Energy management and efficiency

Volker Mertens, CERN

gratefully acknowledging the major material) contributed by S. Claudet / Energy Coordinator of CERN's Accelerator and Technology Sector*

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Outline

- Introduction
- Guiding principles (not only for FCC)
- CERN and energy aspects
- Energy management at CERN
- Energy efficiency evaluation
- Heat recovery projects
- Ideas for FCC
- Conclusions

Introduction

Energy efficiency high on societal agenda in general, and also of science institutions →

- Availability of energy, cost
- Reduction of greenhouse gases (climate change)
- Reduction of other problematic "side-effects" linked to energy "production"
  (dust emissions, (nuclear) waste, landscape consumption, …)

Concerted efforts:

EuCARD-2 (Enhanced European Coordination for Accelerator Research and Development), WP3

ARIES (Accelerator Research and Innovation for European Science and Society)

(see e.g. M. Seidel, 2017: https://indico.eli-np.ro/event/1/contributions/6/attachments/70/106/4_enefficient_seidel.pdf)

FCC

- Operational cost (vs. capital investment for efficient technologies), budget allocation
- Public acceptance
- Socio-economic driver of technological development

20-50-year forecast not straightforward (political and economic climate, crises, new energy sources)

Guiding principles (not only for FCC)

1) Consume less by making good design choices. ← LESS ☺☺
2) Be "energy-aware" and use energy more efficiently. ← BETTER USE ☺
3) Recover and re-use energy (or make it available). ← RECOVER 😐

- Use energy-efficient equipment
- Apply fine-grain real-time monitoring of energy use (awareness, prediction, control of peak power and losses) …
- … and switch off or ramp down what is not in use (optimize power cycles)
- Construct buildings to good environmental standards
- Purchase electrical power from renewable sources (as far as viable)
- Recover "waste" energy (store energy from magnets, heat recovery)

Accelerators are "driving" the energy consumption (not the buildings).

Reconciling demand for highest performance (cutting-edge equipment, long running periods)
with sustainability and reasonable/acceptable cost → not an easy task.

Be realistic !

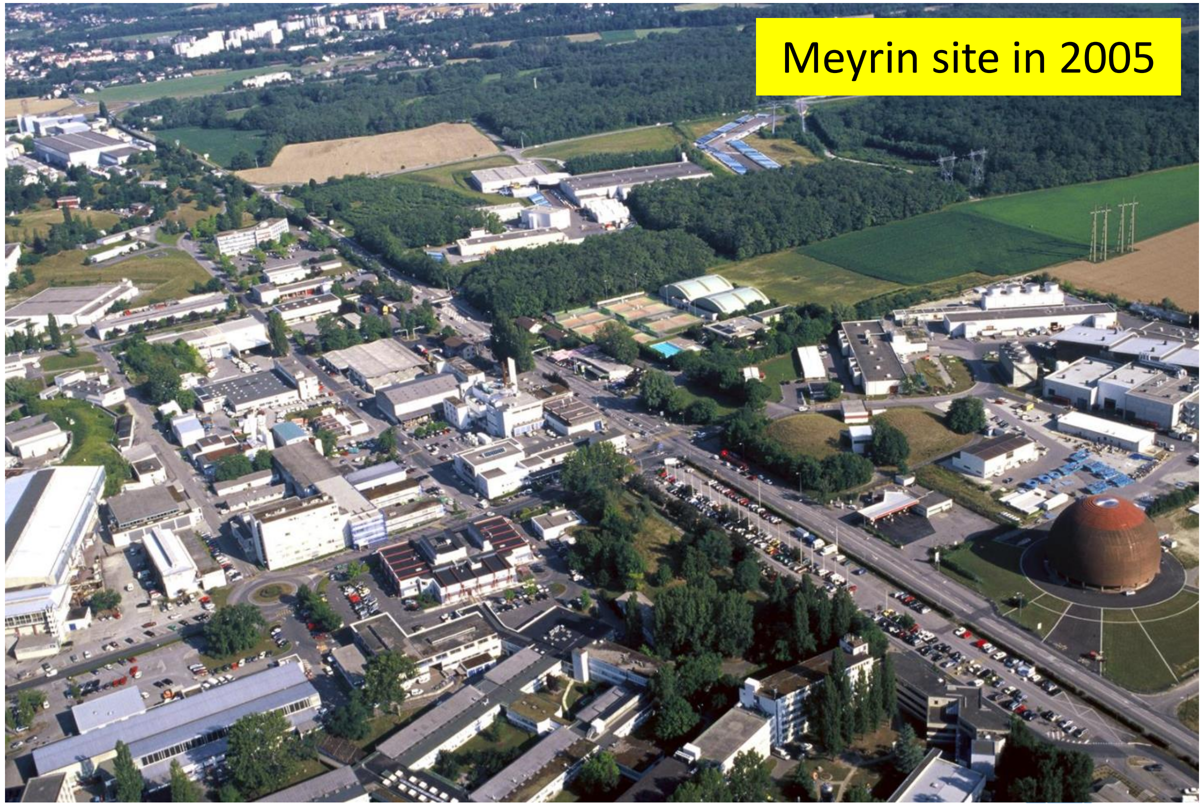
Involve experts from the outset.

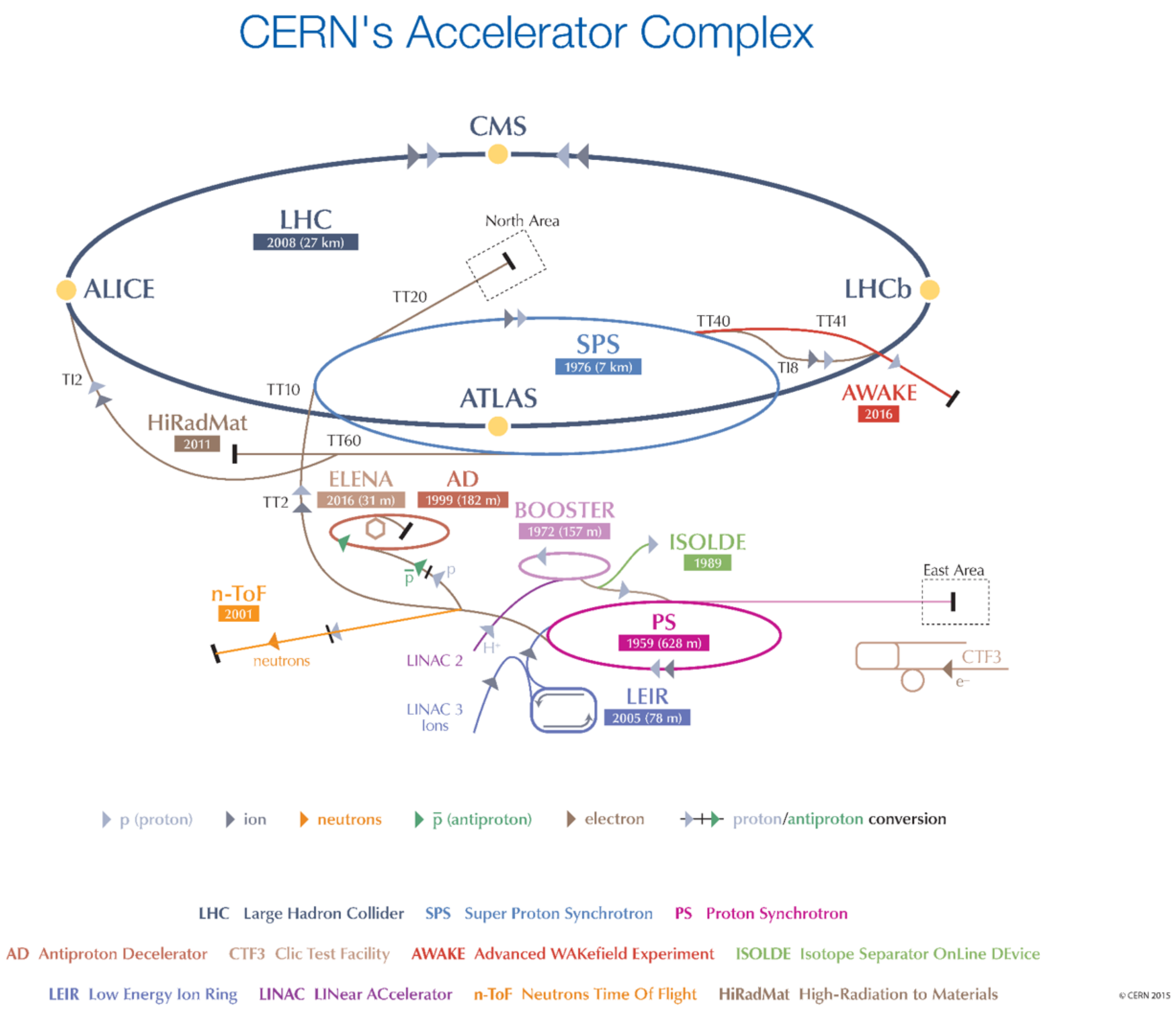
CERN and its accelerator complex

Funded in 1954 as "Science for Peace"

