CERN energy management, energy efficiency analysis & selected projects

Serge CLAUDET, *as CERN energy coordinator for the Accelerator & Technology Sector*

4th Workshop Energy for Sustainable Science at Research Infrastructure,
Magurele-Bucharest, 23-24th Nov'17

CONTENT

- Introduction, *CERN and energy aspects*
- Energy Management at CERN
- Energy Efficiency evaluation, *machines and facilities*
- Heat recovery projects
- Summary

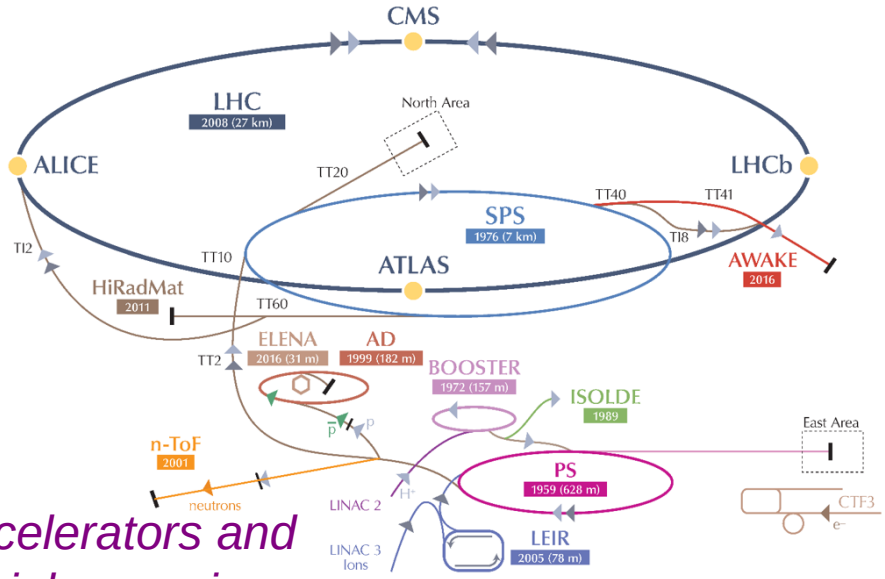
CERN in brief

Funded in 1954 as “Science for Peace”

Now with 22 member states

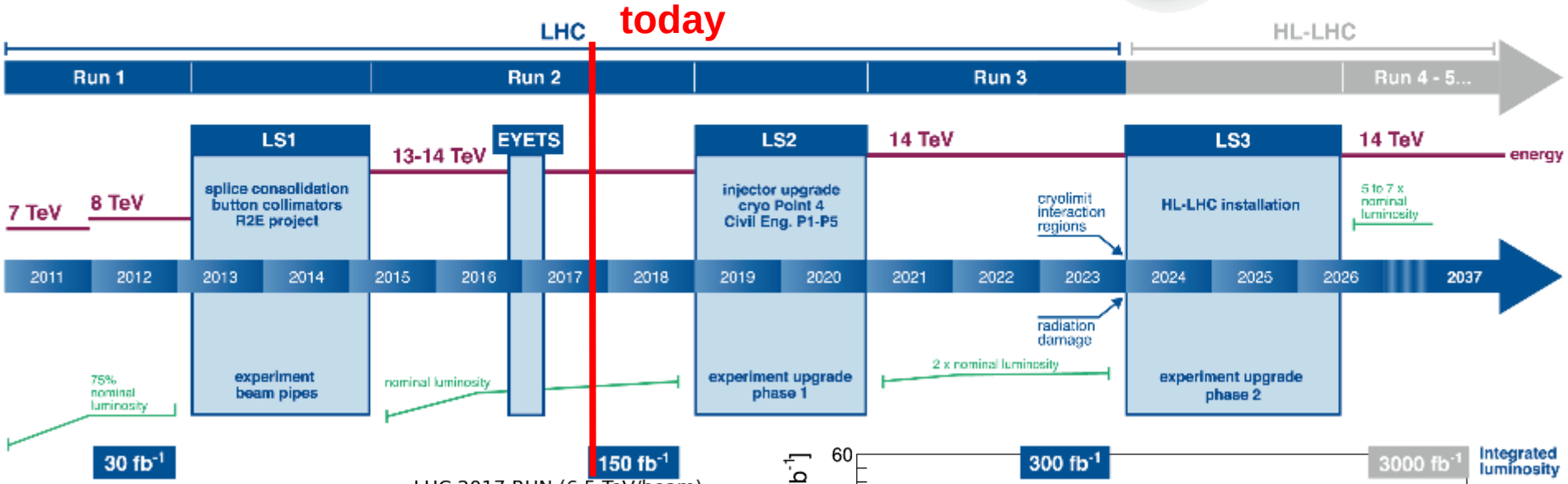
2’300 staff, 1’600 others and 10’500 users

1’100 MCHF annual budget (pro GDP)



A very large technical site for a series of accelerators and detectors serving particle physics towards high energies

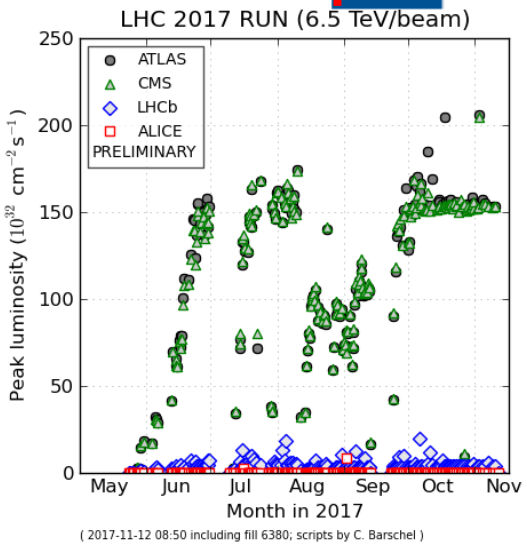
LHC / HL-LHC Plan

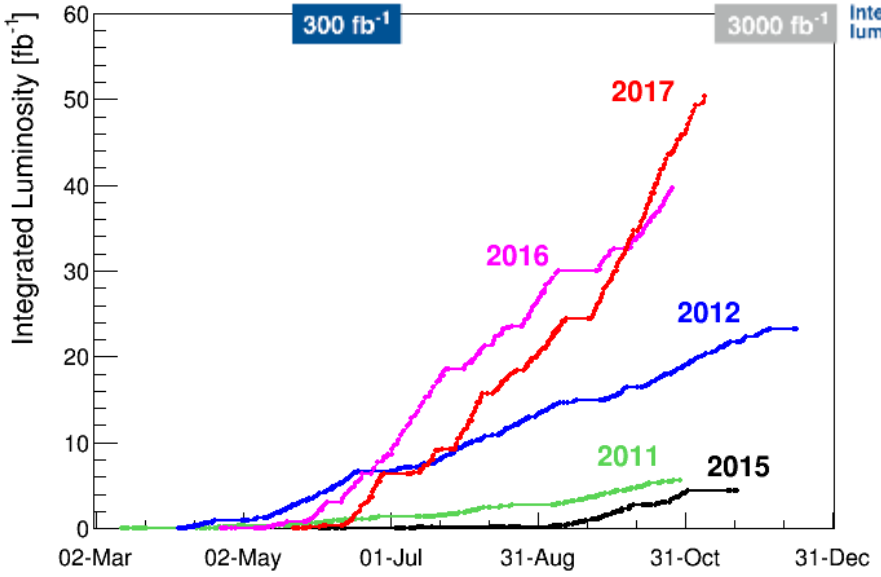


Peak luminosity
$2.2\ 10^{34}\ cm^{-2}\ s^{-1}$

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

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

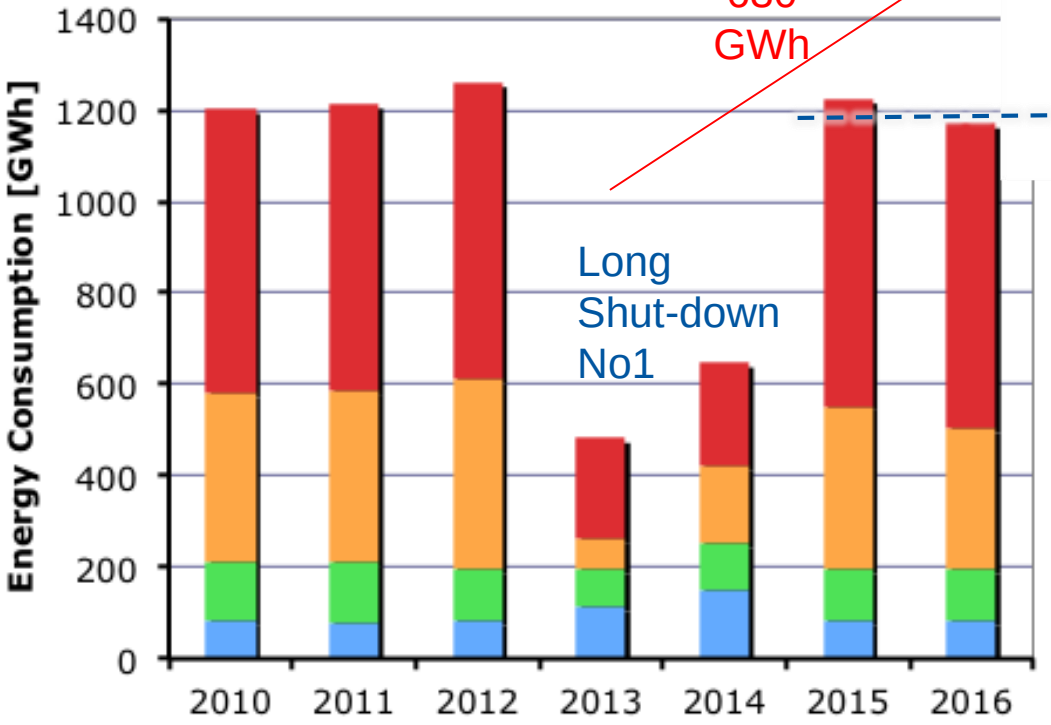




Recent energy consumption

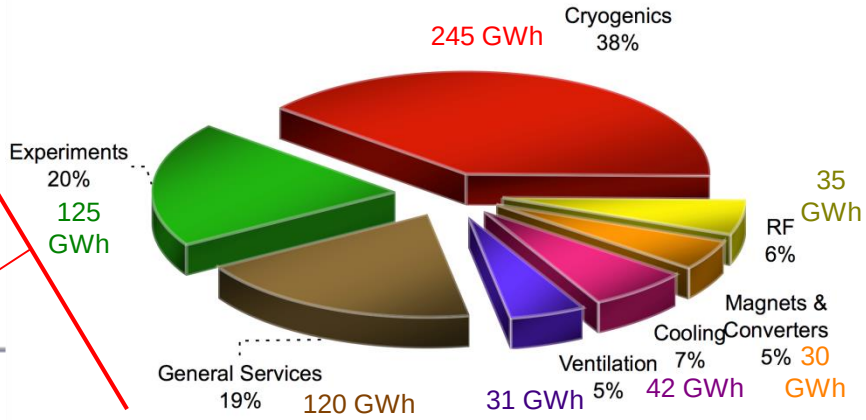
Compiled from yearly EN-EL Energy flyers

