CERN plans towards energy efficiency

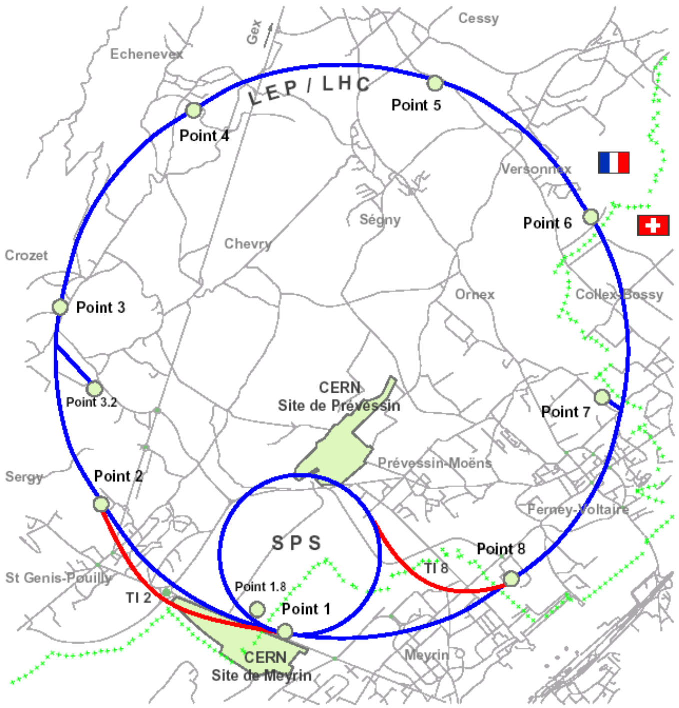
Serge CLAUDET

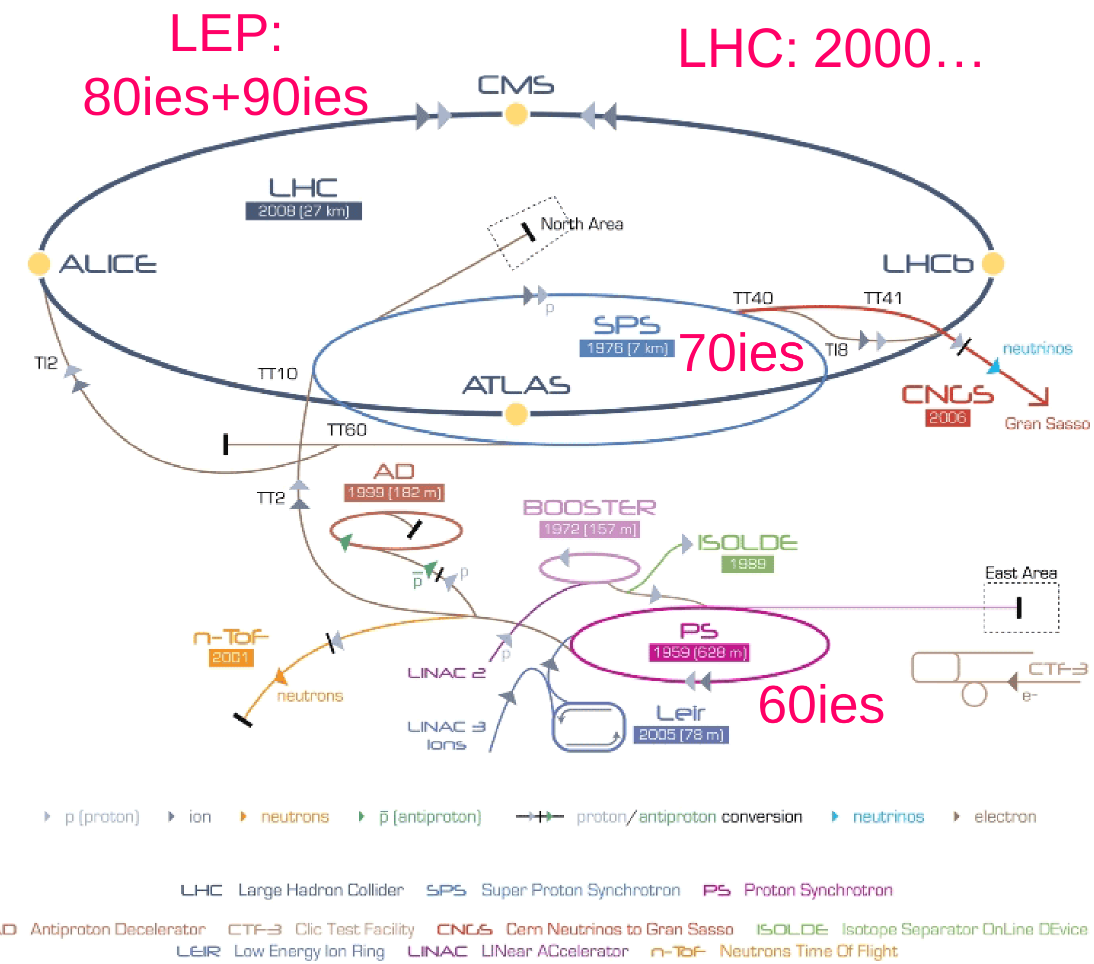
Nov 2014

Content

- Introduction to Energy at CERN
- Tendency, few recent cases
- Perspectives
- Summary

