Sustainability and Future Accelerators, challenge or opportunity?

R. Losito, ATS-DO

29 August 2023,

Future Colliders series of Seminars


REDUCE
REUSE
RECYCLE

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!!!**

Feelings…

What is “*Sustainability*”?

- **Definition of Sustainability :**
  (United Nations General Assembly, 1987)

  - “Sustainable development is development that **meets the needs of present** **without compromising** the ability of future generations to meet their own needs”.

What is “*Sustainability*”?

- **Sustainability pursues two goals**

  - To ensure that we can bring fo[illegible] any [illegible]er[illegible]se **th[illegible]enerates value for mankind**

  - To ensure th[illegible]t **this i[illegible] [illegible]sponsi[illegible]**, so that we do not preclude the possibility for future gene[illegible]ons [illegible]e th[illegible]e

HOW?

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.***

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.

Sustainable Development Goals
CERN input in the process

- The adoption of the SDGs followed two years of consultation and engagement with civil society and other stakeholders around the world.
- As an Observer to the United Nations General Assembly, CERN contributed with input in the Open Working Group on Sustainable Development Goals, **promoting sustained and ring-fenced support for scientific research, and STEM education**.

CERN Director-General Rolf Heuer addressing the Open Working Group on Sustainable Development Goals in December 2013.

The CERN input may be found at https://sustainabledevelopment.un.org/content/documents/4628cern.pdf

Sustainable Development Goals
Role of science, technology and education

- The importance of **science**, **technology development** and **education** is highlighted across different parts of the document, and included in specific targets.
- Activities at CERN has the potential to make valuable contributions across parts of the agenda, enabling the **knowledge** and **competencies** of the Laboratory and the community to **serve society**.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

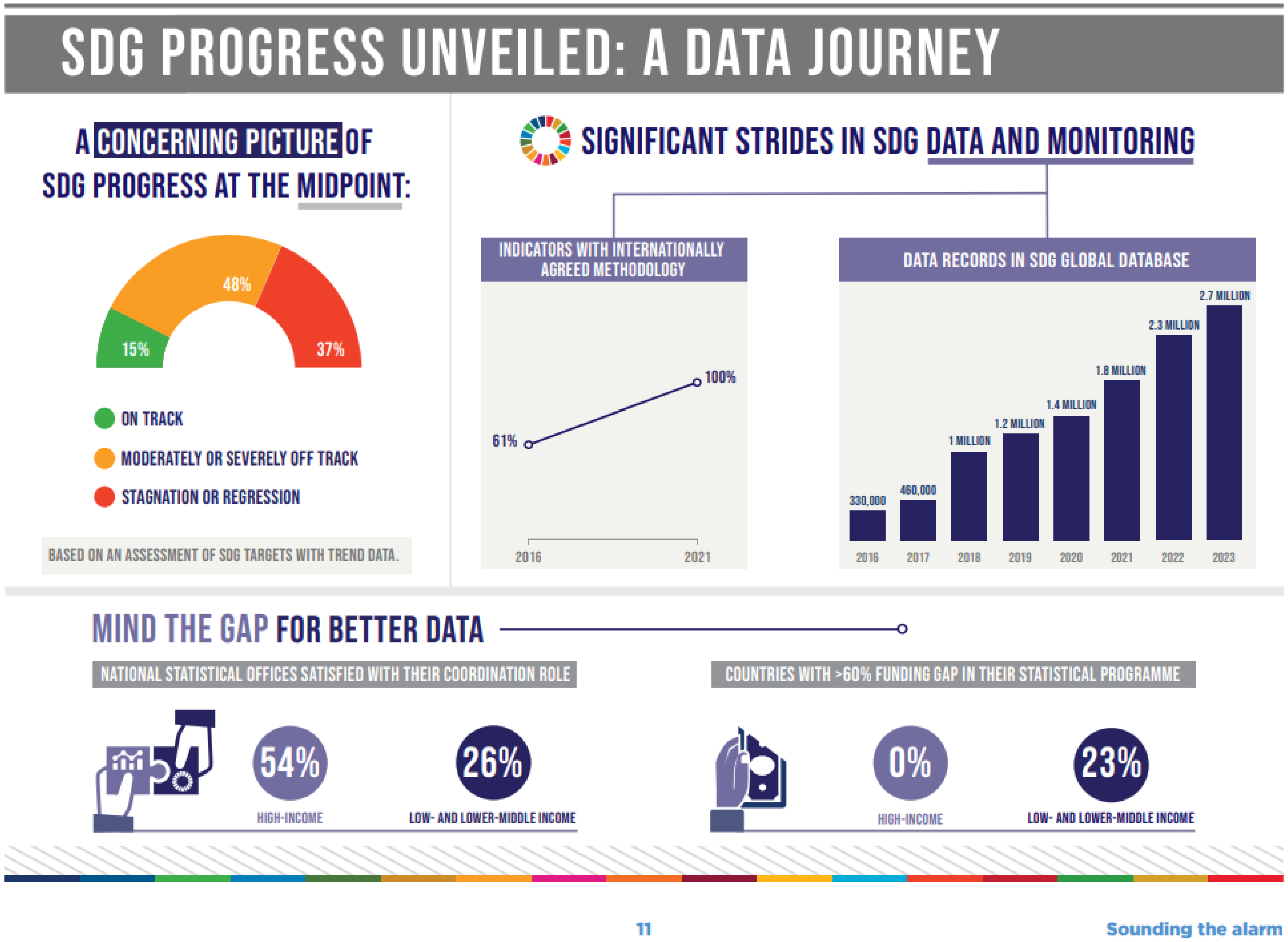
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all