CERN (per activity)



630 GWh

Long Shut-down No1



Breakdown (averaged) per major system for LHC

Towards 1.15/1.2 TWh as well in 2017

Buildings and conventional facilities represents about 10% of the total EL energy consumption, (similar to gas consumption)

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- Energy Management at CERN

New electricity contract signed Autumn 2015 following one year of efforts to quickly learn and get prepared for “market based” mechanisms
(cf dedicated presentation made at 3rd workshop, DESY)

An Energy Management Panel (2nd generation) was set-up at CERN Autumn’15, bringing together representatives of all main consumers and addressing more aspects than only the follow-up of the new electricity contract

CERN Energy Management Panel, 2nd generation

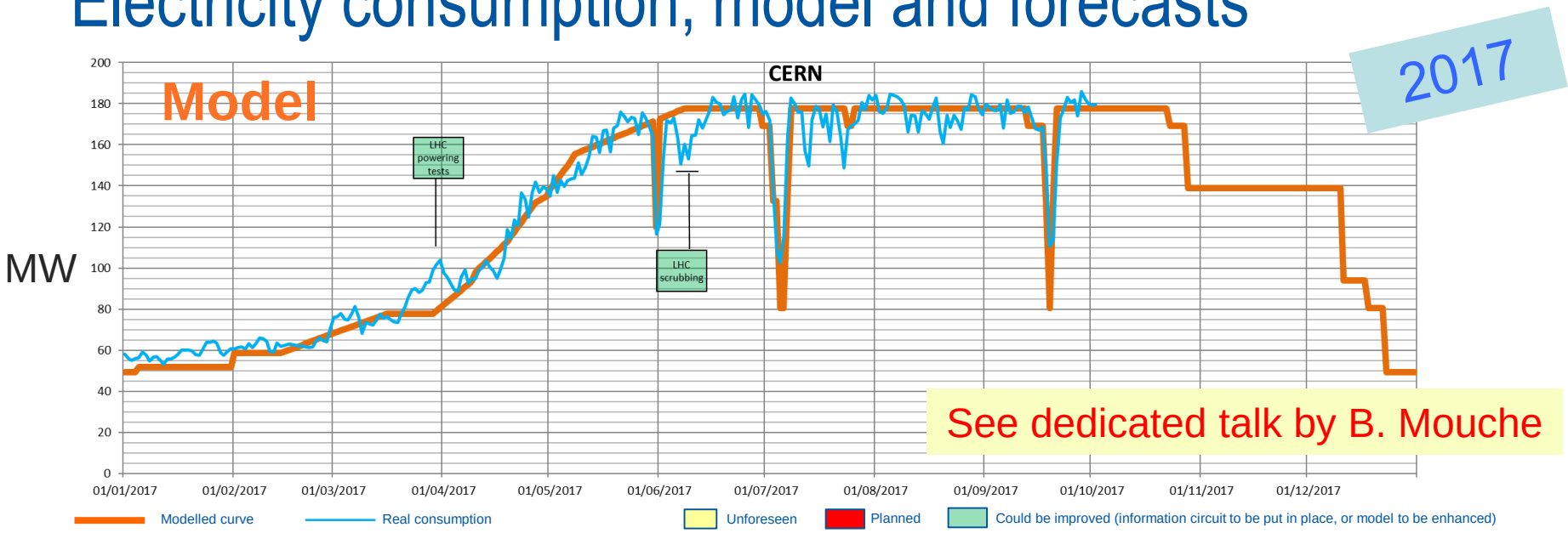
Similar forum was in place at CERN up to 10 years ago (Power subscription, budgetary estimates)

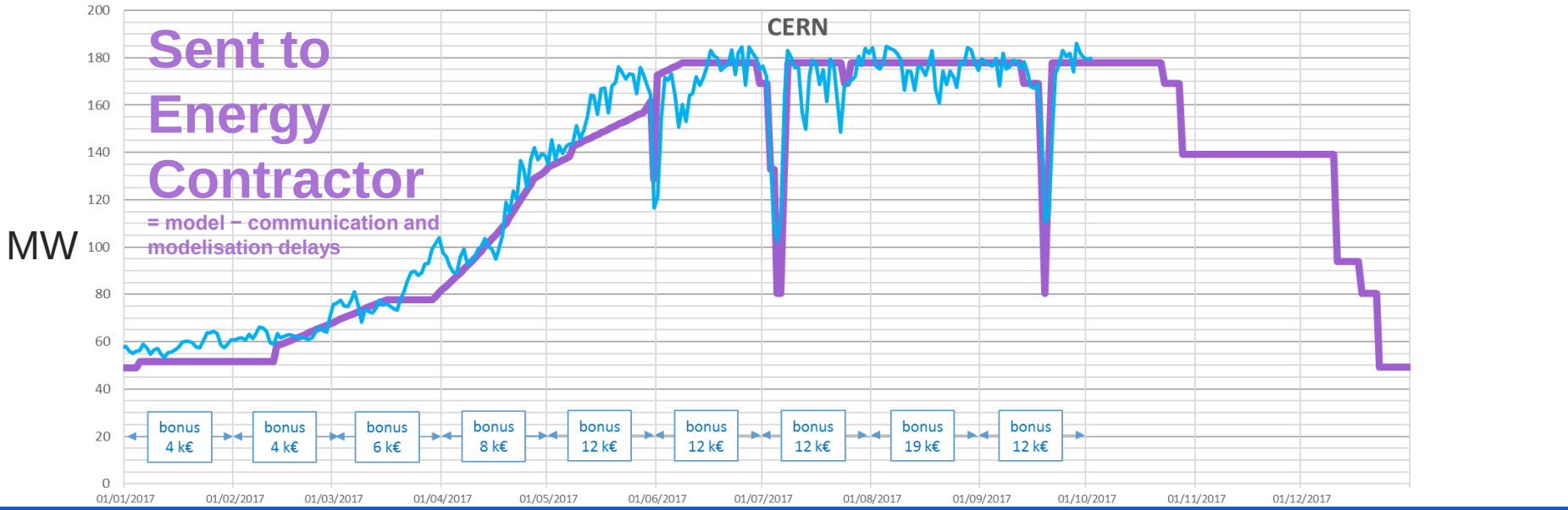
(Oct. 2015)

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

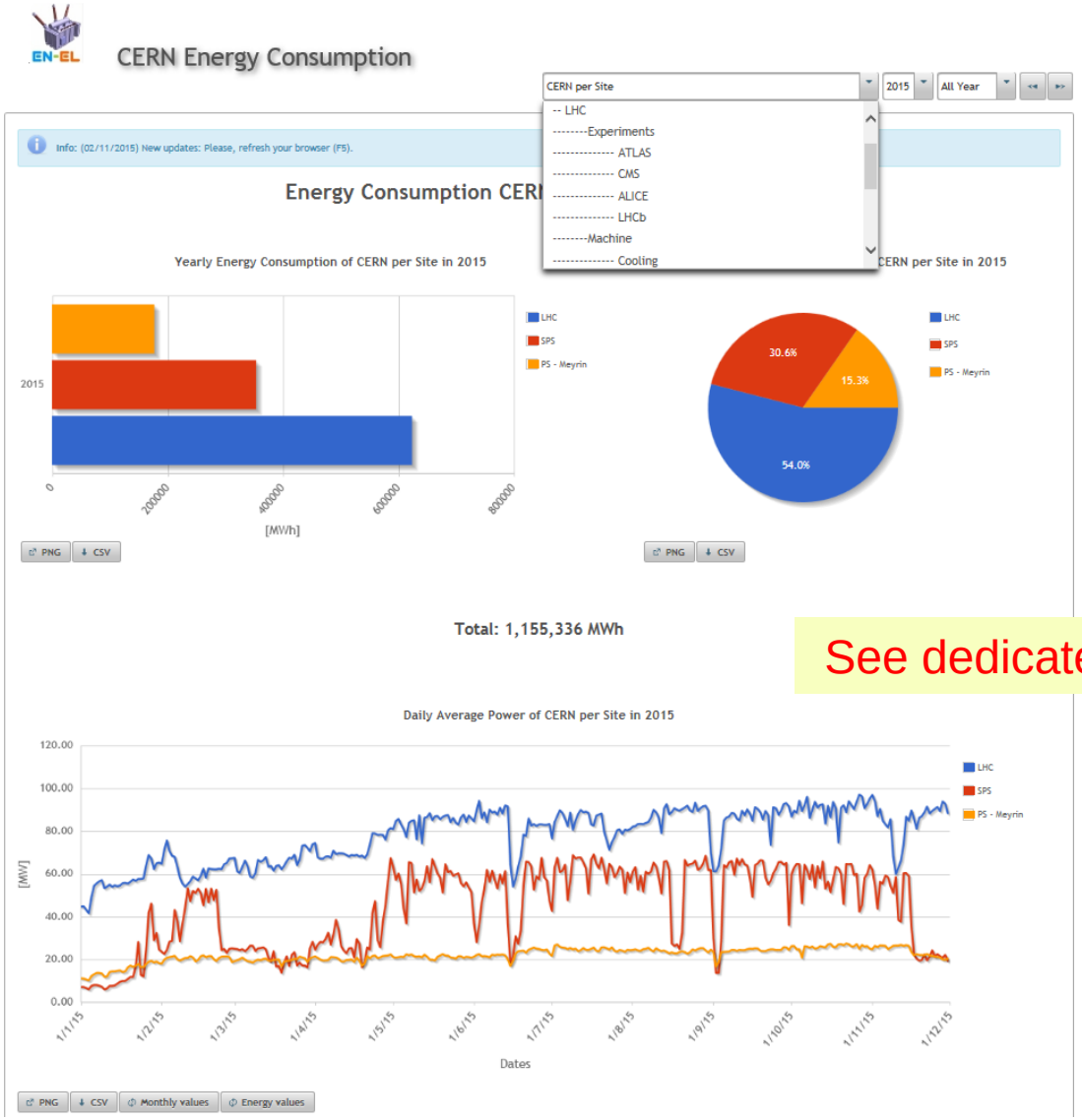
- Make the main energy consumers aware of the new conditions and rules under CERN's new energy supply contracts.
- Compile estimates of CERN's projected power and energy consumption up to and including HL-LHC, in coordination with the various users and EN-EL power network operations.
- Manage CERN energy 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.

