EMFL
European Magnetic Field Laboratory

Energy management at High Magnetic Field Facilities

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Magnet development at LNCMI-Grenoble

LNCMI

with contribution from
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Magnet development at HMFL-Nijmegen

HFML
Science in High Magnetic Fields

State of the Art of High Magnetic fields

MgB_2 | *NbTi* | Nb_3Sn | *YbaCuO* | *Copper Alloys*

5 10 15 20 25 30 35 40 45 50 60 70 T..

MRI

LHC

Commercial magnets for research

Almost unique Magnets

- NMR, 1GHz Bruker (Lyon), (2010)
- Cryogen free magnet, Sendai, Japon (2016)
- NMR, 1,2 GHz Bruker (Univ. Firenze) (2020)
- **Demonstrators** , Tallahassee, LNCMI (2021)

High field Facilities

Continuous Field		Pulsed field
Grenoble, Nijmegen	EMFL European Magnetic Field Laboratory	Toulouse, Dresden
Hefei	CHINA	Wuhan
Sendai	JAPAN	Tokyo
Tallahassee	UNITED STATES	Los Alamos

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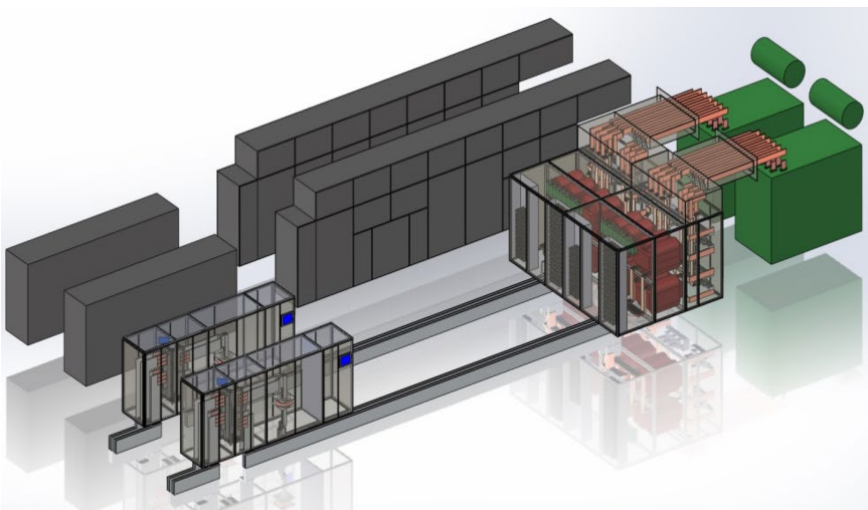
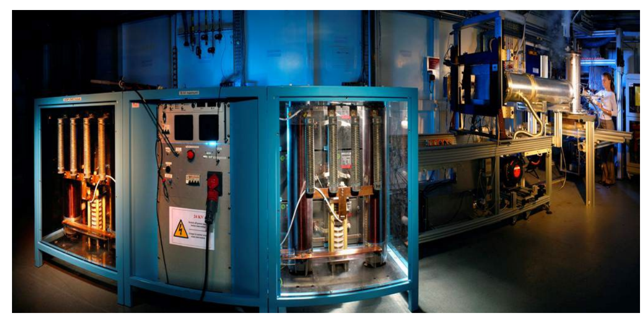
High field Magnets are not commercial products
➔ Facilities are required for researchers

LNCMI

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

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





4 of them are mobile

to perform experiments in other facilities and combine magnetic field with intense lasers, X-rays, or neutrons (LULI, ESRF, SLS, ILL…)

Energy for high field resistive magnets

Pulsed B (~100T)

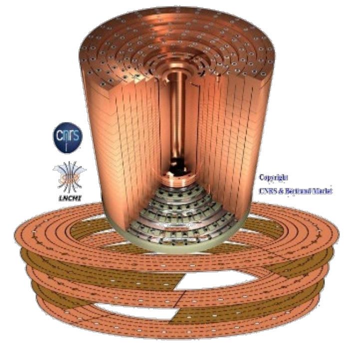
The Maximal pulse duration (~100 ms)
Is given by

$$\Delta t \propto [AI] = \int_{77K}^{T_{final}} \frac{C_v}{\rho} dT$$

20 MJ max. per pulse

➔ 15 MWh per year

Continuous (~ 40 T)



