

A group was established to have an overview of the sustainability activities at DESY

SUSTAINABLE DESY.

SUSTAINABLY FOR NEW PROJECTS

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(F Bordry in the introduction)

Advanced energy concepts and energy efficiency (Hans-Jorg Eckoldt)

PETRA IV

Highest possible efficiency and energy efficient technology are promises of the CDR

- Optimization of PETRA IV Design in terms of energy efficiency and critical materials
- Develop and promote remote access and operation, robotics, automation etc. to reduce necessary travel
- Support and implementation of planed project to make waste heat usable
- Integrate waste heat potentials and sources into PETRA IV design

✓ Use of permanent magnets, optimizing magnet, cable, power supply operation
✓ Energetic optimization of the air and water temperature
✓ Plasma injector concept at full energy *(as potential drivers for future light sources ?)*

SUSTAINABLY FOR NEW PROJECTS

New projects like PIP-II (Tiffany Price), Petra IV (Hans-Jorg Eckoldt), or the Linear collider (Steinar Stapnes) are implementing policies focused on energy efficiency and sustainability.

There will be no future large-scale project without an energy management component, an incentive for energy efficiency and energy recovery among the major objectives
(F Bordry in the introduction)

Sustainability Studies for Linear Colliders
(Steinar Stapnes)

- Overall system design of sustainable accelerator
  - High gradient, low losses, small beam size..
- Optimisation of subsystems and components for energy efficiency and material choice with responsible sources
  - High gradient accelerating cavities with optimal design for reduced losses and reduced waste during fabrication
  - Efficient klystrons
  - Permanent magnets
- Optimize operation strategies
  - Re-cycling of waste heat
  - Power modulation to follow “low cost” power availability
  - Identify & utilize accelerator-specific energy buffers
- Sustainable operation approaches to increase sustainability
  - Reduce power (by higher efficiency)
  - Re-use waste energy (heat)
  - Modulate power according to availability (price)
  - Use regenerative power

ENERGY SAVING TECHNOLOGIES

Progress with Permanent Magnets and return on experience (Joel Chavanne)

- Very positive experience with Permanent accelerator Magnet in EBS
  - Permanent magnet dipoles with longitudinal gradient (DLs)
    - Works as expected, Passive devices in the storage ring , no maintenance
    - Very good stability vs time and temperature up to now
  - PM septa show reliable and stable operation

- The reduction of electrical power at the magnets is substantial
  - PM structures
  - Reduction of current density in resistive magnets
  - ➔ ~1.1 MW less for the storage ring magnets (EBS vs ESRF in 2018)
- The use of Permanent Magnets in accelerators (SR light sources) is developing significantly

Challenges of a megawatt CW class Solid State Power Amplifier for the SPS at CERN (Eric Montesinos)

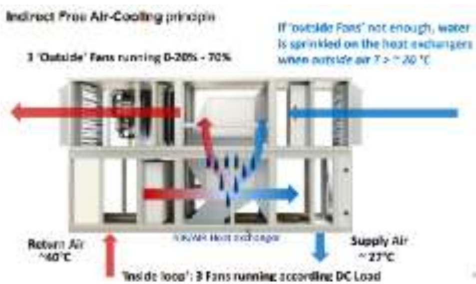
- A lot of possibilities to be (very) efficient with a SSPA solution
  - Fantastically efficient cavity combiners
  - Granularity allowing to operate very close to the best efficient point
  - Granularity allowing for replacement not seen by operation
  - Our availability target has been reached, is 99.99 %
- In addition, we already work on several innovative ideas
  - Integrated modules without cables, Seebeck / Shapal cooler, Embedded spares, new power combiners with higher power density

ENERGY SAVING TECHNOLOGIES

Alternative Superconducting Magnets (Energy Saving Beam Line Magnets ESABLiM)
(Lucio Rossi)

- Use of high temperature superconductors for magnets not only to achieve high field strength, but also for lower field strength for reasons of energy savings.
- Even the refurbishment of existing normal conducting magnets with superconducting coils seems feasible in some cases.

