CERN Accelerates Sustainability!

R. Losito, CERN

3 October 2023

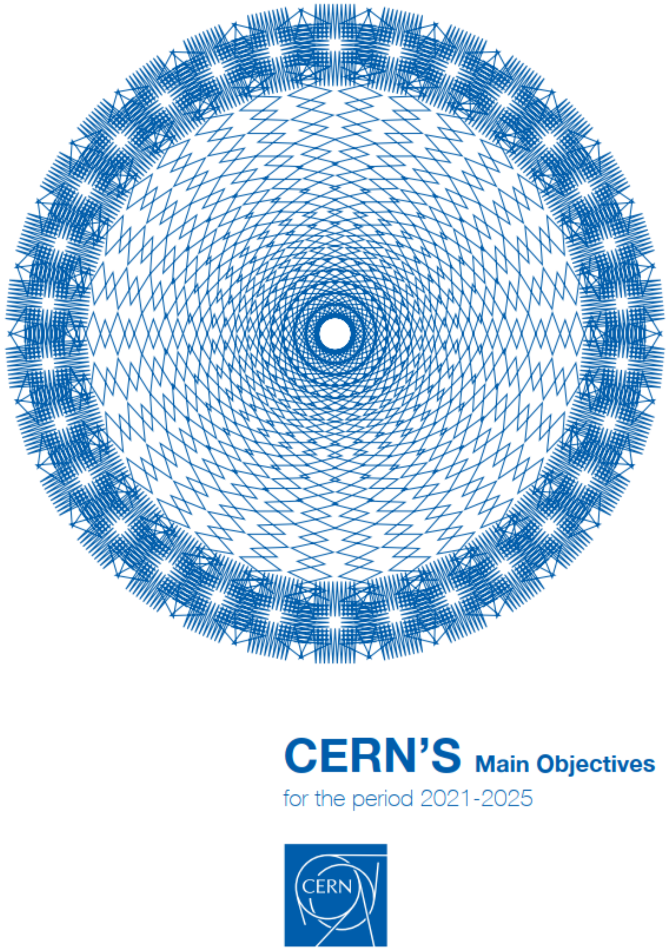
ILO Forum

https://indico.cern.ch/event/1326911/

Management Objectives 2021-2025
Commitment to SDGs

‘One of the Management’s top objectives for the next five-year period is to increase CERN’s impact on society, thereby boosting the Organization’s visibility and consolidating the support of governments and the general public’.

‘Across all these areas of activity, CERN will continue to ensure that their impact also ***contributes to advancing the Sustainable Development Goals (SDG)****, adopted by all United Nations Member States in 2015. Collaboration with CERN’s Member and Associate Member States, with international organisations and other partners will be enhanced to identify and pursue further synergies in support of the SDGs, building on CERN* ***values****,* ***competencies*** *and* ***technologies****’.*



Sustainable Development Goals
The basics

- On 25 September 2015, the United Nations General Assembly unanimously adopted Resolution 70/1, **Transforming our World: the 2030 Agenda for Sustainable Development**, laying out 17 Sustainable Development Goals, aimed at mobilising global efforts to **end poverty**, foster **peace**, safeguard the **rights and dignity** of all people, and **protect the planet**.
- The Goals are **inter-related** and **all countries** have agreed to try to meet all of them **by 2030**.
- The Goals serve to **coordinate actions** by UN agencies, non-governmental groups, businesses and any other entities working on a specific Goal.
- **Yearly meetings** are organised to present the actions undertaken and the progress made.
- Each Goal is broken down into defined and specific **targets** (169 in total) that propose concrete paths to reach each Goal; the targets are all **complementary strategies** to fulfil their respective Goal.
- Each target has then its own **indicators**, which are the variables that can be measured and assessed to report on the progress made.

Mapping
CERN contribution to the Goals

- **2017 initial mapping** => 5 Goals identified for priority
- **2021 updated mapping** => 2 further Goals added – SDG5 and SDG7 => to align with Management Objectives

SDG 3 - HEALTH
CERN helps to develop technologies that contribute to better healthcare for all, such as medical imaging and hadron therapy.

SDG 4 - EDUCATION
Education is one of CERN's core missions. We offer high quality programmes that inspire thousands of students, teachers and young researchers each year.

SDG 5 - GENDER
Diversity is a core value for CERN. Our diversity policy aims at leveraging the added value that comes from bringing together people of different nationalities, genders, professions and ages.

SDG 7 - ENERGY
CERN develops strategies to minimise the increase of energy consumed by the installations, increase energy efficiency and implement energy recovery.

SDG 9 - INNOVATION
CERN inventions are brought to industry through knowledge transfer, to have a positive impact on society and innovation.

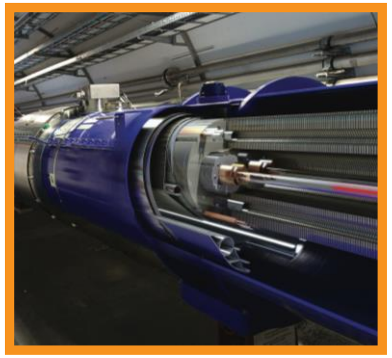
SDG 16 & 17 - INTERNATIONAL COOPERATION
CERN is a successful model for international collaboration. CERN gathers researchers from all over the world, contributing to human knowledge and peace, for the benefit of all.

THERAPY
Accelerators provide particle beams for more targeted cancer treatment.

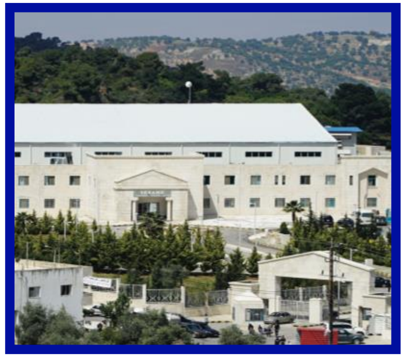
BEAMLINE FOR SCHOOLS COMPETITION
Students from the two winning teams spend a week at CERN to carry out their experiment using a CERN accelerator.

25 BY 25 DIVERSITY & INCLUSION INITIATIVE
First ever targets-based strategy to boost the nationality and gender diversity within the Staff and Fellows population.
.

HEATING LOCAL HOUSING
Heat recovered from CERN's accelerator cooling systems to heat a new residential area in the town of Ferney-Voltaire, benefiting up to 8000 people.



A MAGNET IN THE LHC TUNNEL
Exploring the universe requires new technologies and ingenious engineering to build the machines that explore physics at a new frontier.



SESAME
This new synchrotron light source in Jordan started operation in 2017. It is a unique collaboration between eight Middle East members, modelled on CERN's governance structure.

European Strategy

7

Environmental and societal impact

A. The energy efficiency of present and future accelerators, and of computing facilities, is and should remain an area requiring constant attention. Travel also represents an environmental challenge, due to the international nature of the field. ***The environmental impact of particle physics activities should continue to be carefully studied and minimised. A detailed plan for the minimisation of environmental impact and for the saving and re-use of energy should be part of the approval process for any major project. Alternatives to travel should be explored and encouraged.***

Establishing a Working Group on "Sustainability Assessment of Accelerators"

- We have been commissioned by LDG Chair to draft a charge for a new working group that will develop guidelines and a minimum set of key indicators pertaining to the methodology and scope of the reporting of sustainability aspects for future HEP projects
- This group will effectively define to all new infrastructure proposals what they should quantify and report upon so that fair comparisons can be made between these proposals
- Having clear and common indicators will ensure that projects are not accused of cherry picking only their most favourable sustainability numbers

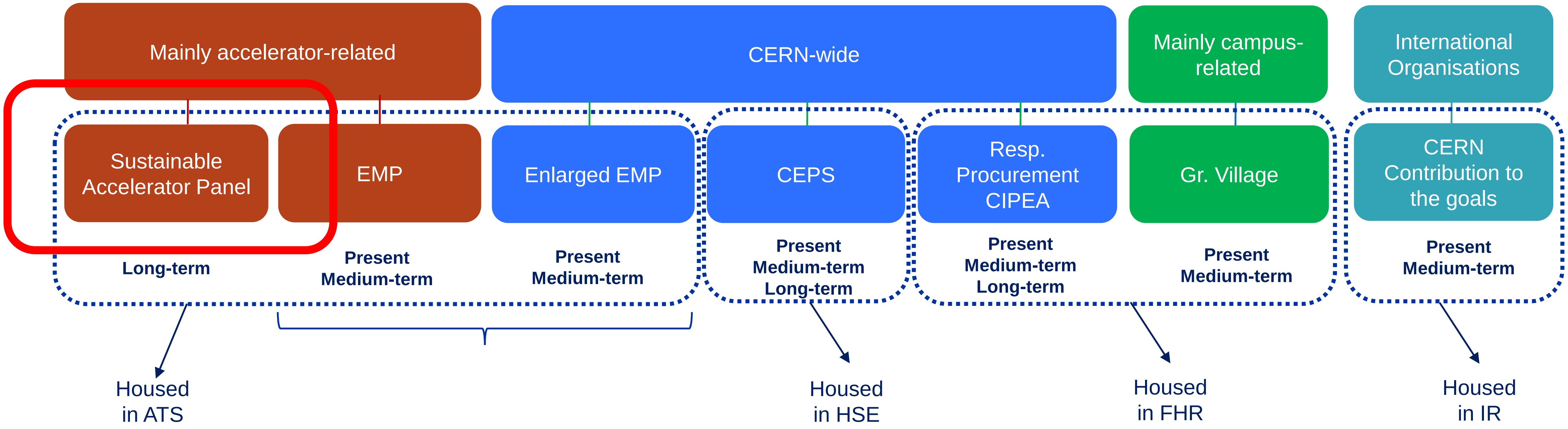
Open Meeting of the European Laboratory Directors Group

J. Clarcke (STFC), B. Heinemann (DESY & U. Freiburg), M. Seidl (PSI)

Jul 10 – 11, 2023
INFN - Frascati National Laboratories
Europe/Rome timezone

Enter your search term

Panels/Activities at CERN with direct impact on SDGs



• Sustainable Accelerators Panel

- **R. Losito, chair**
- **E. Metral, Deputy chair**
- **M. Bernardini, Scientific Secretary**

- Liaise with **future accelerator projects** to develop full lifecycle sustainability as a key consideration at the project inception phase.
  - This should include high-level energy management scenarios.
  - Consider the issue of waste management along the lifecycle at future accelerators; also consider end-of-life dismantling.
  - Identify and quantify the potential of **energy efficient accelerator technology** for use in present and future accelerators.
  - Evaluate the potential impact of **accelerator design and novel accelerator concepts** in present and future machines and initiate studies where appropriate.
  - Explore the use of sustainable materials and components in accelerator construction and evaluate the impact of adhering to international standards in sustainable procurement.

• Sustainable Accelerators Panel

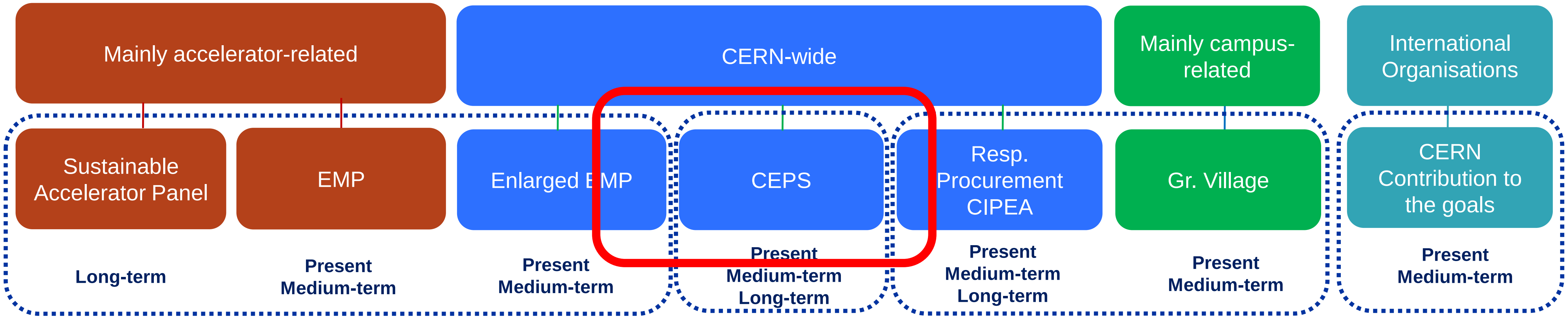
- **Applications**
  - Identify innovative accelerator technology with the potential for use in such applications as power/energy distribution and energy storage.
  - Where appropriate, support exchange with external partners to leverage use of in-house technology in a sustainability context.
- **Disseminate**
  - Collate and publicize CERN's efforts in the sustainable accelerator technology domain; publicize CERN's efforts and track developments at sustainability related conferences and workshops.

• Sustainable Accelerators Panel

- **Collaborate**
  - Monitor and support exchange with partners engaged in alternative forms of energy generation (e.g. ITER, MYRRHA).
  - Explore and exploit where appropriate links into external programmes such as Horizon.
- Overall, act as **forum and focal point** for the diverse efforts in accelerator sustainability at CERN and provide a contact point for interaction with external partners.

The work of the panel is parallel with the ongoing efforts of EMP and Energy Coordination, close communication should be ensured by membership. Given the domains of interest indicated above, the panel is ATS centric and reports to the ATS director.