Need of a permanent turbulent forced flow cooling :

$$h(W.m^{-2}.K^{-1}) \propto V^{0,8} D_H^{-0,2}$$

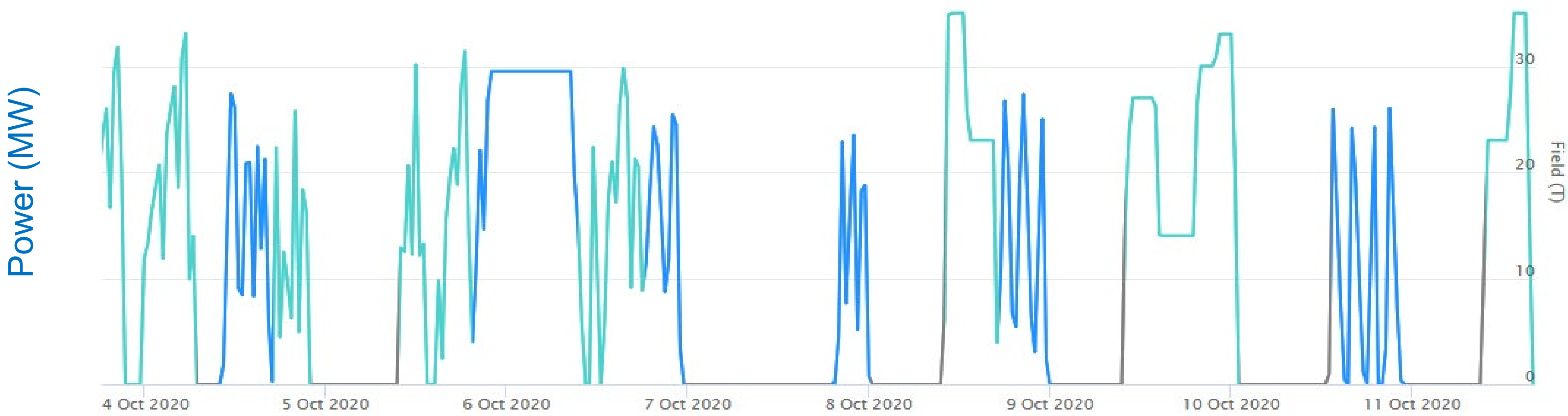
24 MW max of Power

➔ 15 GWh per year

3 large scale facilities on the "presqu'ile" in Grenoble
All cooled from the river "Drac"
(no chillers nor cooling towers)