7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

UN Report on SDGs 2023



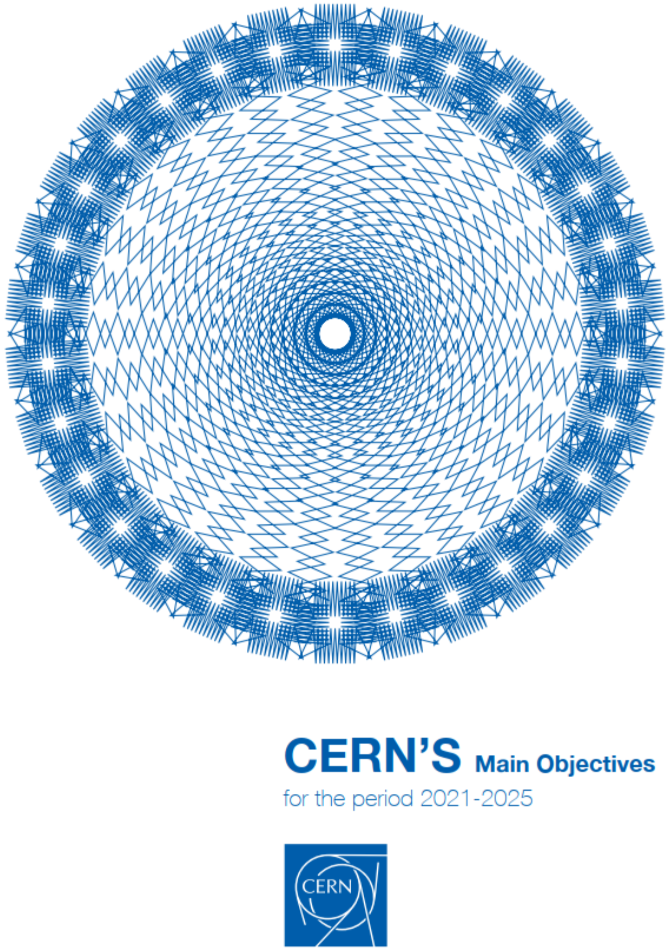
https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf

CERN implements the Roadmap 2030

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****’.*



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.

THERAPY
Accelerators provide particle beams for more targeted cancer treatment.

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.

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

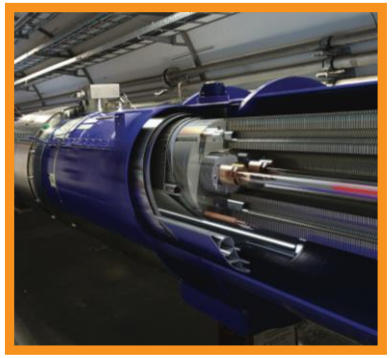
SDG 5 - GENDER
Diversity is a core value for CERN. Our diversity policy aims at leveraging the added value that comes from bringing together people of different nationalities, genders, professions and ages.