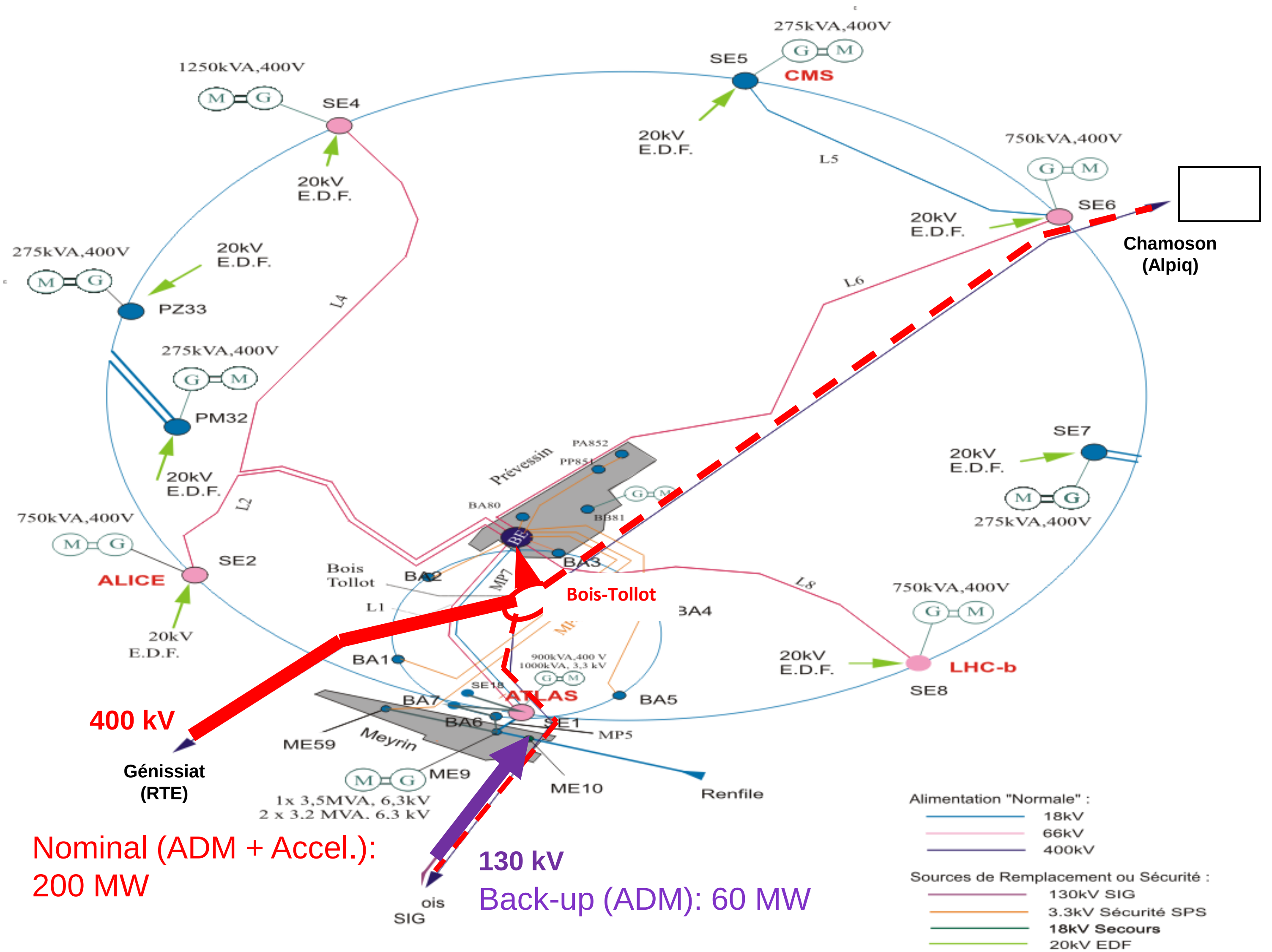
CERN Facilities





Technical sites for a series of particle accelerators and detectors

CERN's Electrical Network (geographical overview)



Orders of magnitude

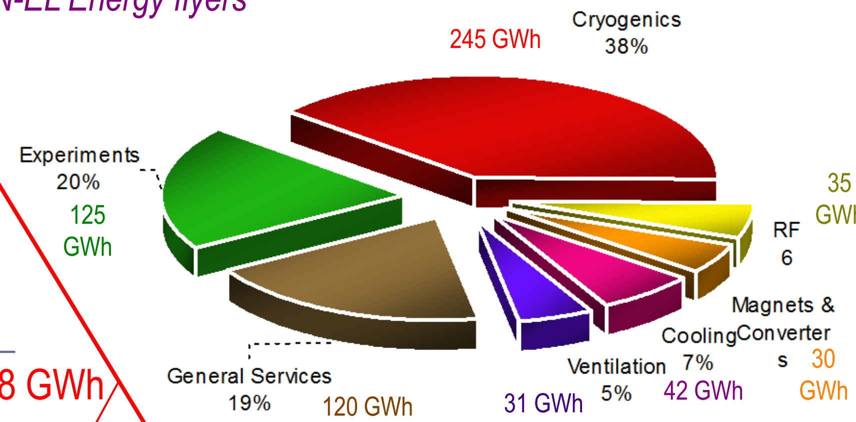
- Electric Power: 1’200 GWh
  - F: 400 kV - Maxi 290 MW (Main feeding line)
  - CH: 130kV - Maxi 60 MVA (emergency or maintenance)

  => Majority of this energy ends up as heat, dissipated in low temperature cooling towers (21-31’C)

- Heating: 90 GWh
  - Natural gas
  - (Fuel)