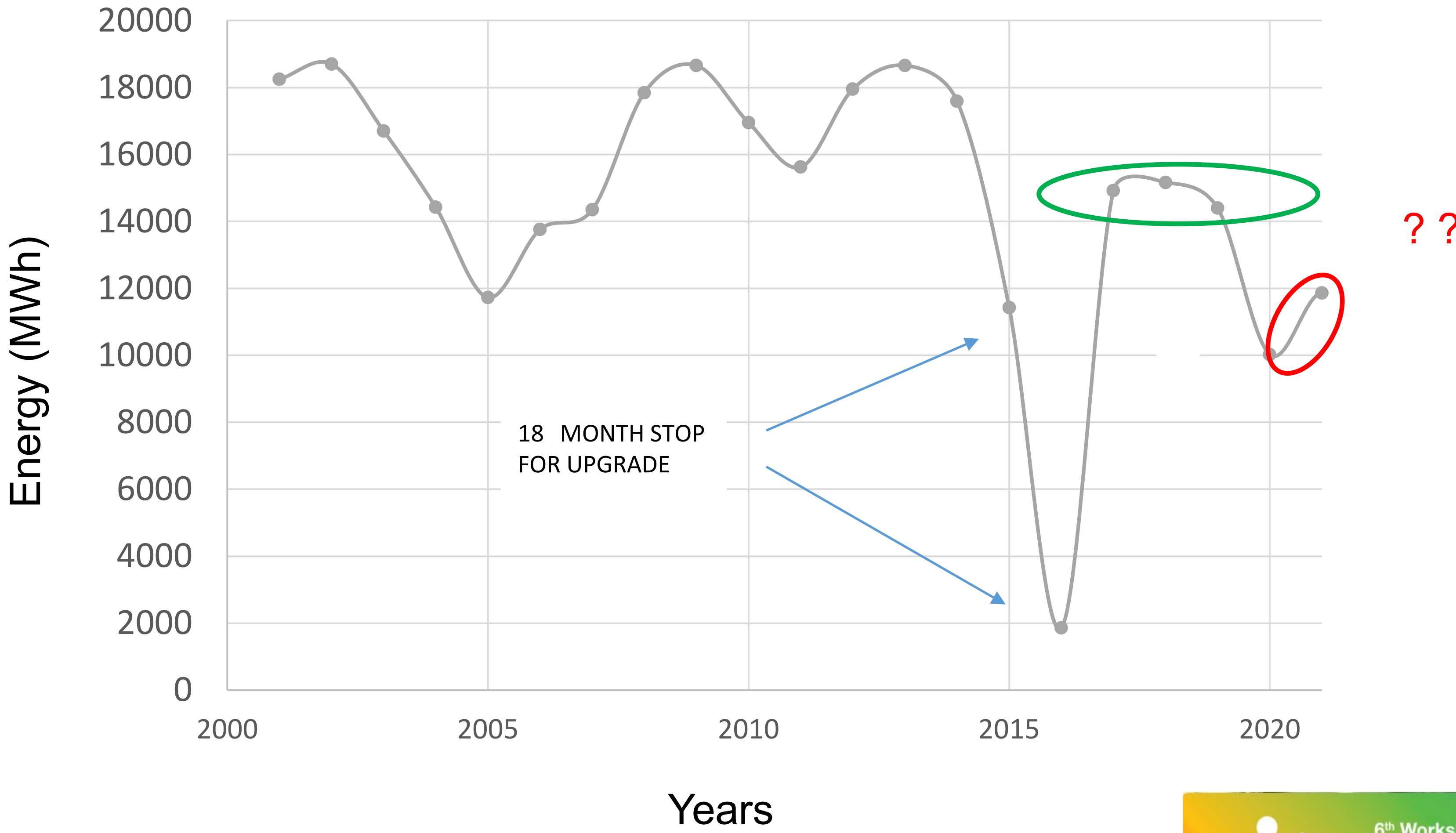
ENERGY vs Time

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

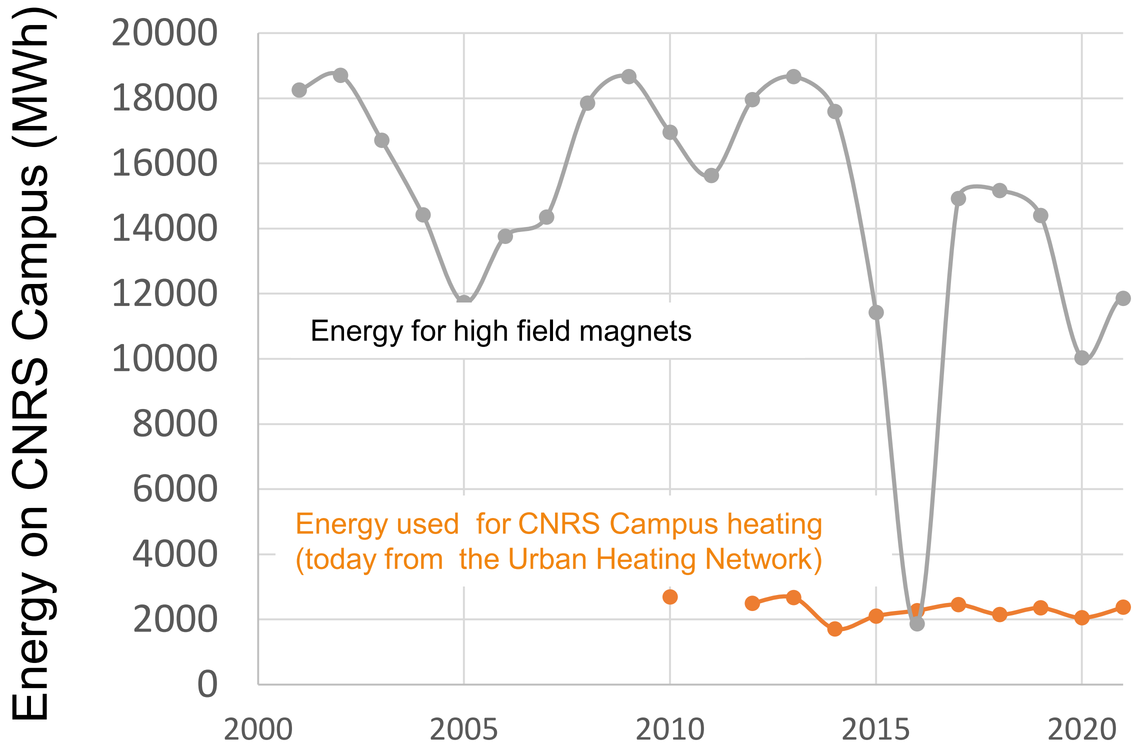


The electrical consumption is a direct image of the researcher strategy
➔ Very high intermittencies.

