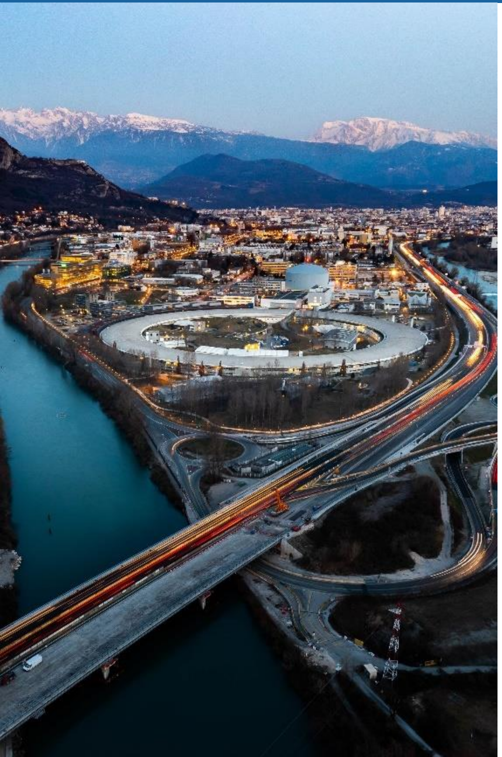
iFAST

Low Emittance Rings workshop 2024

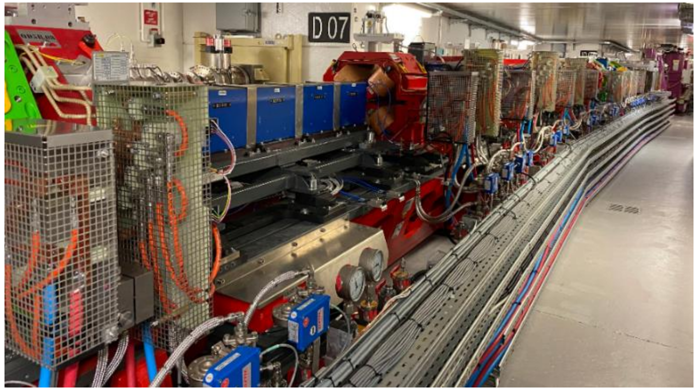
13-16 February 2024
CERN, Geneva



Sustainability and energy efficiency at ESRF

15 February 2023

Jean-Luc Revol



ESRF | The European Synchrotron

OUTLINE

- Context
- EBS contribution
- Overall sustainability
- ESSRI workshops
- Conclusion and outlooks

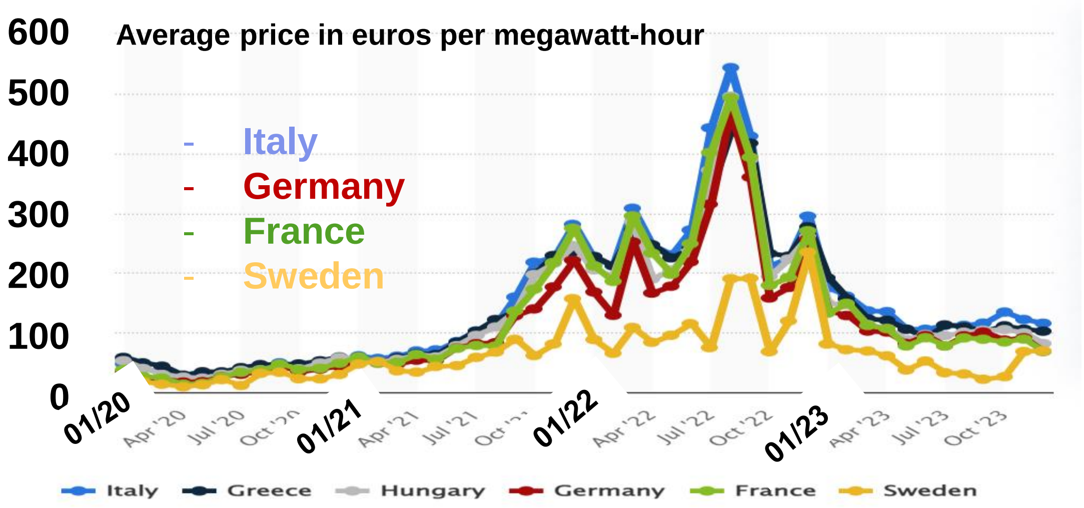
ESRF, Grenoble, 29-30 September 2022

ESSRI: Energy for Sustainable Science at Research Infrastructures

CONTEXT



- Practical experience of climate change with record temperatures, long drought periods, forest fires, floods
- General inflation of energy cost: *Covid19, Ukraine invasion, Unpredictable fluctuations on the energy trading exchange,..*