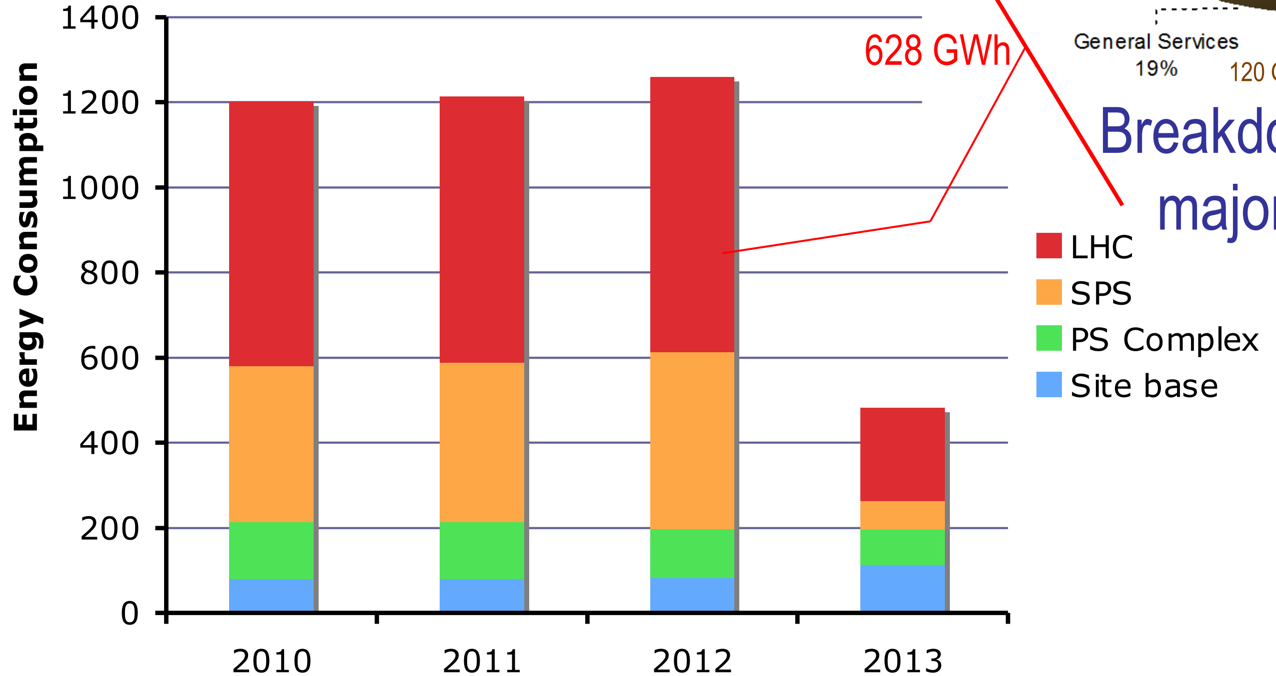
Recent energy consumption

Compiled from yearly EN-EL Energy flyers



Breakdown (averaged) per major system for LHC

CERN (per activity)