Energy for the high field facility in Grenoble (MWh) : statistics



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

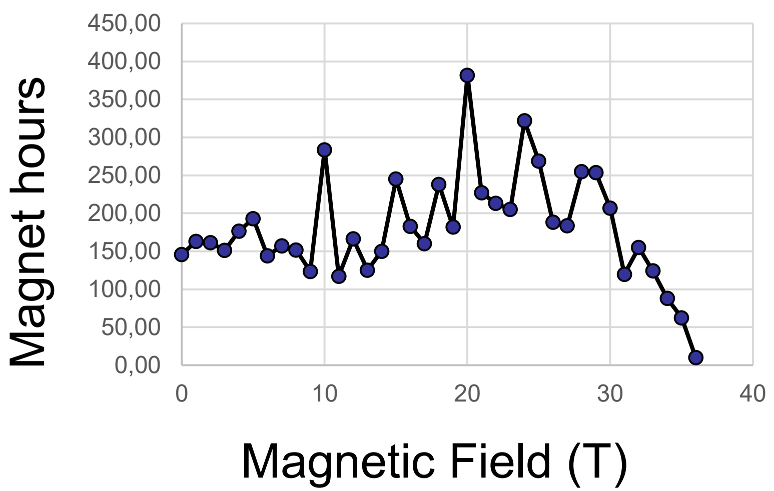


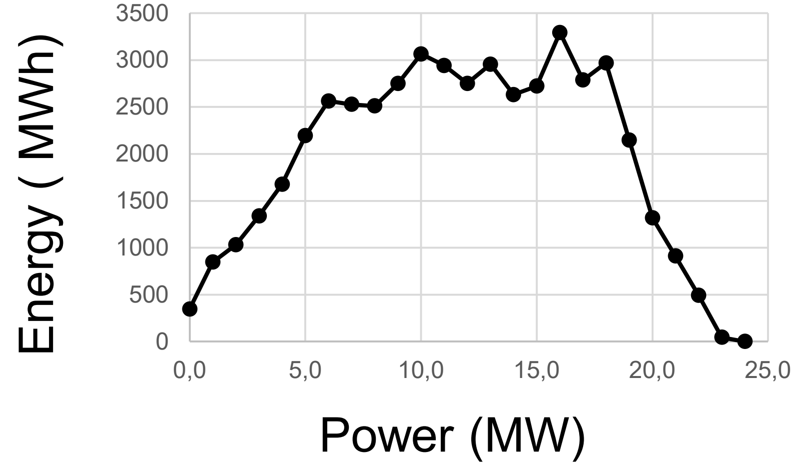
➔Use of HTc superconducting magnets for long duration experiments

➔Ancillary Services for the Electrical Network

➔ Enhancement of resistive magnet efficiency & recovering the waste heat

Use of the two main high field magnet site at LNCMI-G
Jan. 2018 to Sept. 2022





Tendencies

Use of very high field mainly for « sweeping » experiments due to **budget limitation**

➔ **development of HTS magnets for long duration experiments**

The main energy is not spent **at maximal power**

➔ **Consequence on the dimensionning of a heat valorization project**

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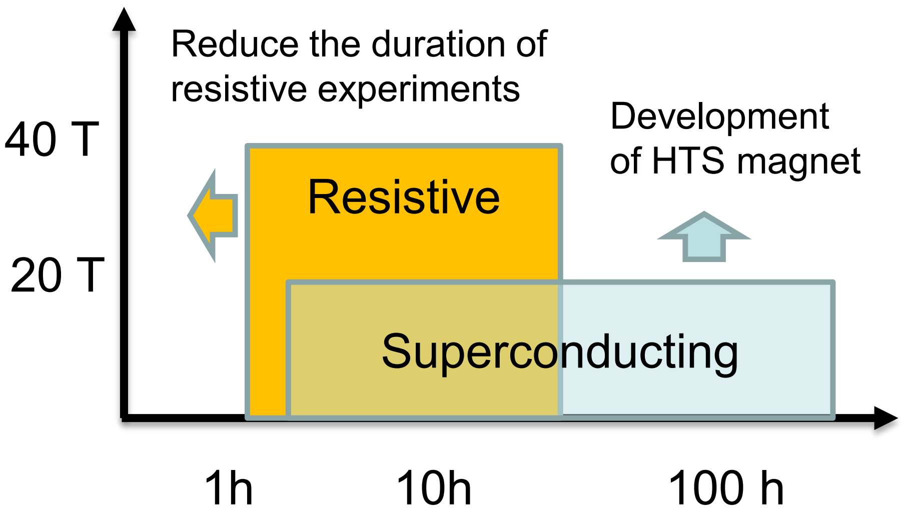
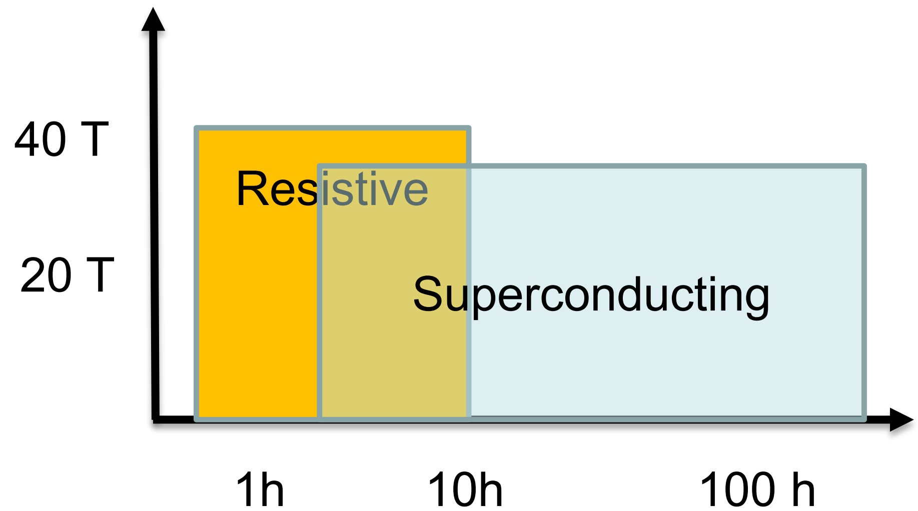
Developping HTS magnets for long duration high field experiments