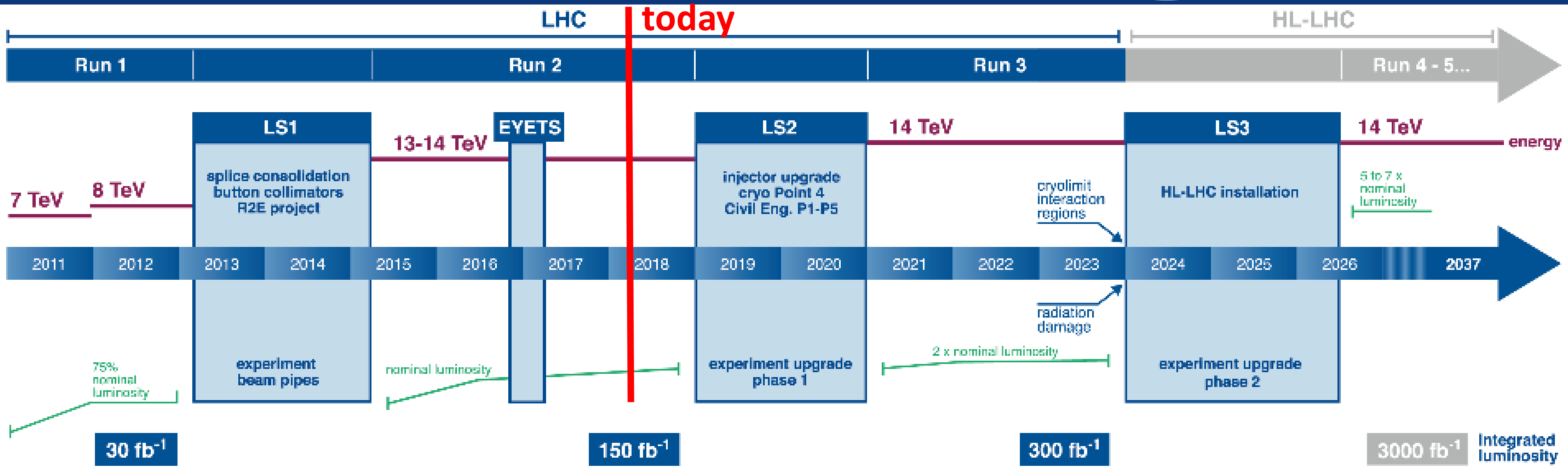
Meanwhile 22 member states

2'300 staff, 1'600 others and 10'500 users





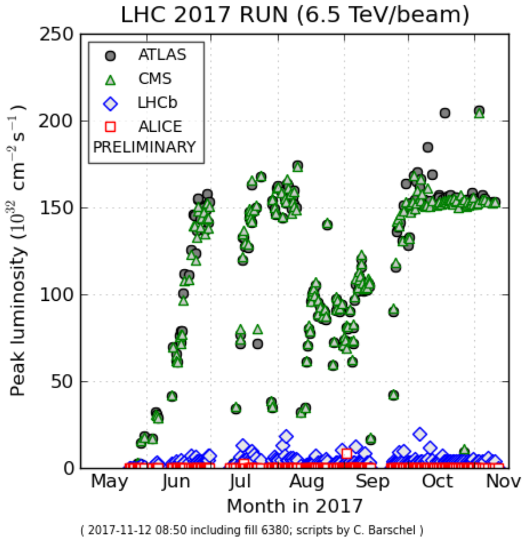
LHC / HL-LHC Plan

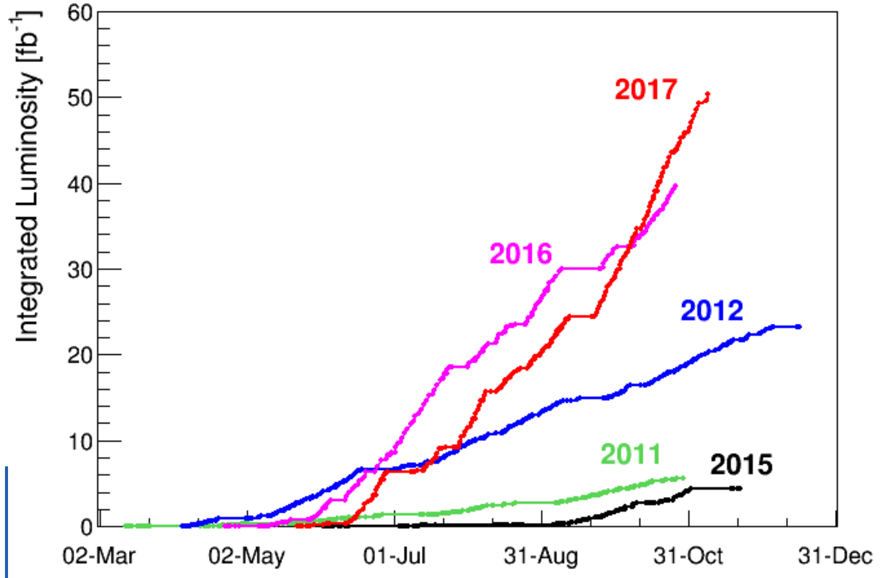


Peak luminosity
$2.2\ 10^{34}\ cm^{-2}\ s^{-1}$

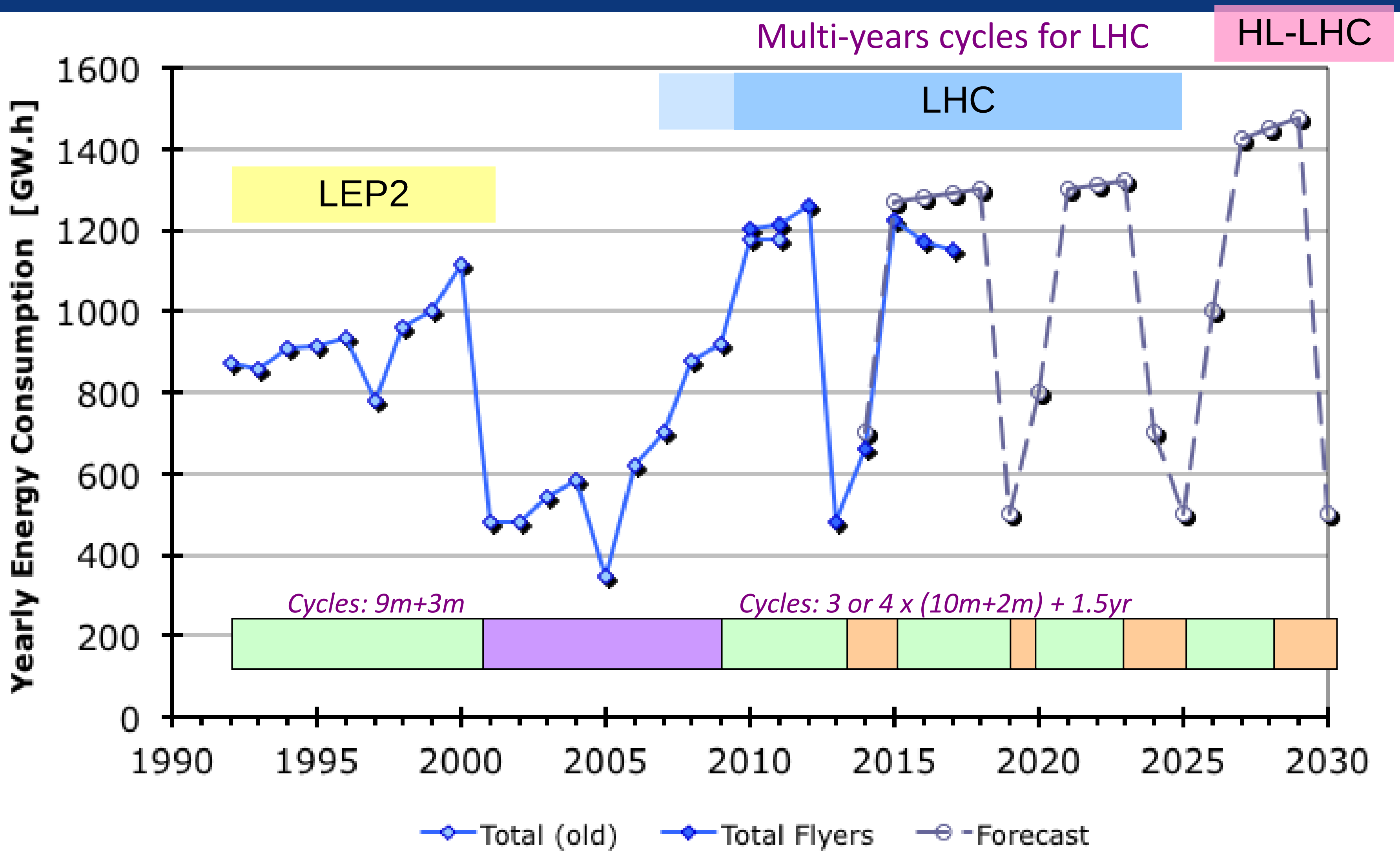
Luminosity levelling
$1.5\ 10^{34}\ cm^{-2}\ s^{-1}$

Nominal luminosity
$1.0\ 10^{34}\ cm^{-2}\ s^{-1}$



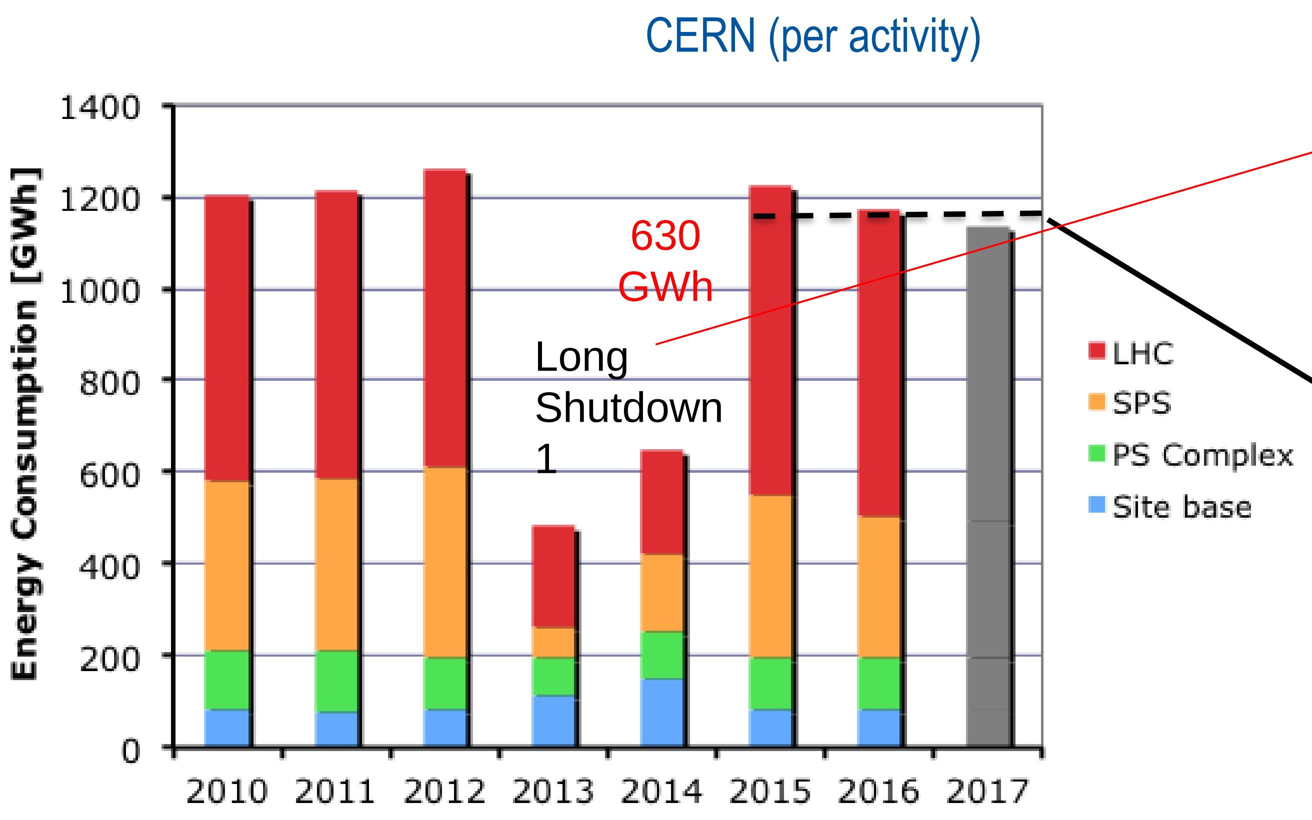


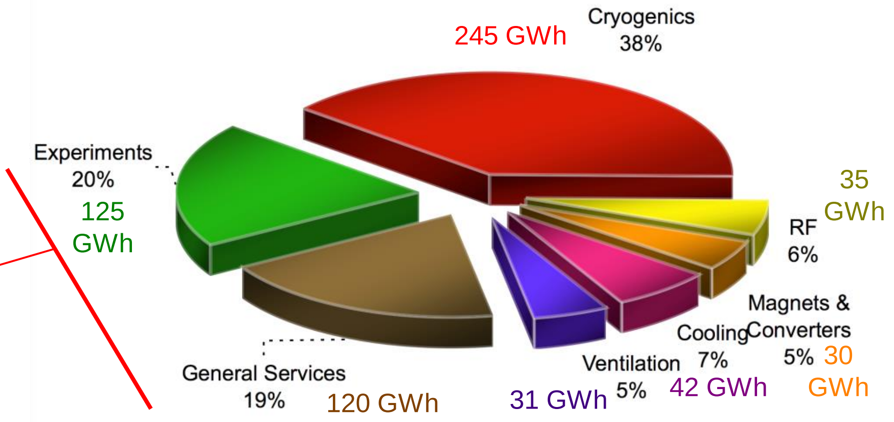
Evolution of energy consumption



Recent energy consumption

Compiled from yearly EN-EL Energy flyers





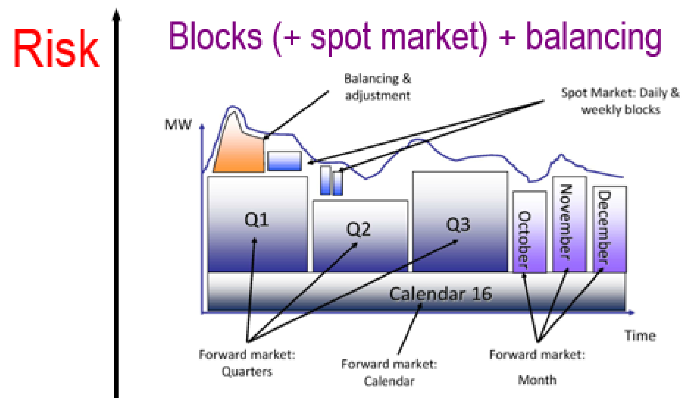
Breakdown (averaged) per major system for LHC