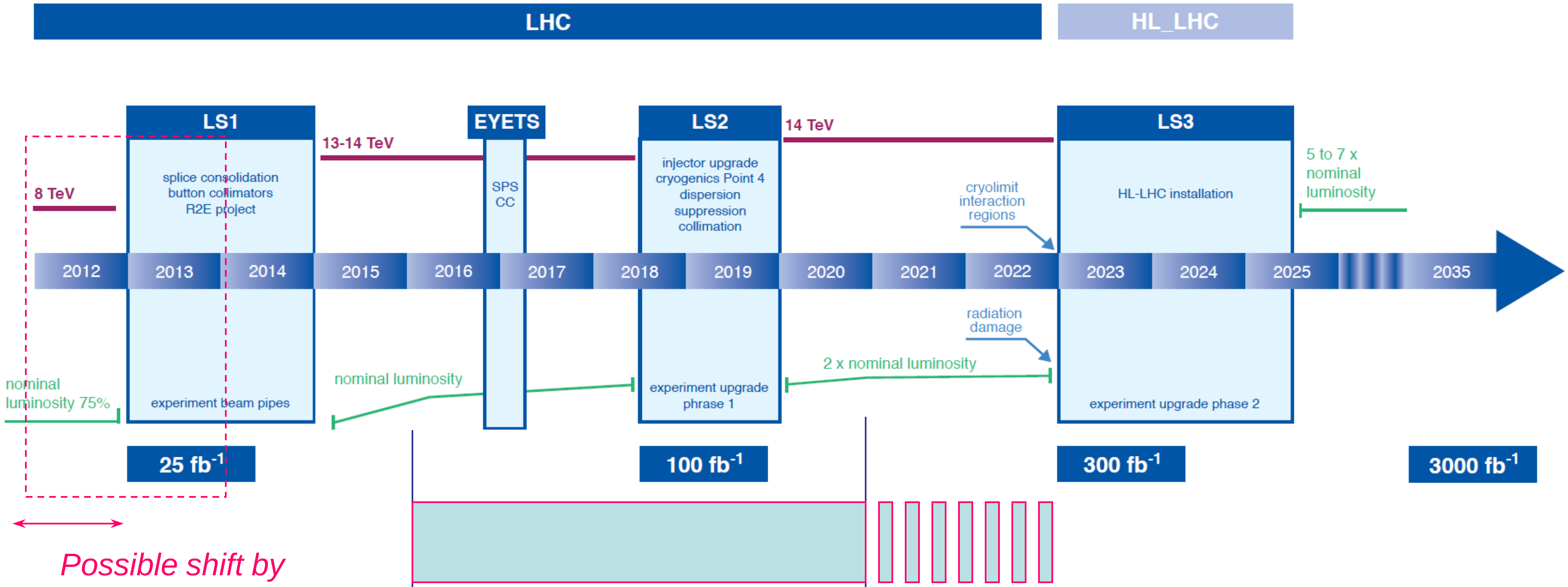


Typical cycle of 3-4 years up, then 1 year down

1.2 TWh 1.3 TWh 1.35 TWh 1.4 TWh

0.5-0.8 TWh 1.0-0.4 TWh 0.8 TWh

New LHC / HL-LHC Plan

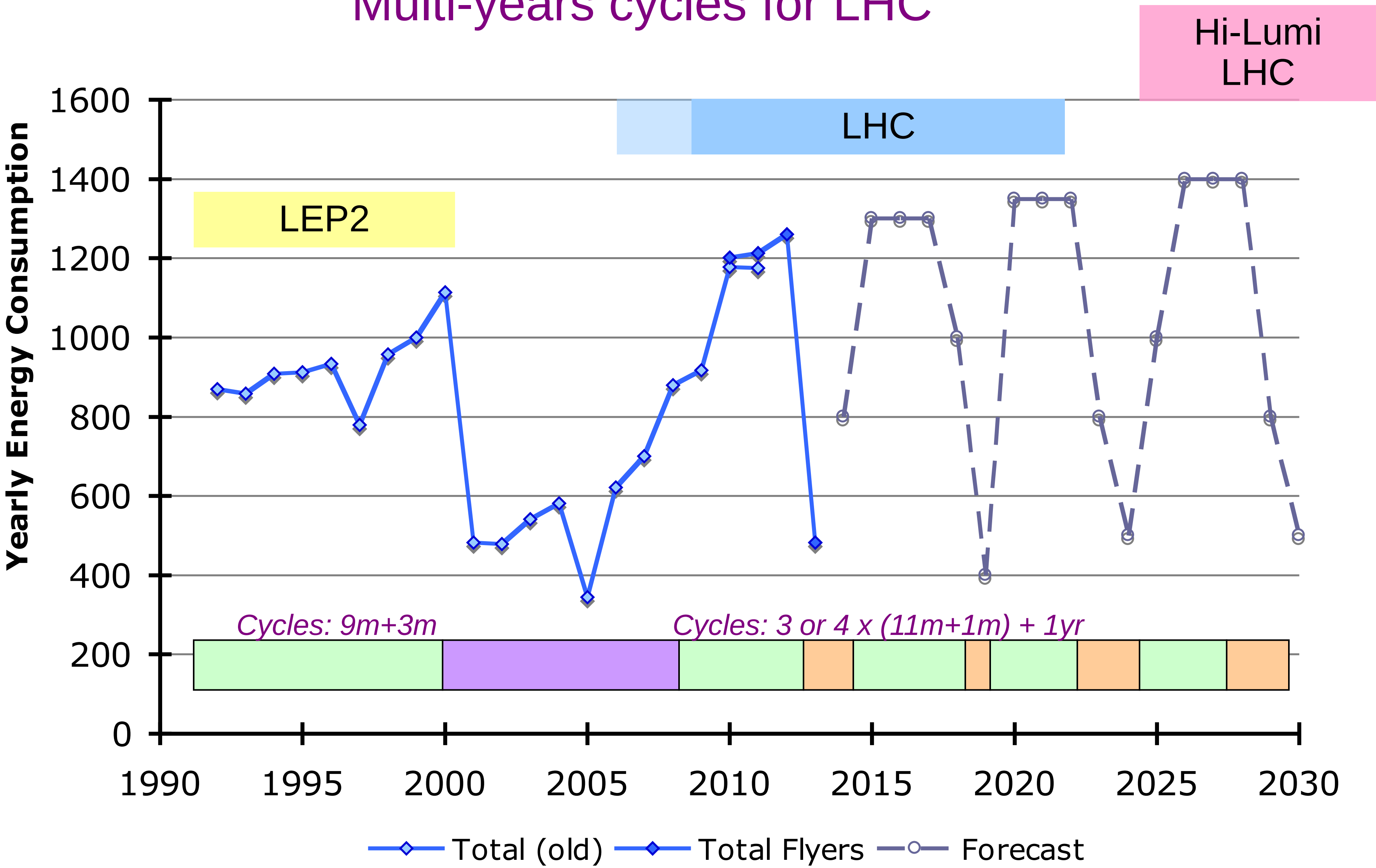


Possible shift by 1 year to match primary goals !

Period for new energy contract

CERN Energy Consumption

Multi-years cycles for LHC



Content

- Introduction to Energy at CERN
- Tendency, few recent cases
- Perspectives
- Summary

Energy concerns and line of action

Scientific goals at minimised primary energy consumption

- Energy efficiency from design stage onwards:
  - Energy consumption considered in selection and design of lattice and sub-systems: minimised global "capital plus operating" costs
  - This requires appropriate evaluation: quoting rather than just ideas !

CERN wide guideline in preparation for retrofits (with thresholds):
- Return below 5 yrs: Potential !
- Between 5 and 12 yrs: Strategic ?
- Above 12 yrs: not adapted …

- Energy management and awareness:
  - Foreseen stand-by modes (1min, 1hr, 1wk, 1month)
  - Operation scenario (seasonal, weekly, daily)

Facsimile of energy bill to be prepared and distributed to activity leaders, with invitation for suggestions

- Waste heat recovery (to be studied)
  - At the highest possible temperature for direct use
  - Two cases identified with serious potential

=> Getting some of these ideas implemented on few specifically selected on-going activities would be an efficient way to be prepared for the future !

Few recent success stories

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

- Buildings:
  - Heat pumps and thermal solar panels (Resto2-B107-B774-SL53)
- Computer center (2011-2012)
  - Free cooling and air flow optimisation
- LHC Cryogenics (2010-2012)
  - Towards higher availability with less machines in operation, resulting in operation modes with an increased efficiency
- SPS Beam operation (2014 onwards)
  - Powering cycles & stand-by modes

CERN Computer Center

Main Room Cooling System

CERN IT Department

What are the energy savings?