National fundings

FASUM (CEA-CNRS) ➔ investment for a 30 T & then 40 T all superconducting user magnet

H2020 supports

SUPER-EMFL

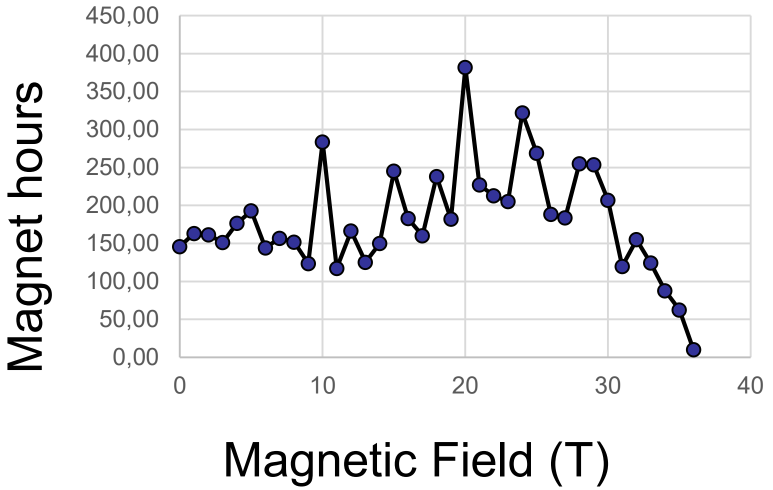
➔ To disseminate the HTS technology through research infrastructure

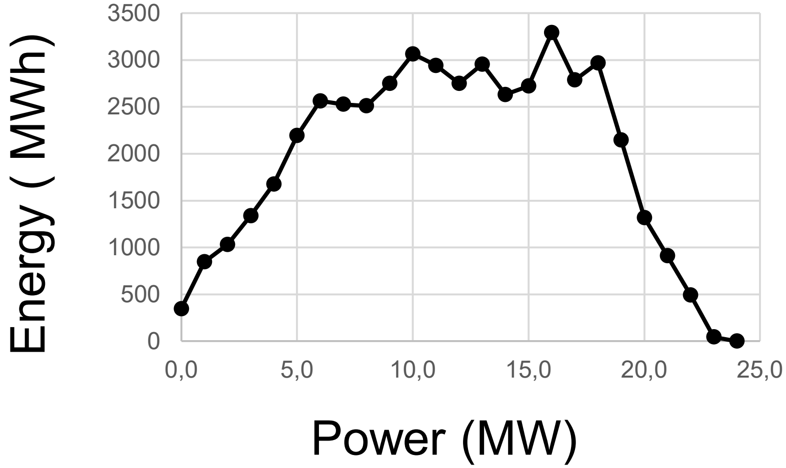
ISABEL

➔ To ensure the long term sustainability of high field laboratories

PROGRESS on this subject to be presented by Xavier CHAUD at the coming 2022 ASC conference

Use of the two main high field site at LNCMI-G
Jan. 2018 to Sept. 2022





Tendencies

use of very high field mainly for « sweeping » experiments
budget limitation

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➔ Consequence on the dimensionning of a heat valorization project