Electricity consumption, model and forecasts





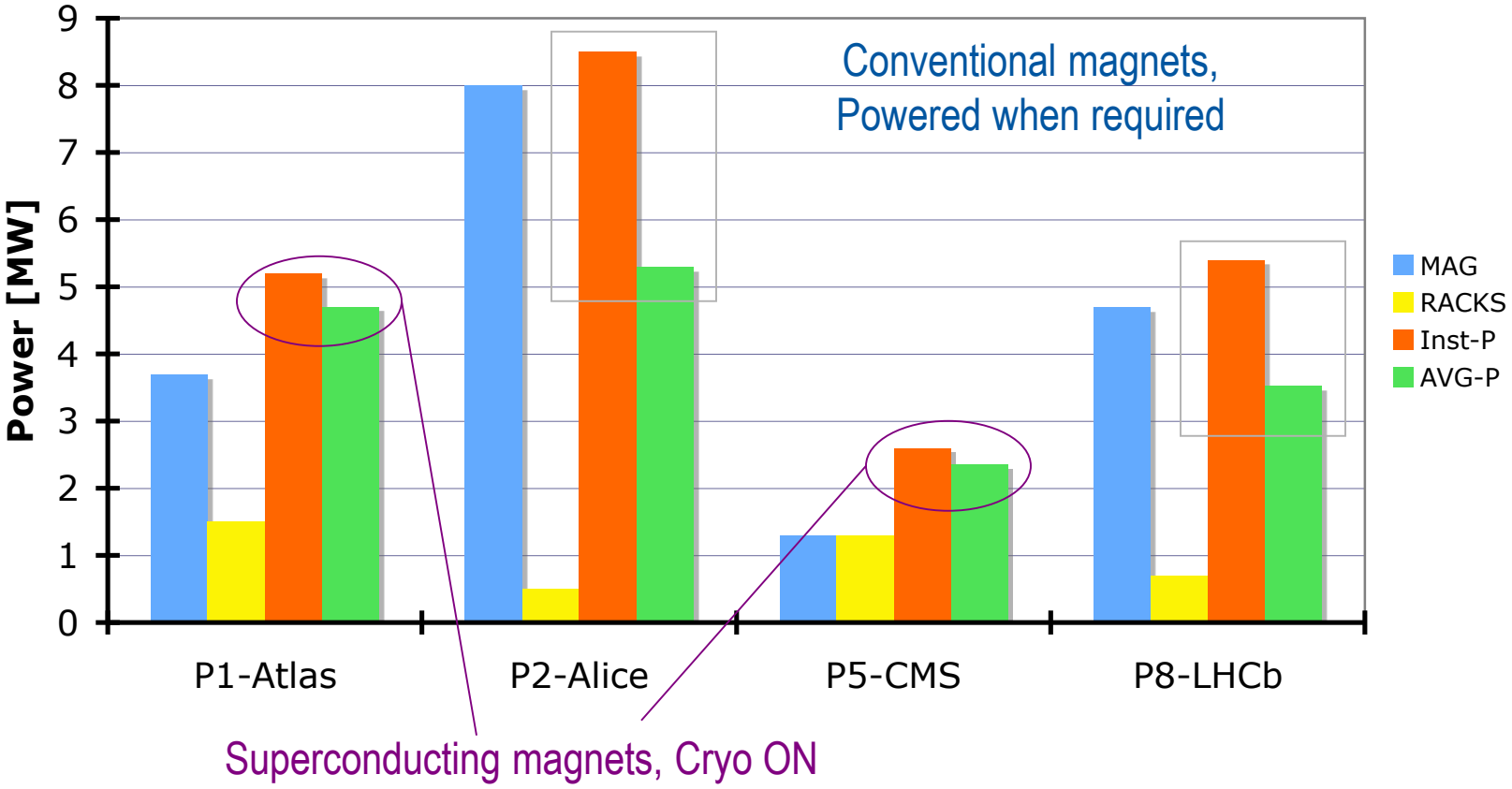
Monitoring energy consumption



Dedicated online tool developed by EN-EL,
Global accuracy better than 1%

See dedicated talk by B. Mouche

Reducing power when not needed: LHC Detectors



Good practice in place including shading for few days, no further significant gain to be expected there (risks!)

Awareness, from EMP-contacts to activity responsibles

(The next step, as after 2 years of EMP we are more or less all aware!)

=> Memo "Virtual invoices" to activity responsible and group leaders, with copy to respective management

Subject: Your share of the CERN electricity bill for 2016

As part of CERN's energy efficiency programme, we wish to raise awareness of how CERN's electricity is used among those responsible for managing its consumption. You are receiving this memo as someone responsible in either a technical, operational or hierarchical capacity for managing a significant fraction of CERN's electricity consumption in 2016.

CERN's research programs do not suffer from energy constraints. Nevertheless, it is our duty to ensure that we make the best, and most efficient, use of energy while fulfilling our research goals.

With a view to improving CERN's energy efficiency at a global level, we are investigating measures such as energy efficient upgrade programmes, possible peak shaving and revised scheduling of activities in order to be more pro-active than we have been in the past with the system of tariffs (up to 2015).

We hope you will find the data provided here to be of interest, and that it will encourage you to look for potential efficiency improvements in your area of responsibility. If you would like more details, or help in evaluating potential opportunities for improving energy efficiency, please don't hesitate to get in touch.

Regards,
The CERN Energy Management Panel

With tables & graphs showing Energy [GWh], *and indicative MCHF* for them and for CERN

Postponed for resources availability, about to resume, for 2017 …

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Energy efficiency for machines *(90% of total)* Success stories

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

- Computer center (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: 5-7 GWh/yr*
  - Powering cycles & stand-by modes

See dedicated talks:
- SPS experience, Q. King
- Energy Storage in Power Converters, Th. Höhn

\+ *East area Project (2019-2020),*

Same principle than for SPS (idle, "power when beam in")

Renovation projects for machines or technical activities

- Incentive to insert “energy efficiency” actions, in a structured way and not as an excuse to do something else!
- In case not straight forward, baseline renovation should be done with “as is” technology, and with incentive included in the call for tender for more energy efficient solutions (like adjudication on CAPEX + OPEX over 10-15 years)
- If specific actions would have to be decided before-hands (like variants), should be evaluated as an alternative, with potential savings quoted in GW.h

=> To be used as a commitment, and to be assessed after

- 2 cases were evaluated for B513 as presented at EMP#5

(*with possible gain respectively of 550 MWh and 935 MWh, but baseline renovation was not decided. At least the case is studied and documented if it would come back)*

Energy efficiency for buildings and site facilities

In fact a must (strong incentive) with market based energy contracts in France
Visit of EdF-RnD site March 31st 2016, evaluation on CERN site 21-22 Nov'16

Plan d'action

Le CERN et EDF ont validé le plan d'action 2016/17. Le tableau ci-dessous présente notamment les actions à entreprendre, les acteurs et planning prévisionnel pouvant évoluer en fonction des contraintes humaines et techniques.

N°	VOIES DE PROGRES						
	Descriptif	Expert Pilote EDF	Equipe CERN	Etat	Date	Commentaire	Livrable / Période
1	Valorisation de la chaleur au Point 1 pour un besoin interne de chauffage (3 chaudières + 1 en fin de vie)	Christine WALLART 06 73 37 70 49	Christophe MARTEL Serge DELEVAL Serge CLAUDET	Visite programmée	21,22/11/16	Evaluer l'intérêt technico-économique d'une PAC pour substituer une partie de la chaleur produite par la chaufferie (1) et/ou le chauffage des halls SM18 et SMA18	Fiche Idée Janvier 2017
2	Valorisation de la chaleur au Point 8 pour besoin externe Réseau de Chaleur	Christophe GAUBERT	Serge CLAUDET	En cours		Valider le régime de températures pour récupérer au mieux la chaleur fatale disponible (CRYO/TAR)	APS Décembre 2016
3	Optimisation éclairage LED des Halls 867, 151, 152 et 157	Michel CHAUVIN 06 21 63 20 76	Christophe MARTEL Serge CLAUDET	pro			
4	Optimisation chauffage du Hall H180 (2) - stratification	Christine WALLART 06 73 37 70 49	Serge DELEVAL Serge CLAUDET	pro			
5	Optimisation production de froid des Restaurants n°1 et n°3 – thermofrigopompe	Christine WALLART 06 73 37 70 49	Christophe MARTEL Serge CLAUDET	pro			
6	Optimisation du parc moteur associé aux TAR	Laurent DURRIS 06 65 79 70 36	Serge DELEVAL Serge CLAUDET	pro			
7	Optimisation de la station d'air comprimé	Christine WALLART 06 73 37 70 49	Serge DELEVAL	pro			
8	Intérêt des transformateurs Hauts rendements	Laurent DURRIS 06 65 79 70 36	Bruno MOUCHE	pro			

(1) **Chaufferie** - 3 chaudières gaz (3x15 MW thermique – 1 chaudière en secours). Une production d'eau chaude moyen situe à proximité d'un bâtiment actuellement vide (possibilité d'intégrer une PAC de forte puissance)

(2) **Bâtiment H180 (≈150m x 80m x 20m)** - 12% de la consommation en chauffage, avec distribution d'eau surchauffée est néanmoins souhaitable de réaliser une mesure de température afin de déterminer la stratification.

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Sorry for the text in French,
This was just to illustrate the fact that it is done seriously by both parties!

After 1st contacts with CERN, potential cases were considered by EdF to be straight forward with many references for them, like large scale manufacturing industries or services (harbors, airports)

Energy efficiency for buildings and site facilities

In fact a must (strong incentive) with market based energy contracts in France

Visit of EdF-RnD site March 31st 2016, evaluation on CERN site 21-22 Nov'16

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1	Heat recovery from P1 to Main CERN Meyrin site, heat pump						
2	Heat recovery from LHC-P8 to external heating network in surroundings						
3	Lighting improvement for some large halls, CERN streets and car parks						
4	Large halls (100m x 40m x 15m) heating improvement						
5	Combined production of warm and cold for CERN restaurants (n100e/day)						
6	Improvements for cooling towers fans & pumps, VFD's						
7	Central compressed air distribution improvements and heat recovery						
8	Power distribution and high efficiency power transformers						

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Preliminary feedback:

- Global situation rather healthy on CERN site, with correct approach in case of revamping (energy efficiency alternatives considered on long term10-15 years)
- Improving monitoring of fluids (air, heating system) could help
- Possible minor gains to be expected with better management of lighting day-nights-weekends, could be worth a specific study at a later stage