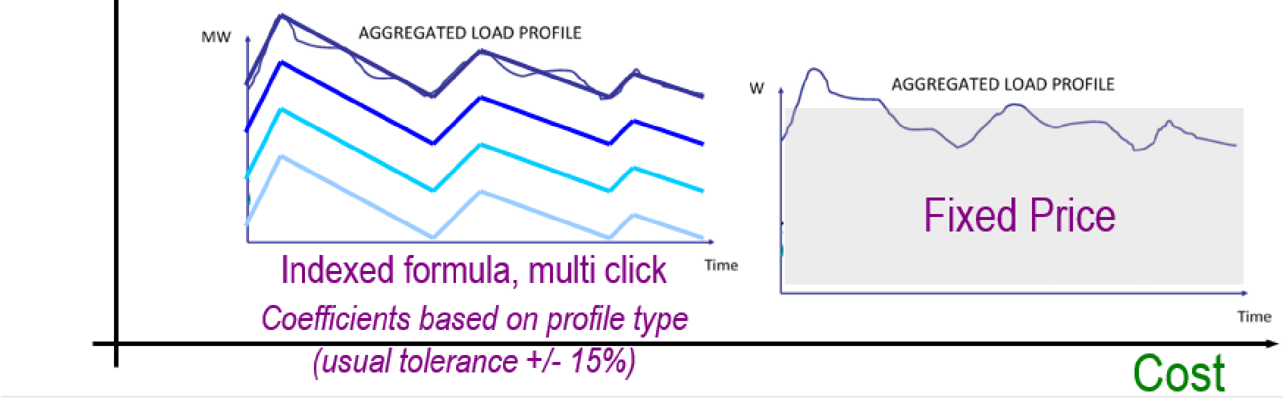
Contained consumption
(SPS-2016, EYETS-2017)

Buildings and conventional facilities represents about 10 % of the total consumption of electrical energy (similar for gas)

Energy Procurement

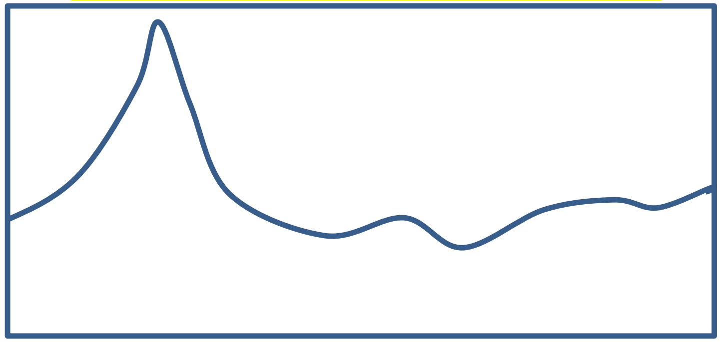
New electricity contract signed in autumn 2015 following one year learning phase, getting prepared for “market” mechanisms.



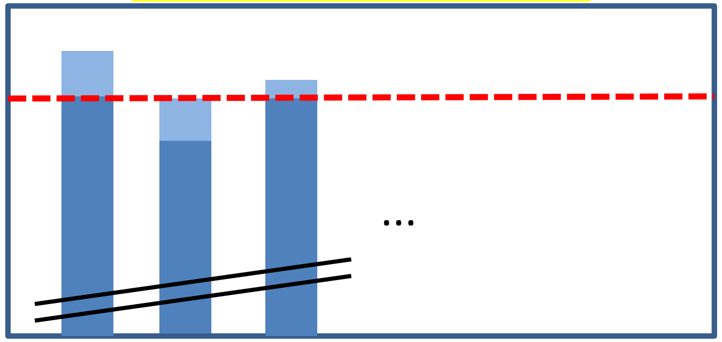


Forecast 2016-2020 (from 2015)

Evolution of electricity price



Adjudication criteria



CERN Energy Management Panel

A similar forum was already in place at CERN up to 10 years ago (power subscription, budgetary estimates)

(Oct. 2015)

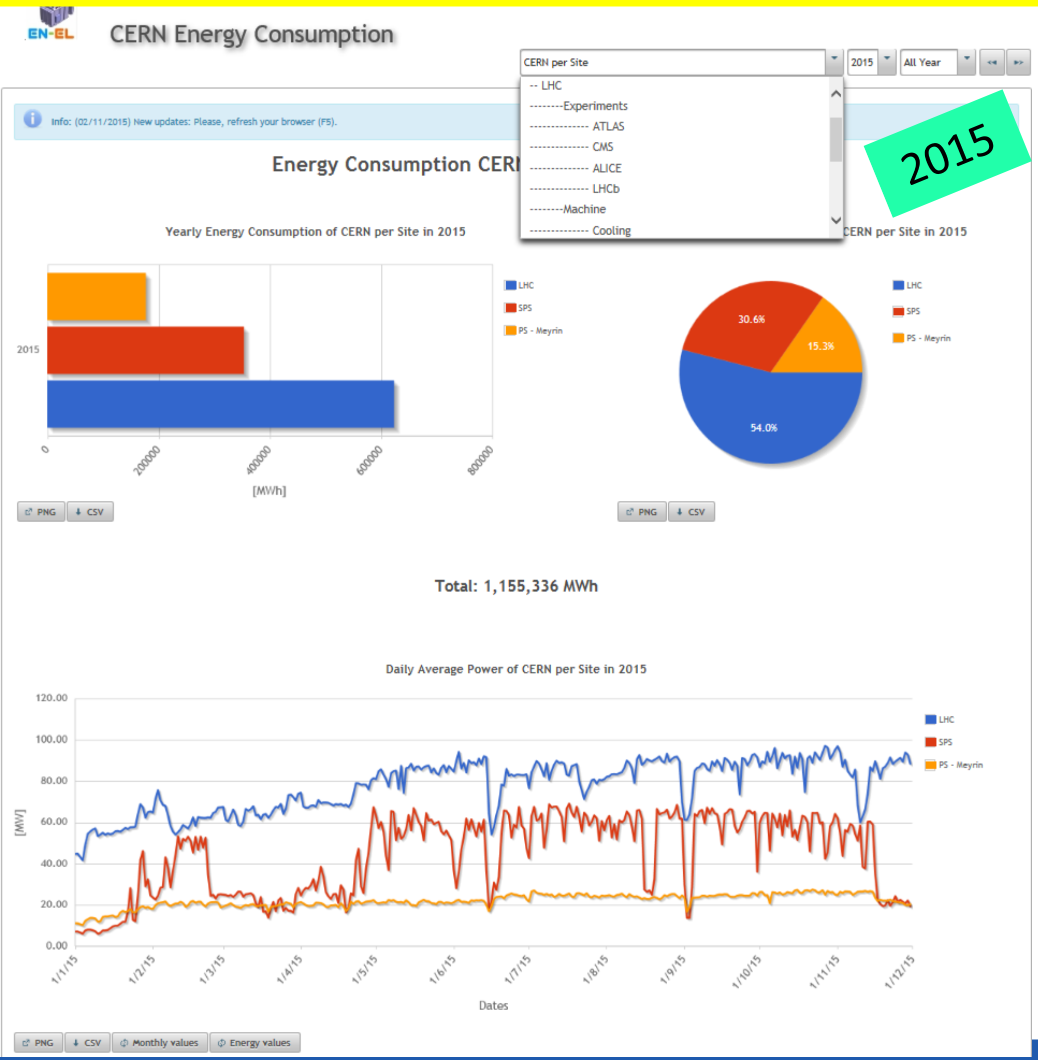
The CERN Energy Management Panel reports to the Director of Accelerators,
and is expected to bring all main energy consumers and stakeholders at CERN together in order to:

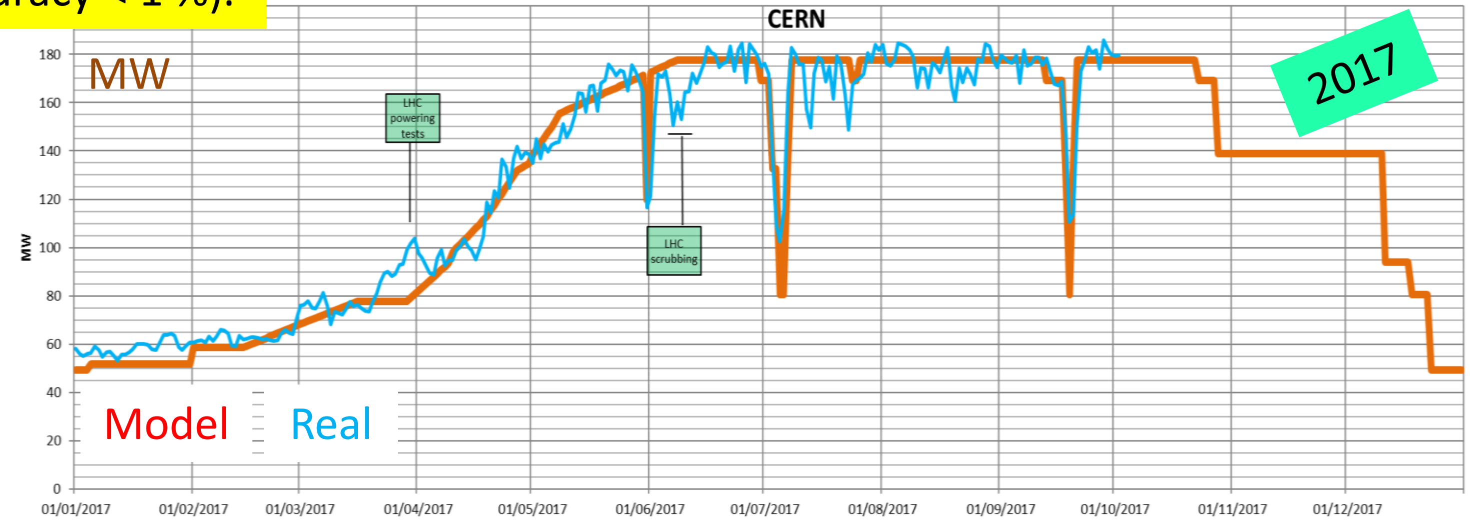
- Make the main energy consumers aware of the new conditions and rules under CERN's new energy supply contracts.
- Compile estimates of CERN's projected power and energy consumption up to and including HL-LHC, in coordination with the various users and EN-EL power network operations.
- Manage CERN energy consumption, with regular checks against planned consumption.
- Define how CERN will handle changes to projected energy consumption due to changes in programs, both foreseen and unforeseen.
- Implement the mechanism by which CERN will inform CERN's energy supplier(s) of changes to the projected energy consumption.
  The mechanism itself will be defined in the supply contract(s).
- Develop degraded operation scenarios for periods of reduced power availability. EN/EL will provide the estimations for the reduced available power.
- Define and implement the mechanisms by which the degraded operation scenarios, as defined above, will be triggered.
- Make recommendations to reduce CERN's energy bill with minimal impact on CERN's operations.