Panels/Activities at CERN with direct impact on SDGs



CERN Environmental Protection Steering Board

- **Main body for prioritization and implementation of environmental objectives**
- **Created in 2017, involves members of the ED, line management and units for management of energy and environmental footprint.**
- **Steers projects for about 40 MCHF**
  - Retention basins and new STEP to control effluents
  - Cooling towers upgrades
  - Dismissal of oil-based transformers
  - Replacement of GHG in detectors
  - Inventory of Scope 1, 2, 3 emissions, biodiversity, Noise & waste managements….
- **Coordinates the editing of the CERN Environmental report**

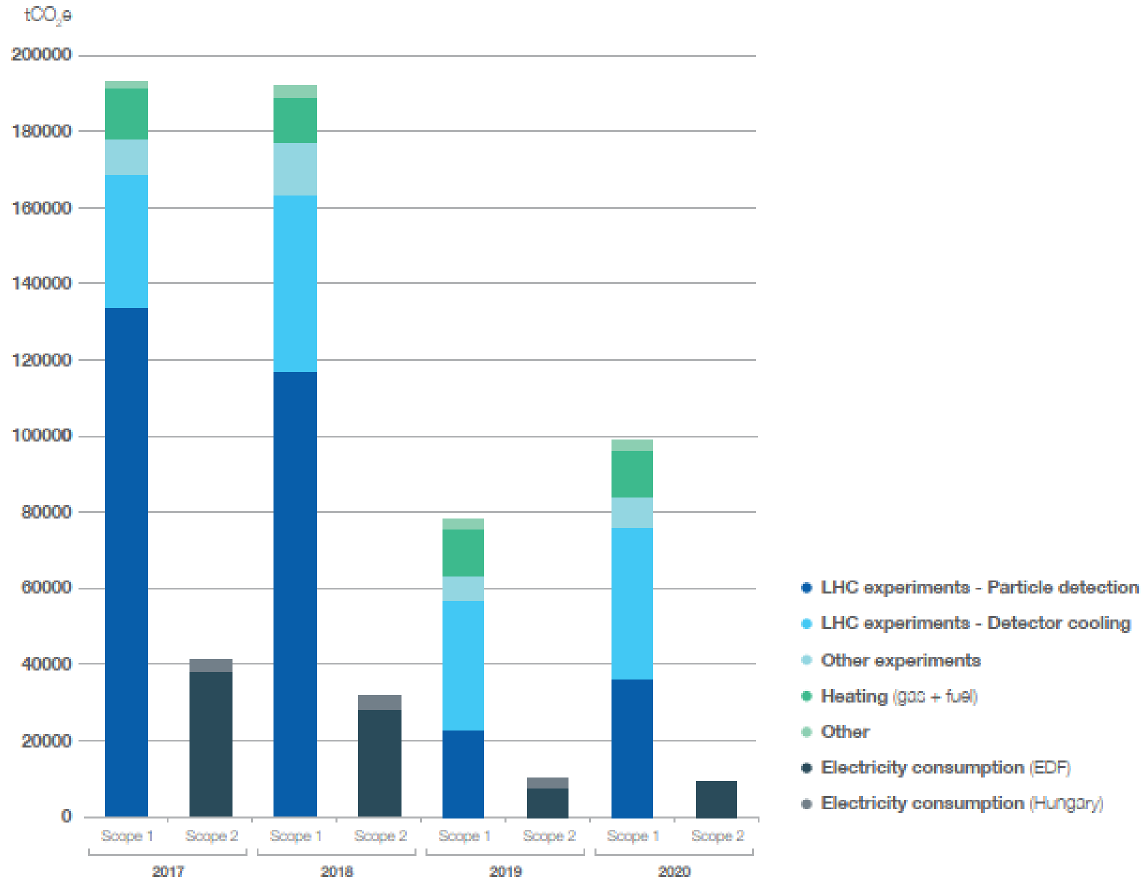
In order to control you need to measure…

- CERN publishes since 2017 environmental reports based on the **GRI (Global Reporting Initiative)** standards

- It includes detailed information about Energy and water supply and effluents management, direct and indirect CO_2 emissions, radiological impact (emissions and waste), conventional waste, Noise.

- Measuring allows to establish objectives and allocate funds…

CO2 Emissions, Scope 1 (Direct) and 2 (Indirect)



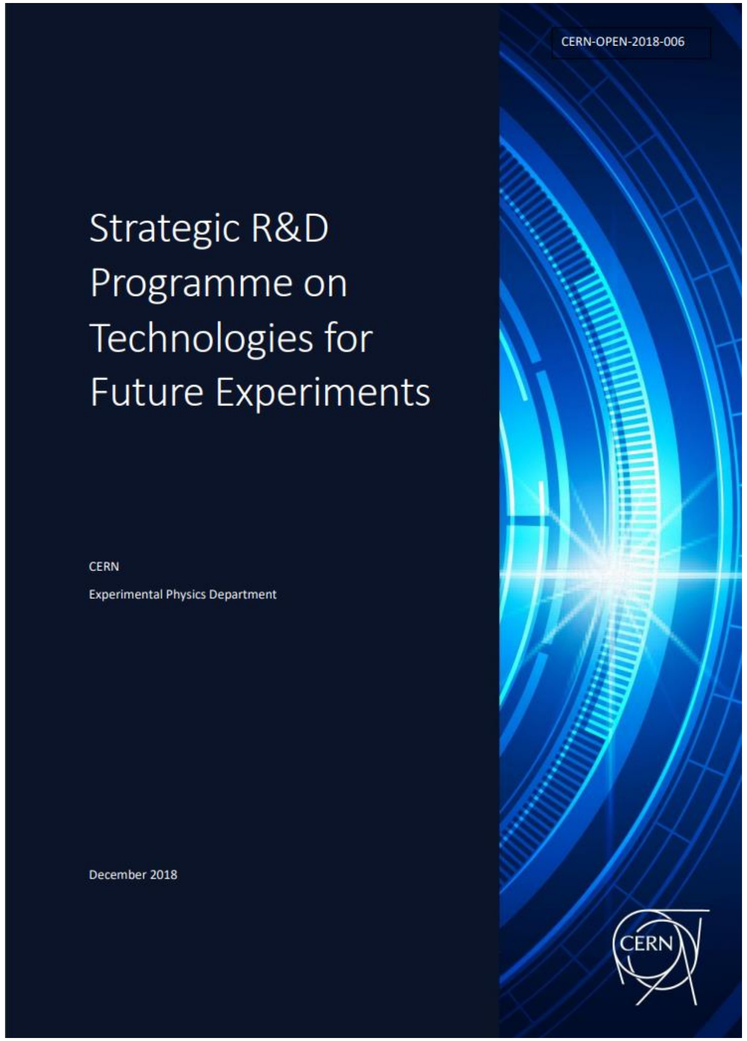
CERN SCOPE 1 AND SCOPE 2 EMISSIONS FOR 2017-2020 BY CATEGORY.

Other includes air conditioning, electrical insulation, emergency generators and CERN vehicle fleet fuel consumption. Emission factors for electricity: EDF Bilan des émissions de GES 2002-2020 for EDF and Bilan Carbone® V8 for Hungary.

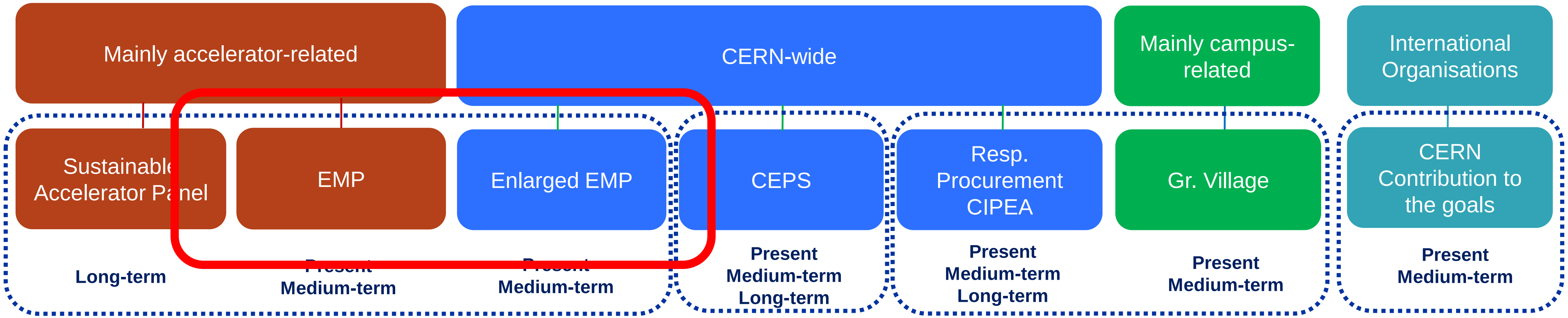
- **The future is bright!!!**
  - Scope 1 emissions dominate CERN's emissions
  - Most of them due to (now) obsolete design of detectors
  - Difficult to eliminate in near future in LHC, but experiments have promised to reduce by at least ~30% with LS3.
    - Repair leaks
    - Change fluids
      - Massive use of CO_2 as coolant
- **For the next generation of colliders, this line will *(almost)* not be there anymore!!!**
- *Scope 3 emissions are less than 5%...*

R&D on Detector technologies

A common issue for many gas based detectors is the need of eco-friendly gas mixtures. In the context of CERN's environmental policy, the CERN Environmental Protection Steering Board (CEPS) is following up on the environmental impact of gas based detection systems. New eco-friendly gas mixtures or novel solutions for the gas system and in the detector need to be investigated: a few critical examples to be replaced are SF_6, $C_2H_2F_4$ for RPCs or CF_4 mainly for timing GEMs [1].



Panels/Activities at CERN with direct impact on SDGs



SDG 7: Affordable and clean Energy

- **CERN is managing its electrical consumption responsibly since at least 10 years, well before the establishment of the SDGs.**
- **Recently issued an Energy* policy with three pillars:**
  - **LESS** : Reduce consumption (consolidation & operation)
  - **BETTER** :
    - Precise Forecasting & Measurement
    - Raising awareness
  - **RECOVER** : Waste energy

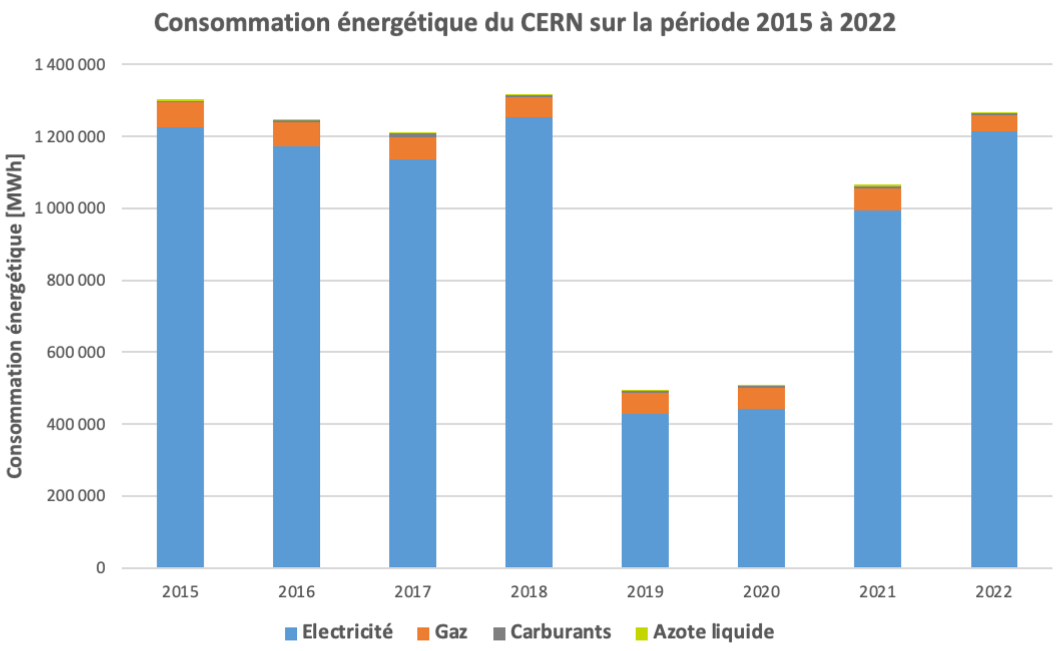
**Energy is not only electricity…*

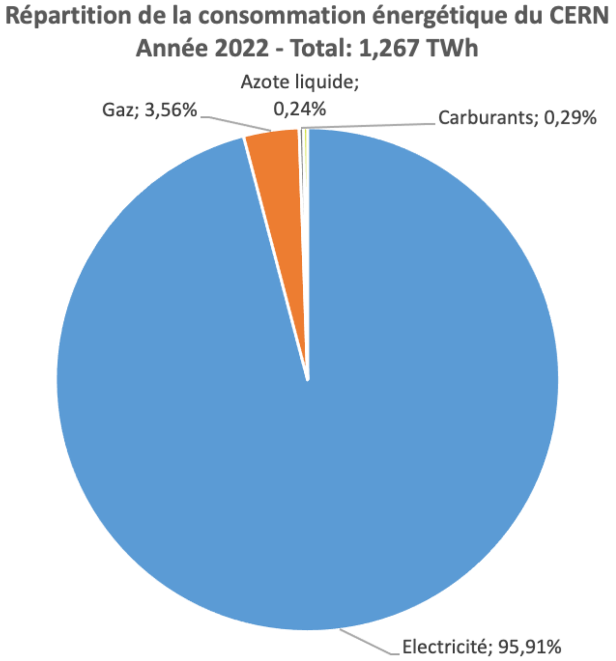
Energy consumption at CERN

- <u>New:</u> Addition of liquid nitrogen as an energy source (following certification audit)

  → 7.3 GWh/year when cooling down the LHC, 3.1 GWh/year otherwise

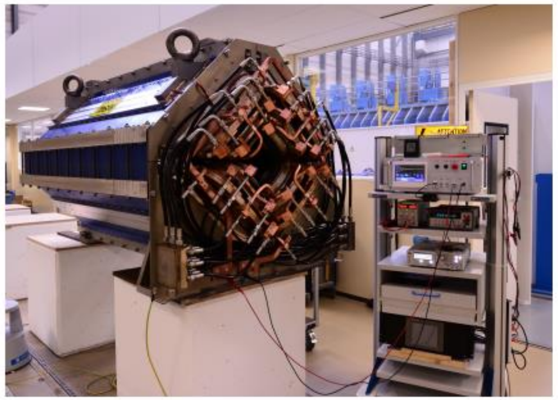
- Consolidated figures





LESS: Improved efficiency, recent cases

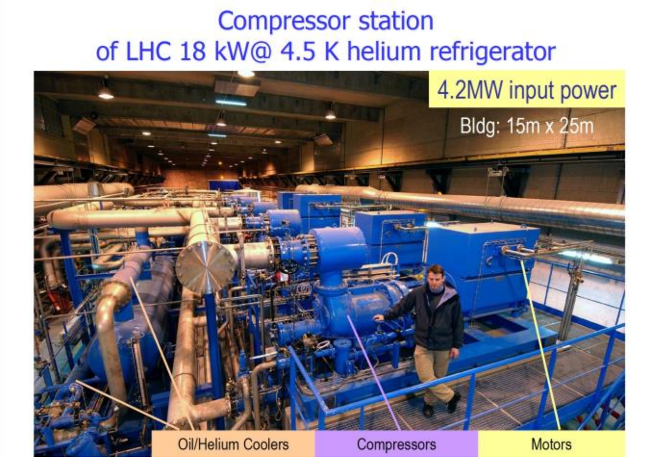
Facility upgrades: East Area Renovation (done during recent LS2)



Powering energy:
From 11 GWh/year to around 0.6 GWh/year
(> 90% reduction)

Warning: Optimisation of a system (powering, cooling) makes sense only when considering collective effects on users !!!