Free Air-Cooling Solution for the Data Centers (Laurent Roy)



- ALICE and LHCb Experiments had need to increase significantly their computing facilities.
- Considering the energy efficiency, modular Data Centers with indirect free air cooling adopted.
- The two computing facilities have been delivered at CERN in time and without extra cost.
- The recent heat wave of summer 2022 (40°C peak) did not cause problems for the cooling system.
- A new Data Center up to 12 MW is in construction at CERN, same approach: to have a high energy efficiency by using outside air but also by recovering part of the heat in winter.

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : PSI (D. REINHARD)

Synchrotron
Light Source
SLS
Upgrade to SLS2

Spallation
Neutron
Source
SINQ

Muon Source
SμS

Free Electron
Laser
SwissFEL

PAUL SCHERRER INSTITUT PSI

Efficiency Measures driven by
- PSI Energy Mission
- and Federal Energy Law

Results of Energy Efficiency Measures at PSI (2013-2020)

Number of measures and projects since 2013:	75 (24 Heat; 61 Power)
Yearly saving of el. energy:	7.4 GWh (-6%)
Yearly saving of heat consumption:	5.2 GWh (-43%)
Total yearly investments (average in 7 years):	1.2 Mio CHF
Total yearly savings:	1 Mio CHF
Total fundings awarded:	3.6 Mio CHF (27 Projects)
Total yearly refund of energy taxes:	2 Mio CHF

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : PSI (D. REINHARD)

PAUL SCHERRER INSTITUT PSI

Example 1, «Cryogenics» Replacement of HE-Compressors
Yearly saving of 1.33GWh (appr. 1% of PSI consumption)

Side effects:
Standardised components allow reduction of spare parts
More space through optimised architectural layout
Lower vibration (SLS)

Example 2, «IT» Server Virtualization
Total Saving: 900MWh/a (45% from 2013)

Example 3, «Operations», Sleep Mode Tool (HIPA+Proscan)
The Sleep software provide the operators the possibility to switch on/off (Standby) various beamlines with a single click of a button. (signalisation in case of outages with no beam longer than 30 minutes). Generic in various systems and applications. Observe and switch off what is not needed!

Example 4, «Campus Infrastructure», high temp. water loop
Yearly Savings: 65`000l (650MWh)

Example 5, «Infrastructure», LED Light in Research Halls
Yearly saving of 300MWh

Example 6, «Air Conditioning», Optimisation of Cooling System

Example 7, «Air Conditioning», Humidity Control

Example 8, «Heating System», Heat Recovery

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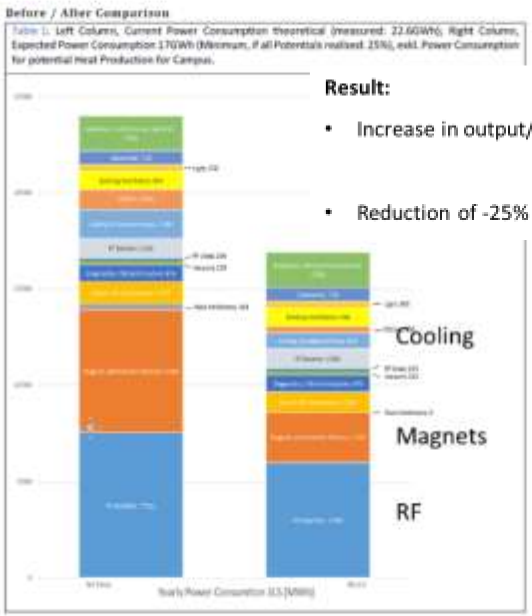
Outlook of future energy saving measures