CERN IT Department

- Not known exactly!
  - Missing important monitoring data before 2010
  - Chillers are used not only for main room but also for other rooms
- Nevertheless we estimate for the changes made in 2010/2011 for the main room
  - With DC load of 2.6 MW and 1.9 MW in main room
  - Annual power consumption of chillers decreased from 6.5 GWh to 1.4 GWh
  - PUE for the entire DC reduced from 1.7 to 1.5
- Switching off 3 AHUs (40 kW each) saves an additional 1.1 GWh

CERN IT Department
CH-1211 Genève 23
Switzerland
www.cern.ch/it

Energy Savings in CERN's Main Data Centre - 3

Optimisation of air distribution (2010/2011)

CERN IT Department

- Analysing and modifying the operation of AHUs to increase the use of free cooling by
  - improving measurement and implementing full automation of air intake and mixing
  - reducing the intake of hot exhaust air
  - modifying the anti-freeze protection
- Maximum server inlet temperature increased from 25 °C to 27 °C (ASHRAE)
- Set points increased
  - temperature of air produced by AHUs increased in steps from 14 °C to 22 °C
  - temperature of chilled water circuit increased from 5 °C to 8 °C

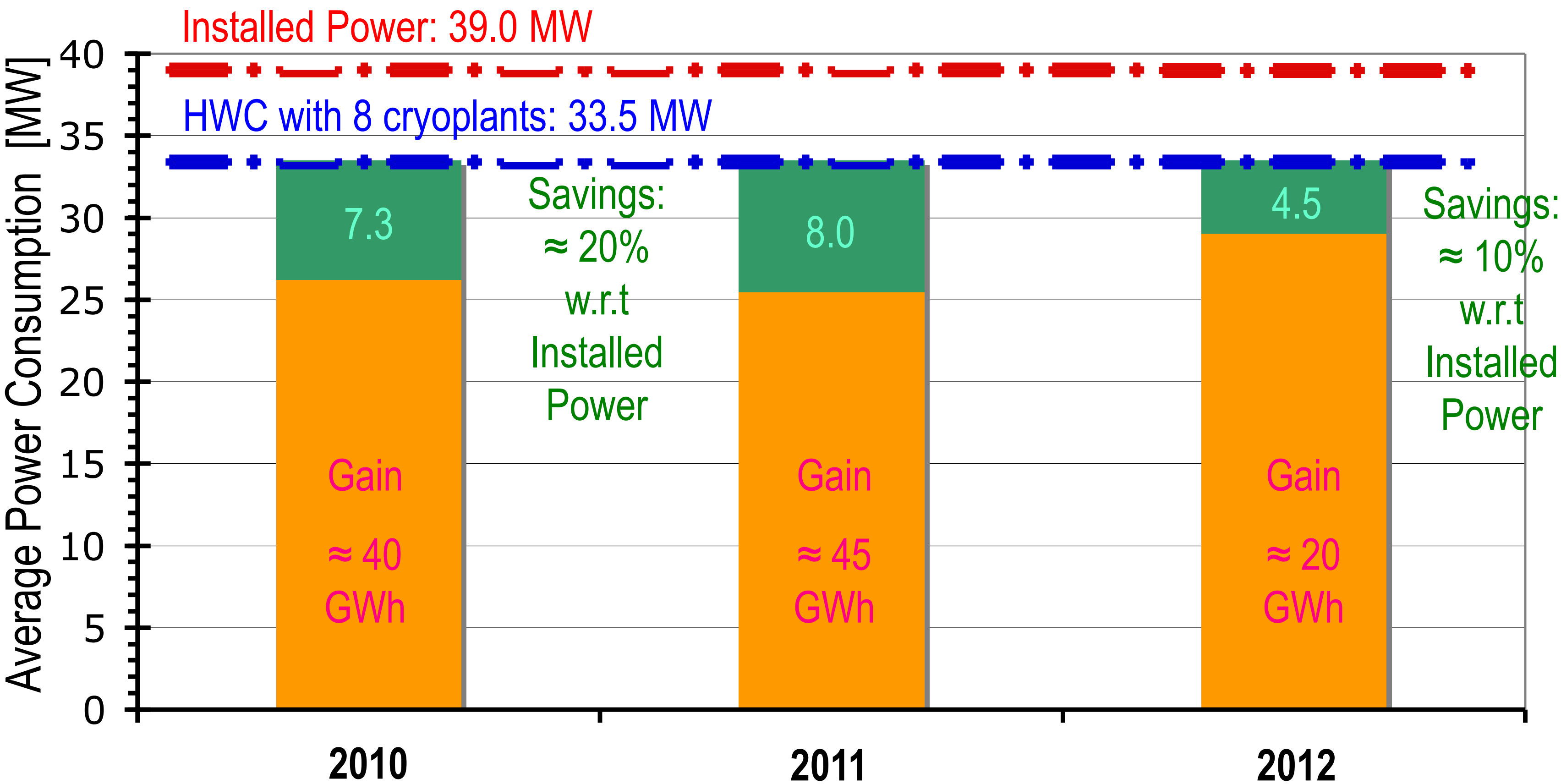
CERN IT Department
CH-1211 Genève 23
Switzerland
www.cern.ch/it

Energy Savings in CERN's Main Data Centre - 2

Gain: 5-6 GWh/yr

A project along the trend, involving several groups, with obvious results and well prepared for next time

Power consumption for LHC Cryogenics



A global effort towards energetic efficiency provided savings of 2 to 3 MCHF per year, but was as well an efficient training for the operation crew contributing to increased availability !

ECO cycles to avoid useless energy ramps (power converters)

Set of stand-by & powering modes

Estimated gain:

5-7 GWh/yr

Intended to be continued: North area (LS2?) and East area (LS3?)

New SPS energy saving scheme

The SPS accelerator complex has received major upgrades during LS1. Among them are new powering controls, which offer the possibility to significantly improve SPS energy efficiency. Along with a cleaner conscience comes also the monetary advantage in the range of several 100 k€ per year. This only became possible by implementing a new power converter control interface based on the software framework FGCD (Function Generator/ Controller Daemon).