New equipment (Cryogenic Refrigerators for HL-LHC)

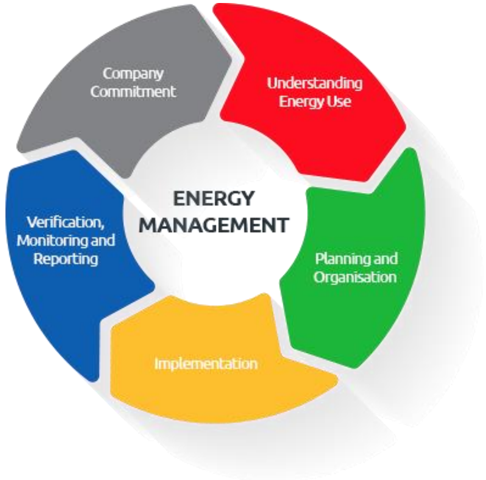


A set of requirements (performance, technology) to allow industry to provide the optimum for a given scenario:

Adjudication: CAPEX + OPEX (10 years)

BETTER: ISO 50001 certification

- **CERN is the first Laboratory ISO 50001 certified.**
- **Certification implies the establishment of improvement goals, and of continuous monitoring.**
- **The process is not limited to the experts on the field: the line and top management have to be continuously informed of the status of the KPIs and take action.**
- **The Energy Management Panel (standard and Enlarged) are the bodies used to manage and control Electricity Consumption.**




afaq
AFNOR CERTIFICATION

Certificat
Certificate

N° 2023/103380.1 — Page 1 / 1

AFNOR Certification certifie que le système de management mis en place par :
AFNOR Certification certifies that the management system implemented by:

Organisation européenne pour la Recherche nucléaire (CERN)
European Organization for Nuclear Research (CERN)

pour les activités suivantes :
for the following activities:

RECHERCHE FONDAMENTALE EN PHYSIQUE DES PARTICULES.

FUNDAMENTAL RESEARCH IN PARTICLE PHYSICS.

a été évalué et jugé conforme aux exigences requises par :
has been assessed and found to meet the requirements of:

ISO 50001 : 2018

et est déployé sur les sites suivants :
and is developed on the following locations:

Adresse	N° SIREN
Esplanade des Particules 1 CH-1211 GENÈVE 23	
9001, route de Saint-Genis FR-01280 PREVESSIN MOENS	445403488

(L'ensemble des activités de l'entreprise sur les sites donnés est couvert par la certification)
(The scope of certification covers all activities carried out on the above-mentioned locations)

Ce certificat est valable à compter du (année/mois/jour) *This certificate is valid from (year/month/day)* 2023-02-02 Jusqu'au *until* 2026-02-01

Julien NIZRI
Directeur Général d'AFNOR Certification
Managing Director of AFNOR Certification

Flashez ce QR Code pour vérifier la validité du certificat

BETTER: Energy performance plan (2022-2026)

- **Main technical document together with the « energy review » including the:**
  - Retained perimeter
  - Energy baseline
  - Summary of actions carried out in the past
  - Energy performance indicators
  - Objectives and targets for the next 5 years
  - Action plan for the next 5 years
  - Benchmark against other research institutes
- **Definition of 8 Significant Energy Uses (SEUs)**
  - Energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement


CONTENTS

Foreword 4
Highlights 6
About CERN 8
Management approach 10
Discovery machines 12
Energy 14
Emissions 16
Ionising radiation 20
Noise 22
Biodiversity 23
Waste 24
Water and effluents 26
Environmental compliance 30
Knowledge and technology for the environment 32
Glossary 34
GRI content index 36

Photos, clockwise from top left: Power transmission line, water measurements, civil engineering works, sheep grazing.

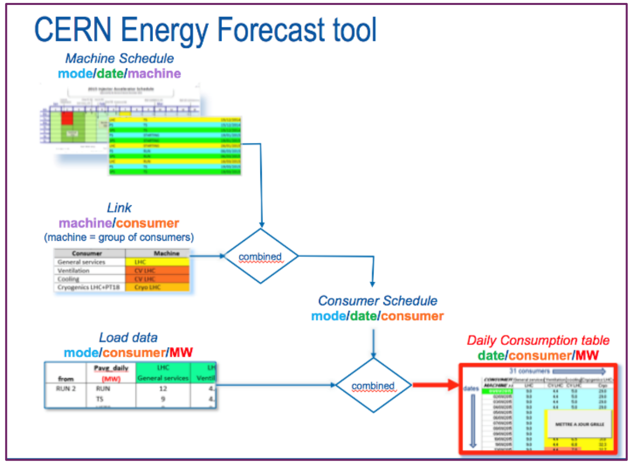
2 | CERN Environment Report

2019 - 2020 | 3

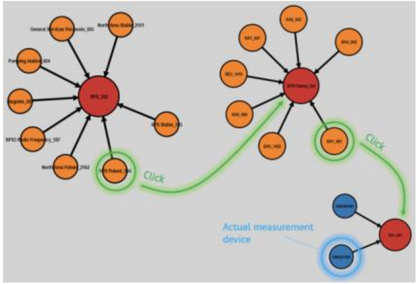
Use sector or use	Energy	Average consumption 2015–2018 (GWh)	Significance of energy use/consumption in %
LHC	Electricity	657 GWh	55%
SPS	Electricity	324 GWh	27%
PS complex	Electricity	125 GWh	10%
Data centres (Meyrin and ALICE and LHCb experiments)	Electricity	32 GWh[4]	3%
Meyrin buildings	Electricity	35 GWh	3%
Prévessin buildings	Electricity	16 GWh	1%
Meyrin heating	Gas	52 GWh LHV	82%
Prévessin heating	Gas	11 GWh LHV	18%

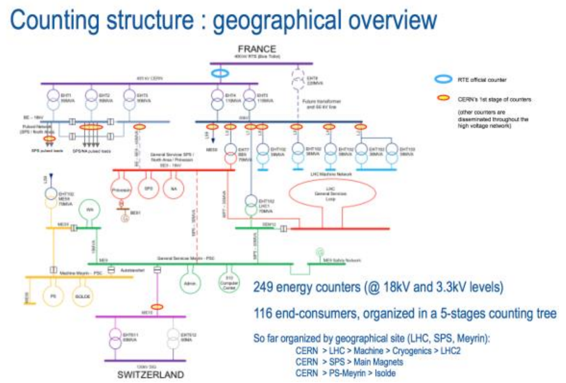
95%

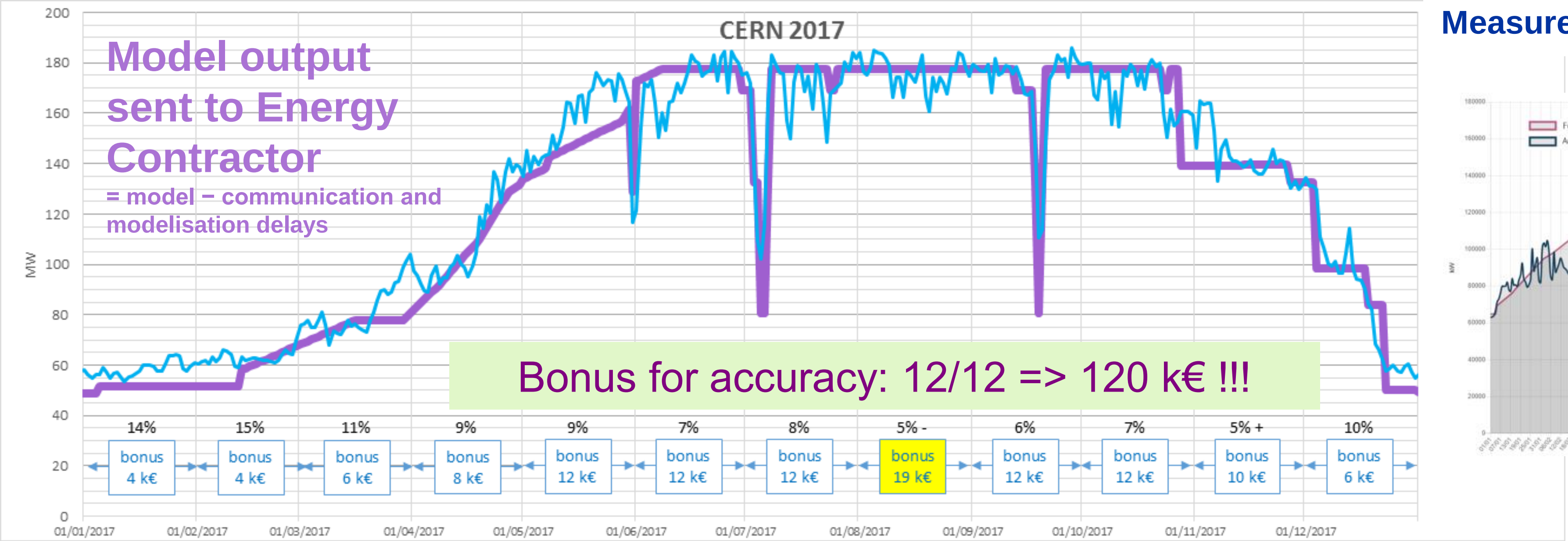
BETTER: Forecasts & measures



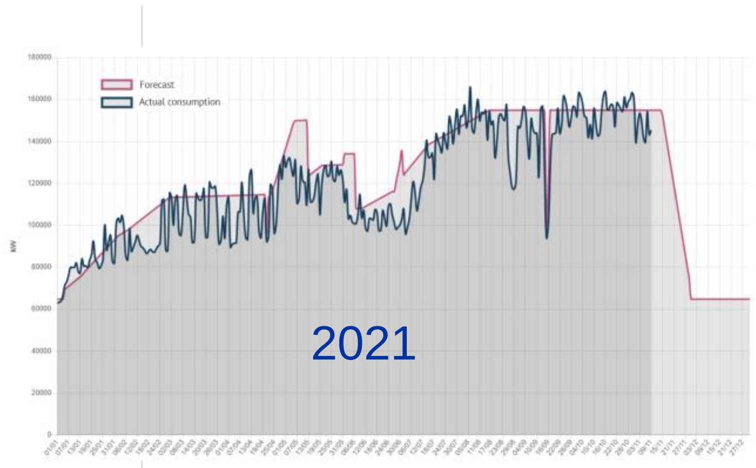
2nd version, integrated in **Web-Energy** tool to combine forecasts & measures







Measures: global accuracy better than 1% !



BETTER: Forecasts & awareness

- **In order to raise awareness, already since years the line management (group leaders, equipment owners) receive a “virtual” invoice for the equipment under their responsibility**

- **It is virtual in the sense that groups are not charged with the mentioned cost, but gives them a sense of the impact of their work, and the possibility to follow up along the years.**

CERN

Year 2017

User LHC Cooling

Date of issue 19-Jan-18
Invoice # LHCCool_2017-1
EDMS # 1886026

This invoice is being sent to **:
olivier.crespo-lopez@cern.ch
serge.deleval@cern.ch
mauro.nonis@cern.ch

Technical contact:
Bruno MOUCHE, EN-EL
bruno.mouche@cern.ch

Your electricity consumption in 2017:	61.3	GWh
Your share of CERN's total consumption:	5.4	%
Your virtual invoice for 2017: (energy + transmission)	2.52	M€

Figures are extracted from the WebEnergy application, with daily prices applied according to CERN's energy and transmission contracts.
https://energy.cern.ch
NB: energy counters are located on the high voltage network, which means that it is not possible to achieve perfect granularity in the counting structure. Some compromises have therefore been made when defining the boundaries between consumers. The counting structure is public and available on the WebEnergy application. For any queries, clarifications or information, please don't hesitate to contact us, or consult the application.