S. Claudet

See dedicated talks: Tertiary infrastructure management, Ch. Martel

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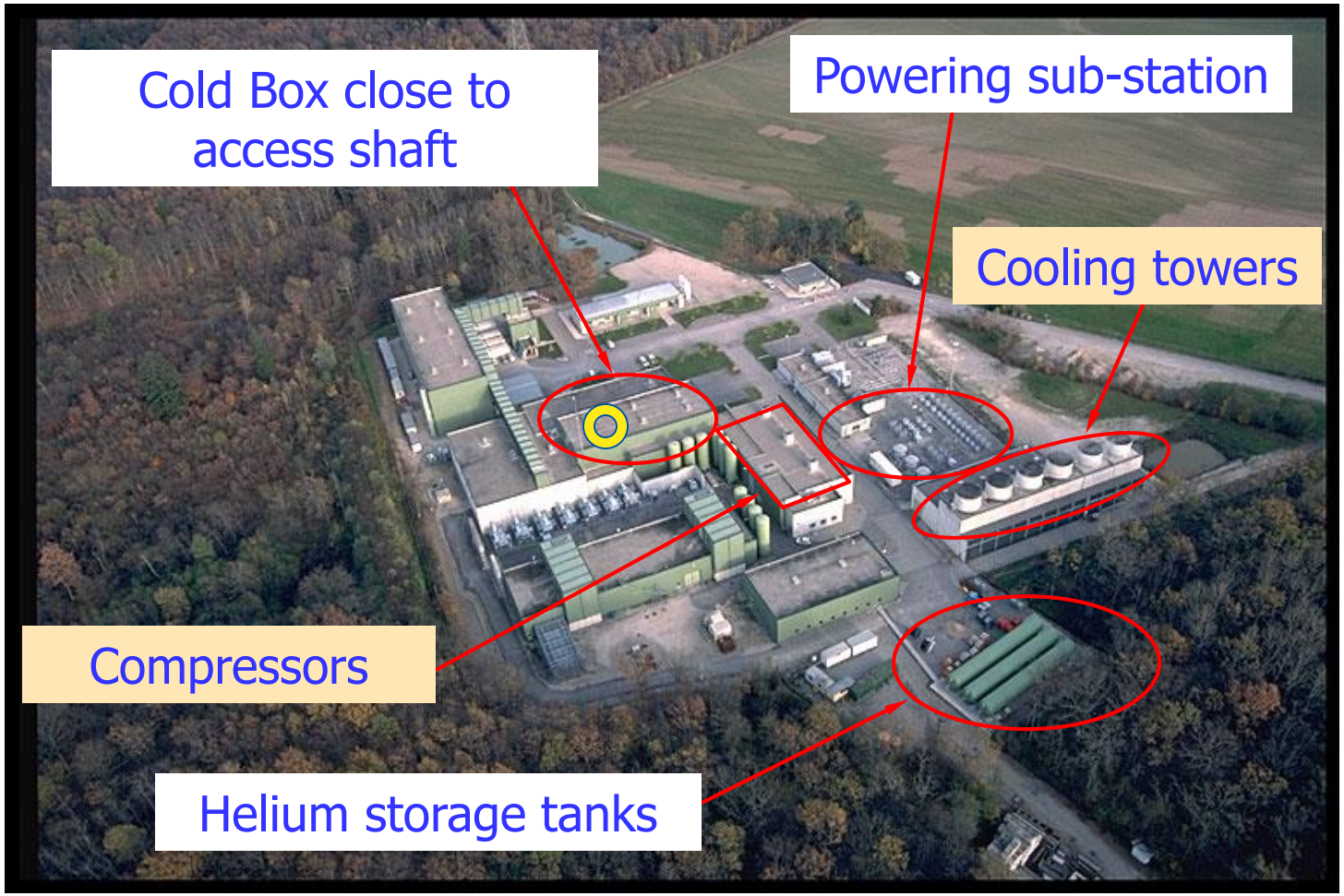
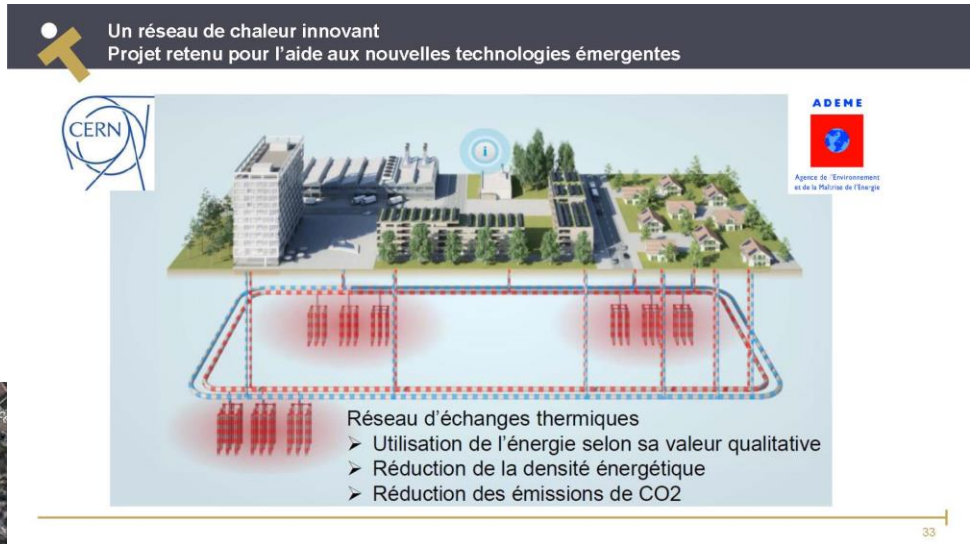
Infrastructure at LHC technical area



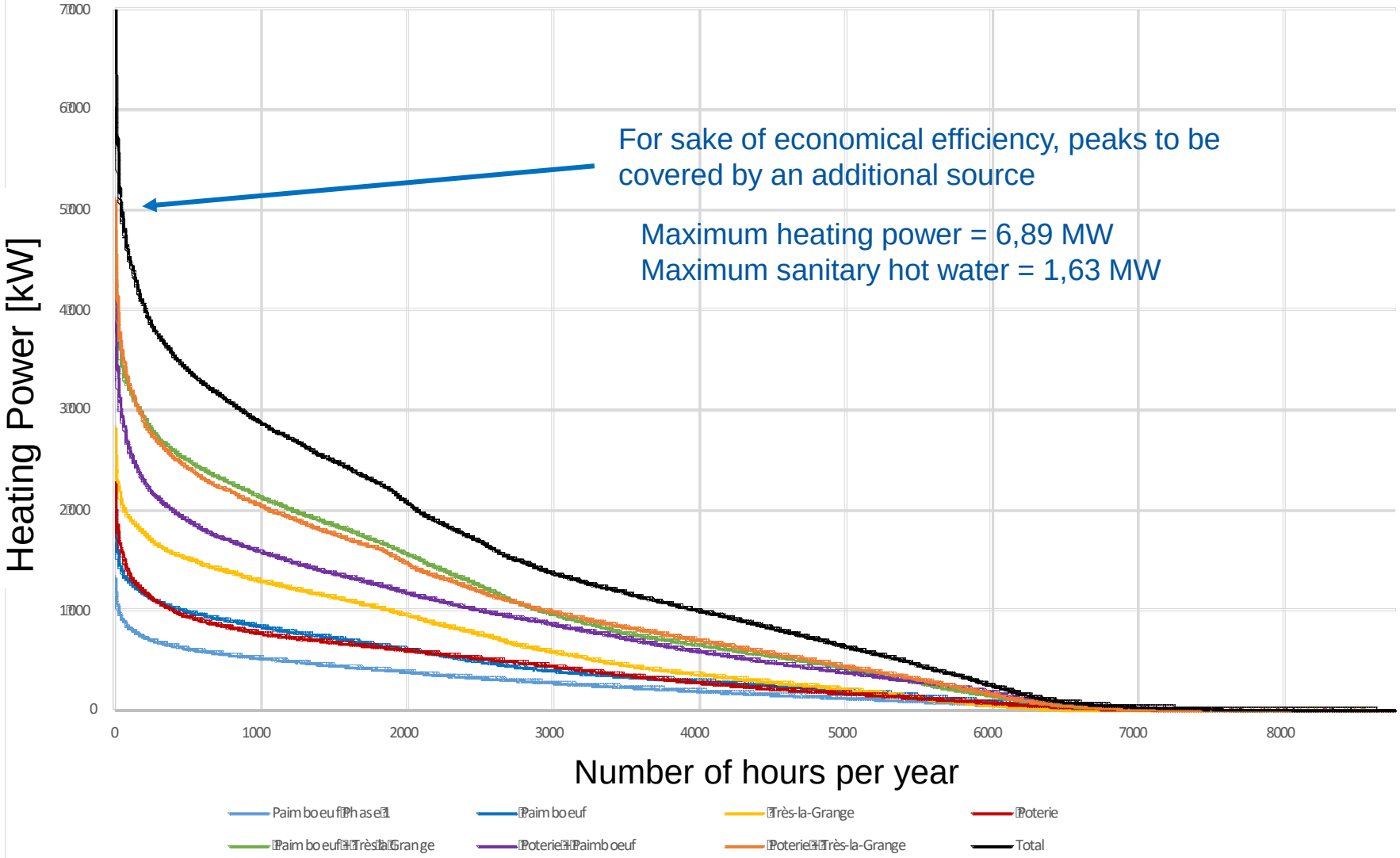
Possible synergy next to a CERN technical site

Heat recovery from CERN-P8 to be injected in a local “anergie” loop (ZAC Ferney-Voltaire)

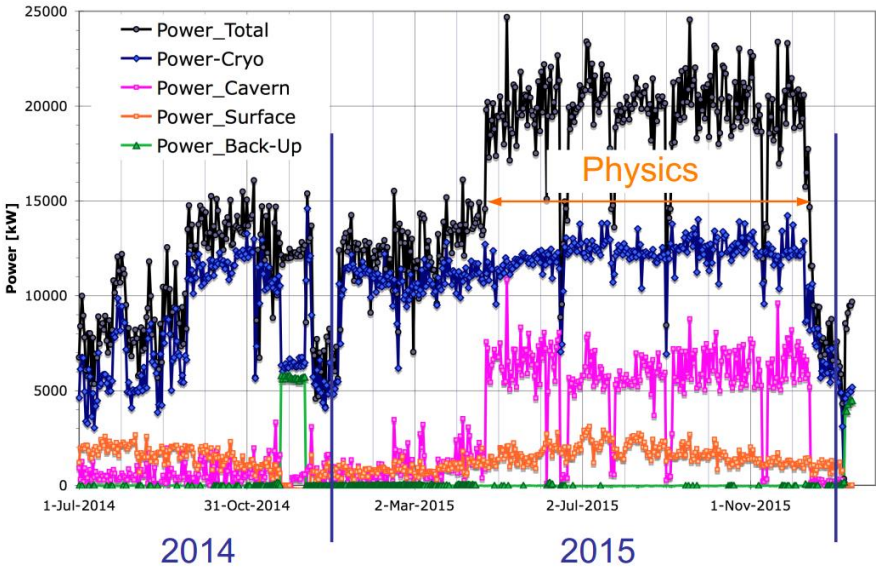


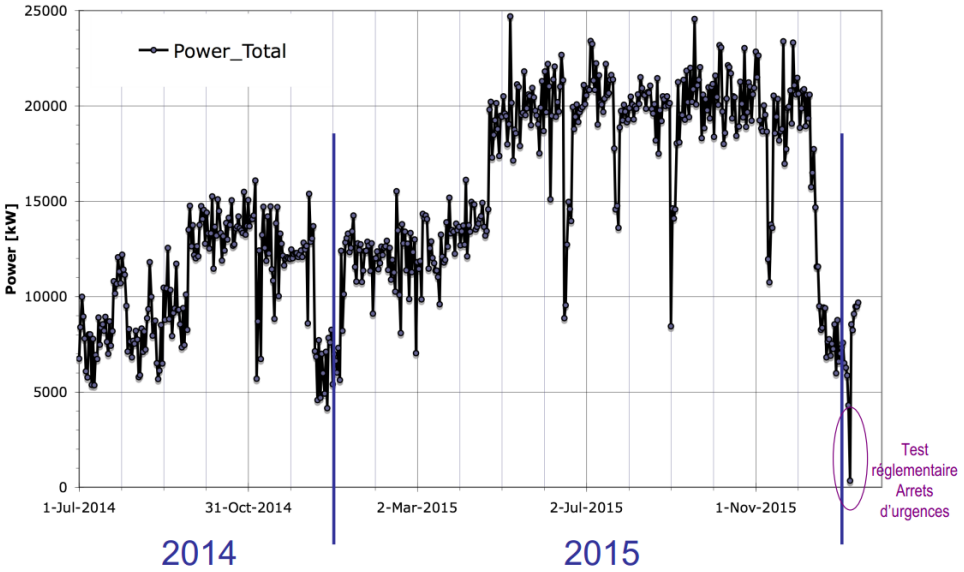
Preliminary technical feasibility done, followed by economical evaluation (2016)