PV plants on PSI roofs	GWh	6
Optimisation Cooling Circuits and Pumps HIPA	GWh	2.5
Contiuous Improovement building technical Infrastructure (10 yeas period)	GWh	1.3
Optimisation Cryogenic Cooling System of Superconducting Test Facility "Sultan"	GWh	2.75
SLS 2.0 Overall Optimisations	GWh	5
Total Power Savings Potential	**GWh**	**17.55**
in % of today`s consumption		12%

Upgrade SLS 2.0

Energy Efficiency Potentials through:

- ”New” technologies & developments
- Optimizing infrastructure concepts
- Adapting to the new boundary conditions



Result:

- Increase in output/utility (beam quality approx. factor 40)

with a simultaneous

- Reduction of -25% energy consumption

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : KEK (TADASHI KOSEKI)

KEK-JAPAN

Large earthquake on March 11, 2011:
Fukushima-dai-ichi exploded and caused serious radiation contamination in the large area.

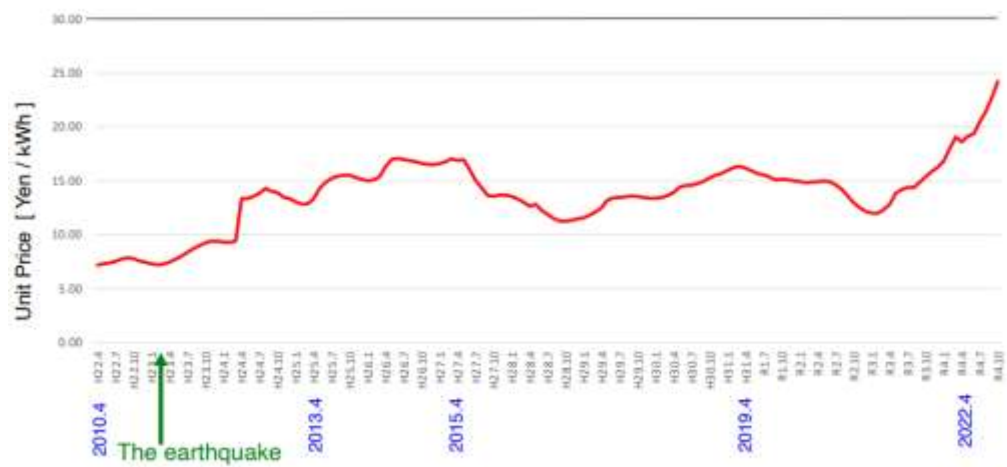
Before the earthquake, 54 nuclear power plants in operation.

As of August 2022:
21 to be decommissioned
10 in operation
10 under review process
for new standards after the earthquake

On Aug. 24,2022, the prime minister of Japan suggested more 7 plants will be restarted after summer of 2023.

In October 2020, Japanese government declared that it aims to achieve carbon neutrality by 2050.

Unit prices of electricity

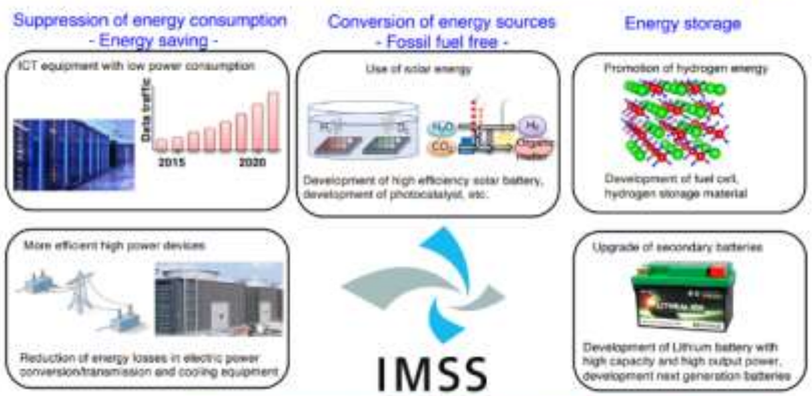


The high cost of electricity is affecting operation time of the accelerator facilities.