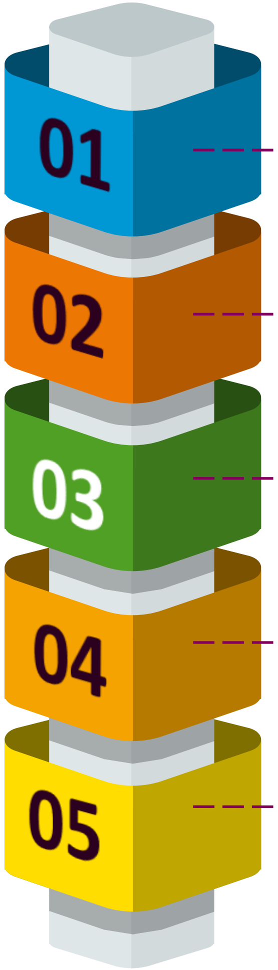
But sustainability in our institutes is mostly limited to energy (and largely electricity) management driven by ……
operational cost reduction!!!

➔ High energy prices and crisis often help and not hinder decarbonisation !!

Some light sources were obliged to reduce user operation due to energy cost (Soleil, Elettra, Solaris…) .

ESRF was able to maintain the operation schedule for users and development but the energy has a large impact on the budget.

REGULATIONS



Green House gas emission report

Periodic report (every 4 years)
Action plan required.

Decret Tertiaire

40% Energy consumption reduction for tertiary buildings in 2030.
Reference year to be defined

Energy saving plan

French initiative : 10% reduction of energy consumption in 2024 (base : 2019).

Loi Climat et Resilience

Car parks solar panels
Minimum 50% of parking places covered by solar panels.

EU climate law : FIT 55

European regulation. 47% reduction on Green House gas emissions in 2030 (base 2005)