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

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

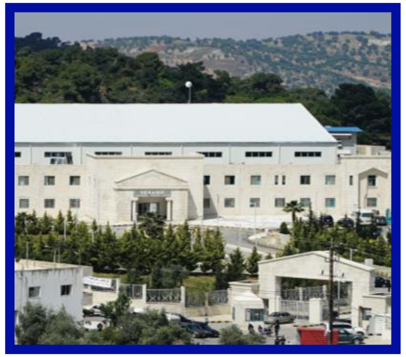
HEATING LOCAL HOUSING
Heat recovered from CERN's accelerator cooling systems to heat a new residential area in the town of Ferney-Voltaire, benefiting up to 8000 people.

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



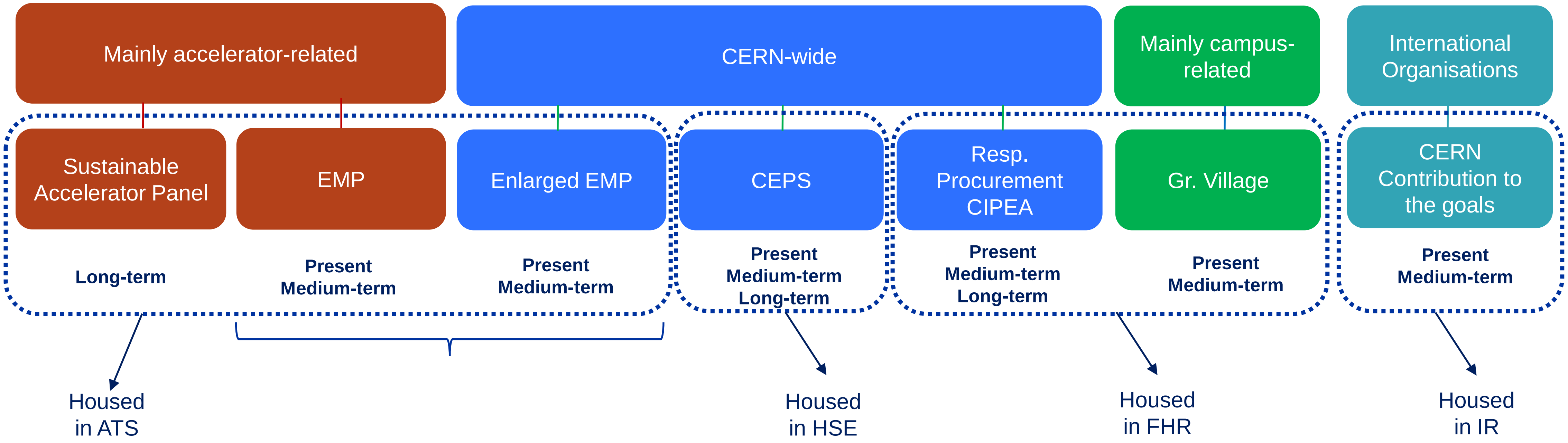
A MAGNET IN THE LHC TUNNEL
Exploring the universe requires new technologies and ingenious engineering to build the machines that explore physics at a new frontier.

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.



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.

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.

• Sustainable Accelerators Panel

Meeting #1

Thursday Mar 23, 2023, 2:30 PM → 4:30 PM Europe/Zurich

30/6-019 (CERN)

MINUTES 23 March...

Videoconference — Meeting #1 — Please log in

2:30 PM → 2:50 PM **Introduction to the Sustainable Accelerators Panel** 20m

Speaker: Roberto Losito (CERN)

Sustainable Acceler... | Sustainable Acceler...

2:50 PM → 3:10 PM **Expectations from the FCC Study (tbc)** 20m

Speakers: Johannes Gutleber (CERN), Michael Benedikt (CERN)

230323_FCC-sustai... | 230323_FCC-sustai...