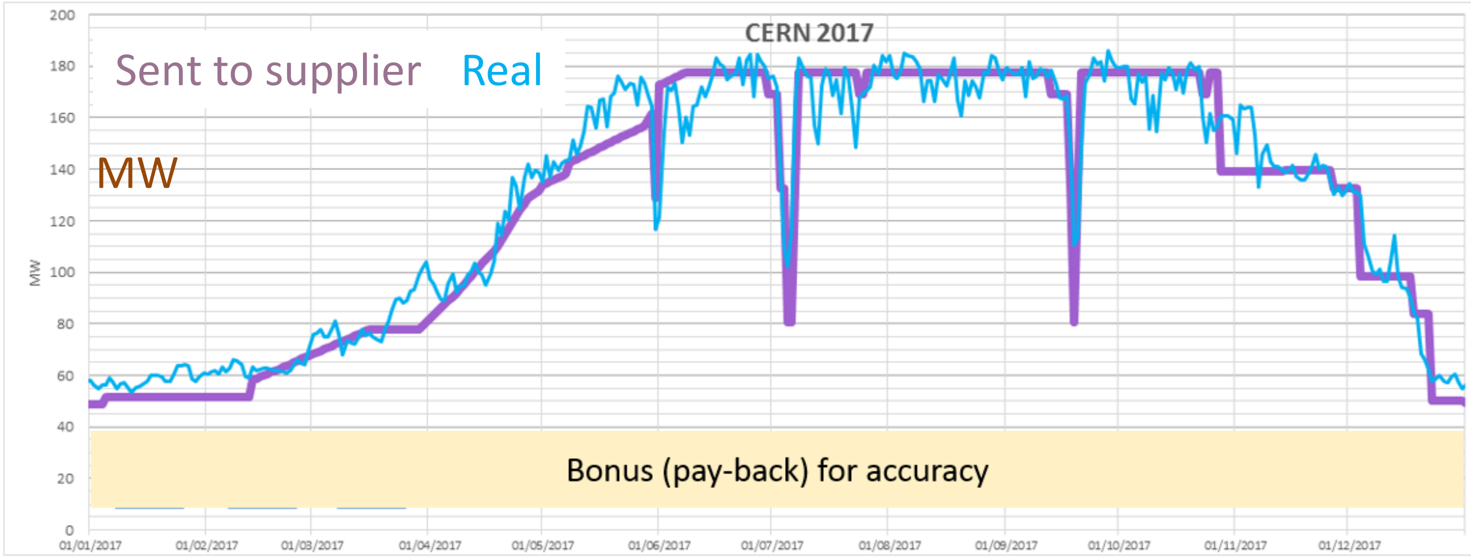
Sending virtual invoices to activity and group leaders, with tables & graphs showing energy consumed [GWh], and indicative MCHF for them and CERN

Forecasting and monitoring electricity consumption

Dedicated online tool developed by EN-EL (global accuracy < 1 %).







Realised improvements
Renovation projects

Initiated by teams, validated by direct management convinced from potential savings

- Computer centre (2011-2012), *Gain: 5-6 GWh/yr*
  - Free cooling and air flow optimisation
- LHC Cryogenics (2010-2012), *Gain ≈ 40 GWh/yr to 20 GWh/yr*
  - Towards higher availability with less machines in operation, resulting in operation modes with an increased efficiency
- SPS Beam operation (2014 onwards), *Gain: 35 GWh/yr to 55 GWh/yr*
  - Powering cycles and stand-by modes

To come: East area Project (2019-2020), principle as for SPS (“power when beam in”)

Renovation projects:

- Incentive is given to insert “energy efficiency” actions, in a structured way.
- In case not straightforward, baseline renovation should be done with “as is” technology, and with incentive included in the call for tender for more energy efficient solutions (e.g. adjudication on CAPEX + OPEX over 10-15 years).

Energy efficiency for buildings and site facilities

Strong incentive with market-based energy contracts in France. Evaluation with external specialists, conclusions in 03/2018.

Large halls (100 m x 40 m x 15 m) heating improvement, stratification?

Combined production of warm and cold for CERN restaurants (n100e/day)

Improvements for cooling towers fans & pumps, VFD's

Central compressed air distribution improvements and heat recovery

Power distribution and high efficiency power transformers

Lighting improvement for some large halls, CERN streets and car parks

Heat recovery from LHC-P8 to external heating network in surroundings

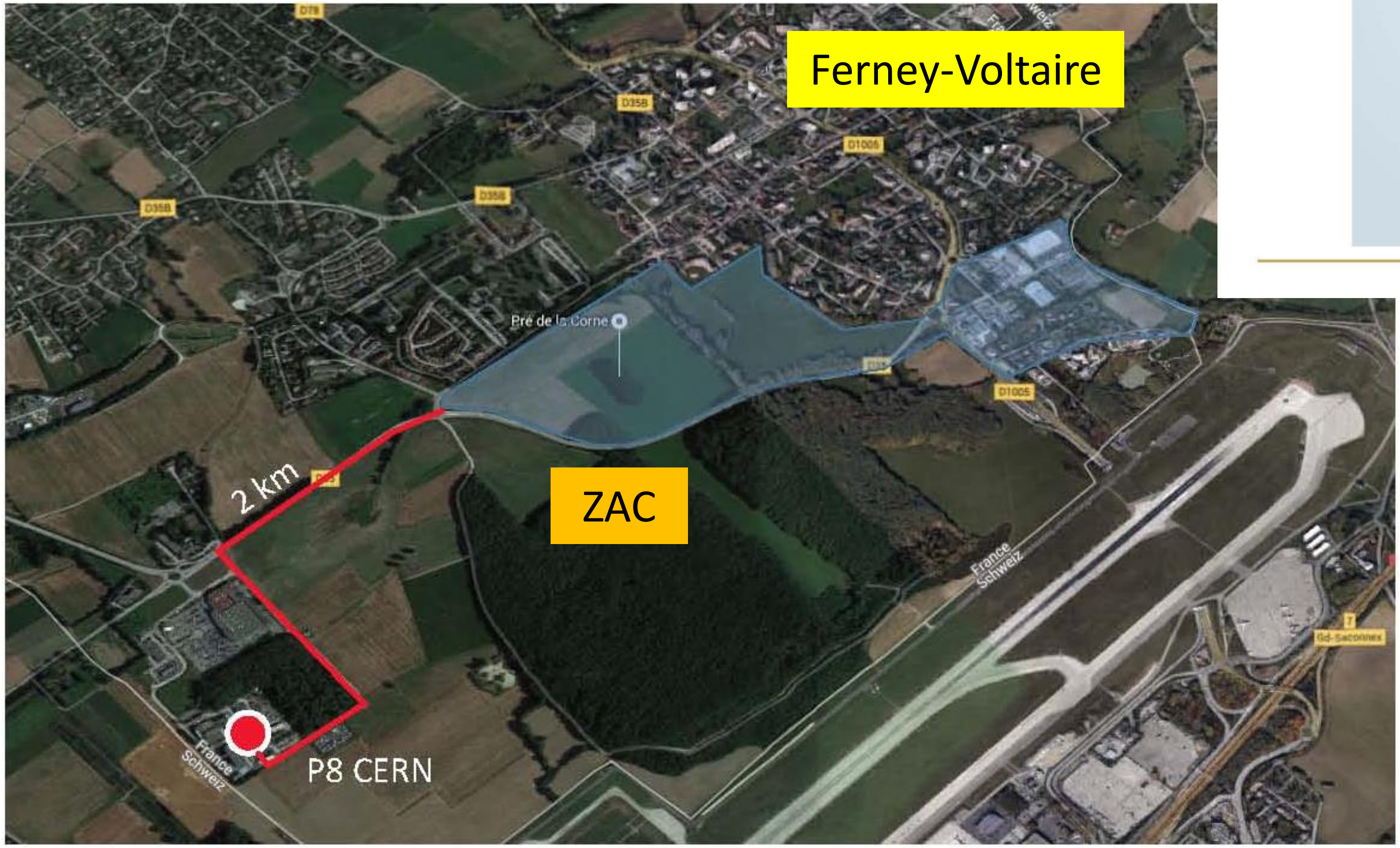
Heat recovery from P1 to Main CERN Meyrin site, heat pump

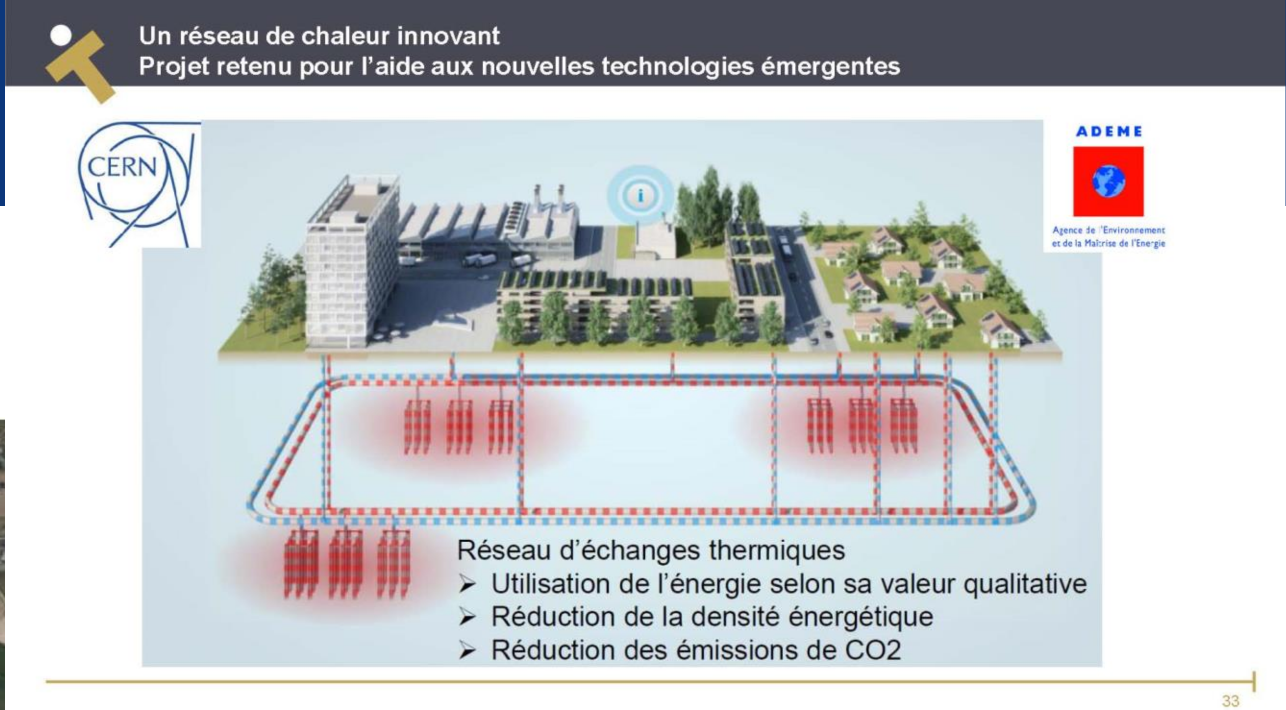
Preliminary feedback:

- Global situation rather healthy at CERN, correct approach in case of revamping
  (energy efficiency alternatives considered on a 10-15 years time horizon (long-term))
- Improved monitoring of fluids (air, heating system) could help
- Heat recovery to be further evaluated; clearly strong potential

Waste heat recovery

Thermal energy from LHC-P8 to be injected in a local “anergie” loop (ZAC Ferney-Voltaire)





Preliminary technical feasibility done, followed by economical evaluation (2016)

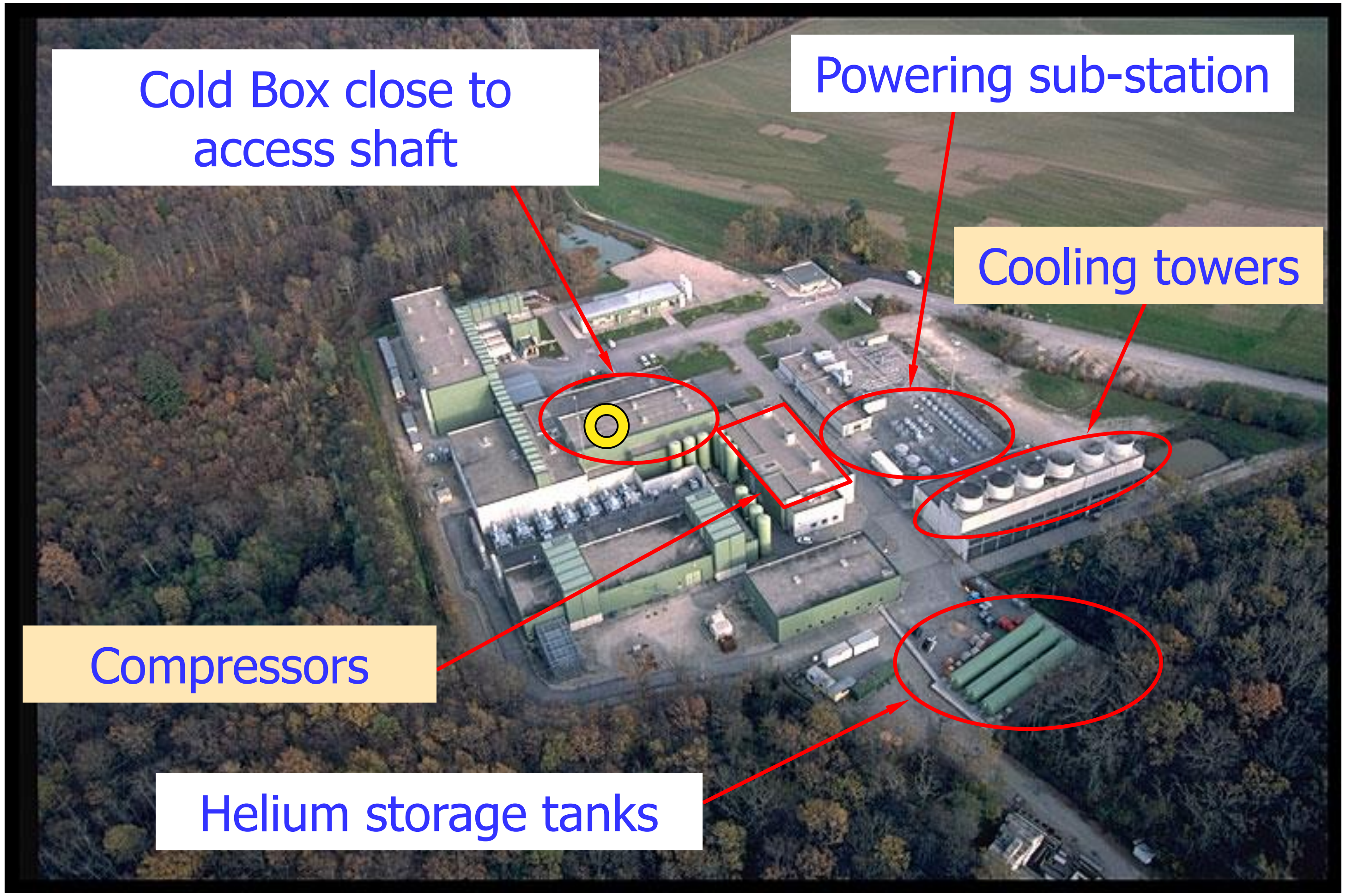
Letter of intent, recalling basic principles (heat recovery when available, balanced costs for CERN on long term) end 2017

Convention to be finalized in Q2/2018

Installation on CERN side on LS2 (2019/20)

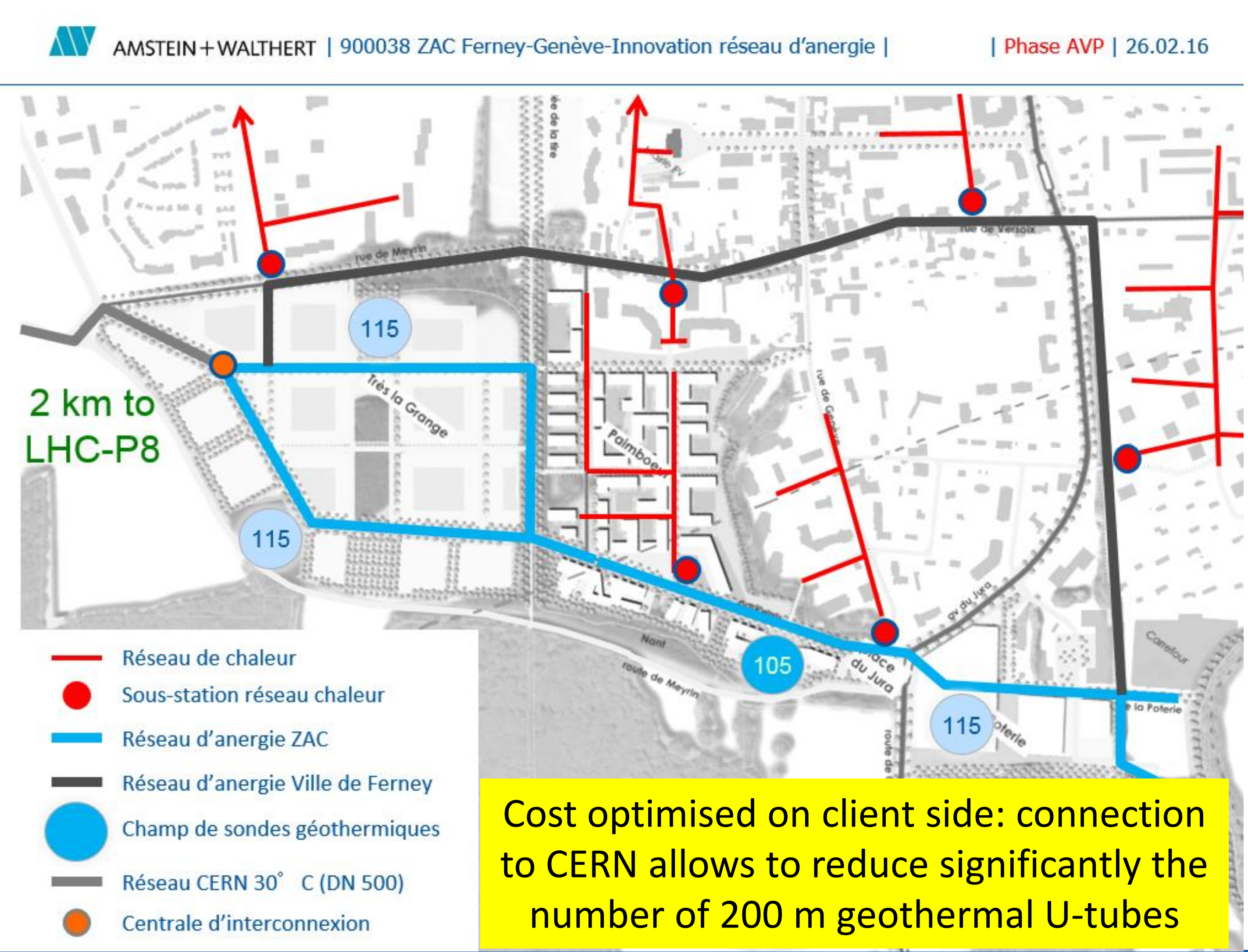
Progressive heat recovery starting 2021

Waste heat recovery

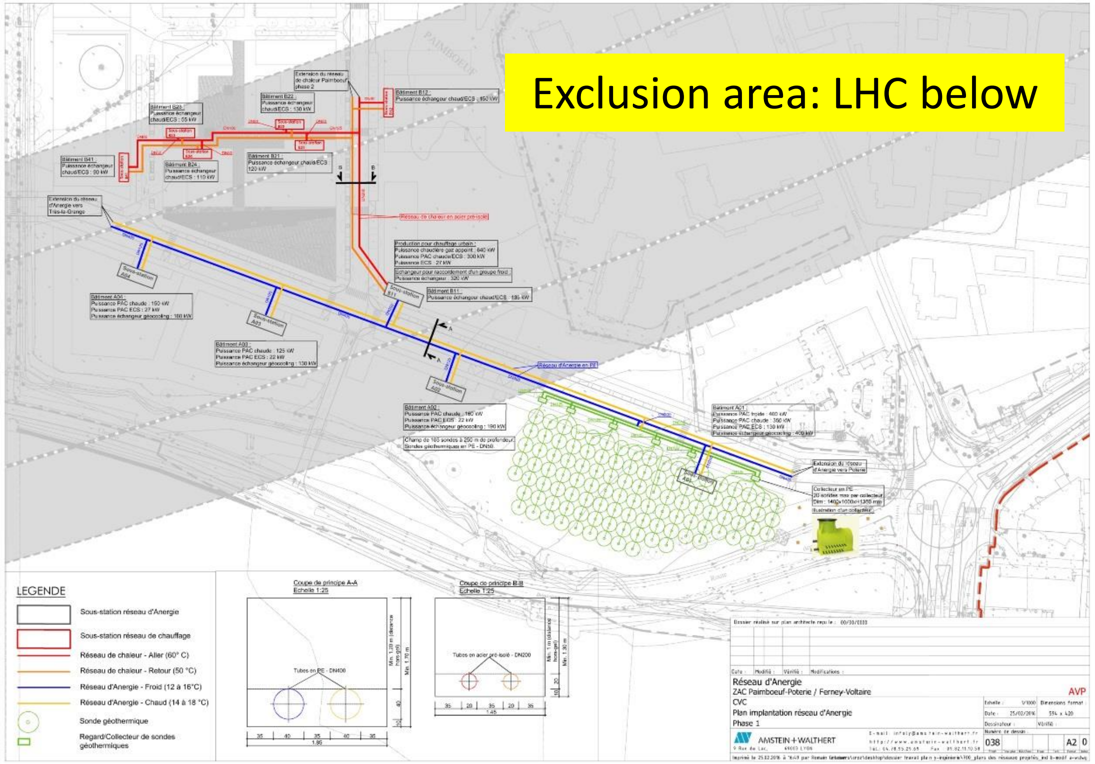


Heat exchangers to be located next to towers, with connections to supply pipe below and external duct towards CERN limit.