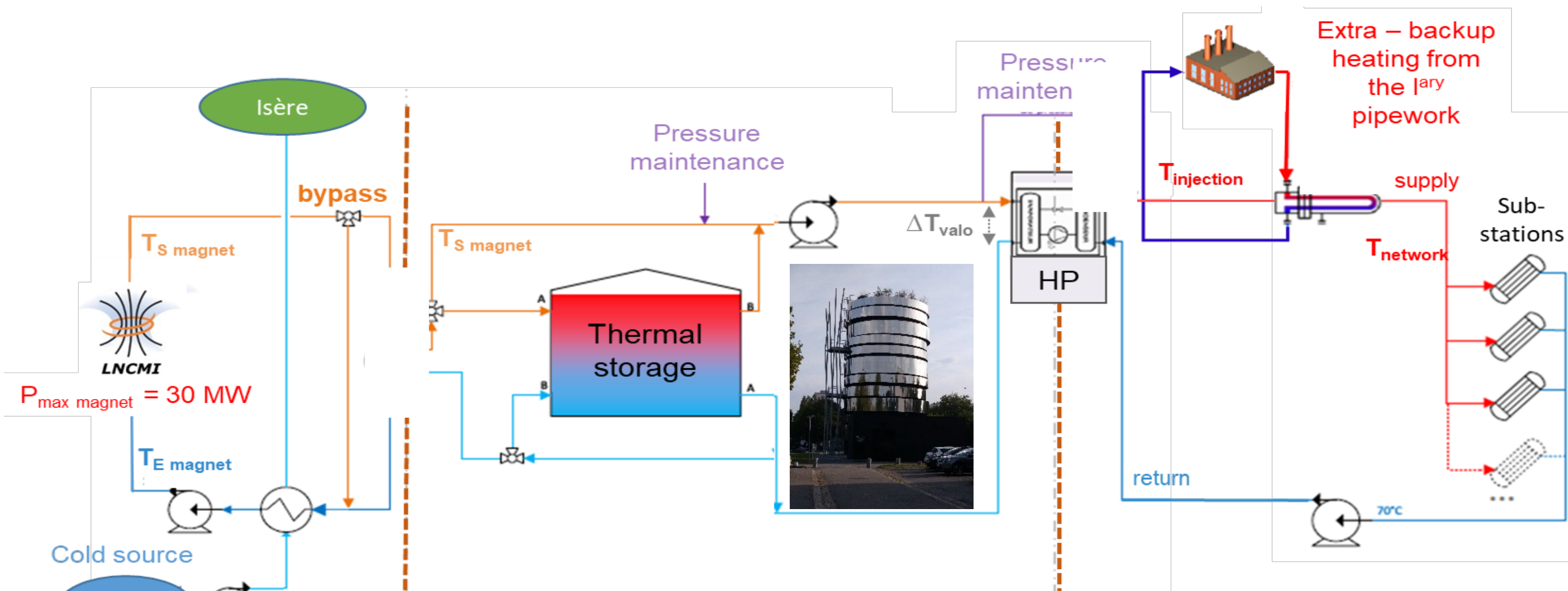
Two cooling loops for the high field laboratory LNCMI-Grenoble

Recovering the waste heat : initial scheme

High magnetic field facility
~15 GWh/y

Grenoble global heating network ~800 GWh/y
District network ~ 25 GWh/y

- Magnets
  - Magnet outlet Temp.
  - Planning, electricity tariffs
- Storage
  - Size and capacity, ΔT
    Operation strategy
- Heat Pump
  - Power level
  - Balance between COP & ΔT



Problem with this ambitious project : large investment needed
➔ Decide to Start with a local project

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

Perimeter : the heating loop of the CNRS buildings

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

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

2023 : final studies
2024 : operation
2025 : *2nd step with a direct connection to the urban heating network (tbc)*

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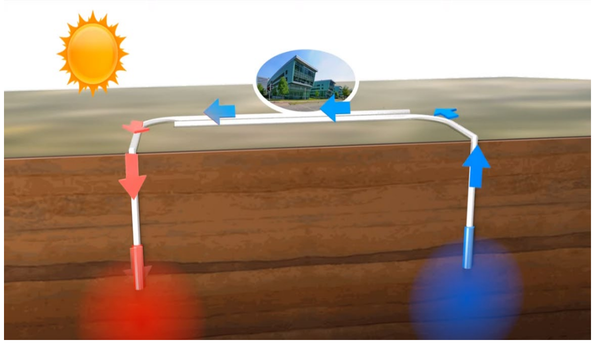
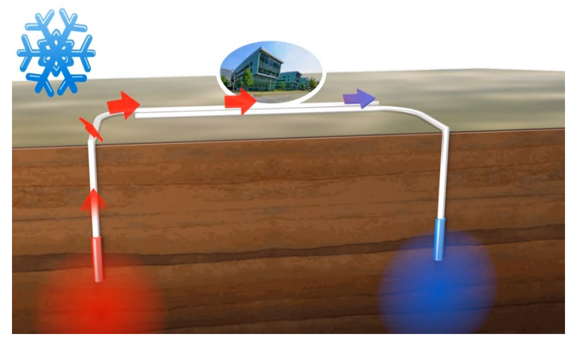
Other solution implemented in high field labs: the Nijmegen Aquifer Thermal Energy Storage