Power breakdown (heating) for various zones



Source des graphiques : CERN – Serge Claudet





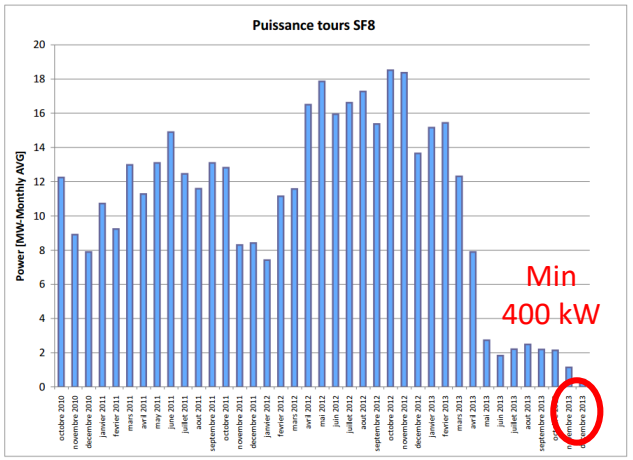
Two alternatives looked at, with the 2nd one matching better with their needs

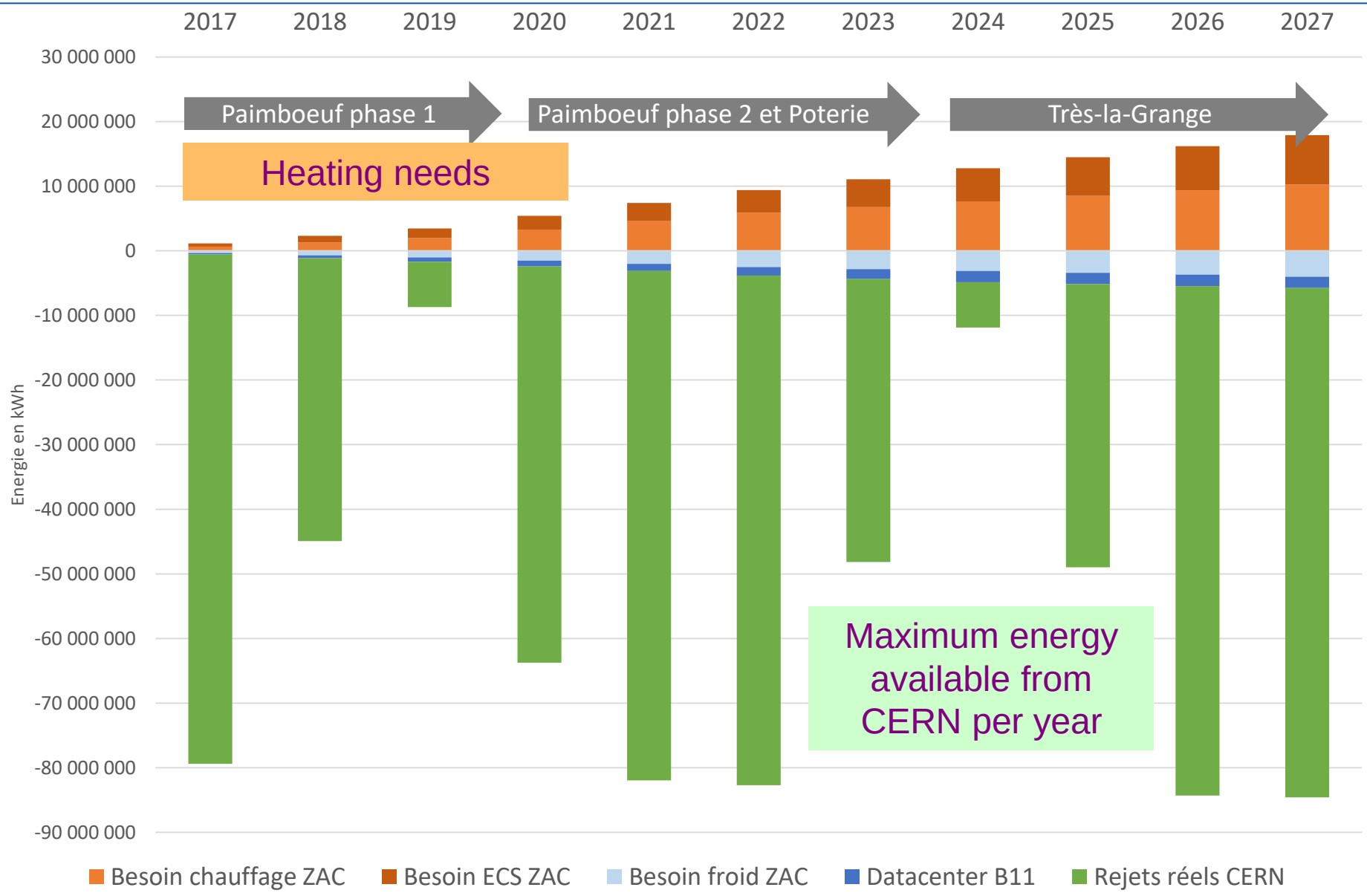
Cryogenics :
4 MW
32'000 MWh/yr at 65°C

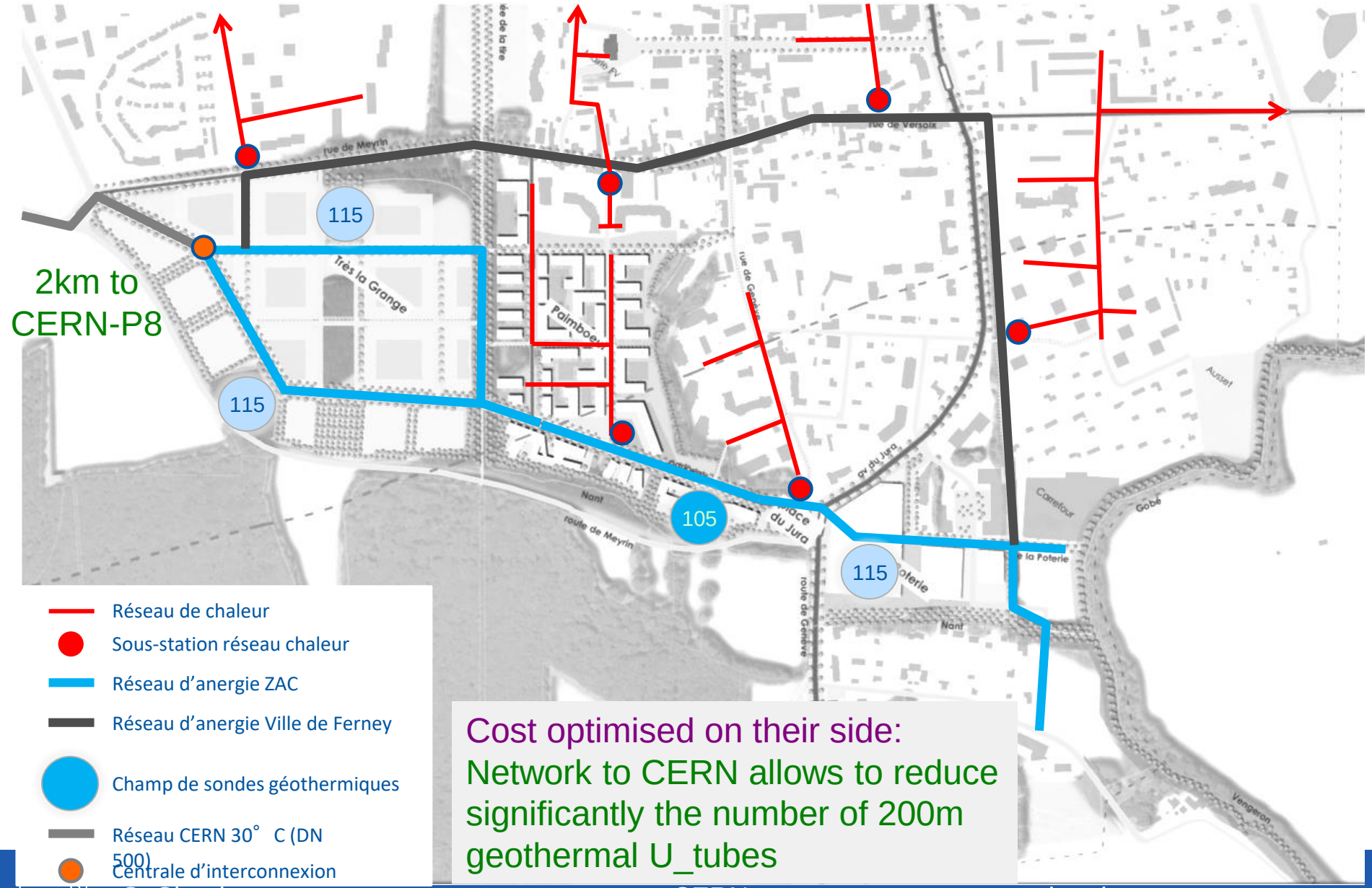
Cooling towers :
0,2 à 20 MW
90'000 MWh/yr at 30°C (base 10 MW)

Rmq: En cas de récupération de puissance à plus haute température 60-65°C, la puissance disponible au niveau des tours serait bien sûr réduite d'autant