3:10 PM → 3:30 PM **Metamaterials as room Temperature Superconductors** 20m

Speakers: Alessandro Danisi (CERN), Dr Carlo Zannini (CERN)

Draft_Panel_March_... | Draft_Panel_March_...

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**

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

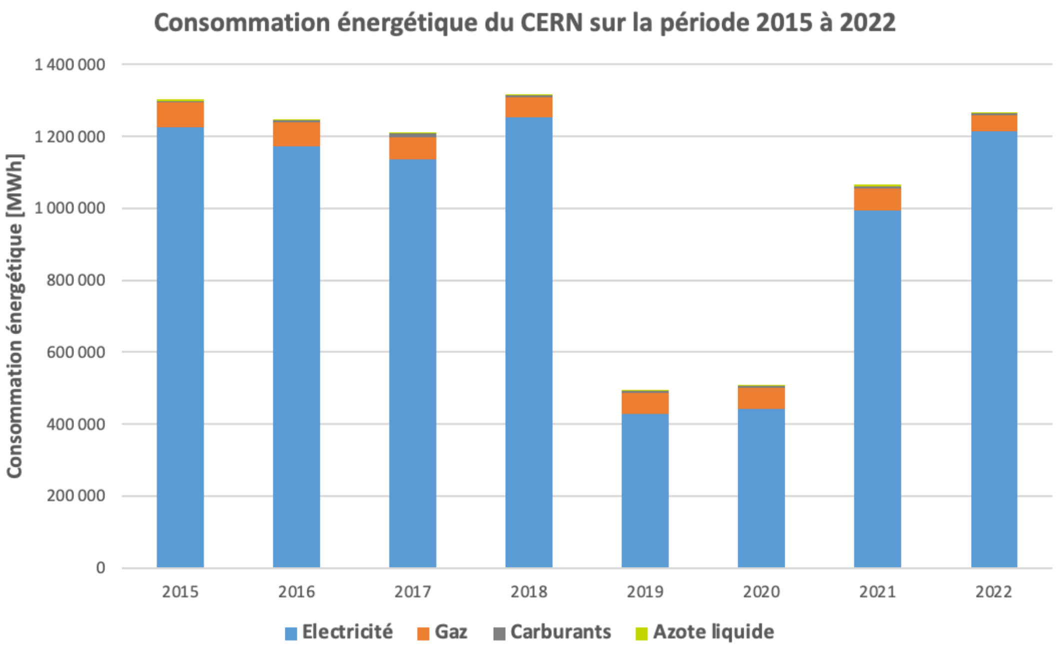
**Energy is not only electricity…*

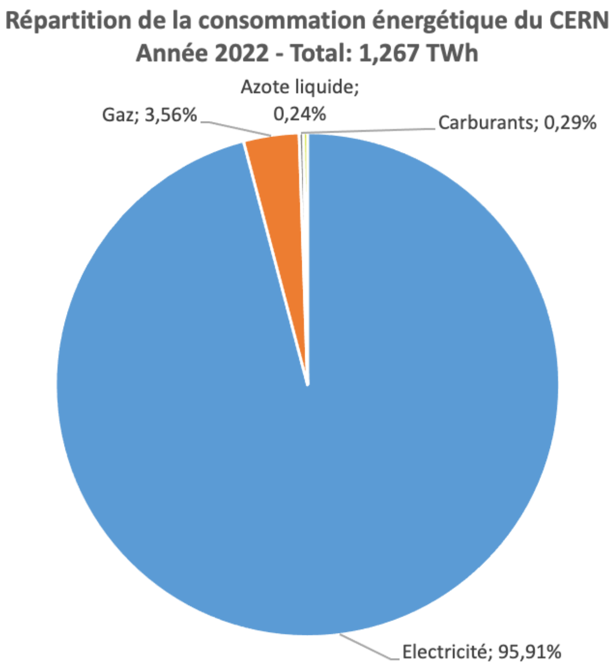
Energy consumption at CERN

- <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

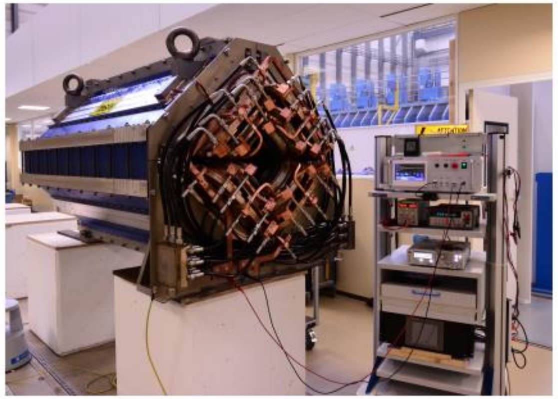
- Consolidated figures





LESS: Improved efficiency, recent cases

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

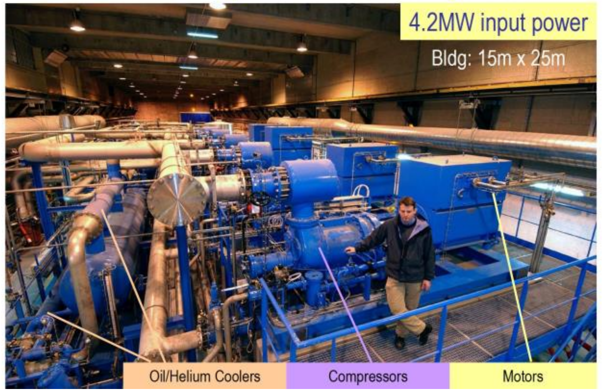


Powering energy:
From 11 GWh/year to around 0.6 GWh/year
(> 90% reduction)

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

New equipment (Cryogenic Refrigerators for HL-LHC)

Compressor station
of LHC 18 kW@ 4.5 K helium refrigerator



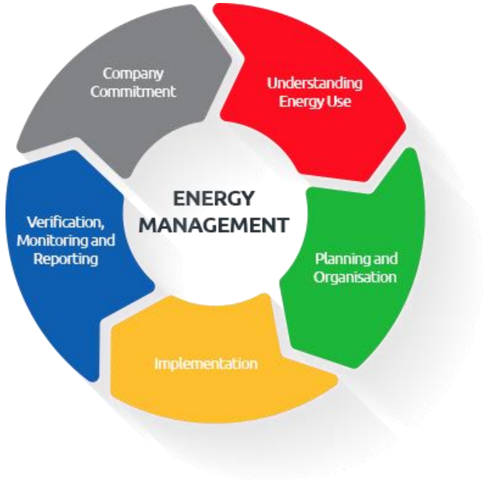
LHC 18 kW @ 4.5 K helium cryoplants