- Aquifers to store cold and warm water
- Heat pumps in building to cool or heat building

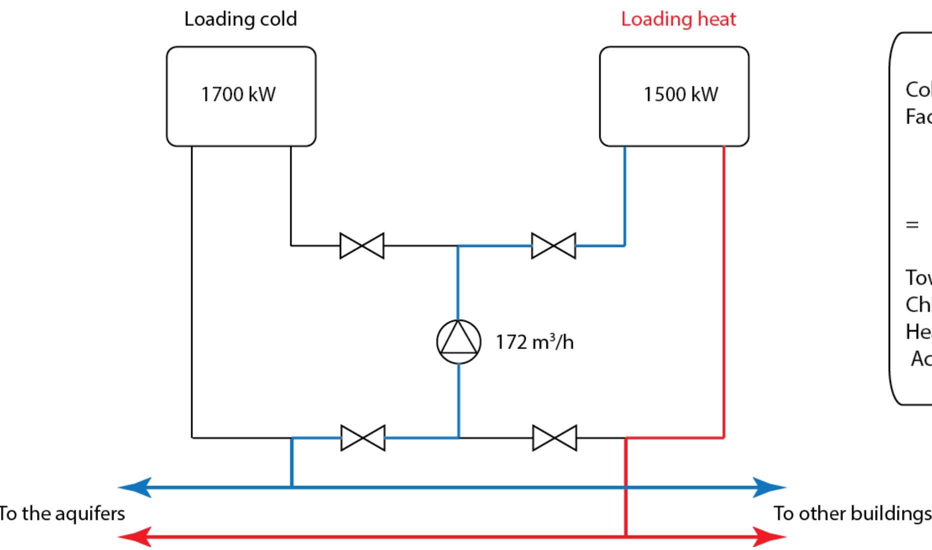


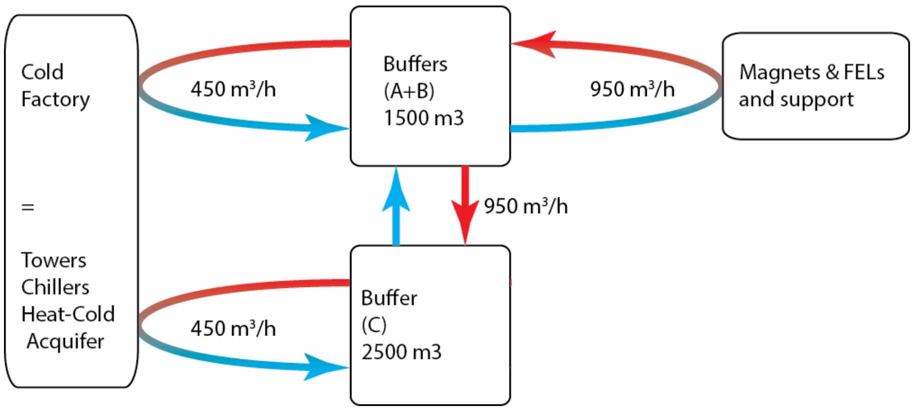


10 wells,
5 for cold storage,
5 for heat storage

Since 2014 : the high field lab is connected to this network.