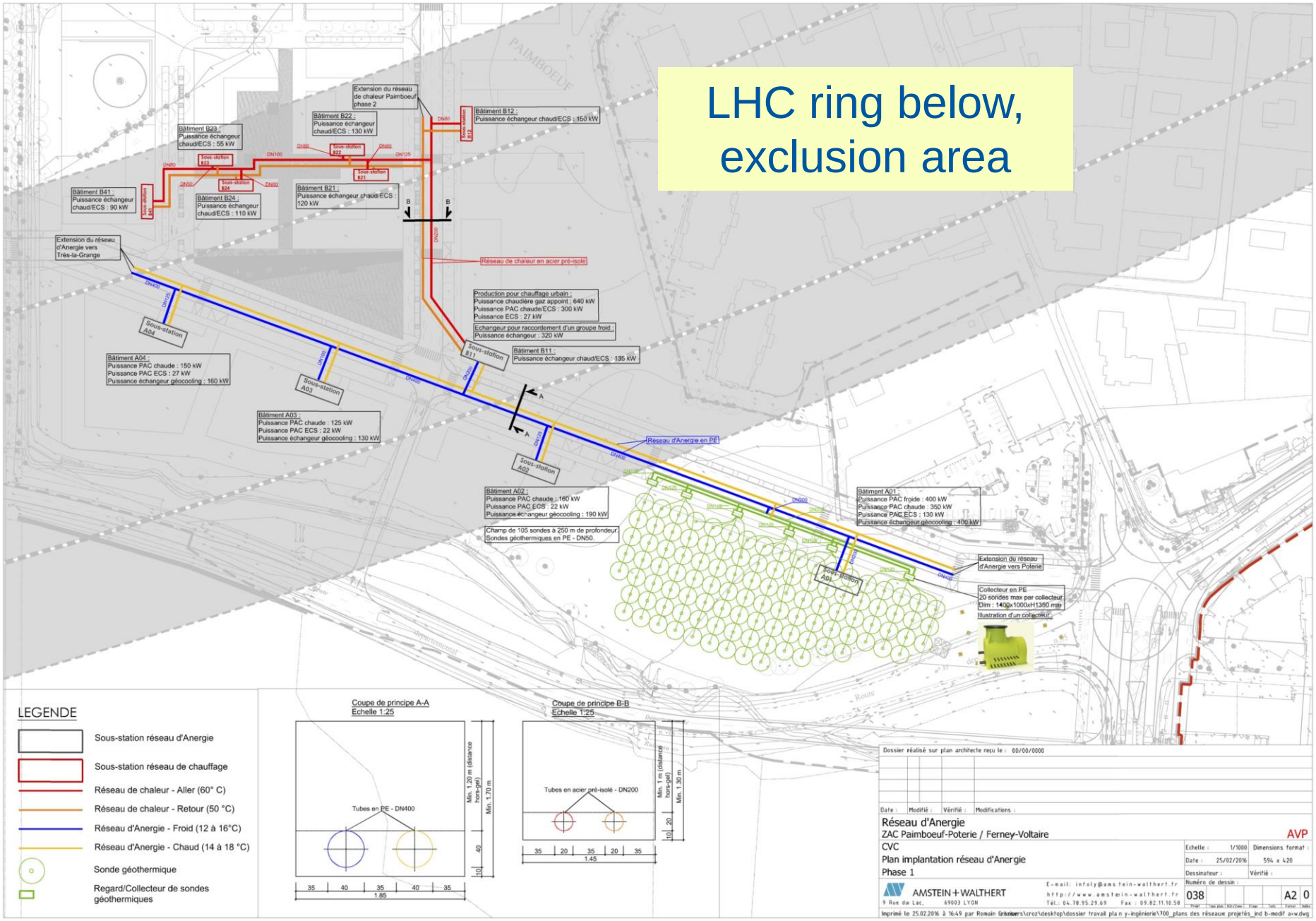
	Moyenne Puissance [MW]
octobre 2010	12.2
novembre 2010	8.9
decembre 2010	7.9
janvier 2011	10.7
fevrier 2011	9.2
mars 2011	13.0
avril 2011	11.3
may 2011	13.1
june 2011	14.9
juillet 2011	12.4
aout 2011	11.6
septembre 2011	13.1
octobre 2011	12.8
novembre 2011	8.3
decembre 2011	8.4
janvier 2012	7.4
fevrier 2012	11.1
mars 2012	11.6
avril 2012	16.5
mai 2012	17.9
juin 2012	15.9
juillet 2012	16.6
aout 2012	17.3
septembre 2012	15.4
octobre 2012	18.5
novembre 2012	18.4
decembre 2012	13.6
janvier 2013	15.2
fevrier 2013	15.4
mars 2013	12.3
avril 2013	7.9
mai 2013	2.7
juin 2013	1.8
juillet 2013	2.2
aout 2013	2.5
septembre 2013	2.2
octobre 2013	2.1
novembre 2013	1.1
decembre 2013	0.4



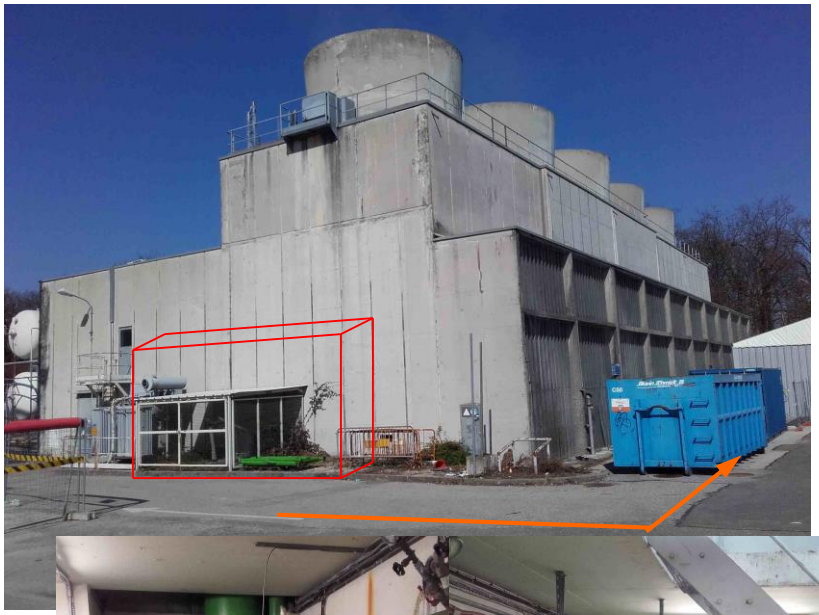

2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
30 000 000
20 000 000
10 000 000
0
-10 000 000
-20 000 000
-30 000 000
-40 000 000
-50 000 000
-60 000 000
-70 000 000
-80 000 000
-90 000 000
Energie en kWh
Paimboeuf phase 1
Paimboeuf phase 2 et Poterie
Très-la-Grange
Heating needs
Maximum energy available from CERN per year
Besoin chauffage ZAC
Besoin ECS ZAC
Besoin froid ZAC
Datacenter B11
Rejets réels CERN

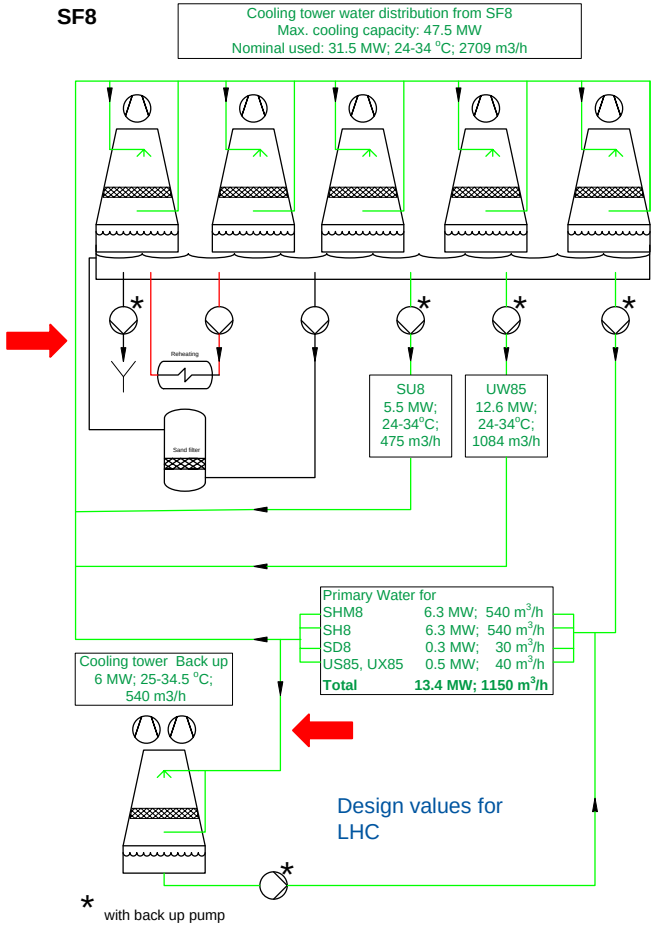


Cost optimised on their side:
Network to CERN allows to reduce significantly the number of 200m geothermal U_tubes


LHC ring below, exclusion area
Extension du réseau de chaleur Paimboeuf phase 2
Bâtiment B12 : Puissance échangeur chaud/ECS : 150 kW
Bâtiment B22 : Puissance échangeur chaud/ECS : 130 kW
Bâtiment B23 : Puissance échangeur chaud/ECS : 55 kW
Bâtiment B41 : Puissance échangeur chaud/ECS : 90 kW
Bâtiment B24 : Puissance échangeur chaud/ECS : 110 kW
Bâtiment B21 : Puissance échangeur chaud/ECS : 120 kW
Extension du réseau d'Anergie vers Très-la-Grange
Réseau de chaleur en acier pré-isolé
Production pour chauffage urbain : Puissance chaudière gaz appoint : 640 kW Puissance PAC chaude/ECS : 300 kW Puissance ECS : 27 kW
Echangeur pour raccordement d'un groupe froid Puissance échangeur : 320 kW
Bâtiment B11 : Puissance échangeur chaud/ECS : 135 kW
Bâtiment A04 : Puissance PAC chaude : 150 kW Puissance PAC ECS : 27 kW Puissance échangeur géocooling : 160 kW
Bâtiment A03 : Puissance PAC chaude : 125 kW Puissance PAC ECS : 22 kW Puissance échangeur géocooling : 130 kW
Réseau d'Anergie en PE
Bâtiment A02 : Puissance PAC chaude : 160 kW Puissance PAC ECS : 22 kW Puissance échangeur géocooling : 190 kW
Champ de 105 sondes à 250 m de profondeur Sondes géothermiques en PE - DN50
Bâtiment A01 : Puissance PAC froide : 400 kW Puissance PAC chaude : 350 kW Puissance PAC ECS : 130 kW Puissance échangeur géocooling : 400 kW
Extension du réseau d'Anergie vers Poterie
Collecteur en PE 20 sondes max par collecteur Dim : 1400x1000xH1360 mm
Illustration d'un collecteur
LEGENDE
Sous-station réseau d'Anergie
Sous-station réseau de chauffage
Réseau de chaleur - Aller (60° C)
Réseau de chaleur - Retour (50 °C)
Réseau d'Anergie - Froid (12 à 16°C)
Réseau d'Anergie - Chaud (14 à 18 °C)
Sonde géothermique
Regard/Collecteur de sondes géothermiques
Coupe de principe A-A Echelle 1:25
Tubes en PE - DN400
Coupe de principe B-B Echelle 1:25
Tubes en acier pré-isolé - DN200
Réseau d'Anergie
ZAC Paimboeuf-Poterie / Ferney-Voltaire
AVP
CVC
Plan implantation réseau d'Anergie
Phase 1
AMSTEIN+WALTHERT
038
A2 0