After years of preparation the TE-EPC group launched a big endeavor during LS1, to replace in SPS the obsolete software framework ROCS by FGCD. On the hardware side the old PowerPC architecture with LynxOS was replaced by new x86 systems with Linux. All this was done in order to renovate and synchronize technologies in CERNs accelerator complexes.

FGCD uses the Mugef power converter controls very differently compared to ROCS and increases their operational flexibility. Thanks to that it was possible to design and implement more dynamic powering schemes in the SPS along with many other improvements. The main idea behind the energy saving scheme is simple: **Do not power the magnets if there is no beam!** As simple as it may sound, it is still a complex task.

So far the programmed SPS beam cycles were usually powered in full as soon as the SPS was ready to accept beam. Saving energy could involve manual interactions, namely switching power converters into standby mode when possible. This was, of course, only possible for long periods without beam. There also existed a dynamic economy mode. But it worked only on fixed target cycles, since the intensity detection was too slow to use it on fast cycling beams. Furthermore it only managed to shorten the time on the high beam energy plateau.

The newly installed FGCD software framework allows a more dynamically adapted powering of SPS magnets in the accelerator ring as well as the transfer lines. There are now three basic modes of energy saving available, *full economy*, *dynamic economy* and *transfer line economy*. All ECO modes can be overruled for testing purposes and the setting up of the machine as well as the transfer lines.

The full ECONOMY (see Fig.1) is triggered by external conditions, which is either the inhibition of SPS or a signal from the French energy supplier EDF. The timing system announces full ECO mode in the telegram. When triggered, the power converter controls wait until the end of the currently played cycle. With the beginning of the next cycle they stay at a power output for a beam energy equivalent of 13.5 GeV, while the transfer lines stay at their minimal current. As soon as the external conditions causing full ECO mode are revoked, the system goes back to normal cycling in the following beam cycle.

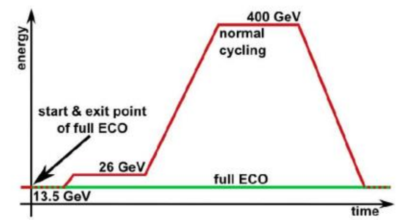


Fig. 1: normal beam cycle & full ECONOMY

The new dynamic ECONOMY (see Fig.2) is triggered in case the beam current transformer (BCT) measures beam intensity below a cycle dependent set threshold 20 ms after the first injection. The deficient beam is then dumped, the SPS ring energy stays at injection energy and the transfer lines stay at their minimal current, waiting for the next cycle. Transfer line TT10 and the North Area however remain powered for the moment. To counter hysteresis effects in the main magnets, there is also the possibility of pulsing to an adjustable energy level at the end of the economy cycle. Its usage policy has still to be defined in a dedicated test run.

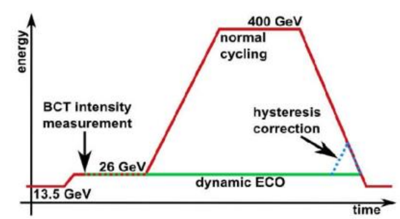


Fig. 2: normal beam cycle & dynamic ECONOMY

During normal cycling, energy can be saved as well by pulsing transfer lines depending on the beam destination. This means only transfer lines which are needed for the current beam extraction, according to their programmed destination, are pulsed during the cycle.

The energy savings result also in substantial monetary savings. One fixed target beam costs about 8€ and LHC beams between 2€ and 4€ per acceleration cycle execution in SPS alone. With the new dynamic ECO mode applied on the run statistics of the 2012, one could save more than 300k€ per year. The destination dependent transfer line economy could save in this case approximately another 33k€. The full ECO mode will likely save a good amount as well - experience shows that shorter injector inhibitions due to technical reasons do happen once in a while. Furthermore avoiding pulsing of equipment throughout the machine reduces its wear and thus prolongs its lifetime.

It is clear by now, that operational costs in form of power consumption cannot be ignored anymore. Today no new accelerator can be built without taking this into account. Existing infrastructure needs to be checked as well for possible improvements in energy efficiency. The operations group started early 2013 with dedicated efforts in this direction. The SPS energy savings is only the first fruit of this ongoing process which has come to light. Other improvements are possible and the goal is to generalize the concepts described above for all cycles and in all zones. The upgrade of the North Area power converter control system is intended for LS2.

A similar renovation project is also foreseen for the TT2 transfer line in PS during LS2. For the East area the idea emerged of replacing DC powered un-laminated magnets by ones that can be pulsed. But so far this renovation project seems only realizable for LS3.

Detailed information on the "SPS LS1 Controls Upgrade" can be found in the functional specification, EDMS no. 1335590.