** please feel free to contact us to update this list.

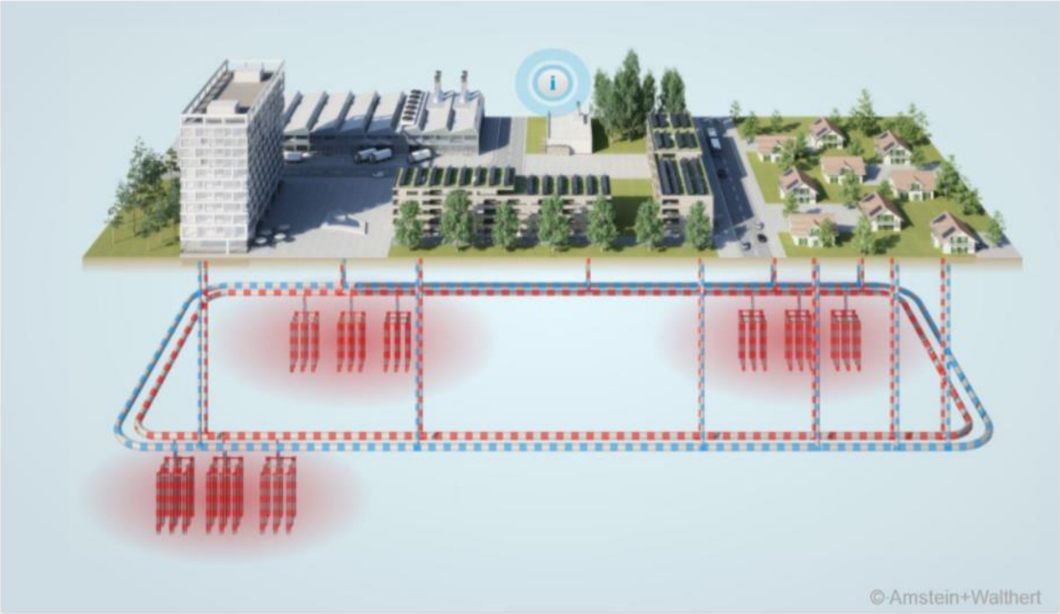
LHCCool_2017-1 (1/2)

RECOVER

Comment réchauffer un quartier en refroidissant le LHC

L'eau chaude issue du système de refroidissement du LHC au point 8 va être récupérée pour chauffer un nouveau quartier de la commune avoisinante de Ferney-Voltaire

23 JUILLET, 2019 | Par Anaïs Schaeffer



Des sondes géothermiques implantées dans le sol sous le nouveau quartier (les 9 « grappes » rouges sur l'image) permettent de stocker de la chaleur.

uvelle Zone d'aménagement concerté (ZAC) actuellement en construction à Ferney-Voltaire. En rouge, le réseau de récupération de chaleur qui reliera le point 8 à ce nouveau quartier (Image : Territoire d'Innovation)

Action plan

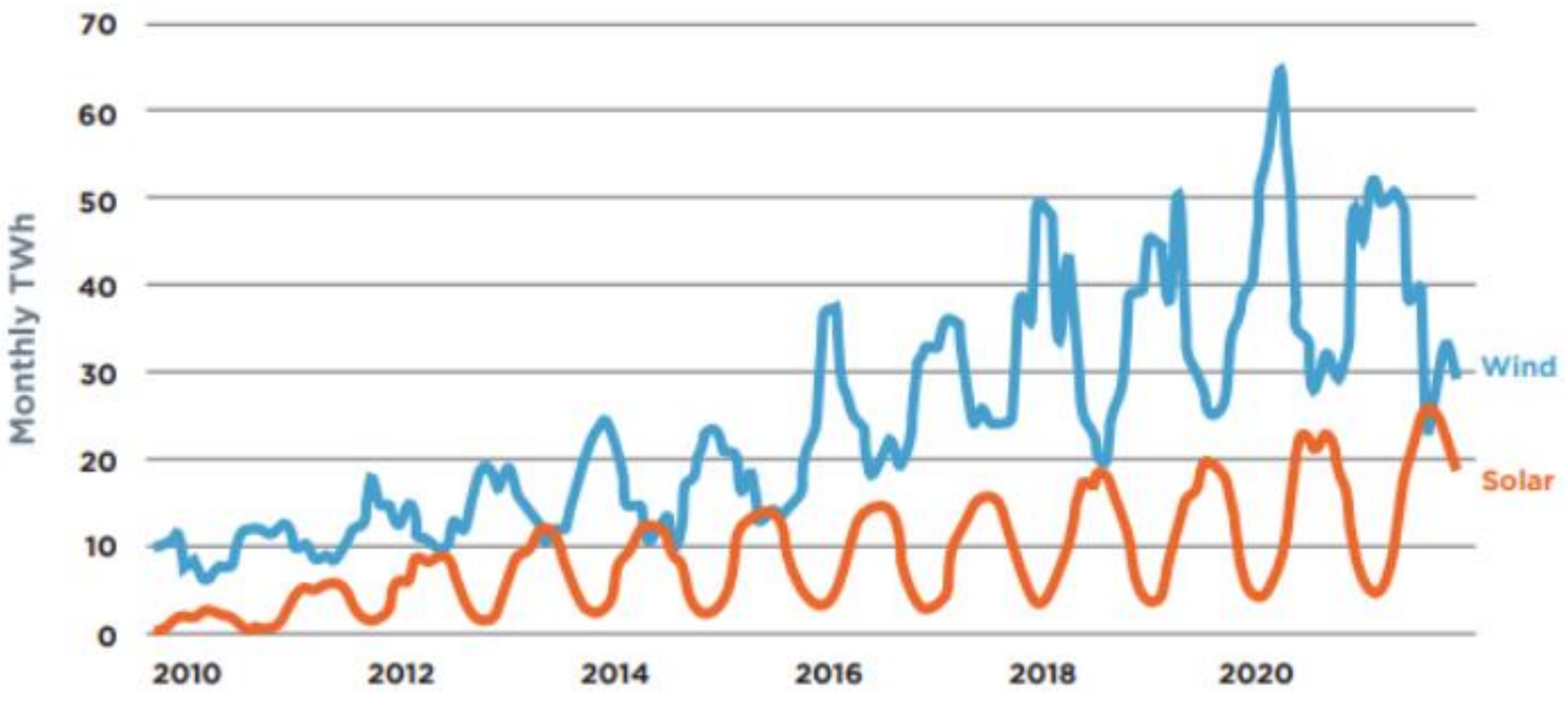
	Energy saved
Cooling and ventilation consolidation projects	6 GWh/year
75 consolidation projects for buildings	10 GWh/year
Science Gateway	200+ MWh/year
Optimisation of Cryo operations mode	25 GWh/year
Heat recovery projects	
Meyrin and Prévessin	30+GWh/year
Ferney-Voltaire	20 GWh/year (for the neighbors)

Will we have renewables on site?

Area needed to generate 1.3 TWh/y

(no contingency, no distribution, no storage…)

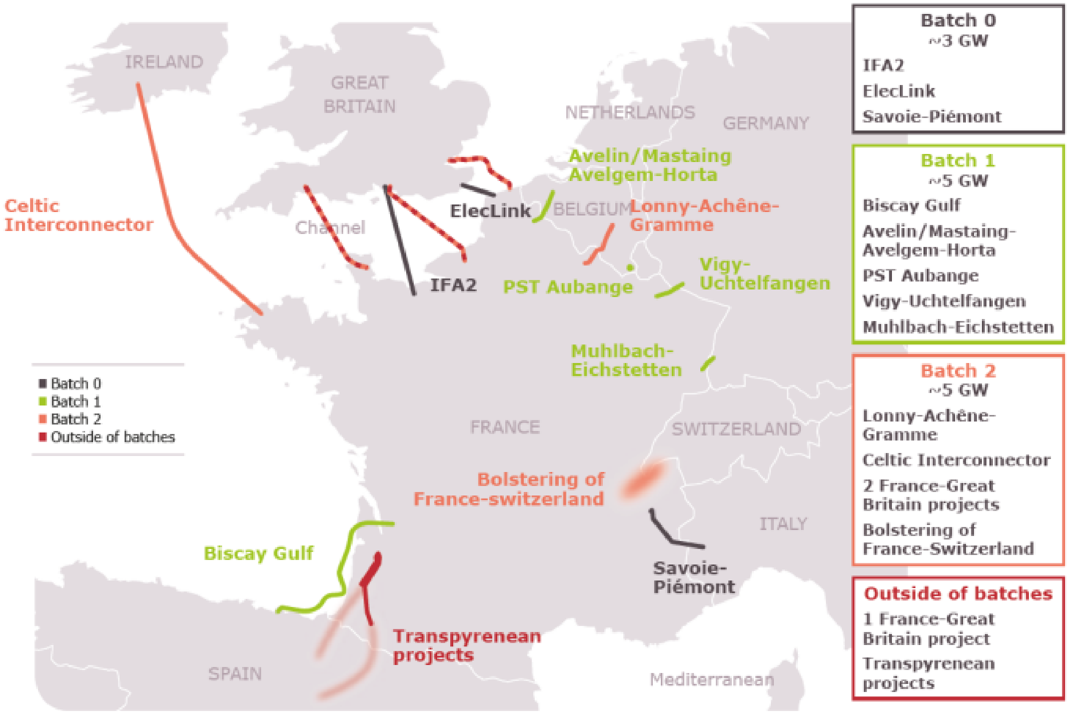
WIND AND SOLAR GENERATION IN EUROPE



Source: International Energy Agency

O'Connor (2023) Supergrid – Supersolution

Reinforcing the European Grid



French Transmission Ten Year network development plan - 2019 edition

15 GW in 2015

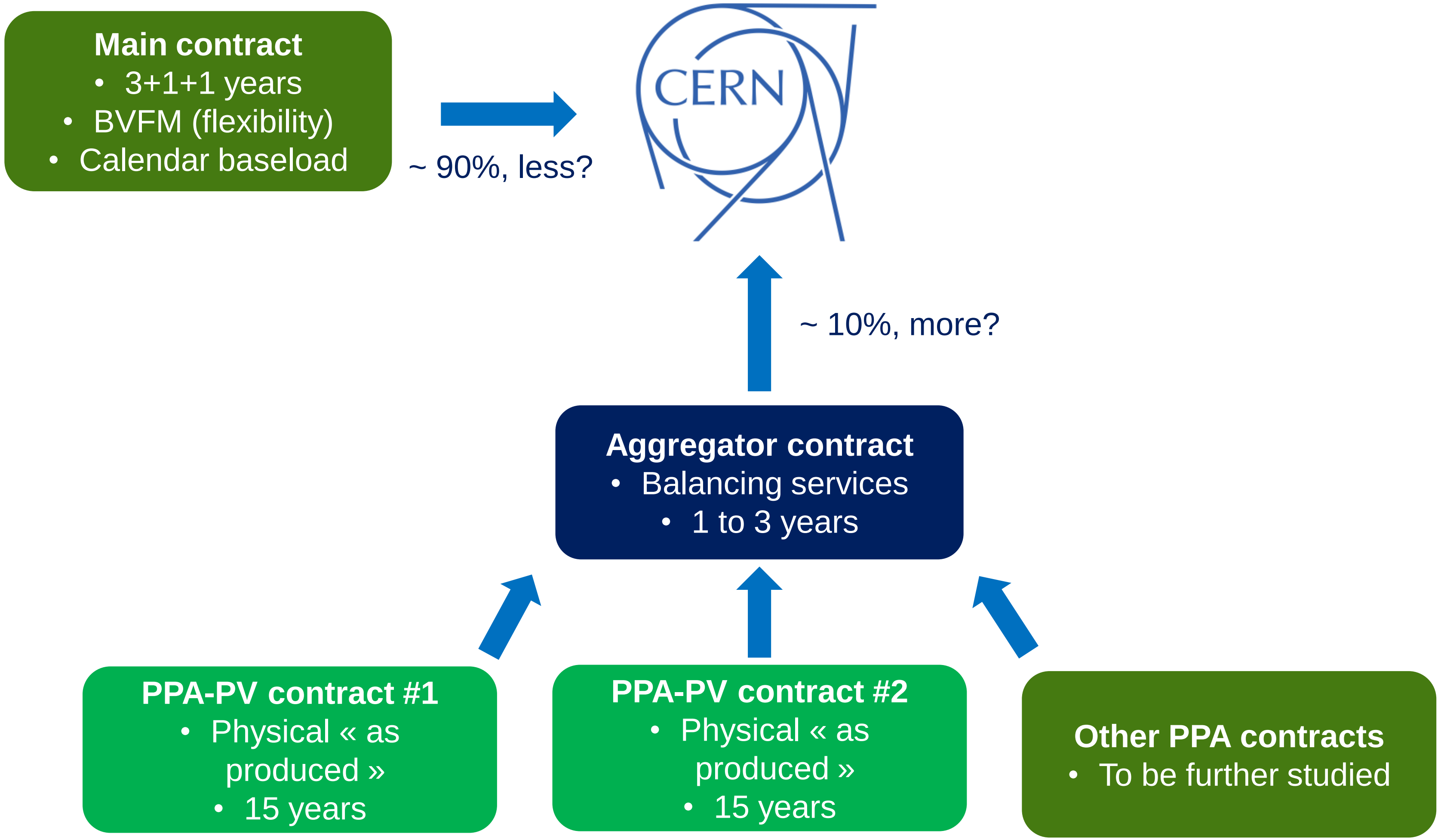
30 GW in 2035

- Power Exchange Capacities **doubled by 2035**
- 39 GW of Capacities by **2050**

How can we procure CO_2 free energy?

- **We already do!!!**
- 80% of our energy comes from French Nuclear, the rest is purchased on the market through EDF and reflects the standard mix of French energy.
- The EU is establishing a new policy that aims at encouraging the investment in renewables, targeting at the same time stability for the producer and for the customer through 2 mechanisms:
  - ***Power Purchase Agreements*** : between producers and large consumers, long (>15 years) contracts at fixed or indexed price with limiting mechanisms
  - ***Two-way Contracts for Difference***: Between providers and public entities, used to stabilise the price for both the consumers and the providers limiting losses for the providers but also unjustified gains.