CERN - SF8 cooling towers





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

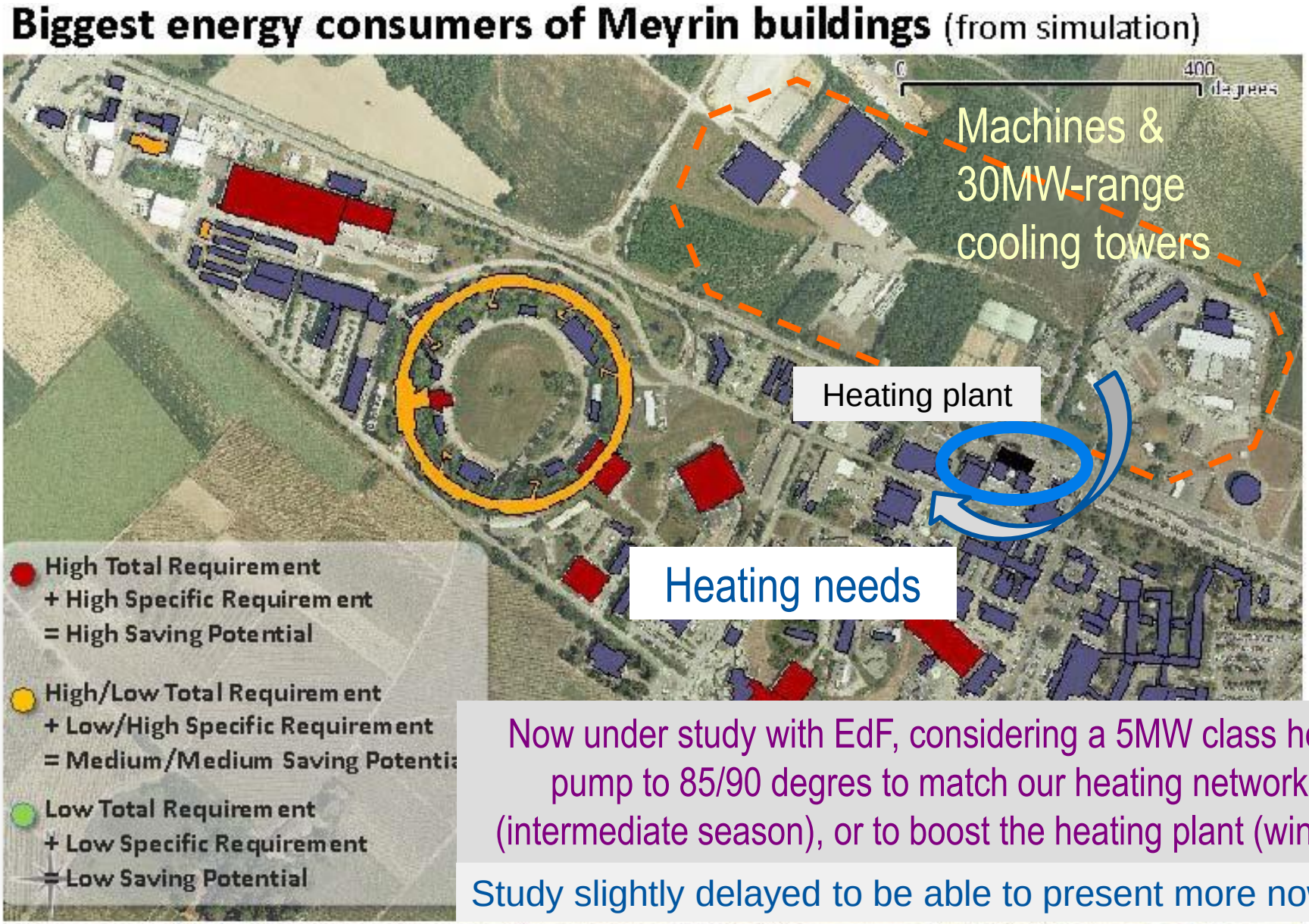
Next steps foreseen

- Formal aspects:
  - Letter of intend being prepared to confirm our intentions towards external party by end of 2017, recalling some basic principles (heat recovery when available, balanced costs for CERN on long term)
  - Convention (contractual) with representative of France locally to be finalised Q2-2018

- Technical aspects:
  - Clarification of all parameters of the project to be frozen
  - Technical study to be made for CERN activities
  - Most likely connections to 30˚water pipes and valves to be installed in 2019-2020 during long shut down 2
  - Completion of piping on CERN site and connection to heat network 2021

- Progressive heat recovery in/after 2021, adapted to our accelerator schedule and with progressive learning

Heat recovery project CERN-CERN, under study



Now under study with EdF, considering a 5MW class heat pump to 85/90 degres to match our heating network (intermediate season), or to boost the heating plant (winter)

Study slightly delayed to be able to present more now …

Summary

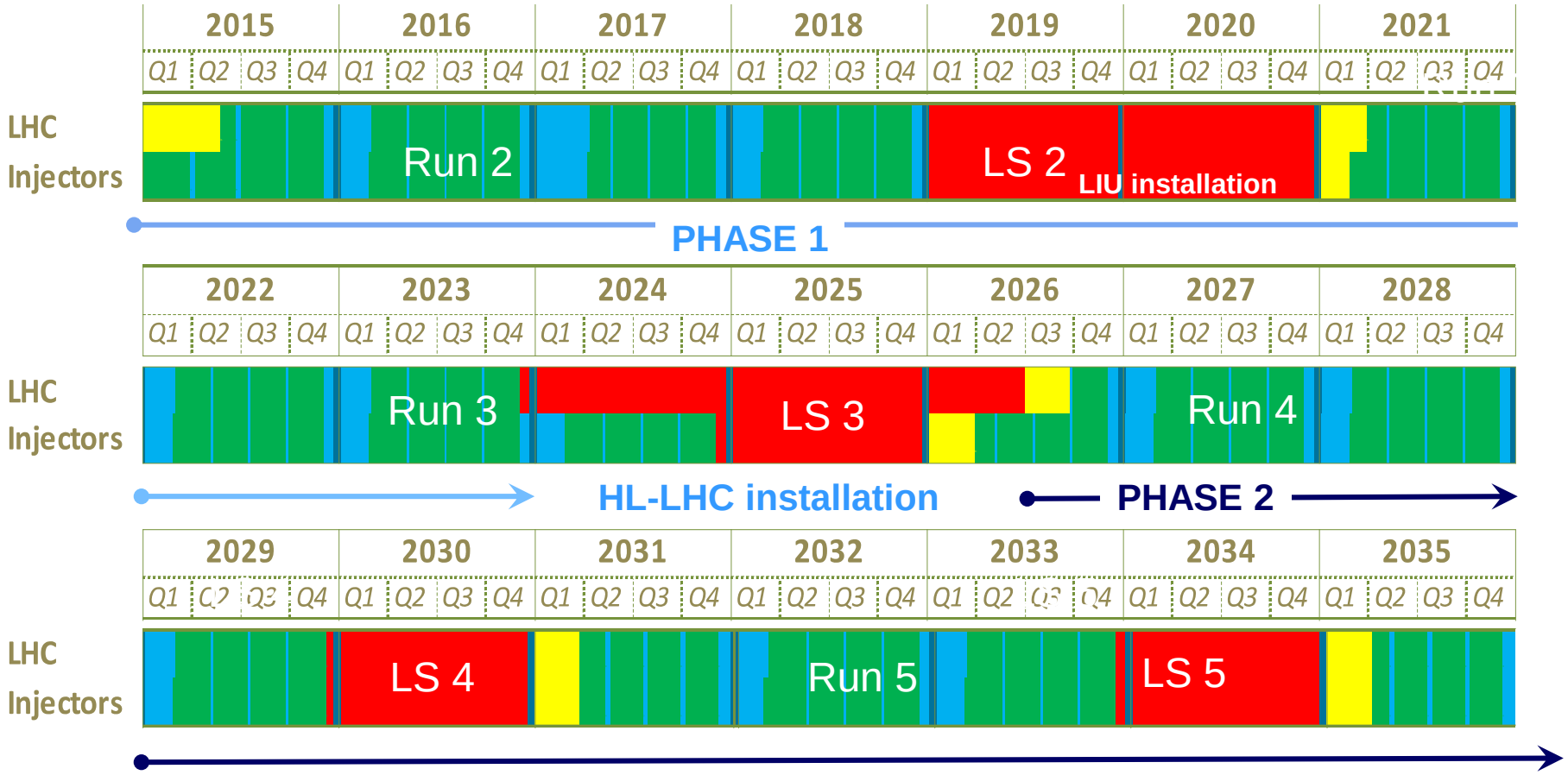
- At CERN level, primary energy consumption kept constant while LHC is producing more physics output, mostly due to initial design choices (superconductivity w.r.t normal conducting)
- Energy management is now in place with good forecasts and monitoring tools. Energy efficiency awareness is progressively diffusing through the CERN community
- A series of energy efficiency studies have been started, with not so many easy savings to be expected. Two heat recovery projects of MW class are under study, with decisions to be taken in 2018

Thank you for your attention!

Complementary slides

LHC roadmap

LS2 starting in 2019 => 24 months + 3 months BC
LS3 LHC: starting in 2024 => 30 months + 3 months BC
Injectors: in 2025 => 13 months + 3 months BC

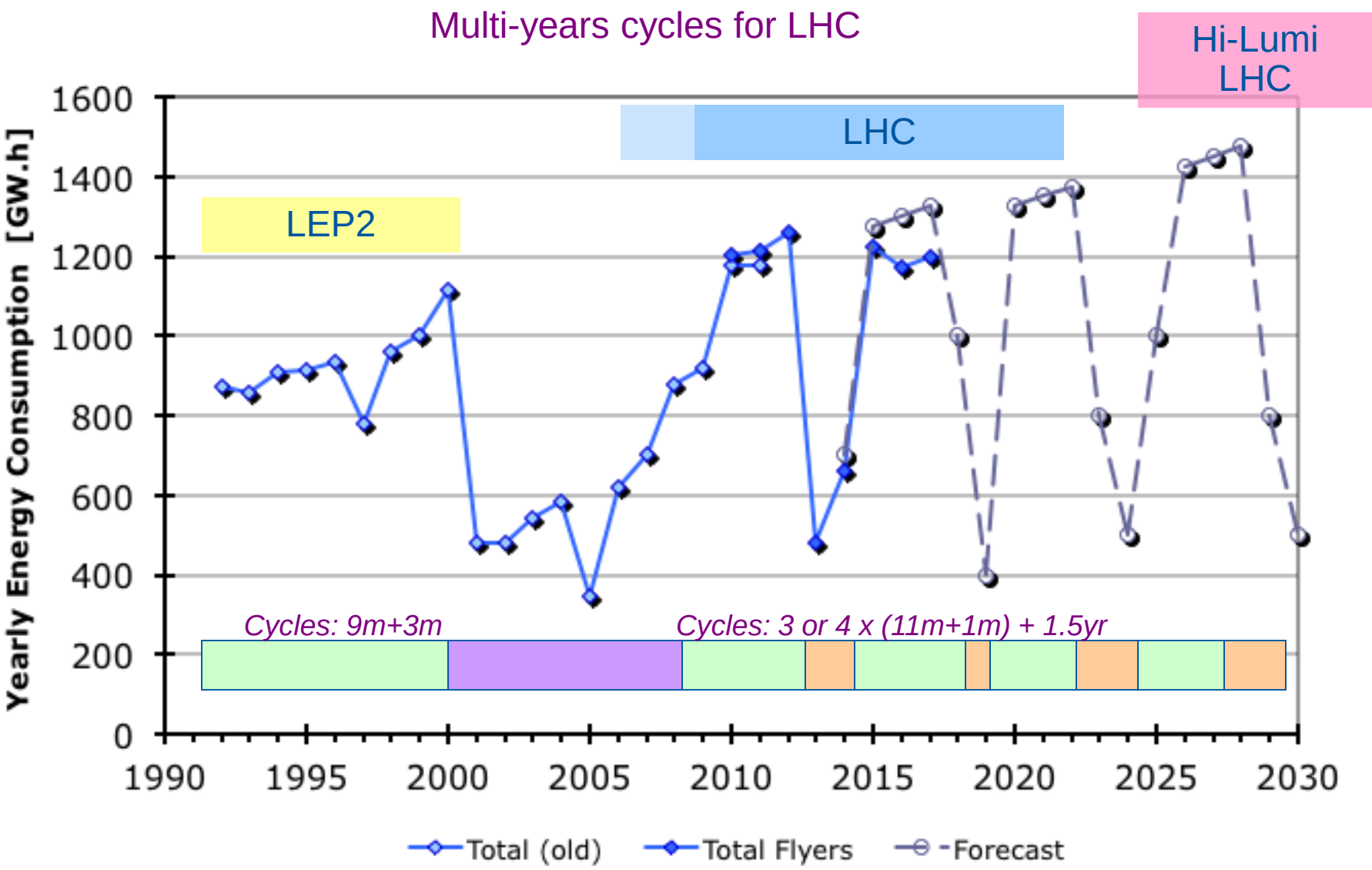


Main topics from mandate

Proposal to proceed by steps,
stronger global efforts at the beginning and more targeted once going