33 kW @ 50 K to 75 K, 23 kW @ 4.6 K to 20 K, 41 g/s liquefaction

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

Ce document est signé électroniquement. Il constitue un original électronique à valeur probatoire.
This document is electronically signed. It stands for an electronic original with probationary value.

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

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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

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

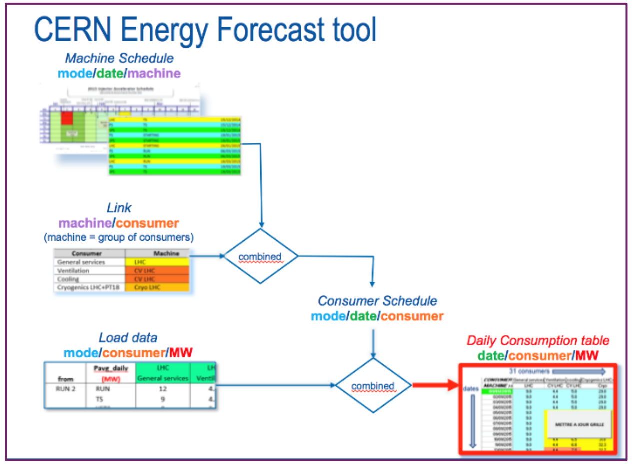
2 | CERN Environment Report

2019 - 2020 | 3

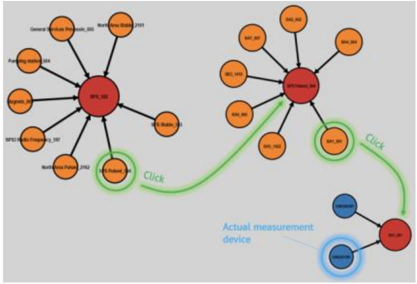
Use sector or use	Energy	Average consumption 2015–2018 (GWh)	Significance of energy use/consumption in %
LHC	Electricity	657 GWh	55%
SPS	Electricity	324 GWh	27%
PS complex	Electricity	125 GWh	10%
Data centres (Meyrin and ALICE and LHCb experiments)	Electricity	32 GWh[4]	3%
Meyrin buildings	Electricity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