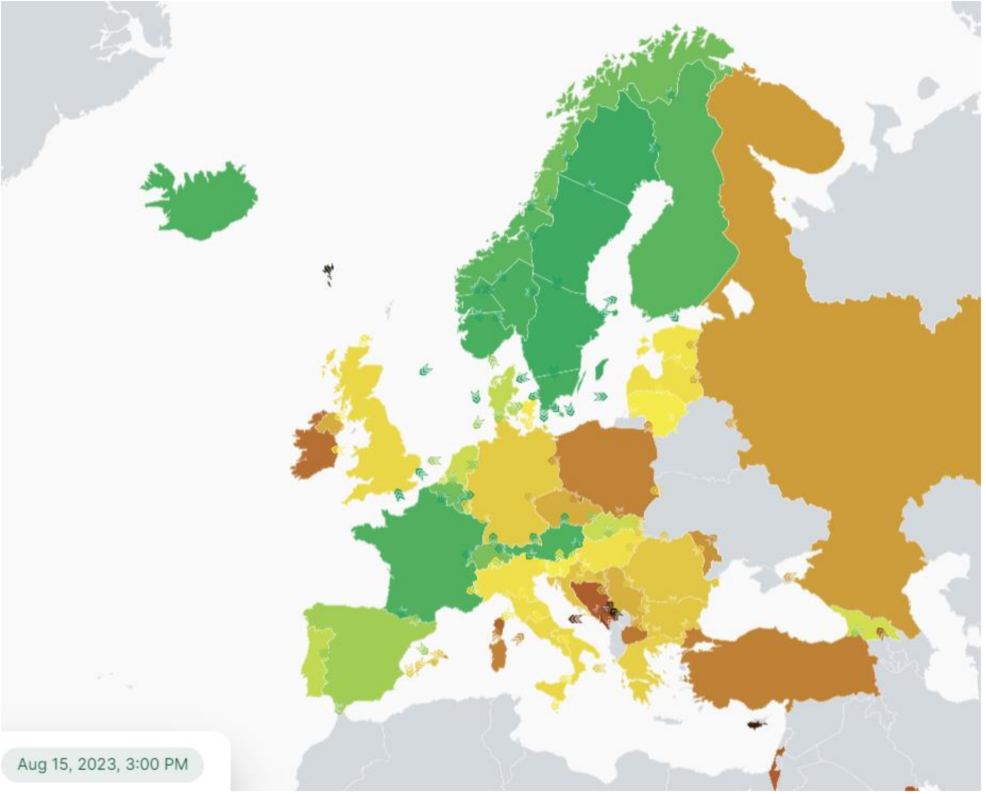
PPA implementation at CERN



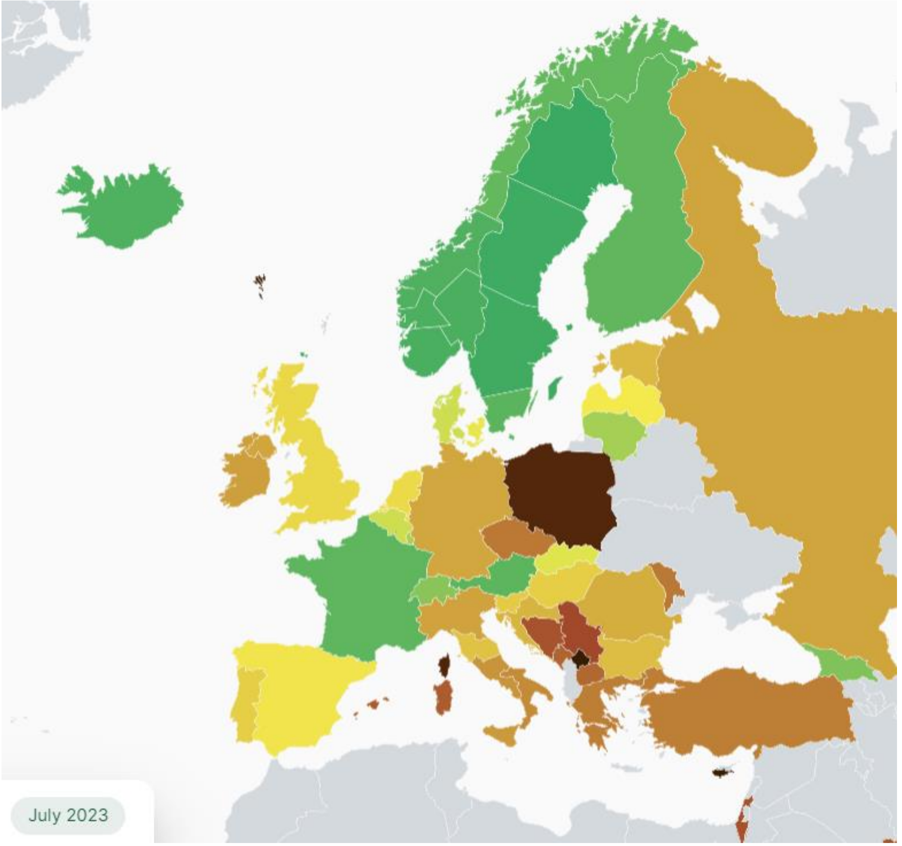
How can we procure CO2 “free” energy?

https://app.electricitymaps.com/map

24 h (15 August)



12 months



Running on renewables and when electricity is cheap

Two studies in 2017:

- Supply the annual electricity demand of the CLIC-380 by installing local wind and PV generators (this could be e.g. achieved by 330 MW-peak PV and 220 MW-peak wind generators) at a cost of slightly more than 10% of the CLIC 380 GeV cost.
  - Study done for 200 MW, in reality only ~110 MW are needed
- Self-sufficiency during all times can not be reached but 54% of the time CLIC could run independently from public electricity supply with the portfolio simulated.

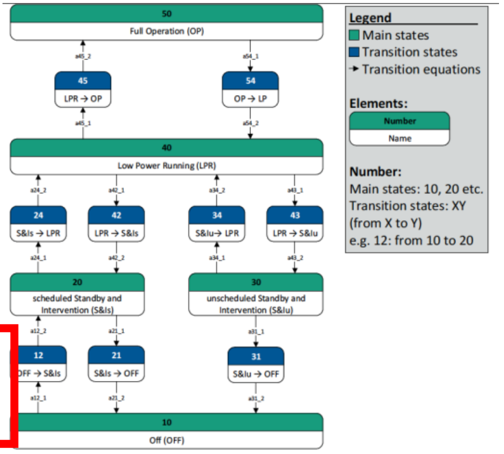


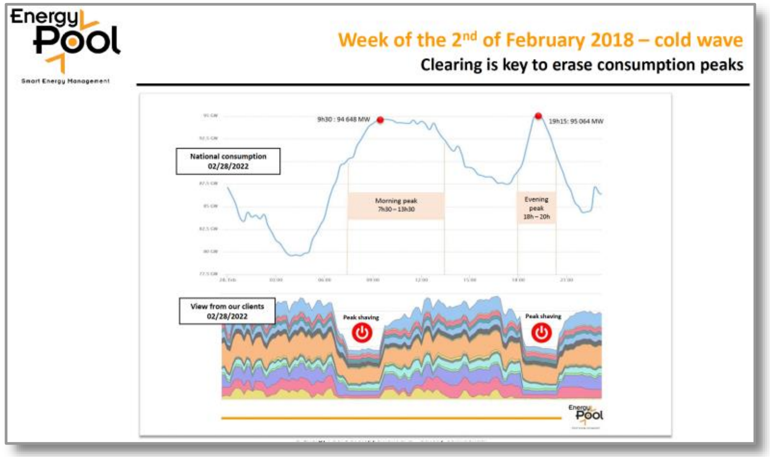
Figure 1-1: Schematic representation of the finite state machine

- Can one run an accelerator as CLIC in a mode where one turn "on" and "off" depending prices (fluctuating with weather, demand, availability etc) ?
- Specify transition times (relatively fast for a LC) and the annual luminosity goal
- Significant savings – but the largest saving is the obvious one, not running in the winter.
- Flexibility to adjust the power demand is expected to become increasingly important and in demand by energy companies.

More information (link)

(Regenerative) Power availability varies
Linear accelerators have no stored beam -> ideal for flexible operation

Study by Fraunhofer institute considered running
on renewables and participating in **demand side flexibility**



C. Gaunand, B. Remenyi: *Introduction to Demand Side Flexibility*
ESSRI Workshop 2022 https://indico.esrf.fr/event/2/contributions/94/

LifeCycle mindset

Life Cycle Assessment

Context

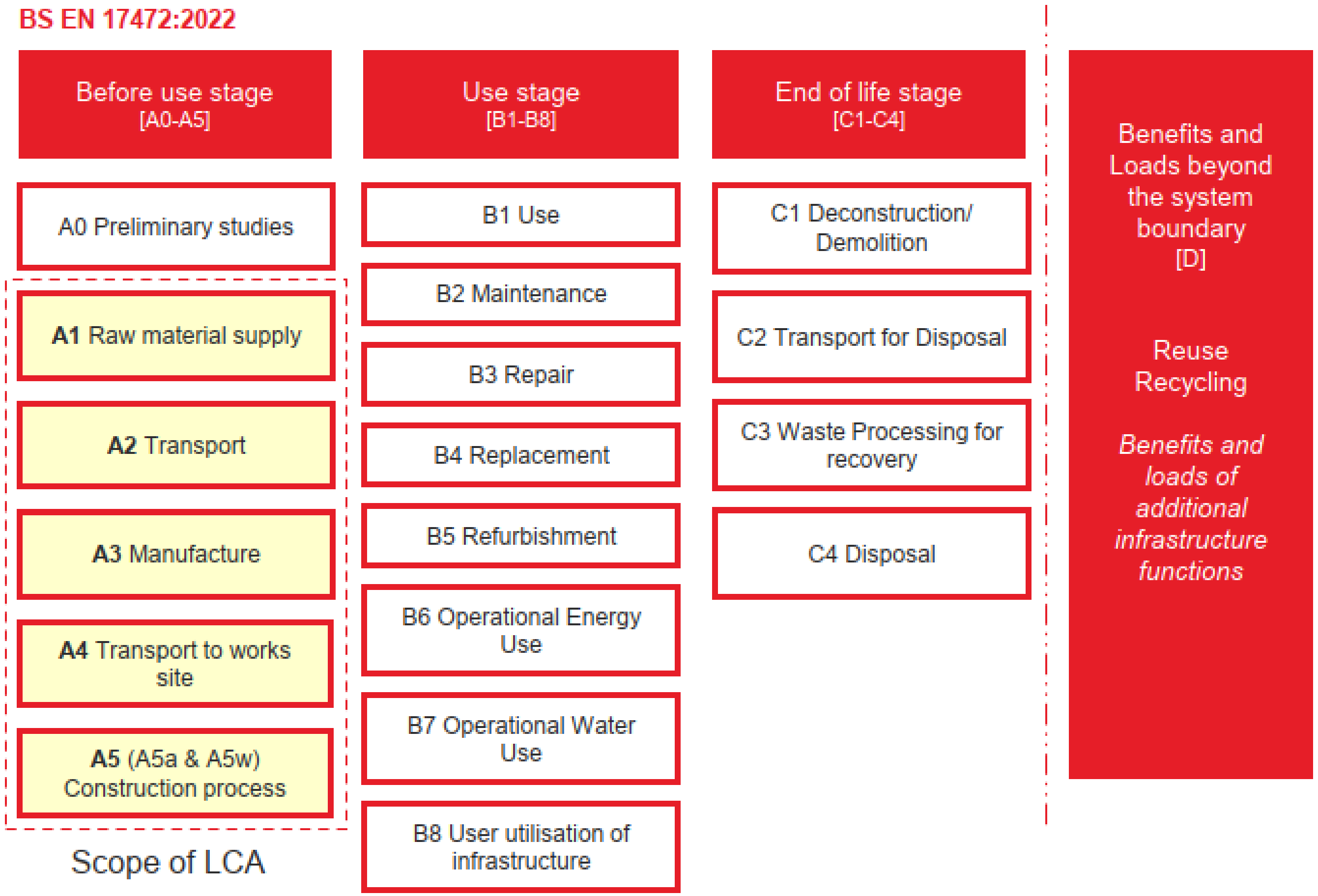
A Life Cycle Assessment (LCA) systematically assesses the environmental impact of a product or asset throughout its life cycle. The purpose of this LCA is to inform a baseline indication of the environmental impact of the underground construction of CLIC and ILC, and to identify opportunities where reductions in environmental impact can be made to help inform decision makers and future design optimisation.

The life cycle is broken down into life cycle modules, as outlined in BS EN 17472:2022.

A LCA can be completed for different parts of the life cycle, most common being A1-A3, A1-A5, and A-C modules.