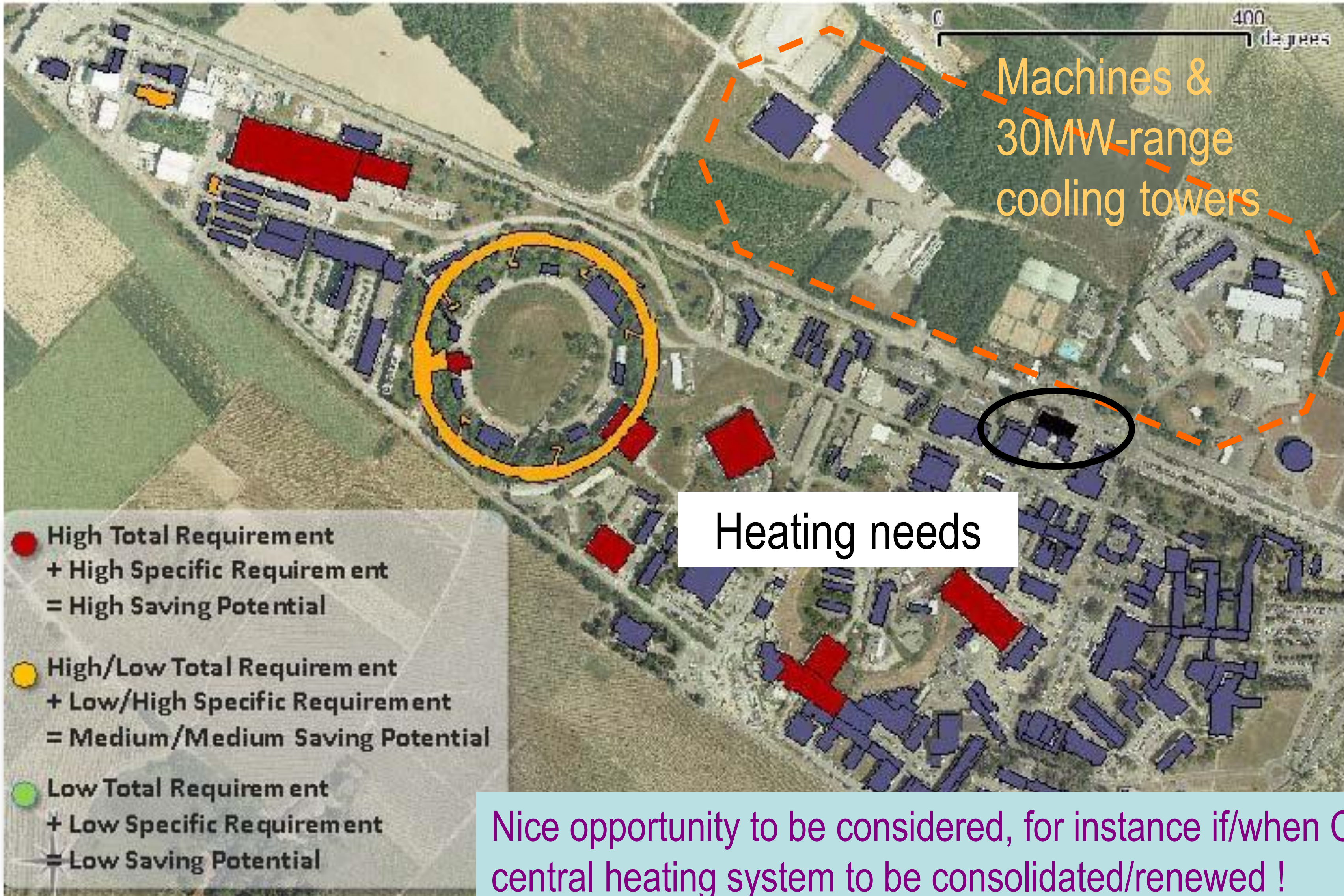
V. Kain, S. Cettour Cave, C. Kittel, S. Page, J.-C. Bau

Content

- Introduction to Energy at CERN
- Tendency, few recent cases
- Perspectives
  - Getting more teams properly focussed
  - Selection of few significant projects
  - 3rd Energy Efficiency workshop, Desy-Oct'15
  - Support for new accelerator projects
- Summary

Buildings with highest specific energy

Biggest energy consumers of Meyrin buildings (from simulation)



Nice opportunity to be considered, for instance if/when CERN central heating system to be consolidated/renewed !

Identifying good practices, stimulating new ones

CERN · EUROPEAN SPALLATION SOURCE · ERF European Association of National Research Facilities – Open to International Access

Workshop Energy for Sustainable Science

Energy management for large-scale research infrastructures

13th – 14th October 2011

Lund, Sweden

Programme

Thursday, 13th October

09:30 – First plenary session
Venue: Auditorium
(Chair: Colin Carlile, CEO ESS)

09:30 – Welcome and goals
Representatives from the organisers

10:00 – Energy and climate challenges for research infrastructures
Catherine Césarsky, High Commissioner CEA

10:30 – The energy future of large scale facilities
Jonas Abrahamsson, CEO E.ON Nordic

11:00 – Coffee

11:30 – Energy 2020: a strategy for competitive, sustainable and secure energy for Europe and the SET-Plan
Henrik Bindslev, Vice Dean for research at the Faculty of Science and Technology, Aarhus University, and Chairman EERA

1

2nd Workshop **Energy for Sustainable Science** at Research Infrastructures

CERN, GENEVA, SWITZERLAND 23-25 OCTOBER 2013

ENERGY.SUSTAINABLESCIENCE2013@CERN.CH
HTTP://CERN.CH/ENERGY.SUSTAINABLESCIENCE2013

MAIN THEMES

- Energy Management at Research Infrastructures
- Procurement and Financing of Energy
- Energy Efficiency at Research Infrastructures
- Energy Efficiency in Computing Centres
- Sustainable Campus Development and Management
- Energy Quality and Operation
- Green Technologies developed at Research Infrastructures

INTERNATIONAL ORGANIZING COMMITTEE

Mike Ashworth	STFC
Frédérick Bordry	CERN
Frank Lehner	DESY
Carlo Rizzuto	ERF
Thomas Parker	ESS