Waste heat recovery

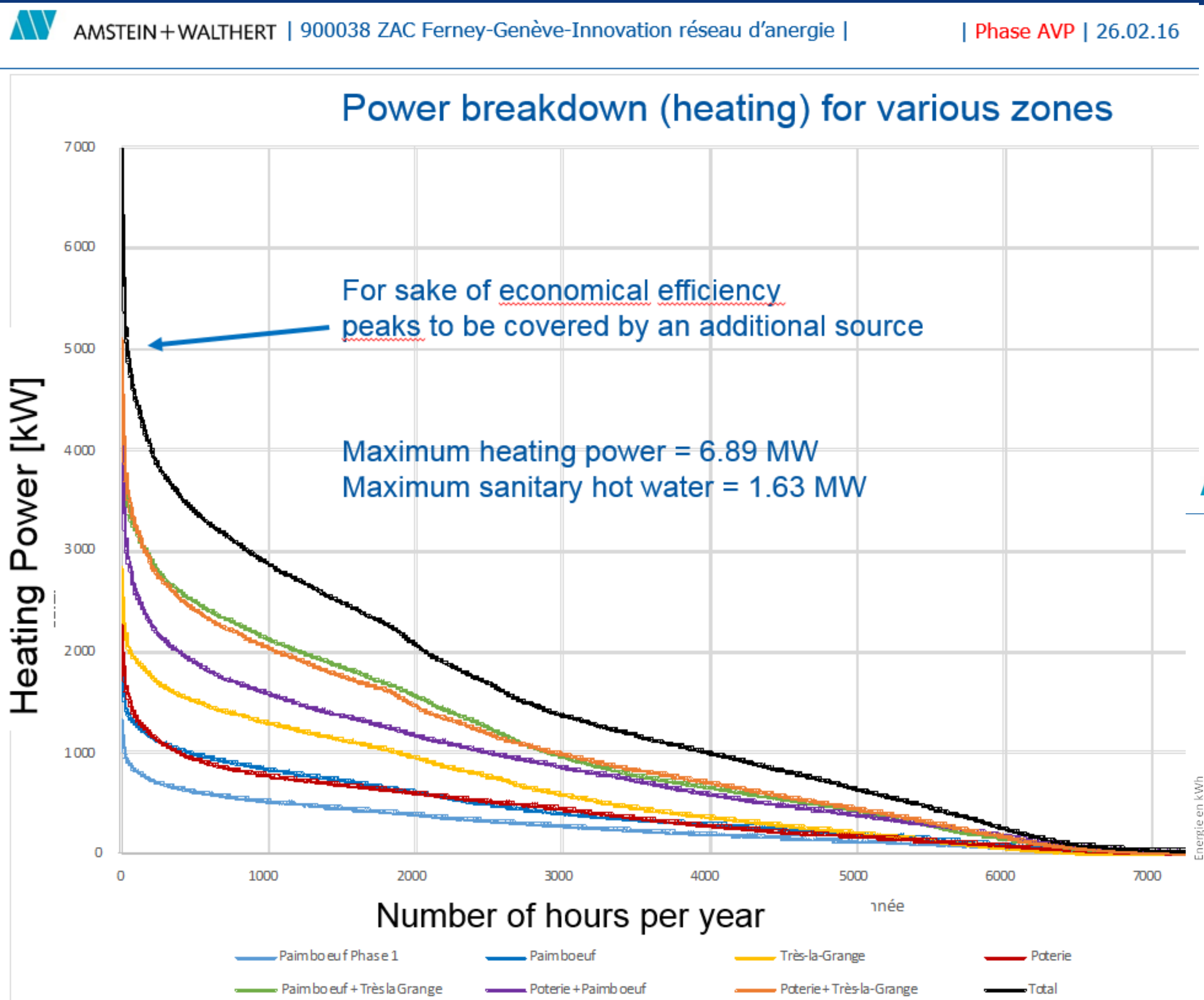


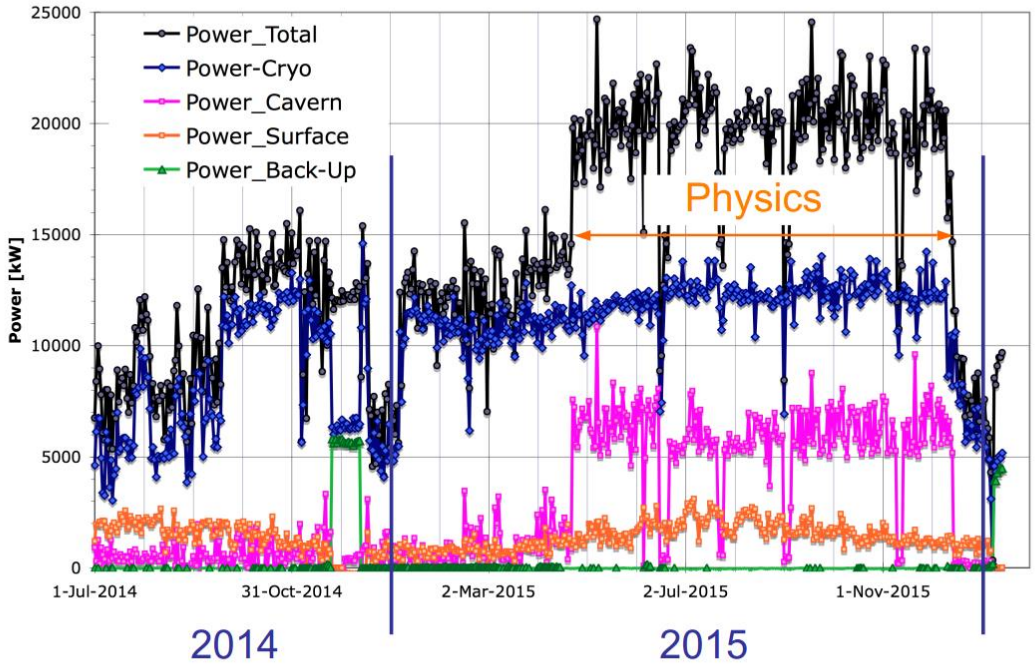
Cost optimised on client side: connection to CERN allows to reduce significantly the number of 200 m geothermal U-tubes

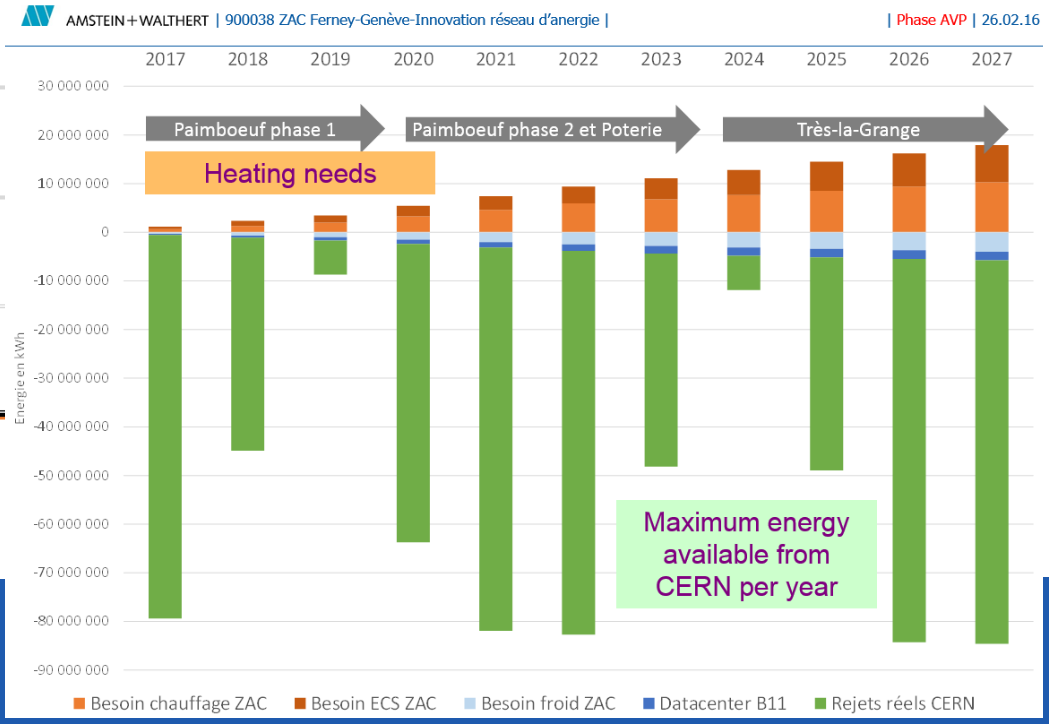


Exclusion area: LHC below

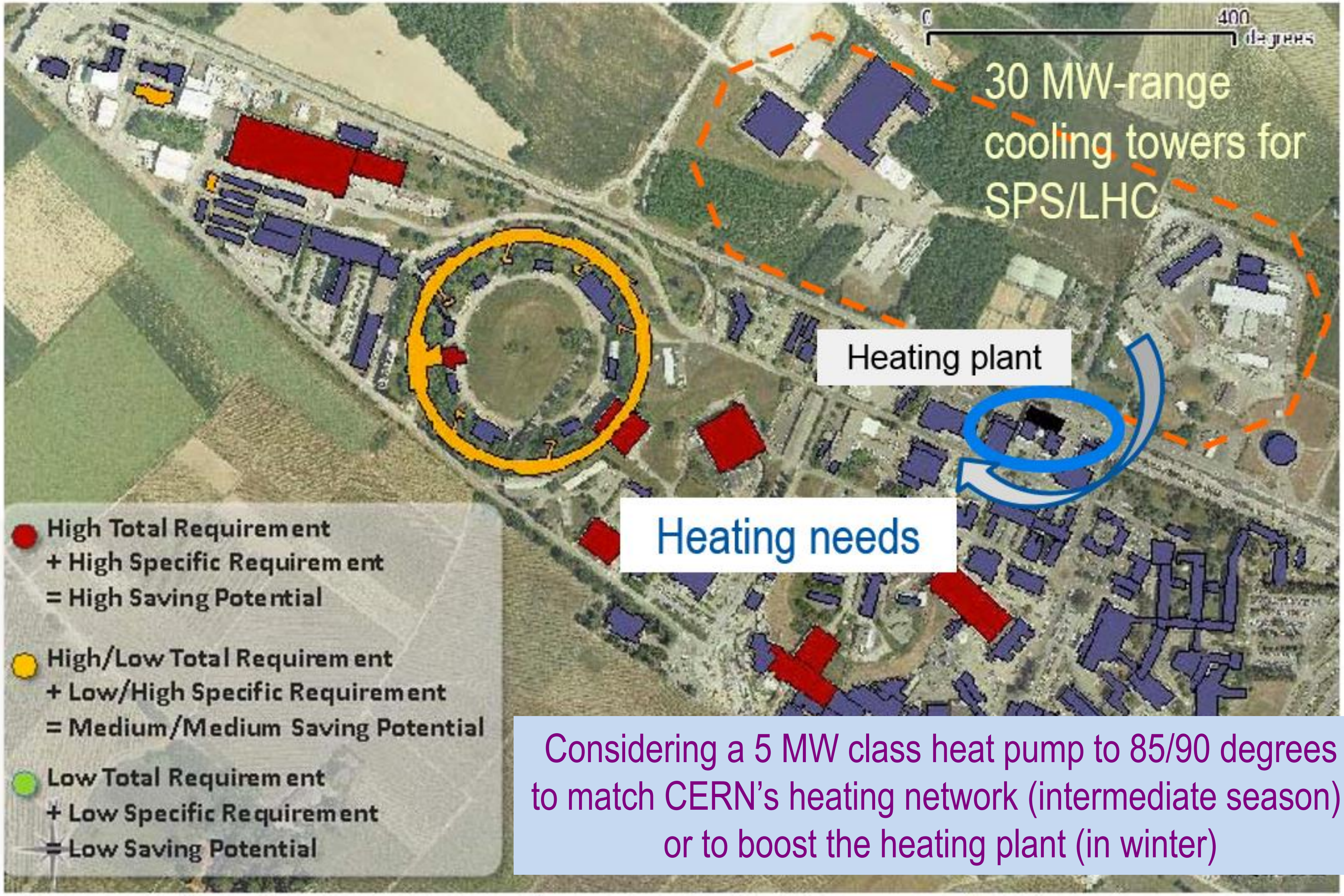
Waste heat recovery







Internal heat recovery (study with EDF)