THE ESRF: FACT AND FIGURES

Light source in operation since 1994, Grenoble, France

22 partner nations

Budget: 115 million euros, Staff: 700 people

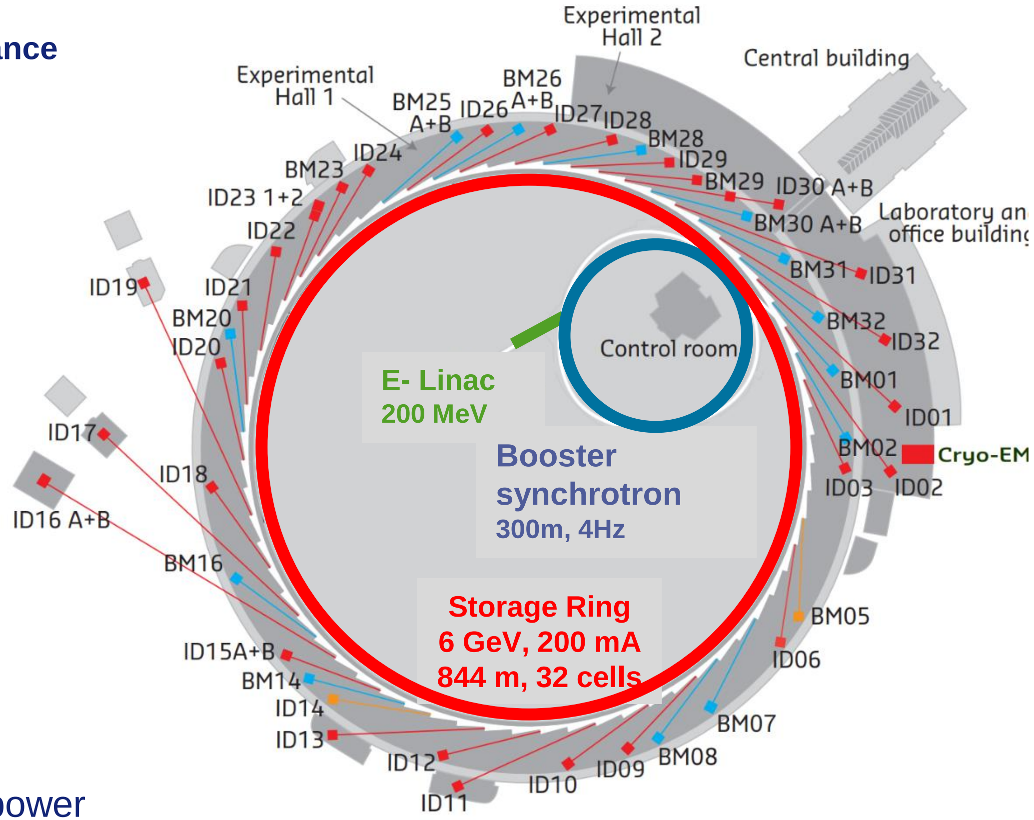
5500 hours of beam delivery

1500 experimental sessions

49 beamlines

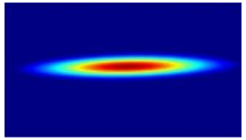
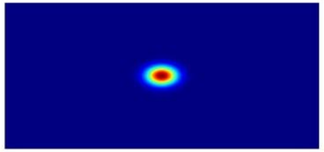
Upgrade programme 2009-2023 (2 phases):

- **New beamlines**
- **Renew infrastructures and support facilities**
- **New storage ring source (EBS)**

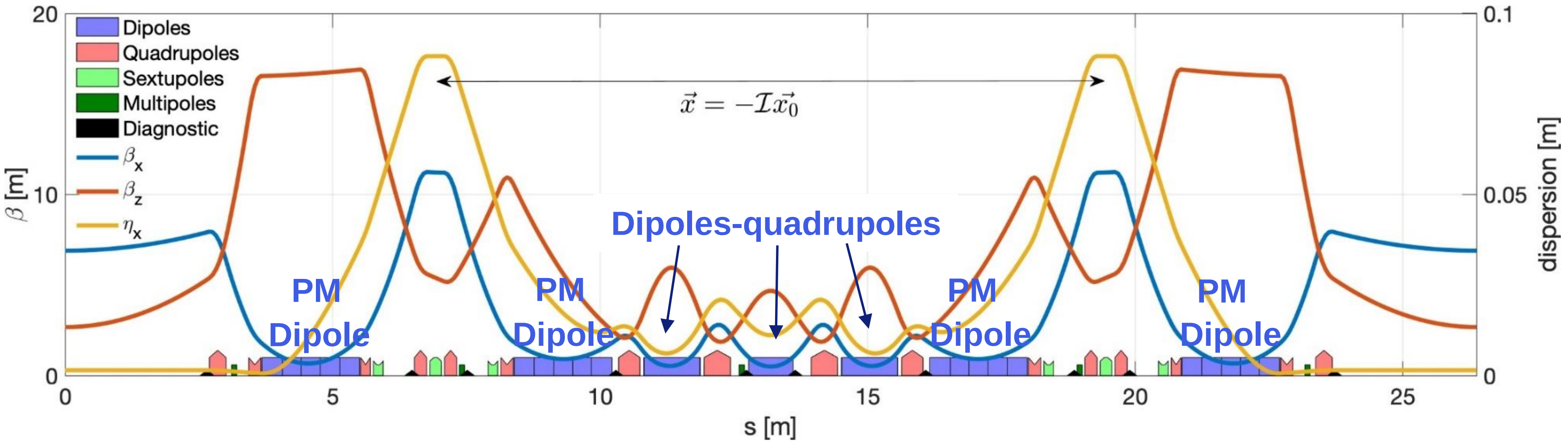


The **Extremely Brilliant Source (EBS) 2015-2020**:

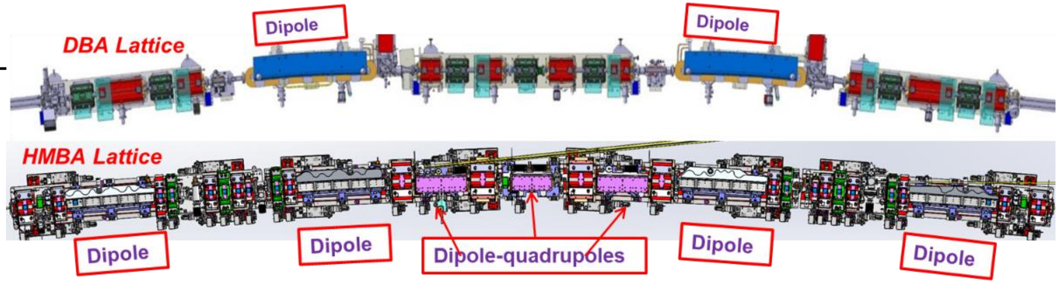
- Decrease the horizontal emittance
- Increase the source brilliance
- Increase the source coherence
- Keep as much as possible of the infrastructure
- Minimize operation costs, particularly wall-plug power