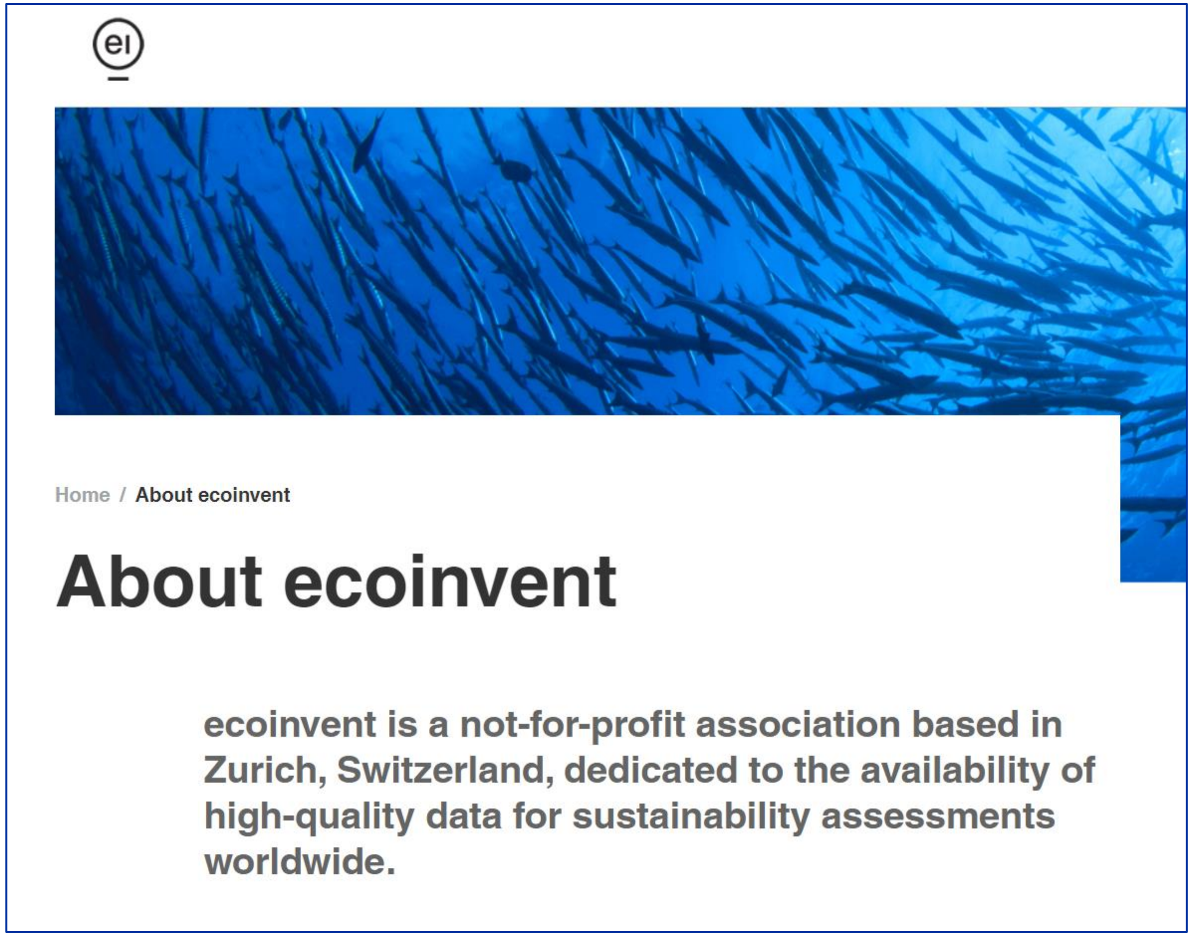
The scope of this LCA is A1-A5, which includes the raw material extraction to construction activities on site. A5 is split into A5a and A5w, construction activities and material wasted on site, respectively.

This final report evaluates A1-A5 for the three proposed linear colliders as highlighted in section 1.1.



An example: CLIC & ILC tunnels LCA

- **At the beginning of 2023, CLIC & ILC decided to go through an LCA exercise for the tunnels (no accelerator component or detector, no technical infrastructure…).**
- **The exercise was based on the specific instruction coming from the standard BS EN 17472:2022 which provides a specific calculation methodology for civil engineering construction works**
- **Performed with software SimaPro 9.4.0.2 with Ecoinvent 3.8 database.**
  - It's important to underline again that the results do not intend to give a real, precise number, but rather to compare among different projects and different phases of the project…

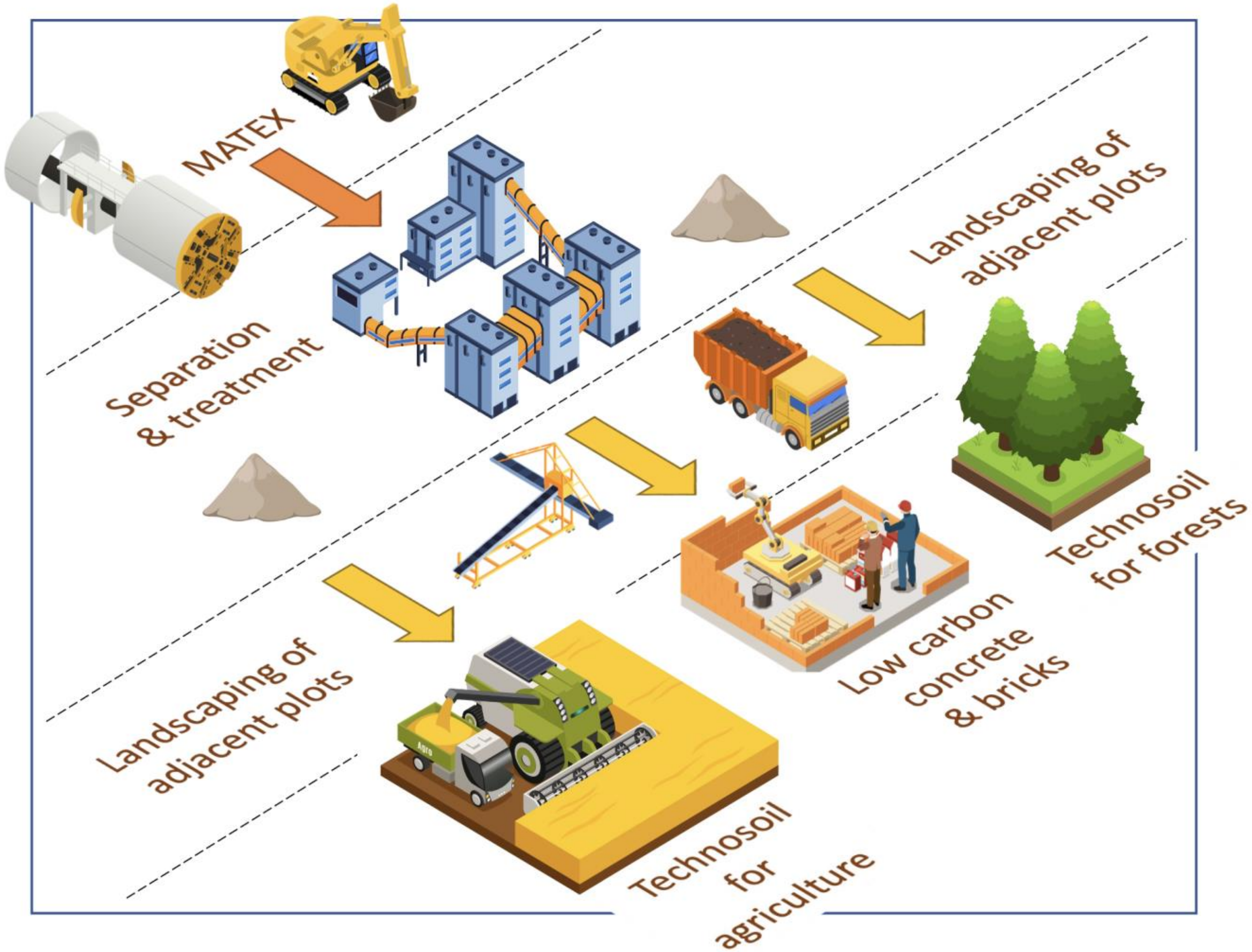


“Mining the Future®”

- **Publication** of the competition on 1st May 2021
- **First phase** ended in October 2021: **12 proposals, 4 selected by the international jury (9 members)**
- Proposed applications focus on **different phases of the excavated material treatment and reuse**.
- Type of participants: **Key players in excavation projects** as well as new startup and research institutes
- **Second phase**: 4 selected are progressing with the feasibility study to **bring the proposal to at least TRL4*** . Submission by end of June 2022.
- **Final event** with announcement of the winner**:** 27 September 2022.

TRL: Technology readiness level. Level 4: Technology validated in laboratory

A ”locally innovative” approach



The priority for FCC is to **propose a large-scale re-use of excavated materials** including carbon capture potentials (follow up of Mining the Future®, which was seen by the EC as an excellent initiative).

The aim is to re-use the material locally as much as possible, keeping transport nuisances low and providing fertile soil for agriculture and re-forestation.

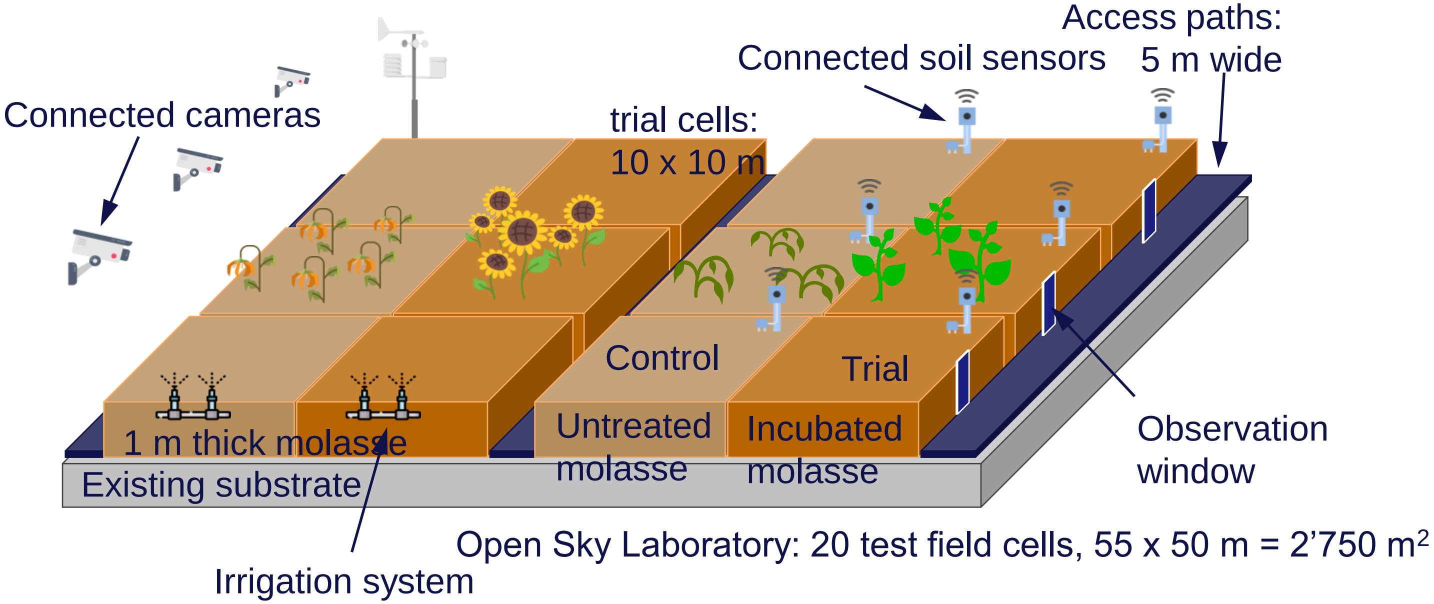
Work is ongoing since December 2022 to etablish the framework for a **real-scale demonstration** of the innovative solutions.

Courtesy of J. Gutleber

Next steps

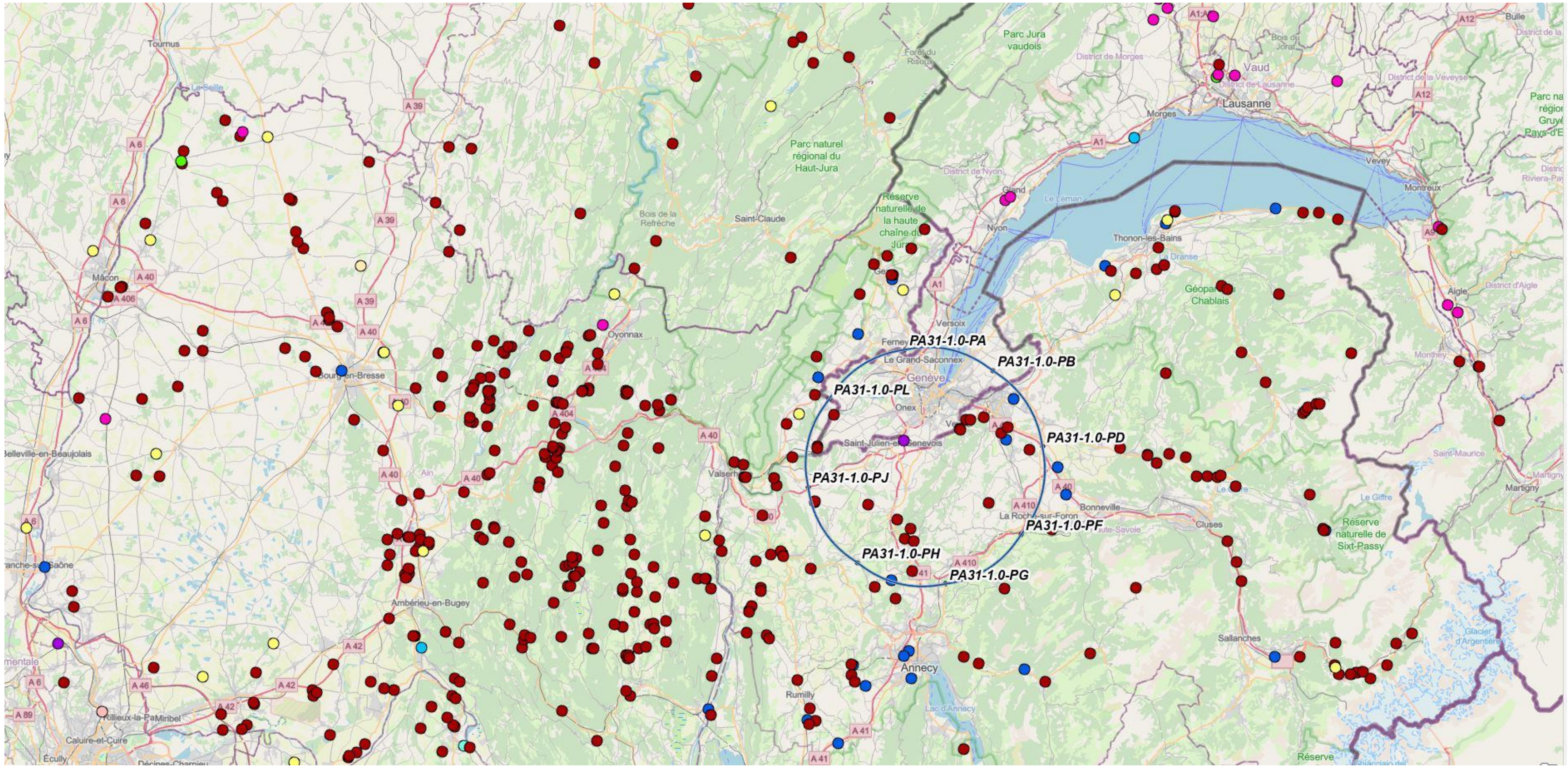
Proposals need to be
- **demonstrated at real scale level**
- **developed jointly** with the host state technical public administration services (e.g. DT, DDT, DREAL) and local actors
- **validated and accepted** by the host state authorities accompanying CERN.