- 2 — Awareness: Each main consumer (all of us by definition) should be able to present:
  - Power consumption for idle-nominal-maxi or by modes like ramps, physics, f(Intensity, Energy)
  - Energy consumption per year (Run, LS, and evolution with I)
  - Corresponding cost, at least an idea at +/- 20 %
- 1 — Energy forecasts and management:
  - Based on the above, update of the model (principle?, updated figures, transitions)
  - Specifically with Ti (BMo/SCl/JNi), evaluate the reporting capabilities for updated forecasts based on recent consumption and short term plans
- 1 — Changes in programs:
  - Done for 2018 (Run2 extended by 6 months)
  - Next foreseen for progress with definition for intensity ramp-up Spring 2016
  - Rules and Mechanism for transmission of updated scenarii to be defined (BMo, SCl)
- 3 — Degraded operation scenarios for reduced power:
  - EN-EL note and Ti priority list to be communicated for review by all of us, and definition of priorities
- 2 — Recommendations to reduce CERN's energy bill: (with minimal impact on CERN's operations)
  - What can each of us do to reduce it' s consumption by 5%, by 10%, more ?
  - What could be done (including us or others) on a system to achieve the same targets (5%, 10%, …)?

CERN Energy Consumption



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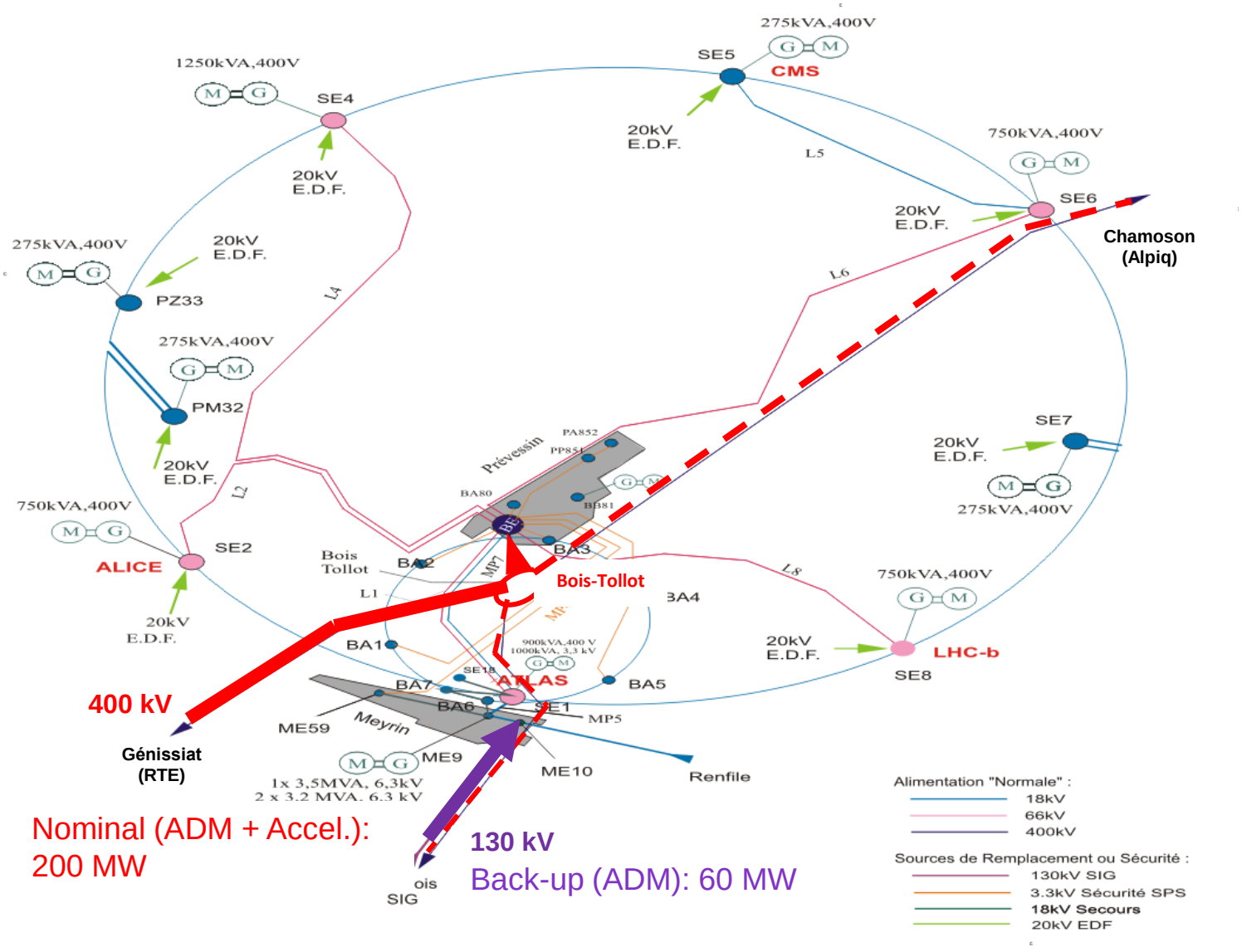
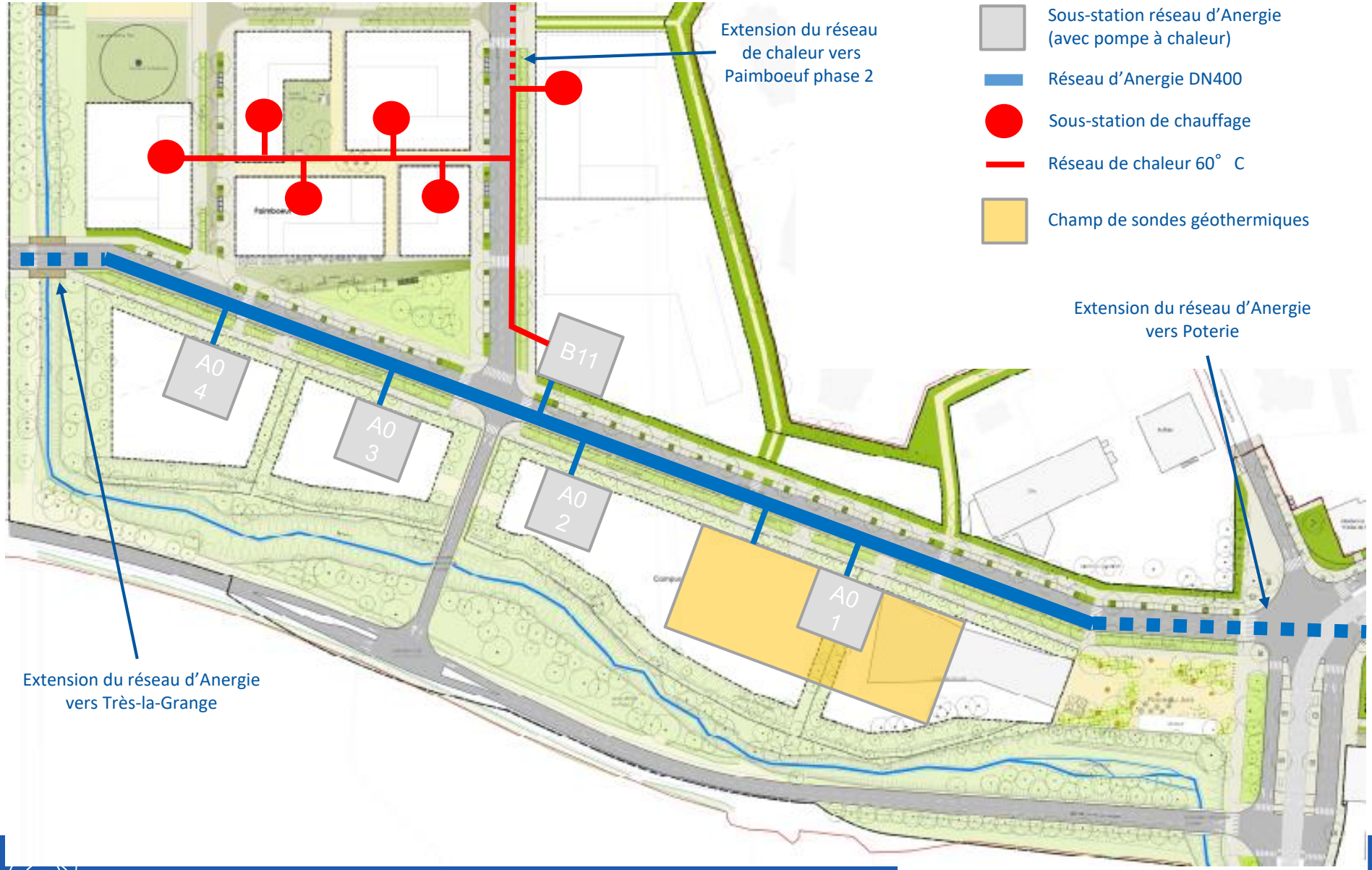
Distribution électrique au CERN *(aspects géographiques)*




D78
D35B
D35C
D1005
Pré de la Corne
2 km
ZAC
P8 CERN
France
Schweiz
Gd-Saconnex


Extension du réseau de chaleur vers Paimboeuf phase 2
Sous-station réseau d'Anergie (avec pompe à chaleur)
Réseau d'Anergie DN400
Sous-station de chauffage
Réseau de chaleur 60° C
Champ de sondes géothermiques
Extension du réseau d'Anergie vers Poterie
Extension du réseau d'Anergie vers Très-la-Grange
A0 4
A0 3
A0 2
A0 1
B11