4000 pm.rad  →  133 pm.rad

EBS UPGRADE LATTICE



	Units	ESRF	ESRF-EBS
Energy	*GeV*	6	6
Circumference	*m*	844.4	844
Lattice		DBA	HMBA
Current	*mA*	200	200
Lifetime	*h*	50	25
Emittance H	*pm.rad*	4000	133
Emittance V	*pm.rad*	4	10*



31 magnets per cell instead of 17

*Free space between magnets (for one cell): **3.4m** instead of **8m***

MAGNETS OPTIMIZATION

Space limitation, Wall plug power, Performance, Procurement, Installation, Operation

Resistive magnets

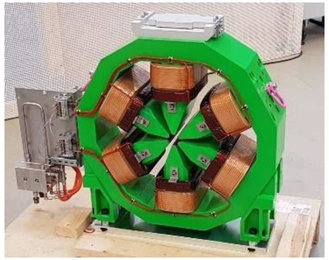
Copper cross section adapted for reasonable current density

- ~ 3 A/ mm^2 @ nominal working point

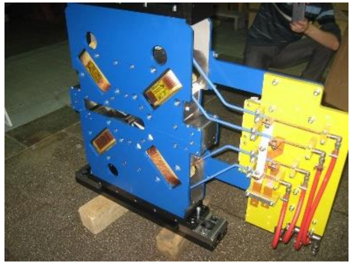
High & Moderate Gradient

Quadrupoles

Sextupoles



Octupoles



Permanent magnets

Primarily for fixed field magnets

➔ **Dipoles**

Wall plug power=0
Affordable technology (and cost)
Experience with insertion device construction

Sm_2C0_{17},

➔ ***Also for septa***

(Some) tunability and flexibility should be maintained for the lattice.

POWER AND ENERGY CONSUMPTIONFOR THE MAGNETS

ESRF :	2018	EBS
Dipoles (D)	720 kW	0
Correctors and Steerers	10 kW	11 kW
Other magnets	1625 kW	1059 kW
Dipole-quadrupoles (DQ)		16%
High gradient quadrupoles (HGQ)		*29%*
Moderate gradient quadrupoles (MGQ)		*44 %*
Sextupoles (S)		10%
Octupoles (O)		1%
Total	**2355 kW**	**1070 kW**
Energy for one year operation (7200 H: USM+MDT)	**16.9 GWh**	**7.7 GWh**

Very positive experience with Permanent Accelerator Magnet for EBS:

- Works as expected, passive devices in the storage ring, no maintenance
- *… and no cabling, no power supply, no cooling, no vibration, easier installation and better operational reliability*
- Very good stability vs temperature, based on passive compensation
- Electrical power required for the EBS magnets ➔ half that of the previous lattice
- DQs and HGQs could be permanent magnets (no tuning required), 476 kW additional saving

Storage Ring
Total electrical power:
6350 kW [2018]
***4100** kW [EBS]*

Permanent magnet is convincing for operation,…but the overall sustainability is less obvious considering the extraction and production issues

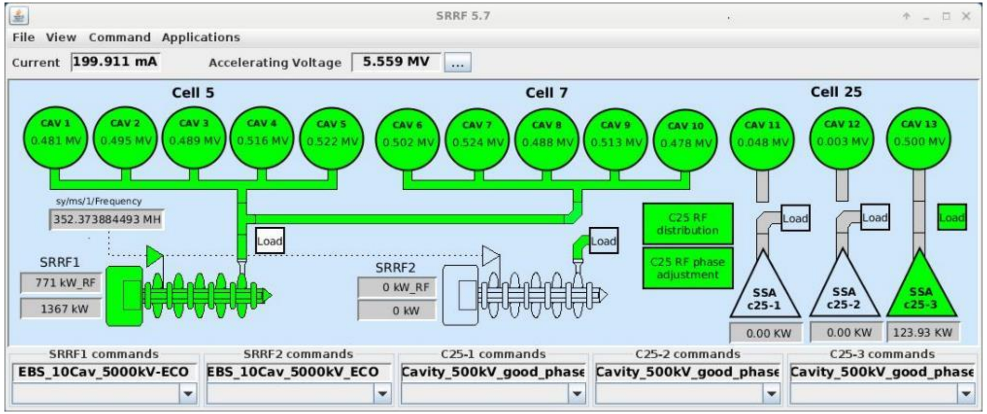
RADIO-FREQUENCY CONSUMPTION

Storage Ring Total power:

1300 kW RF [2018], — *Radiation loss 4.88 MeV/turn+ 0.5 (ID)*
5 Five 5-cell, 2 single-cell cavities
9 MV total voltage

***900** kW RF [EBS],* — *Radiation loss 2.5 MeV/turn + 0.5 (ID)*
13 single-cell cavities
5.5 MV total voltage

EBS_RF configuration



Efficiency AC ➔ RF:

Klystron:	53%
Present SSA:	47%
New SSA *(to replace Klystron)*:	59%

ECO mode *(applied since October 2022)*: **Reduction of total accelerating voltage** from **6.0** to **5.5 MV**

- **And Increase AC to RF conversion efficiency:**

  150 kW SSA operated way below nominal power, at 90 …100 kW, where the efficiency was low.

  ⇒ Increase the Klystron power by increasing Cav 1 to 10 voltage from 4.5 to 5.0 MV

  ⇒ Operate with only 1 SSA at 0.5 MV

RESULT:

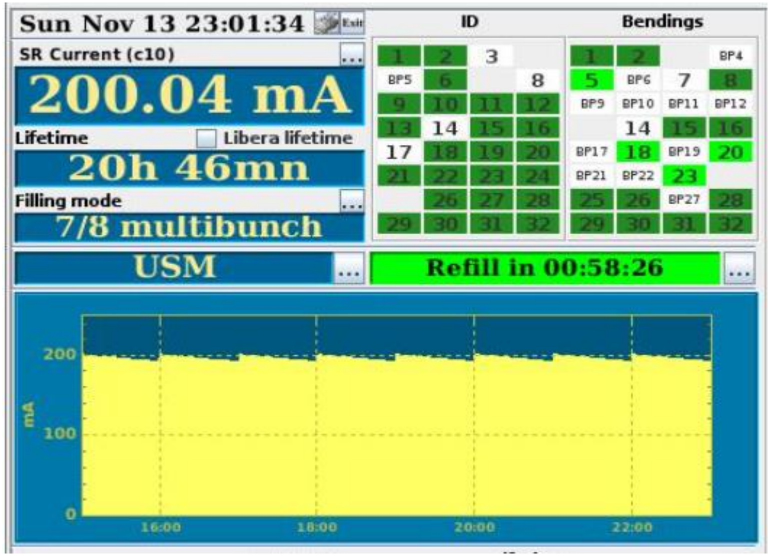
- **200 kW AC power savings** at 200 mA
- **Same beam lifetime** for typical ID losses
- *500 kW total savings possible if operation at 100 mA*

Storage Ring Total electrical power:

6350 kW [2018]

***4100** kW [EBS]*

LIFETIME, INJECTION EFFICIENCY AND INJECTOR USAGE



EBS parameters:

Beam lifetime larger than 20 hours

Injection efficiency in the order of 70%

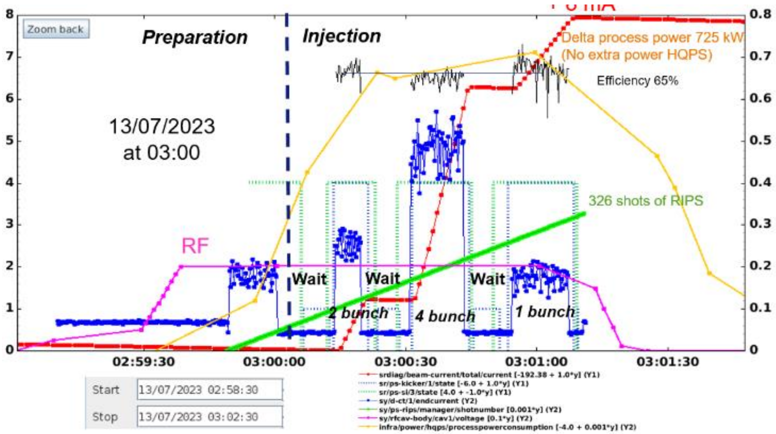
Top-up every 1 hour

Typical injection in 2022:

725 kW for the injector during 2 mn. every 1 hour

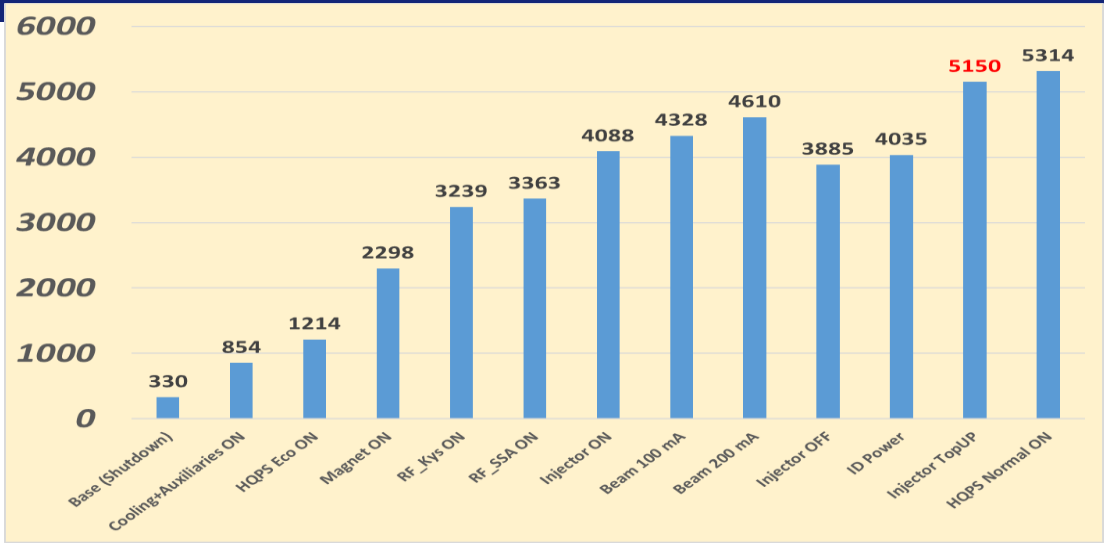
(*45s for preparation, 70s for injection with only 32s beam on*)

➔ 25 kWh



During machine development time, optimisation of the programme and guidelines is imposed for the usage of the injector.

TYPICAL POWER CONSUMPTION



854 kW *Base with cooling and auxiliaries ON*

Base Power in shutdown: 330 kW

360 kW HQPS consumption mode ECO:

(with transient up to 800 kW when SYRF switched ON)
In normal mode 510 kW (transient 731 kW).

2149 kW **P**ower consumption of the storage ring without beam:

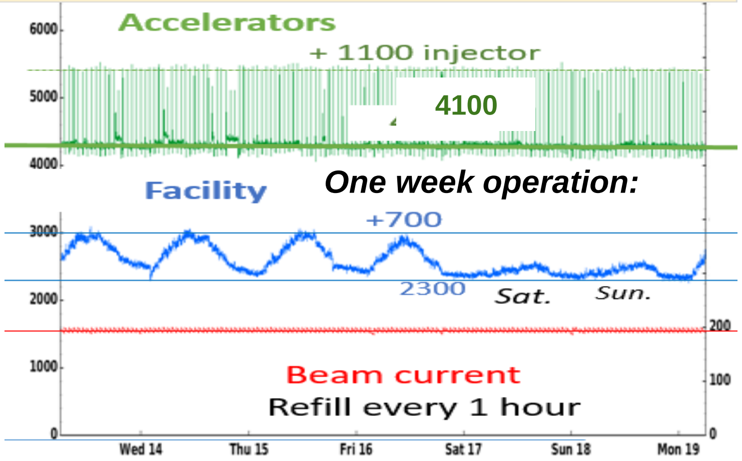
(Magnets: 1084 kW
RF: Klystron: 941 kW SSA: 124 kW)

522 kW Beam power at 200 mA

150 kW ID power (<u>90 kW average</u>)

4035 kW Total for the storage ring

+725 kW Injector consumption *(RF : 176 kW ; Magnets: 560 kW)*



<u>Total electricity consumption of the institute:</u>

	4100	*kW for the SR at 200 mA*
+	*725*	*kW every hour for 2 mn for injection* *(1100 max with transient)*
+	*2300*	*kW base facility consumption* *for labs, office, Experiments,…*
+	*700*	*kW facility fluctuation for staff activity*