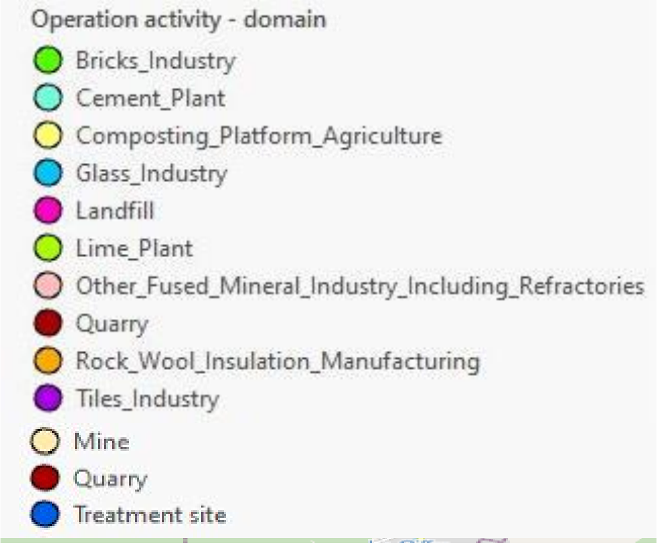
Phases:
- **Identification of demonstration land plots**
- Definition of **type of culture (crops, trees, etc.) and parameters to be monitored**
- **Study of tolerance to pollution**



Courtesy of J. Gutleber

Regional opportunities





The collected data will be used to:

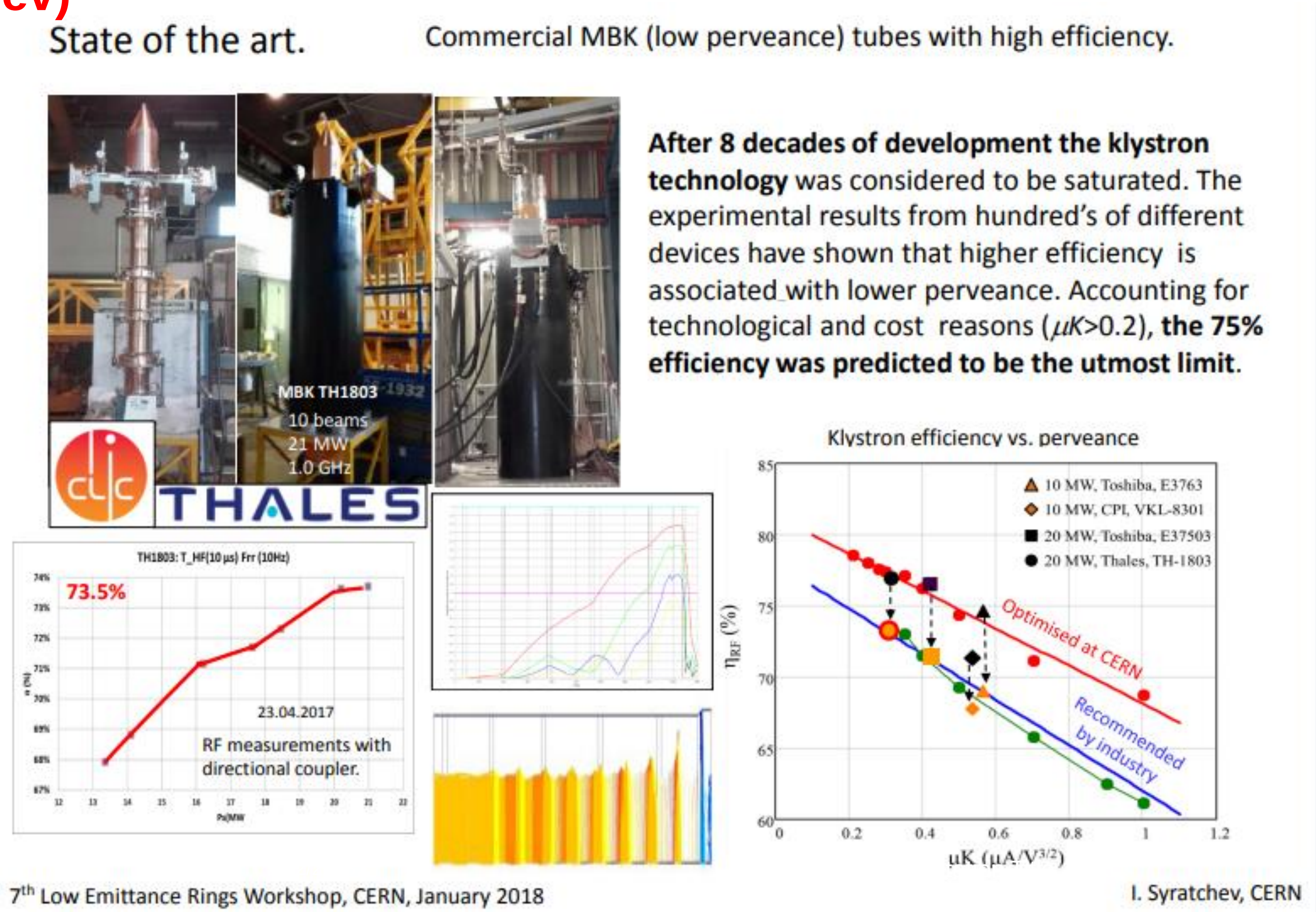
- build a **preliminary cost analysis** for the excavation material reuse and disposal.
- develop **scenarios for a LCA study** for the potential construction of railroad connections.

Example: Renaturalisation of the river “Aire” in Geneva

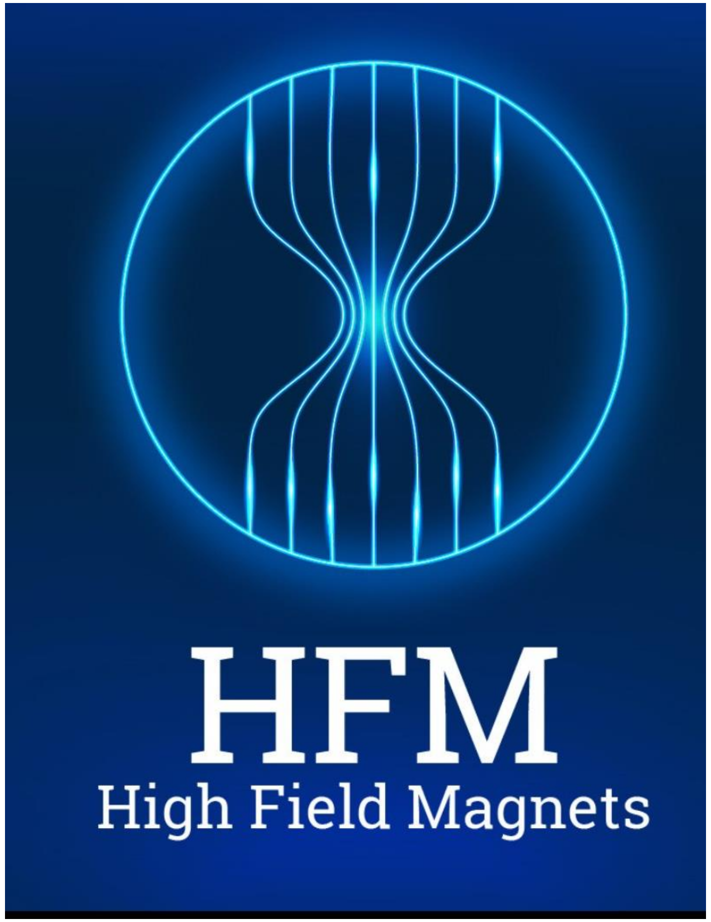
Our force: New technologies, new approaches

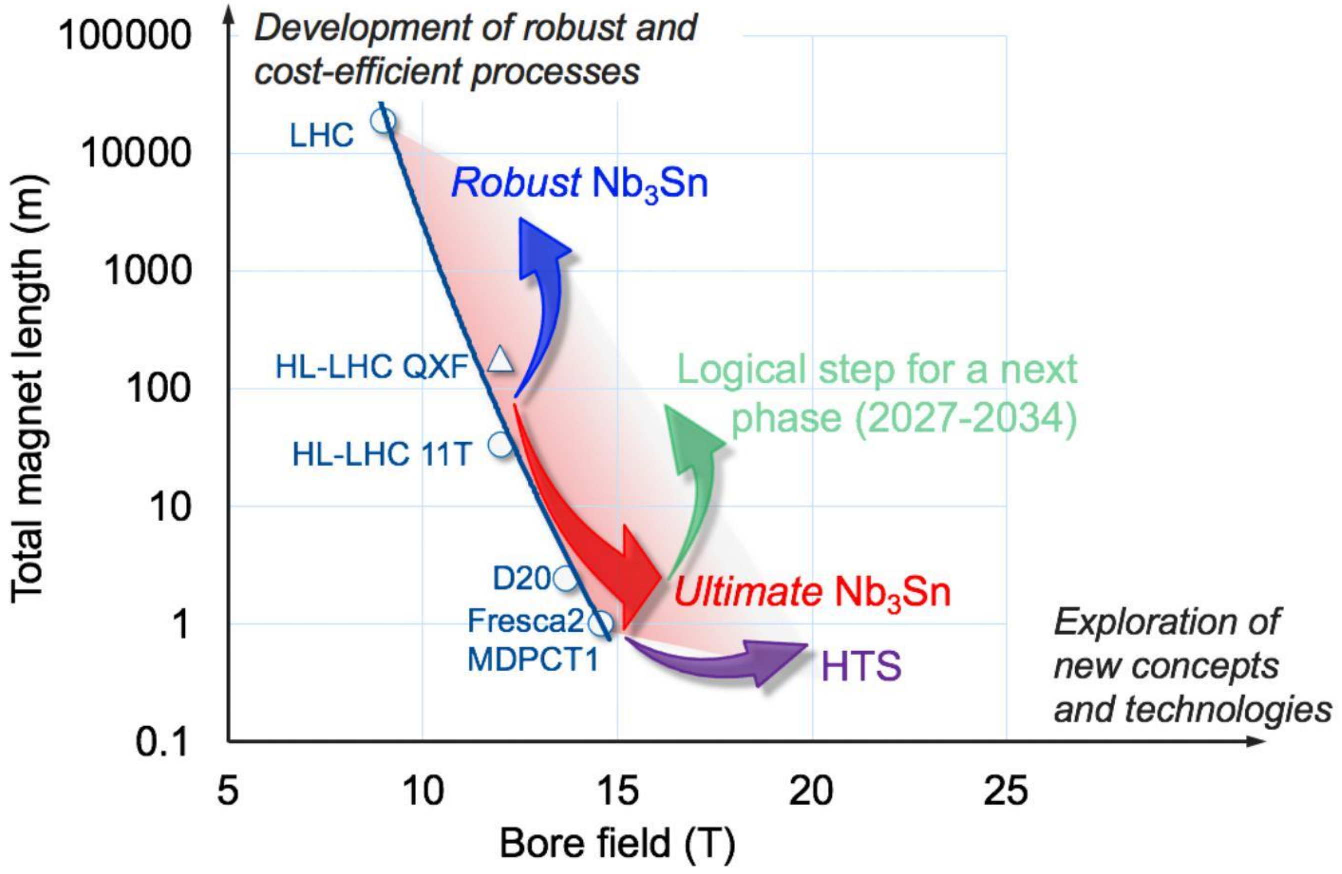
(Incomplete collection of ongoing actions…)

High Efficiency Klystrons
(I. Syratchev)



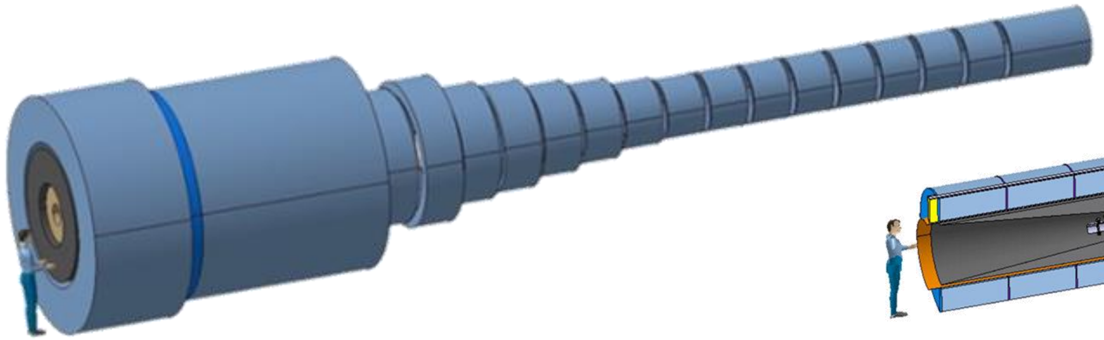
Superconductivity: High Field Magnets

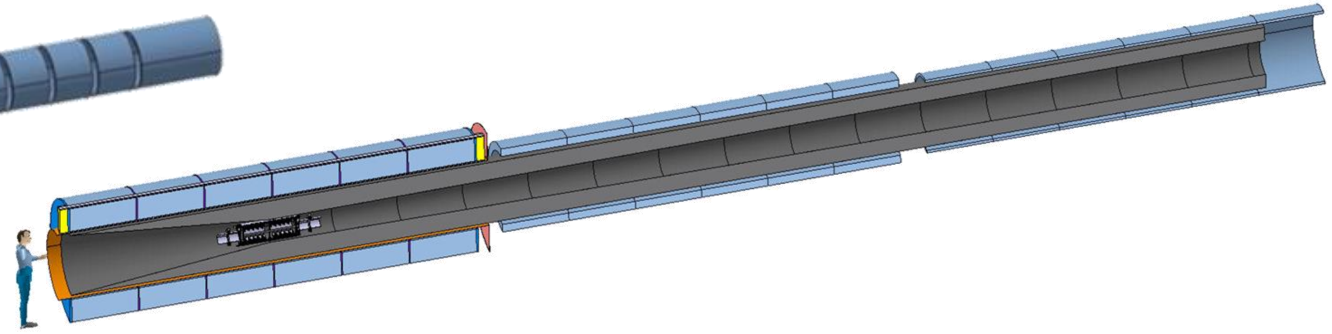




HTS is the future?