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : KEK (TADASHI KOSEKI)

- Review of J-PARC operation and development
- Review of the Electron/Positron accelerators Linac, SuperKEKB, PF/PF-AR operation and development to increase experimental efficiency
- R&D with ICASA (Innovation Center for Application of Superconducting Accelerators)
- Research and developments of low carbon technologies

KEK IMSS (Institute of Materials Structure Science) is contributing low-carbon technology developments by research using multi-probe with four beams; neutron and muon beams at MLF, SR beams at PF/PF-AR and slow positron beams at SPF.



IMSS continues to study of the various materials to solve these issues using multi-probes.

KEK reinforces challenges for sustainable society

- Research and developments on low carbon technologies
- Efforts for energy saving in accelerator facilities
- Cooperation with academic, industrial and areal communities

Booklet:
" KEK efforts toward carbon neutral"

DC Field in Grenoble
24 MW to power the high field resistive magnets.

24 MW max of Power

➔ **15 GWh per year**

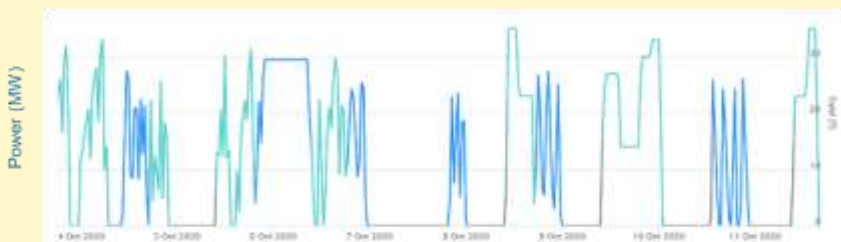
Pulsed field in Toulouse
Various **capacitors** banks (10 kJ to 14 MJ)

20 MJ max. per pulse

➔ **15 MWh per year**

ENERGY vs Time

In high field facilities : only one user at a time :



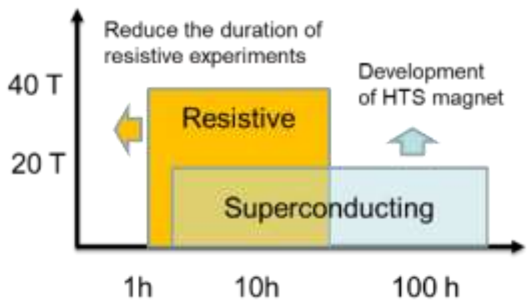
The electrical consumption is a direct image of the researcher strategy
➔ Very high intermittencies

Which solutions for a sustainable (resilient ?) energy management at high field facilities ?

- ➔Use of HTc superconducting magnets for long duration experiments
- ➔Ancillary Services for the Electrical Network
- ➔ Enhancement of resistive magnet efficiency & recovering the waste heat

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : LNCMI (F DEBRAY)

Use of HTc superconducting



National fundings
FASUM (CEA-CNRS) ➔ investment for a 30 T & then 40 T all superconducting user magnet
H2020 supports
SUPER-EMFL
➔ To disseminate the HTS technology through research infrastructure
ISABEL
➔ To ensure the long term sustainability of high field laboratories

Recovering the waste heat

1st step for recovering the waste heat :
a local loop on CNRS Campus

Needs : 2 GWh per year (provide by the urban heating network

Objective 10 to 30 % could be covered by the high field lab. without heat pump nor storage

Service to the Grid at LNCMI

➔ **From December 2020 :** LNCMI has participated to the balance of the electrical grid though :

These mechanisms were made operational thanks to **a 2 day ahead planification.**
A total of 15 operations were organised within an experimental programme with an aggregator

➔ **Next step** ***:*** feasibility studies of piloted consumption for **frequency regulation (1st t and 2nd reserve)**