ATES & High Field Magnet Laboratory in Nijmegen



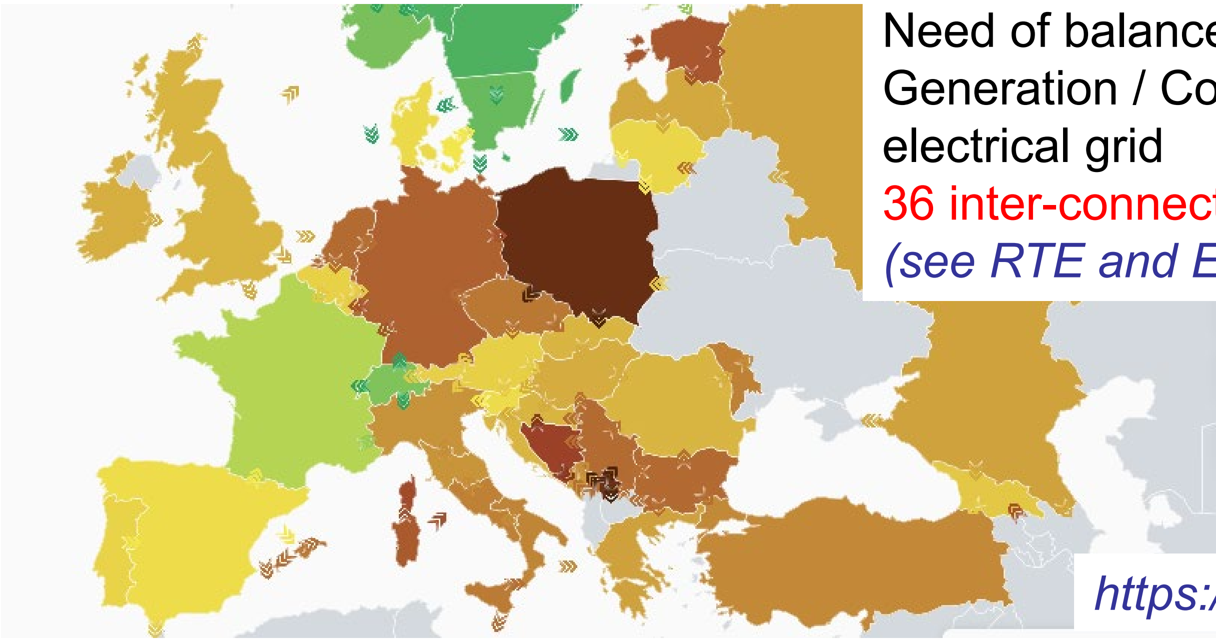


HFML
Science in High Magnetic Fields

Heat is stored in 1500 + 2500 m^3 buffer

➔ **Re-use ~15% of the 10 GWh annual energy consumption**

ELECTRICAL GRID : ELECTRO-INTENSIVE RESEARCH INFRASTRUCTURES CAN CONTRIBUTE ACTIVELY TO THE STABILITY



Need of balance at any time between Generation / Consumption on the electrical grid

36 inter-connected countries in Europe

(see RTE and Energy Pool this morning)

https://app.electricitymaps.com

Flexibility of Research Infrastructures :

Ability to modulate (or to withdraw) our consumption

- for a given period of time
- at different time scales (corresponding to 1st, 2nd and 3rd Reserve)

to contribute to the balance

➔ Major issue for the energy transition

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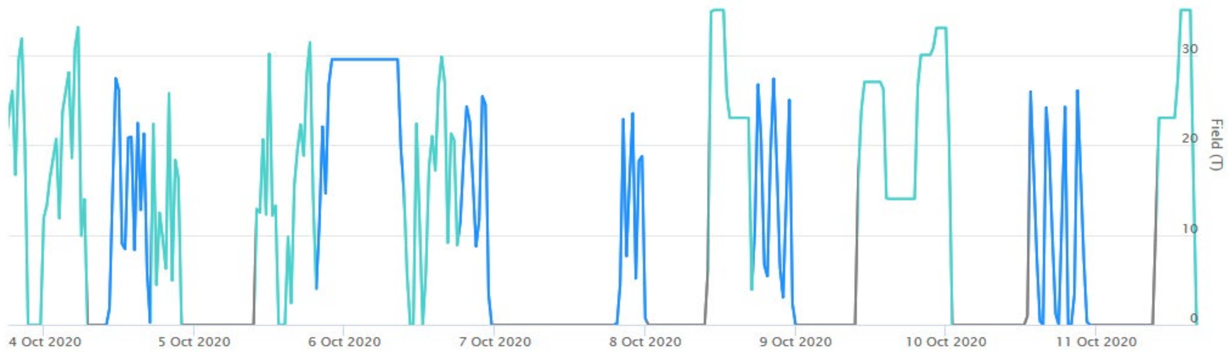
SERVICE TO THE GRID AT LNCMI



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

- **“NEBEF”,** load shedding mechanisms ➔ capacity to shift an energy block
- **“PP2”** , capacity mechanism (during winter peaks) ➔ capacity to withdraw from the grid

These mecanisms 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 *:*** faisabiliby studies of piloted consumption for **frequency regulation**
(1^{st} & 2^{nd} reserve mecanisms, see Energy Pool presentation)
Could be an interesting collaboration with Synchrotron facilities

➔ Objective to increase the number of operations

CONCLUSIONS

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at Research Infrastructures

Energy management in high field facilities

- Optimise the usage
- Services to the Grid
- Services to the District (heat valorisation)

➔ 3 intricated themes with the User at the center of the process

What do we need to go further (and faster) ?

➔ Easier access to energy data for efficient studies
(OTE project in Grenoble),

➔ Transverse gouvernances on Energy issues,

➔ Publish to learn from each other
.. but not only the sucess stories.

We thanks suports from :

« Cellule Energie » CNRS

Isabel Project (Europa H2020)

Interdisciplinary Project IDEX, UGA

➔ *About the interdisciplinary approach
to advance on these 3 items
see presentation of* ***Fréderic Wurtz*** *in this session.*