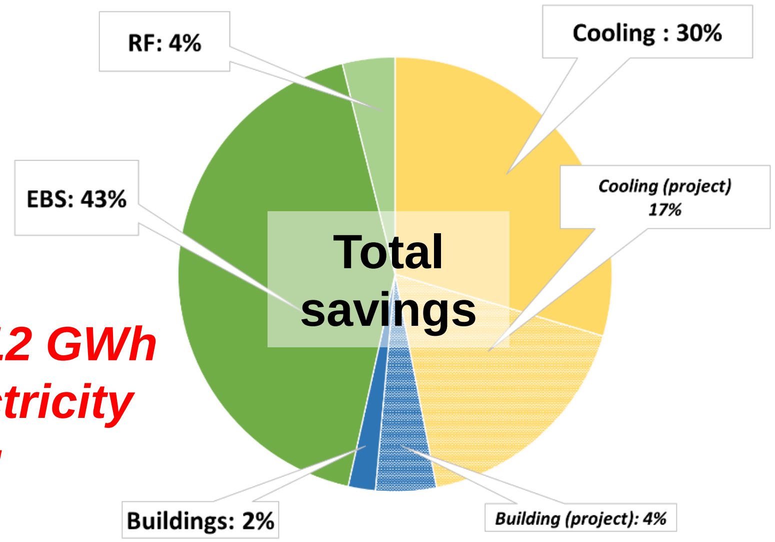
ENERGY MANAGEMENT FOR THE WHOLE INSTITUTE

Today:

Electricity consumption: 50 GWh / year

Heating consumption: 7.1 GWh / year
(District heating network)

Cooling: DRAC River
(free cooling)



EBS: 12 GWh of electricity saving

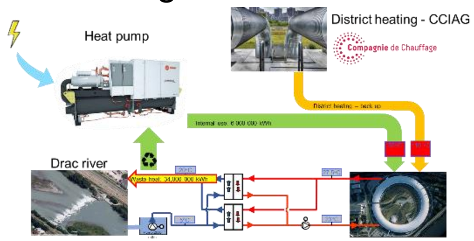
Total energy savings :

25	GWh	*done*
6.1	GWh	*in project*

Buildings: LED lightning, insulation,…
Cooling: Pumping system, regulations, refrigerators, heating pump..
Accelerators: EBS, RF

Next:

- Heat recovery from cooling which should provide 93 % of the experimental-hall heating



- Installation of solar panels
- Guest house wall insulation
- Data centers consumption (3.5% today) will increase in the years to come *(heat recovery)*

THE ESRF : SUSTAINABILITY WITH A REDUCTION OF TRAVELS

- Full remote access possibilities for users to reduce travel

	Number of experiments				
Year	Total	Onsite	Hybrid	Remote	
2018	2831	2285	91 (3%)	455 (16%)	Prior EBS
2019					*Shutdown*
2020					*COVID*
2021					*COVID*
2022	2295	1276	245 (**11%**)	774 (**34%**)	EBS

✓ Well adapted to repetitive experiments and automated beamlines (macromolecular crystallography, commercial clients..)

✓ Hybrid access is favoured with the presence of experts on site to support the local scientists