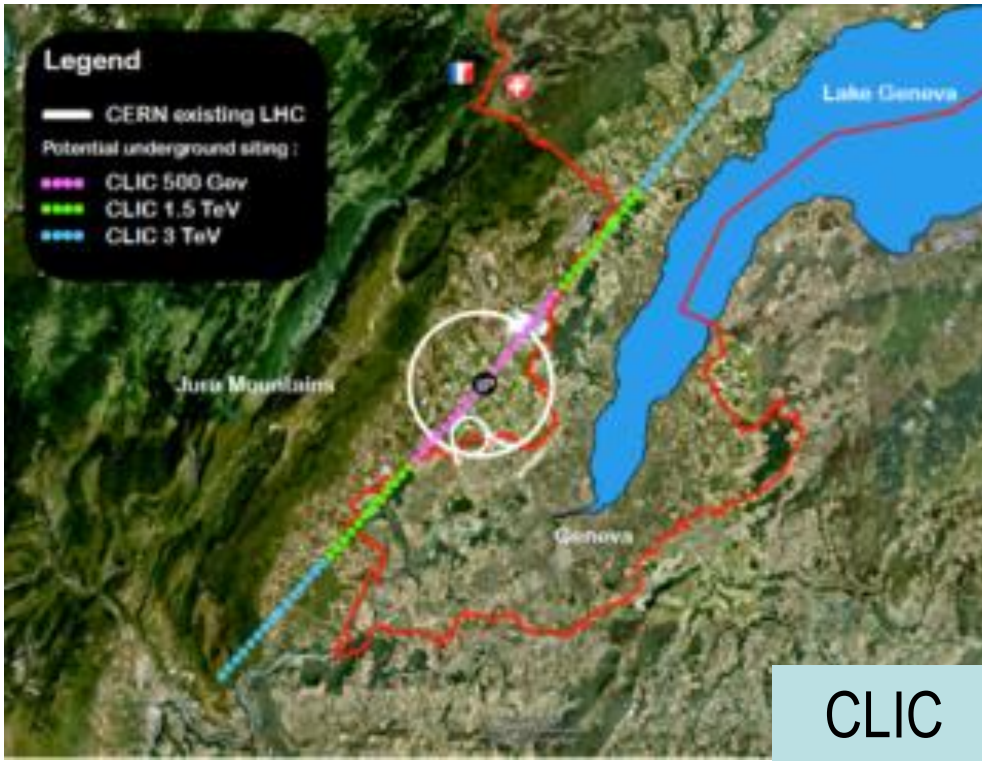
LOCAL ORGANIZING COMMITTEE

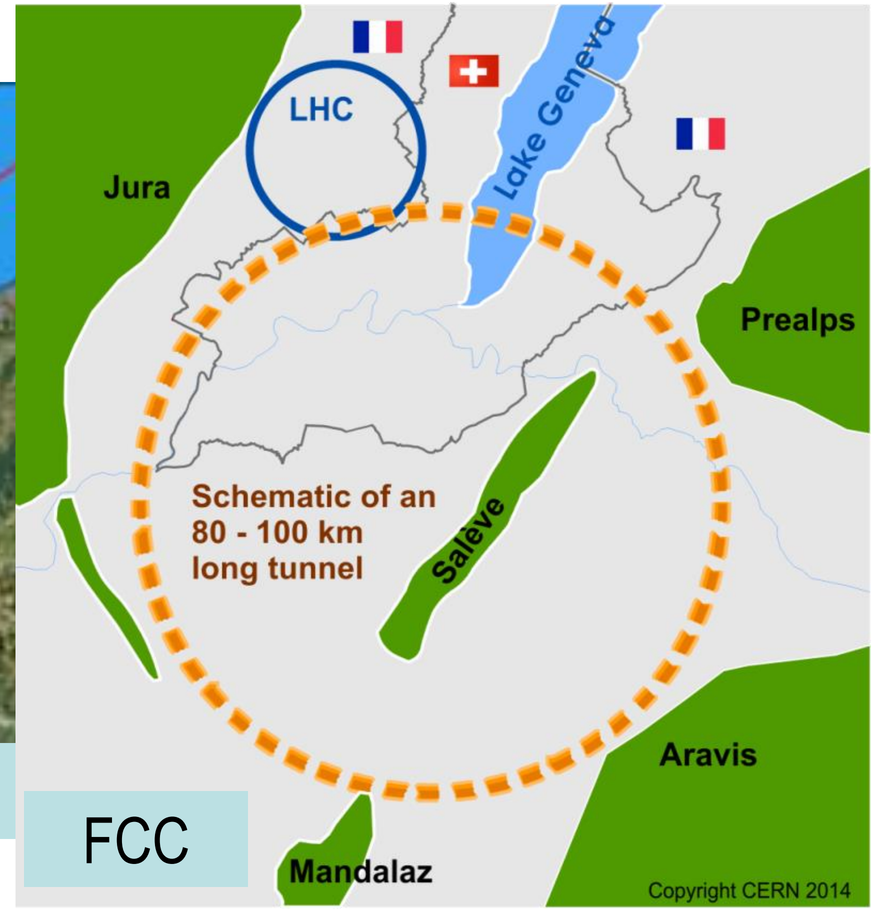
Giovanni Anelli	Vincent Dore
Frédérick Bordry	François Duval
Helfried Burckhart	Marina Giampietro
Jean-Paul Burnet	Friedrich Haug
Fritz Caspers	Tjitske Kehrer
Enrico Chesta	Philippe Lebrun
Serge Claudet	Mauro Nonis

CERN · EUROPEAN SPALLATION SOURCE · ERF European Association of National Research Facilities – Open to International Access

3rd workshop foreseen in October 2015, with Desy as host

Studies for new accelerators





For these large projects with power consumptions slightly larger than the present CERN value, energy efficiency concerns is one of the design criteria

Summary

- Energy efficiency in research infrastructure:
  - It is becoming a must (sure for communication, progressively with facts, at the level of 1-3% for recent actions)
- Energy efficiency should be considered as an engineering parameter, not only as a concept-wish-dream
  - Safety, Quality assurance are part of our goals and priorities, why not Energy awareness ?
  - Evaluation, measurements, specific metrix and trends are essentials
  - Specific actions are being prepared to help for this
- No future accelerator projects without energy efficiency (more generally sustainability?) as part of the objectives
  - One should minimise primary energy consumption and (then) heat rejection
  - Specific selected programs on existing infrastructures is a clever way to get the energy awarness culture as well as proven references.
    It is visible from outside (communication) and useful for the future !

Once again, congratulations for organising such an event, best wishes !

Spare slides

Infrastructure at LHC technical area