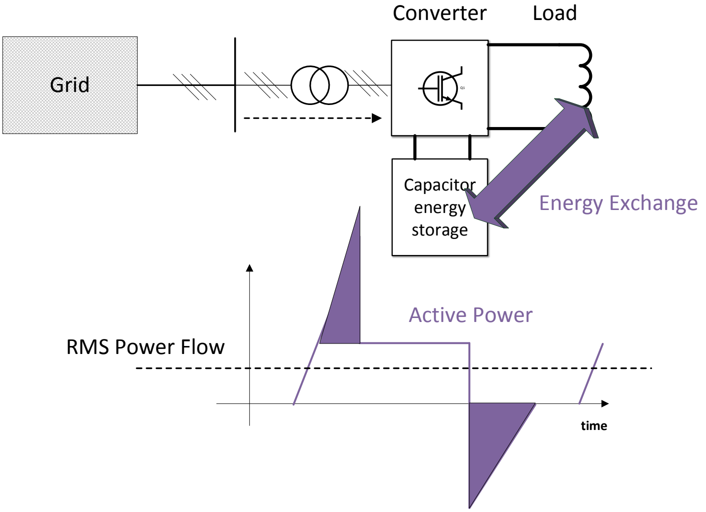


Biggest energy consumers among buildings on Meyrin site

Considering a 5 MW class heat pump to 85/90 degrees to match CERN's heating network (intermediate season), or to boost the heating plant (in winter)

Storing energy from magnets at FCC

Peak energy to flow between load and storage



Similar to already realized PS main powering system

To be generalized as much as possible for efficiency.

Peak Power of the Converter= 60 MW

2 x 2,5 MVA

18 MJ

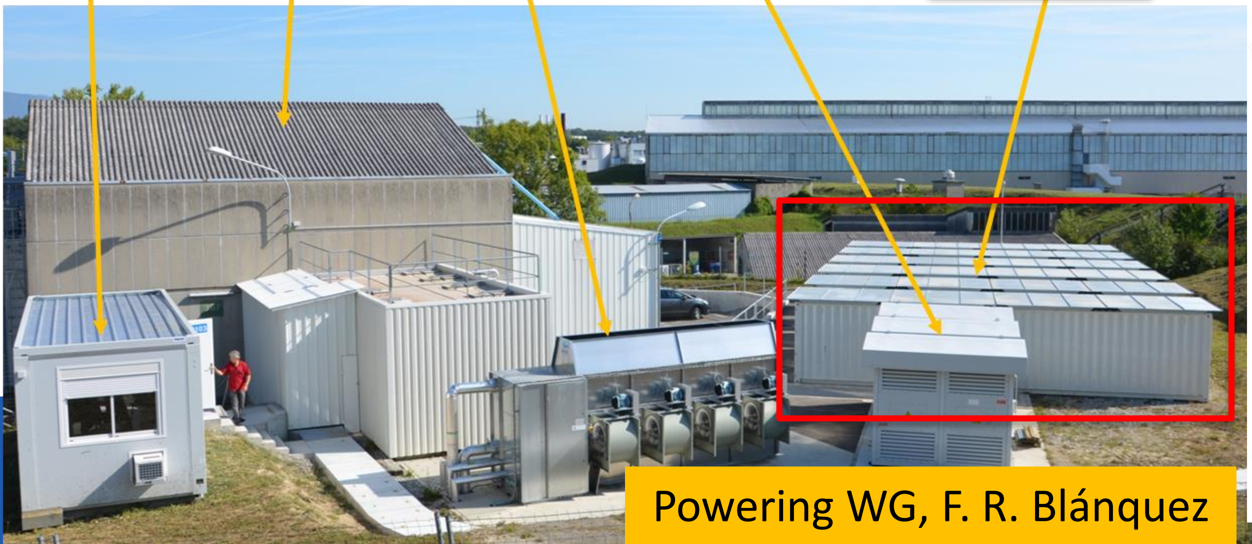
Control Room

Converter hall

Cooling Tower

Input Transformers

Capacitor banks

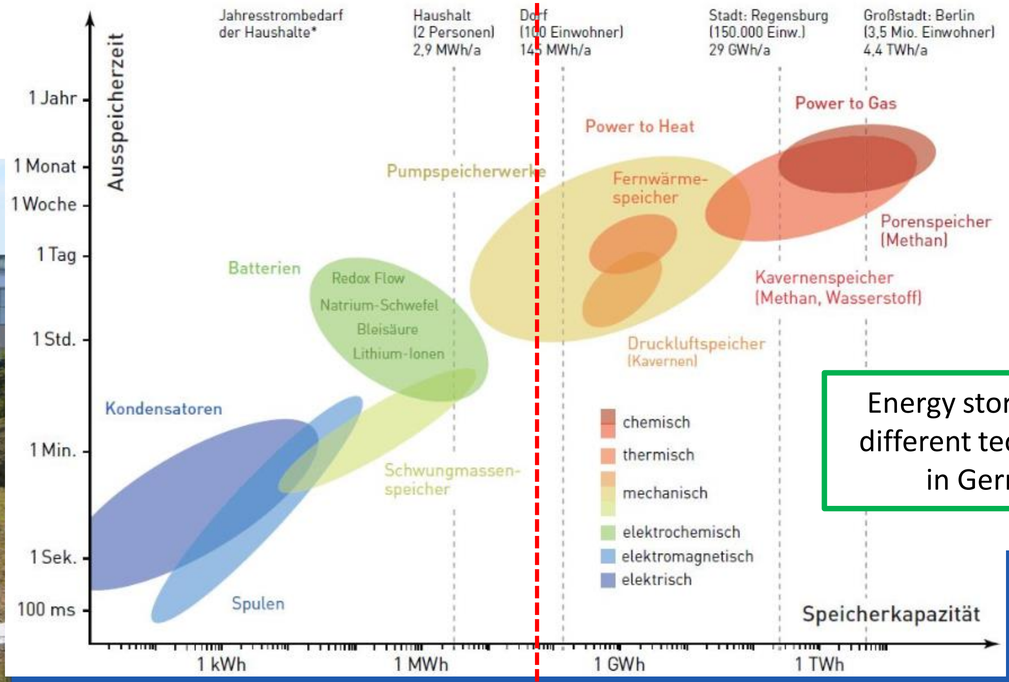


Powering WG, F. R. Blánquez

FCC power converters should be switch-mode (LHC: thyristor) → Possibility of DC storage, smaller AC link, less harmonics injected in AC, no reactive power compensation required, more efficient.

Storage dimensioning per dipole circuit (*100): 1.65 GJ = 458 kWh + cable/connection losses + charge/discharge losses = 550 kWh

Storage cycle relatively slow → suited for battery storage (ca. 10 19” racks per circuit (LHC PC = 20 racks). Presently promising: LTO = Lithium-titanate (lower energy density but excellent cycling performance). *Expect further evolution.*



TH Regensburg, FENES-Report 2013 http://www.energie allianz-bayern.de/cms/Speicher/Energiespeicher/Speichertechnologien-in-D.JPG

Energy storage systems using different technologies realised in Germany by 2013

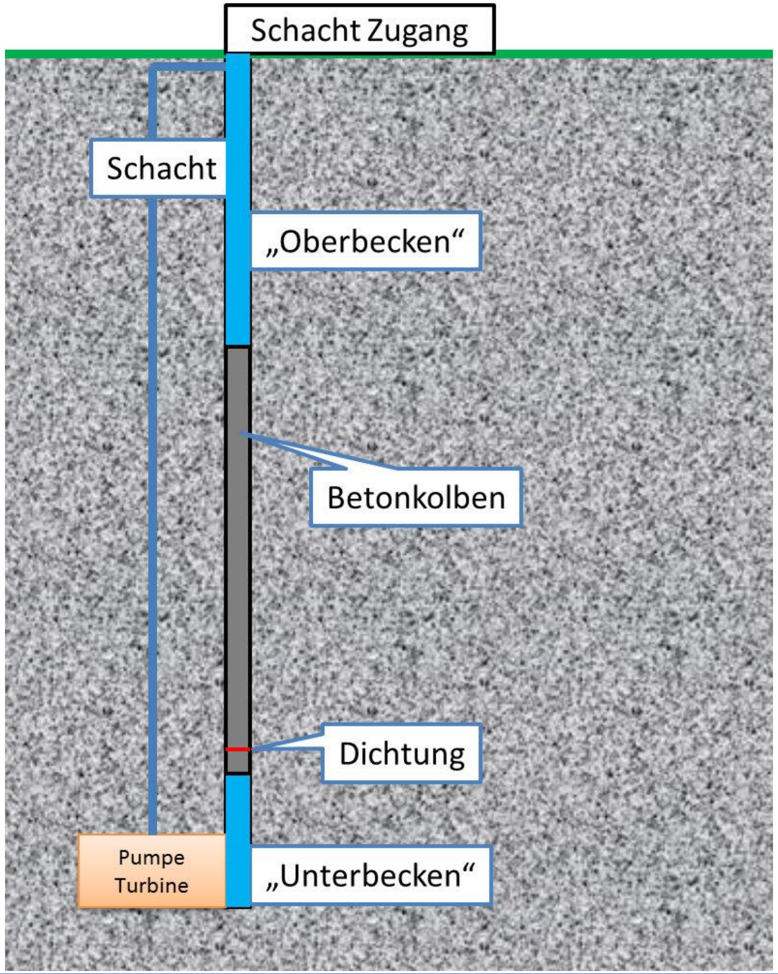
Other types of energy storage

https://heindl-energy.com/

$E = m*g*h$

Example:
d = 100 m,
h = 200 m,
Δh = 100 m
→ 68 MWh
(w/o losses)