➔ **Objective to increase the number of operations**

ESRF ENERGY CONSUMPTION OVERVIEW

Electricity consumption before EBS = 65 350 MWh
after EBS = 53 000 MWh (-20%)

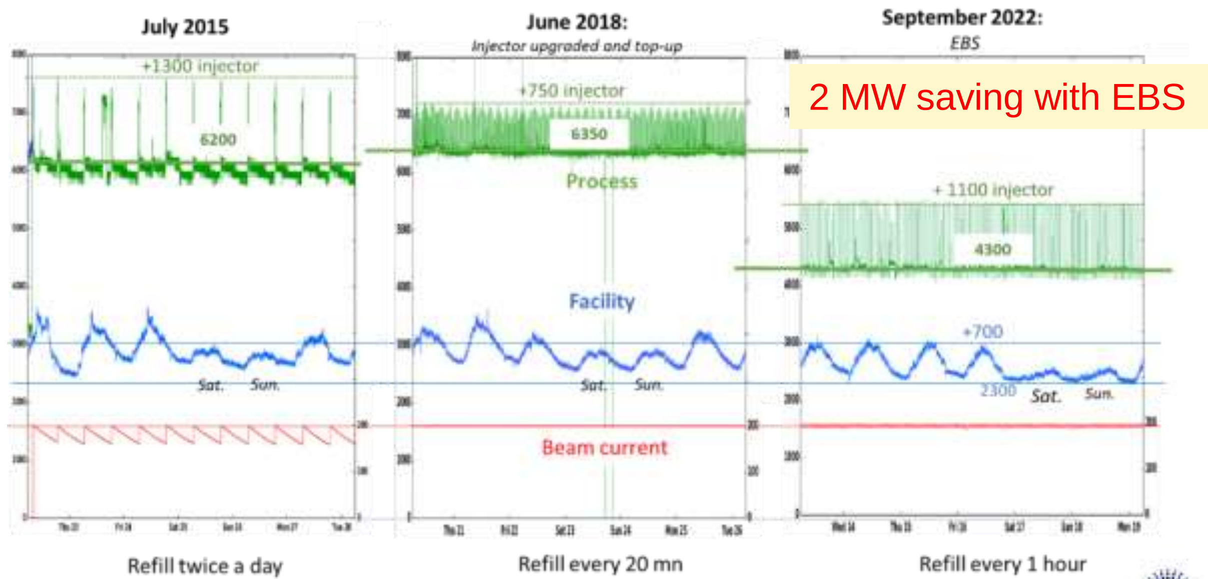
Back up from flywheel for short duration events (< few seconds)

Heating District heating network (CCIAG) 7 600 MWh / year

CoolingDRAC River cooling (free cooling)

ESRF Upgrade Phase 1 (2009 -2015)
ESRF Upgrade Phase 2: (2015-2023)
Including a complete rebuilt of the storage ring:
The **ESRF Extremely Brilliant Source** :

- Decrease the horizontal emittance
- Increase the source brilliance
- Increase the source coherence



The European Synchrotron | ESRF

ENERGY MANAGEMENT AT RESEARCH INFRASTRUCTURES : ESRF (C NEVO)

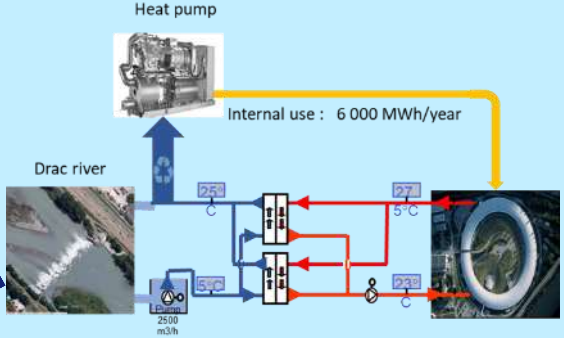
Actions implemented	En. saving/y.
Speed drives on cooling system	3 030 MWh
Improvement of the DRAC river water pumping system, free cooling	2 100 MWh
High efficiency refrigeration condenser	2 000 MWh
Hot water temperature regulation on the ESRF heating system	1 200 MWh
Installation of LED lighting in the EXPH	490 MWh
Thermal insulation improvement of the Common building roof	80 MWh
Machine consumption reduction (EBS) - 2019	12 000 MWh
TOTAL	20 900 MWh