Target & Capture Solenoids for the Muon Collider





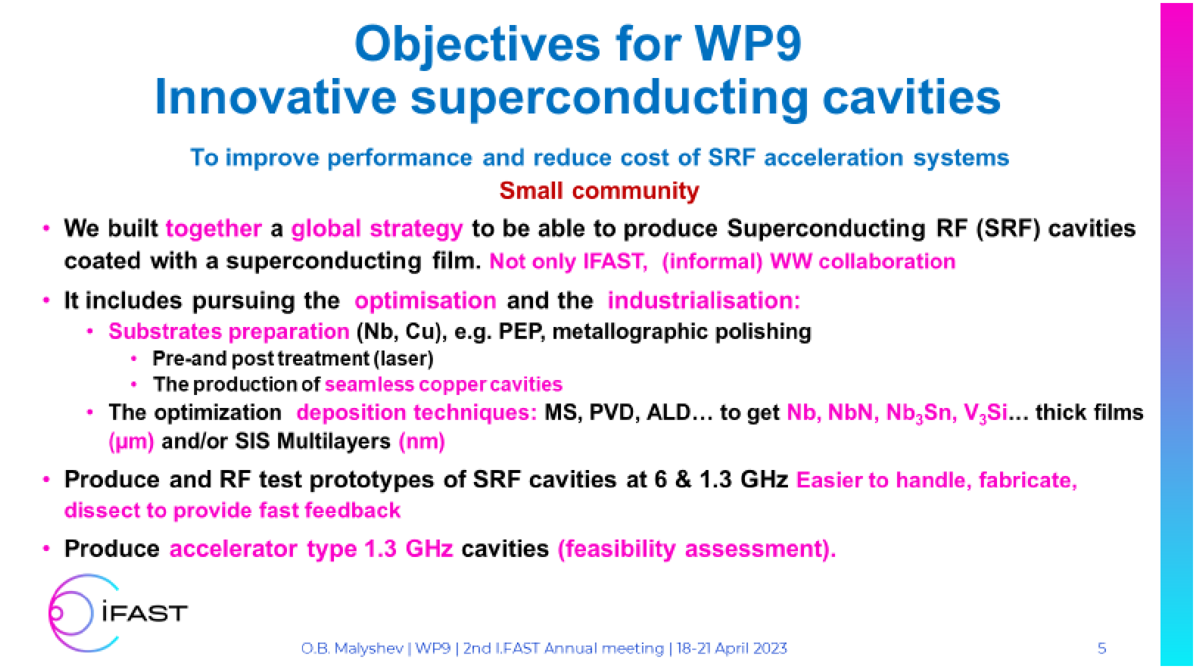
US-MAP
Proposal
(<2016)

E_M = 2.9 GJ
T_{op} = 4.2 K
M_{coils} = 200 tons
M_{shield} = 300 tons
P = 12 MW

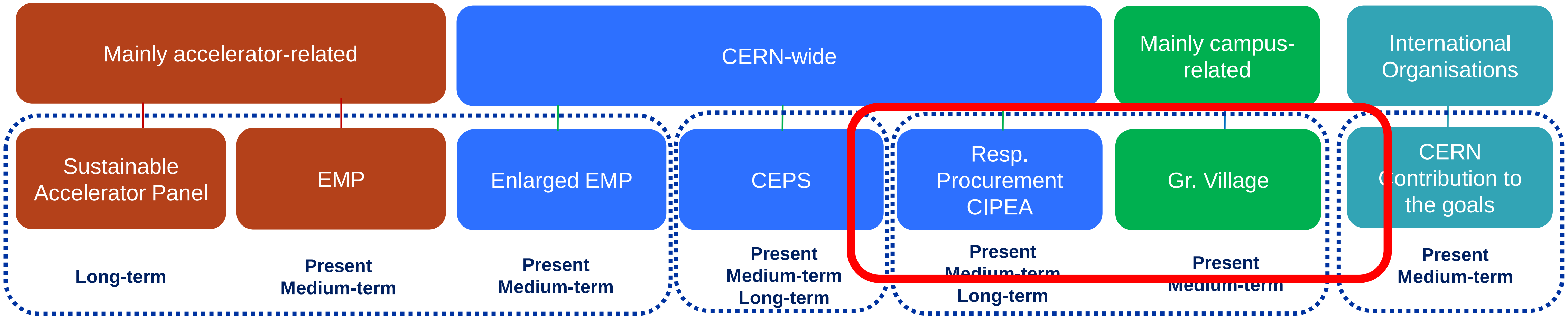
EM = 1 GJ
Top = 10…20 K
Mcoils = 110 tons
Mshield = 196 tons
P = 1 MW

IMCC
Proposal
(2023)

Superconductivity: RF



Panels/Activities at CERN with direct impact on SDGs



CIPEA – CERN Innovation Programme on Environmental Applications

- Transverse programme started in 2022 on the initiative of the Knowledge Transfer Group to foster Environmental Applications based on CERN technologies with potential global impact

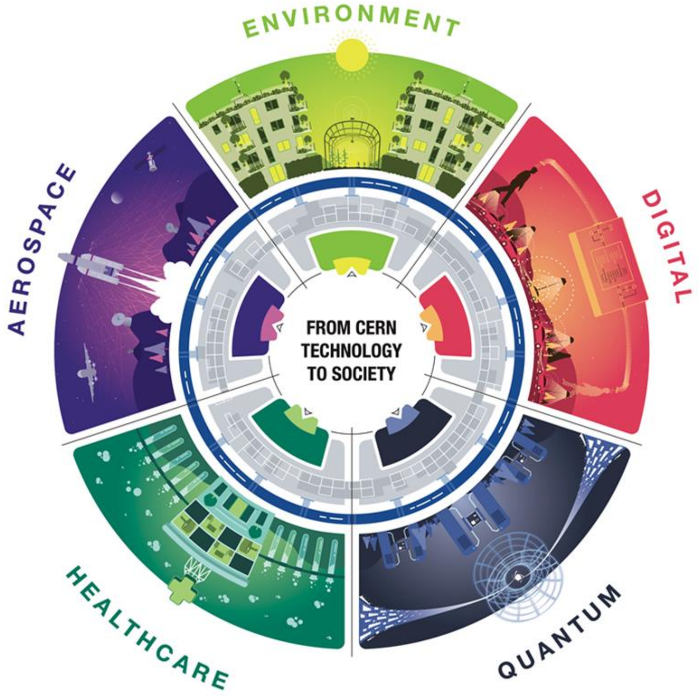
- High Level Strategy

- Call for Ideas 2022

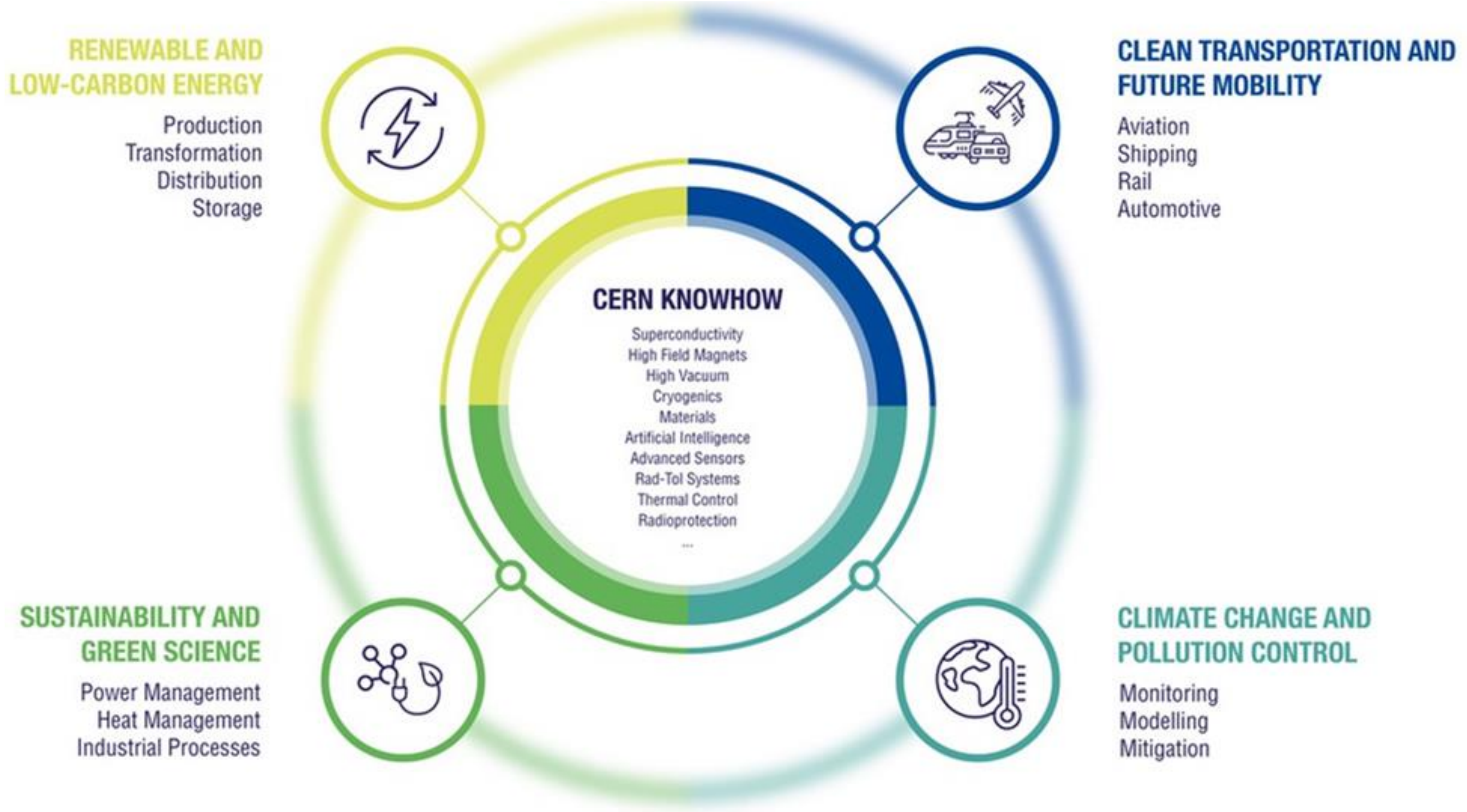
- Poles of Competence

CIPEA CERN Innovation Programme on Environmental Applications

CERN KT Knowledge Transfer *Accelerating innovation*



CIPEA - High Level Strategy



CIPEA – Flagship Projects under Implementation

RENEWABLE AND LOW-CARBON ENERGY	Agreement with **GTT** to support the design of large cryostats for the maritime transportation of liquid hydrogen	GTT – Technology for a Sustainable World 
CLEAN TRANSPORTATION AND FUTURE MOBILITY	Partnership with **Airbus** to assess SC power distribution options for future electric/hybrid airplanes using liquid hydrogen	AIRBUS 
CLIMATE CHANGE AND POLLUTION CONTROL	Collaboration with **ESA** Phi-lab to develop AI algorithms to analyse Earth Observation space images for climate monitoring	esa 
SUSTAINABILITY AND GREEN SCIENCE	Project with **ABB** to improve energy efficiency of CERN cooling and ventilation with smart sensors and digital twins	ABB 

Conclusions

- **Sustainability is a complex problem, that requires an holistic approach**
  - Solid and attractive physics case
  - Optimisation through technologies, materials, recycling waste….
  - Visible return to society (Education, training….)
  - Capability to communicate to general public

Drive discovery and creation of knowledge
Driver of innovation
Integration of research communities
Strong links to industry
Collaborative ecosystem
Societal impact
Outreach and education

Acknowledgement

This presentation contains a collection of slides presented at different events by many colleagues & industrial partners:

- **C. Warakaulle, A. Scharma, S. Claudet, N. Bellegarde, I. Syratchev, E. Chesta, S. Stapnes, M Seidl, A. Ballarino, JP Burnet, L. Bottura, B. Bordini, J. Van D'Hondt, A. Stocchi, L. Bromiley, J.A. Osborne, B. Shepherd, J. Clarcke, L. Ulrici, B. Heinemann, G. De Carne…**

- **A. Lotan (Enviroet)**

- **ARUP**

- **J. Fitzgerald (SuperNODE)**

- **Apologies to those I may have forgotten!!!**