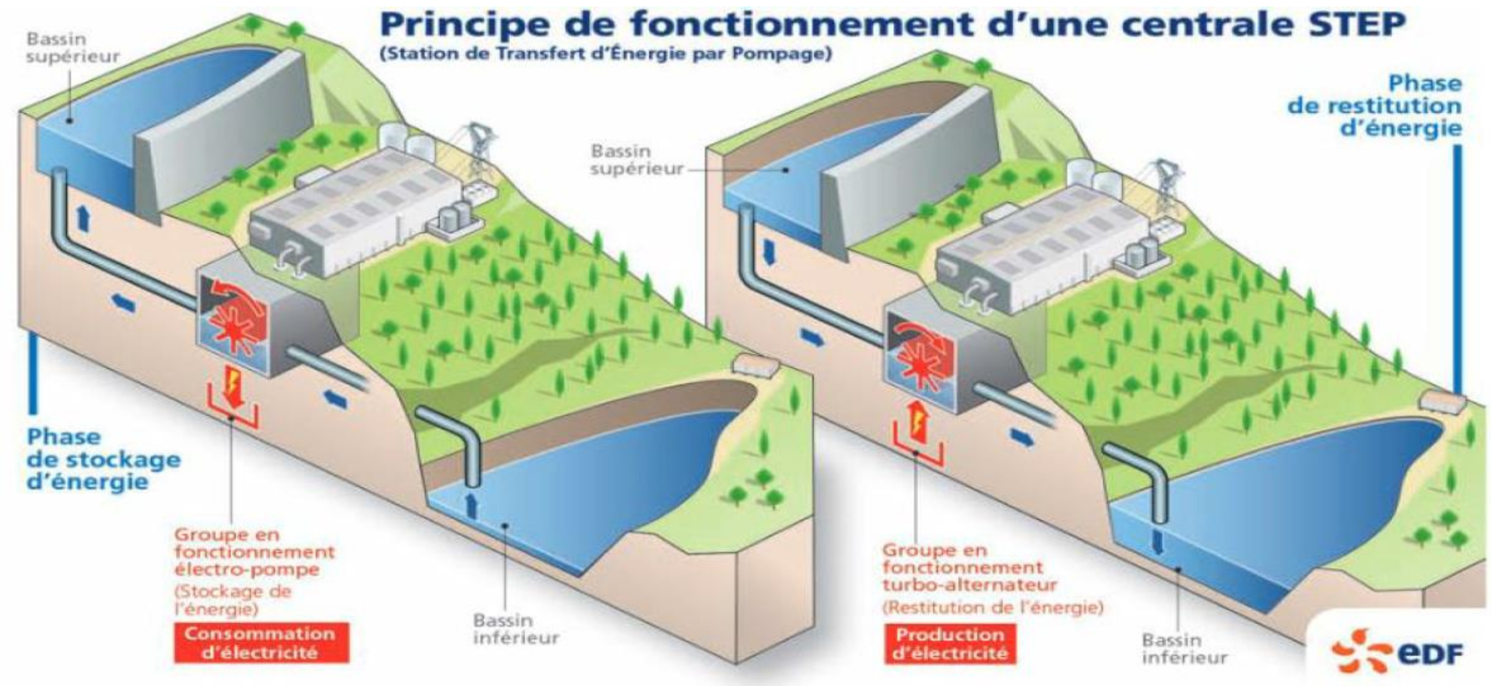
https://www.gravitypower.net/



Re-using construction shafts or excavated spoil (9E6 m^3 = 210 m cube) ???

Other types of energy storage

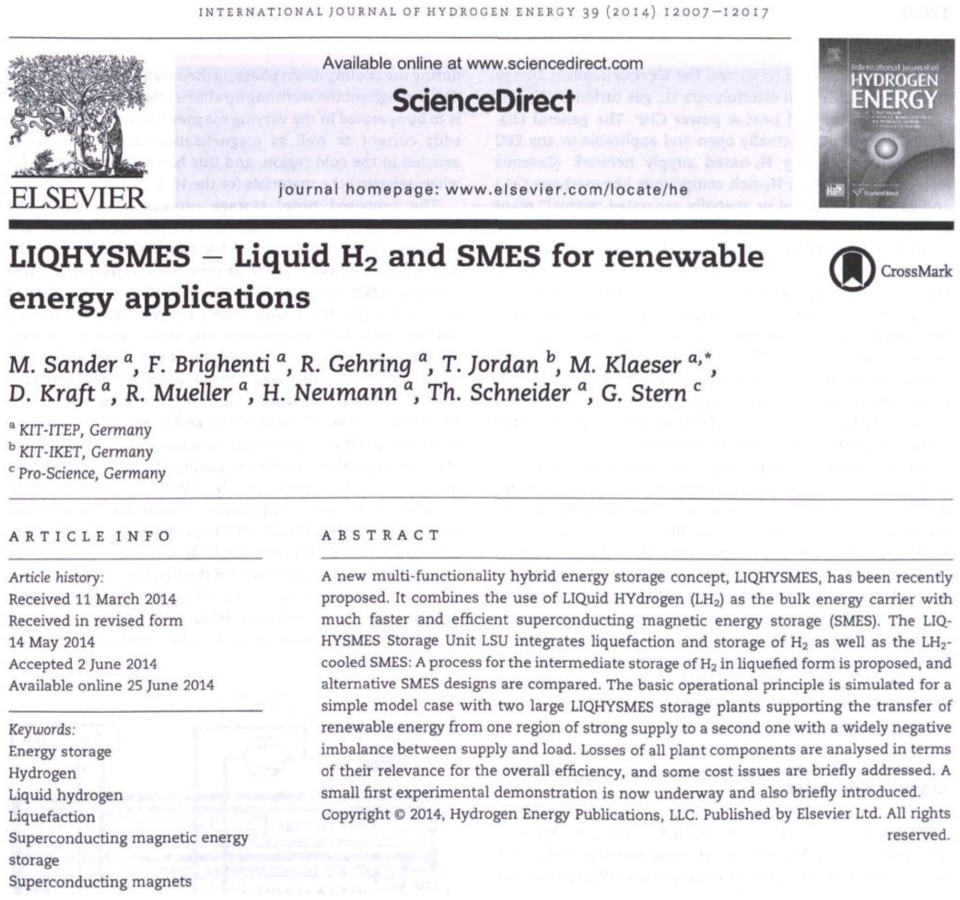
http://www.visiatome.fr/Local/visiatome/files/908/STEP.pdf



Storage power plant – not needed for FCC, but possibly interesting for electricity provider, profiting from FCC civil engineering ??

SMES, possibly in combination with larger (but slower) energy storage.

Proposal by KIT: LIQHYSMES



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LIQHYSMES – Liquid H_2 and SMES for renewable energy applications

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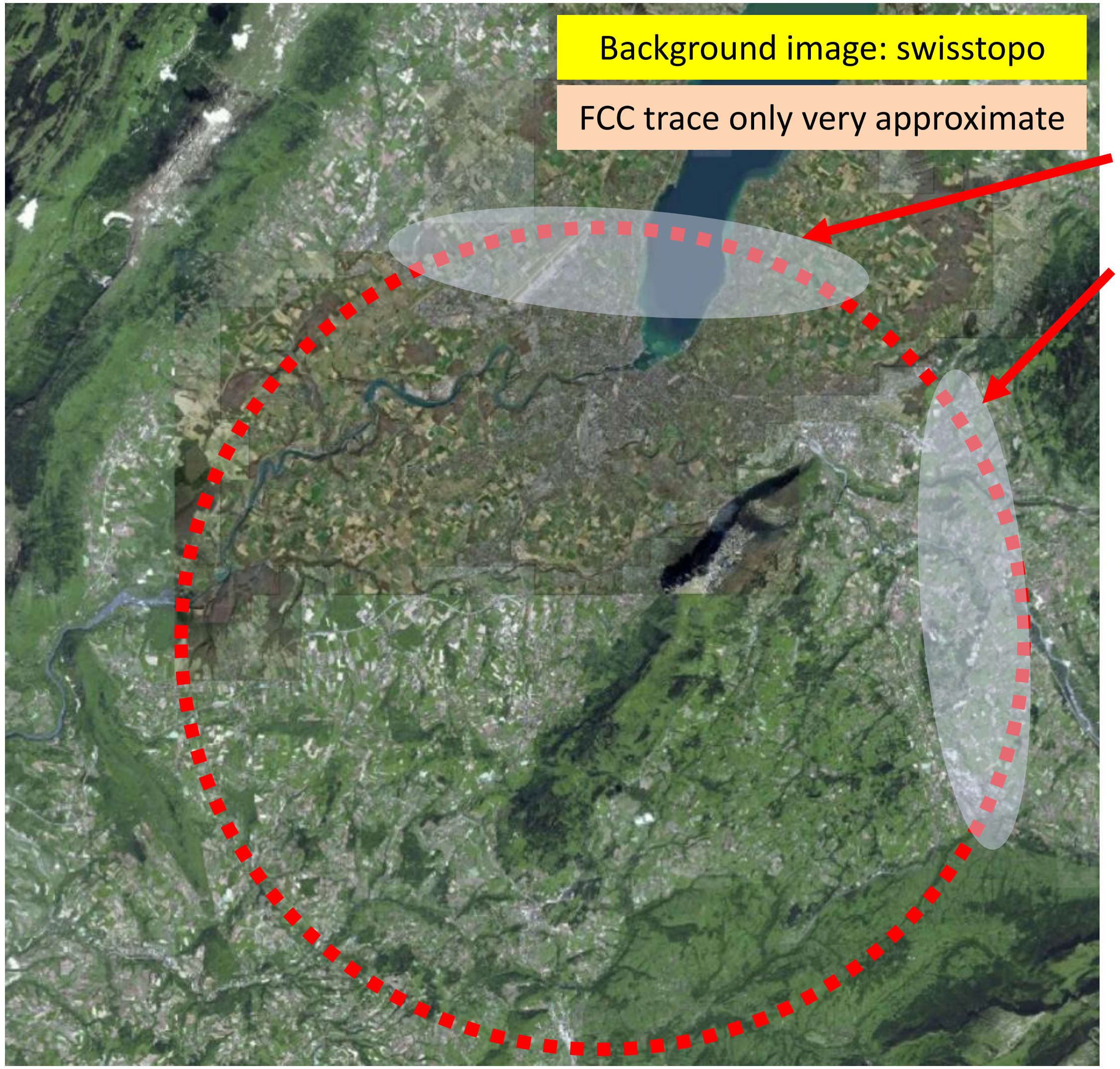
ABSTRACT

A new multi-functionality hybrid energy storage concept, LIQHYSMES, has been recently proposed. It combines the use of LIQuid HYdrogen (LH_2) as the bulk energy carrier with much faster and efficient superconducting magnetic energy storage (SMES). The LIQHYSMES Storage Unit LSU integrates liquefaction and storage of H_2 as well as the LH_2-cooled SMES: A process for the intermediate storage of H_2 in liquefied form is proposed, and alternative SMES designs are compared. The basic operational principle is simulated for a simple model case with two large LIQHYSMES storage plants supporting the transfer of renewable energy from one region of strong supply to a second one with a widely negative imbalance between supply and load. Losses of all plant components are analysed in terms of their relevance for the overall efficiency, and some cost issues are briefly addressed. A small first experimental demonstration is now underway and also briefly introduced.

Waste heat recovery



Points with greater density of habitations: A, B, C (in CH)

Points with greater density of habitations: D, E, F (in F)

Requirements/opportunities/infrastructure conditions (heating networks) to be evaluated.

Points in rather rural areas: G, H, I, J, K, L

Opportunities for development (e.g. „Technoparcs“, indoor farming) to be evaluated.

→ Potential exists; details to be studied in relation with host states.

Concluding remarks

1. Consume less by making good design choices. LESS

   At CERN level, primary energy consumption has been kept constant while LHC is producing more physics output, mostly due to initial design choices (superconductivity w.r.t normal conducting).

2. Be “energy-aware” and use energy more efficiently. BETTER

   Energy management is in place with good forecasts and monitoring tools.
   Energy efficiency awareness is progressively diffusing through the CERN community.

3. Recover and re-use energy (or make it available). RECOVER

   A series of energy efficiency studies have been started (with not many easy savings to be expected).
   Two MW class heat recovery projects are under study, with decisions to be taken in 2018.

At FCC, peak power demands (accelerator ramping) should be shaved off by local energy storage.

Potential for heat recovery exists, but needs in-depth study (be realistic).

Other possible synergies (energy providers, infrastructure development) can be evaluated.

Technical evolution should (and will) help.

CERN

www.cern.ch

Annex

CERN's electrical distribution