Proposed action	Energy saving/y.	CO2 saving (tons)	ROI (years)
Water, heating and ventilation systems control improvement	1 184 MWh	60	0 to 3
Lighting : LED lighting in central, hall, corridors	1 270 MWh	44	3.6
Heat recovery from primary cooling circuit	3 700 MWh	425	4
Machine operation improvement	TBD	TBD	TBD
Total actions	6 150 MWh	530 tons	

(850 tons + 530 tons) / 11000 = 12% decrease

Heat recovery from primary circuit project

93% of EXPH heating needs can be covered by the heat pump



Not a lot to gain now on the accelerators, Mostly done with an optimization of the RF working point (1.1 GWh for one year)

AND ALSO…

- ERLs and Sustainability *(Andrew Hutton ,Jefferson Lab):*
  - ERLs have an additional advantage by recovering the energy in the beam after use: status of the R&D
- Sustainable Accelerator R&D (BenShepherd, STFC Daresbury Laboratory)
  - Developing key technologies to improve the efficiency of particle accelerators, expertise in Sustainable Accelerators
- Water, reduction in consumption and treatment of effluents from cooling towers (Serge Deleval, CERN) Improvement of wet cooling towers, Reduction of consumption - Re-cycle - Reduction of effluents
- Rare Earth and Life Cycle Management (Denise Völker, Head of Sustainability, DESY)
  - Review of life cycle assessment of a product system throughout its whole life, example permanent magnets, Niobum
- A big science facility as a living-lab for energy transition: the LNCMI use case (Frédéric Wurtz, UGA) A laboratory at Grenoble university to built models and study socio-economic impacts
- Energy management for the Future Circular Collider (FCC) (Jean Paul BURNET CERN)
  - Estimation of the huge power demand for FCC, energy saving plan, electrical infrastructure needed
- Towards ISO 50001 certification at CERN (Serge Claudet, CERN)
  - Definition of energy performance indicators, Energy consumption forecast established, Energy Performance Plan done, Internal and certification audit planned

❖ --------------------------

- Transmutation of Nuclear Waste with Accelerator-driven Systems (Maurice BOURQUIN, TRANSMUTEX):
  - Nuclear waste, ADS for transmutation and energy production, Status of ADS technology
- Extreme Brilliant Source: A new Light Source – first scientific highlights (Michael Krisch, ESRF):
  - Review of related sustainability science, EBS scientific highlights in sustainable energy & environment

CONCLUSION: A SUMMARY OF THE WORKSHOP IN ONE SLIDE

The analysis of the situation is clear

We need to act on the climate change

We need to adapt more the production to the consumption and vice-versa (flexibility)

We need to see the bigger picture

We need to react to the increased energy cost

Means and tools are there

Technology is there (or almost there)

Methodology and tools are there (or almost there)

Investment is often associated to an increase of performance

Funding from EU or national gov for efficiency and sustainability is showing

What next ? or what is missing?

- We have to conduct new projects and new designs with efficiency and sustainability in mind but also as a primary specification
- Integrated technical, experimental and human behaviour is progressing but must be enhanced toward higher flexibility
- We have to measure our scientific productivity also as a function of the energy consumption
- Energy sobriety is a key asset
- ……

NEXT EVENT

The next edition will be organized in 2024 by CIEMAT in Madrid, Spain.

ESSRI

7th Workshop on Energy for Sustainab
Science at Research Infrastructures.

September (tbc), 2024
Madrid.

MANY THANKS FOR YOUR ATTENTION