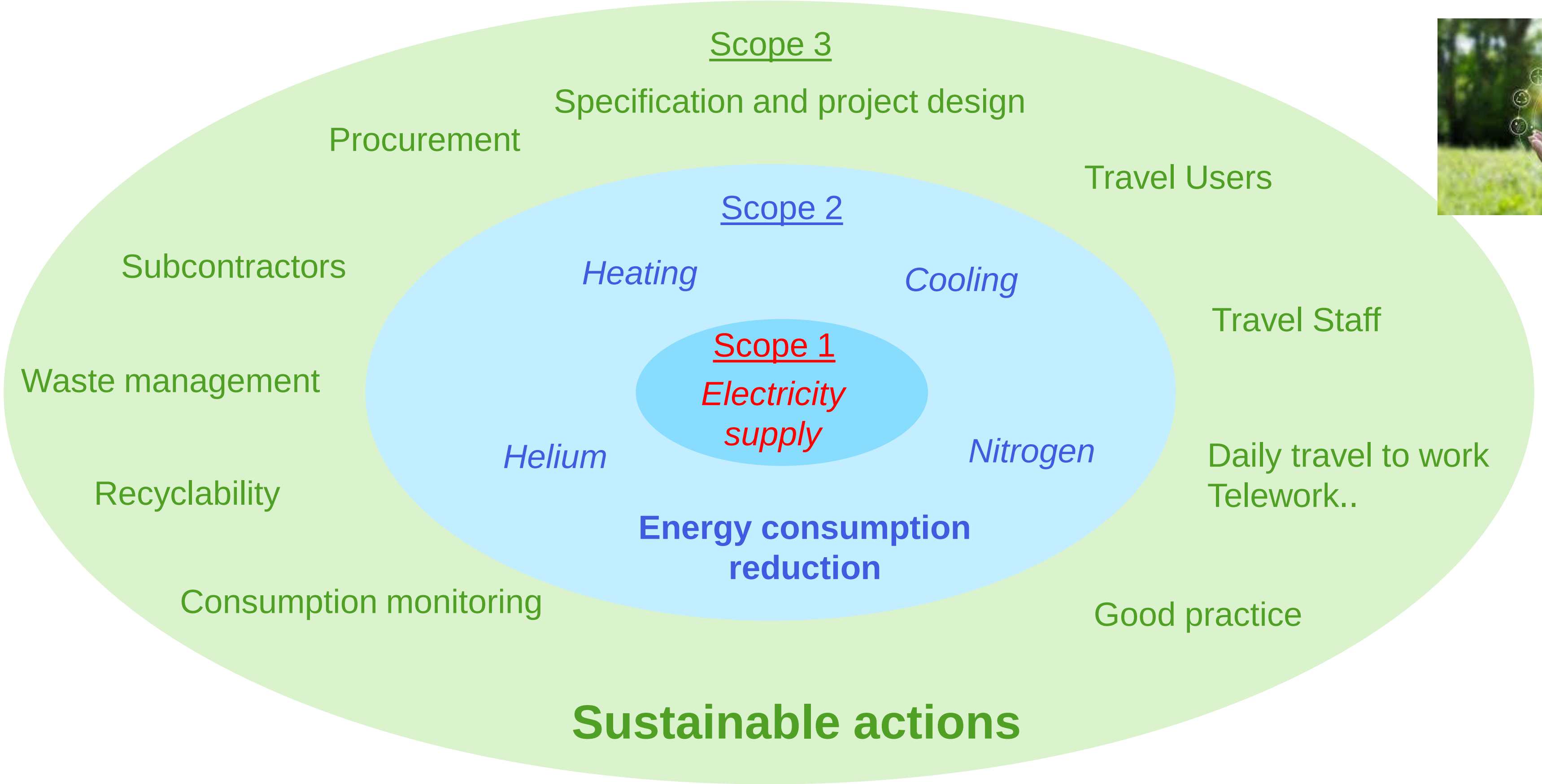
- Full remote access possibilities to the accelerators to support machine studies and for interventions
  (expended since COVID pandemic but will be re-discussed due to cybersecurity)

- Incitation to a reduction of the staff professional trips and the use of remote meetings

CONCLUSION FOR THE ESRF

- The use of permanent magnets for accelerator design proved to be efficient and reliable
- The EBS upgrade allowed a drastic reduction of the electricity consumption and this associated to an increase of performance
- Significant effort have been done on the reduction of energy consumption on the infrastructure
- All the efforts vanished by the drastic increase of the energy cost, nevertheless it allowed the continuation of a normal operation program
- Sustainability should not be limited to energy management, significant efforts have also been done on the user side and an action plan have been initiated for a more sustainable procurement
- Life cycle is an important issue for facility upgrades *(ESRF old machine was "only" treated as waste with some income)*

OVERVIEW OF SUSTAINABILITY FOR LIGHT SOURCES



Light sources are not the largest energy consumers but the
economical and societal aspects are today key concern for us

GENERAL CONCLUSION

The analysis of the situation is clear

- Act on the climate change
- Think sustainable
- React to the increased energy cost
- Reduce and adapt the energy consumption
- Have a broader vision of the situation

Means and tools are there

- Technology
  (or almost there)
- Methodology and tools
  (or almost there)
- Investment is often associated to an increase of performance
- Funding from national or international agencies for efficiency and sustainability
  (or emerging)

What should be next ?

- Conduct new projects and new designs with efficiency and sustainability as **primary specifications**
- Enhance flexibility in the technical, operational, experimental and human behaviour and actions
- Measure the "scientific productivity" as a function of the energy consumption and the sustainability
- **Define sustainability metrics for field of activity**

ESSRI WORKSHOP SERIES

The 6th ESSRI workshop in a series and was held at ESRF in Grenoble in September 2022 at the ESRF.

<u>Main themes:</u>

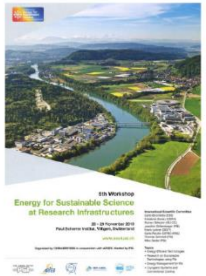
- *Energy management at research infrastructures and resulting experience*
- *Sustainability of equipment, materials and resources*
- *Energy-efficient technologies*

2011: ESS
Lund - Sweden

2013: CERN
Geneva Switzerland

2015: DESY –
Hamburg - Germany

2017: ELI-NP -
Bucarest - Romania



2019: PSI
Villigen - Switzerland

MANY THANKS FOR YOUR ATTENTION