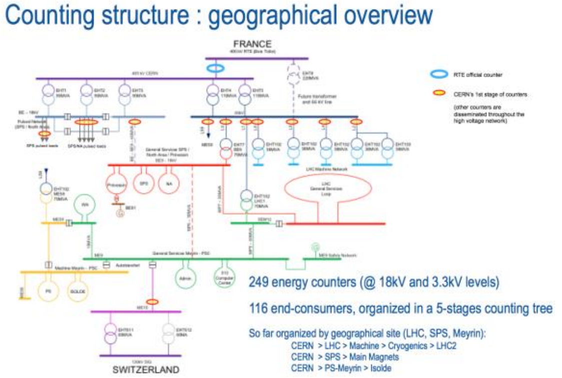
95%

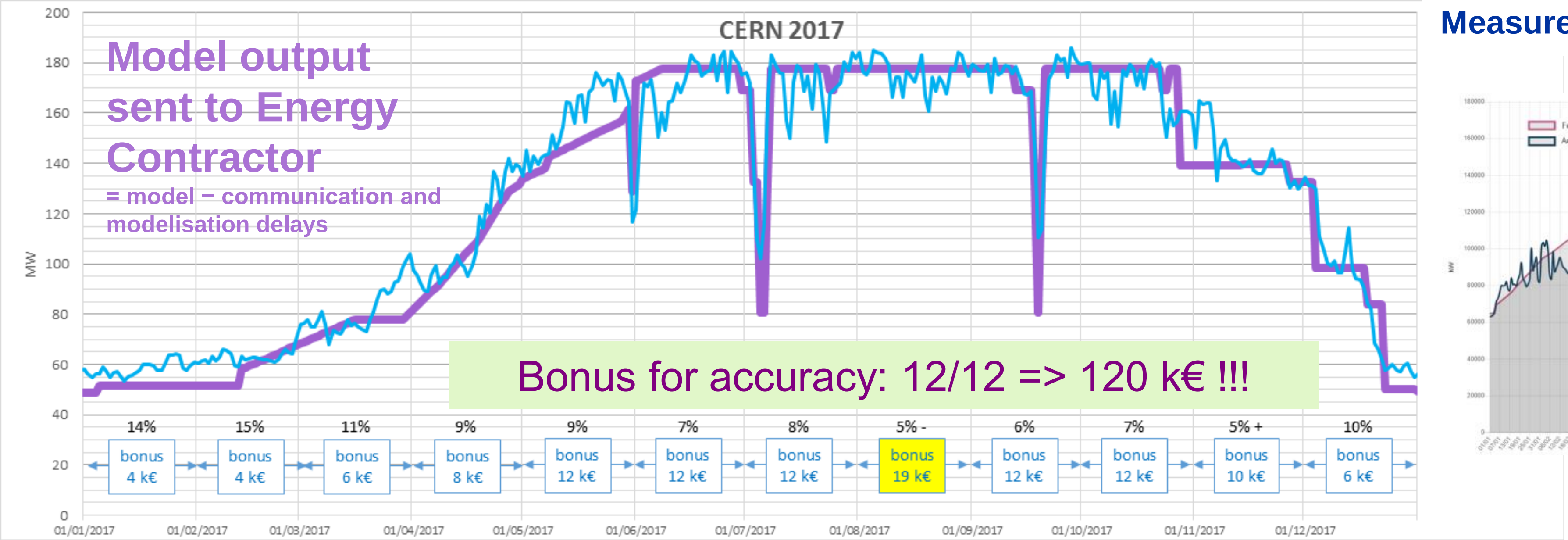
BETTER: Forecasts & measures



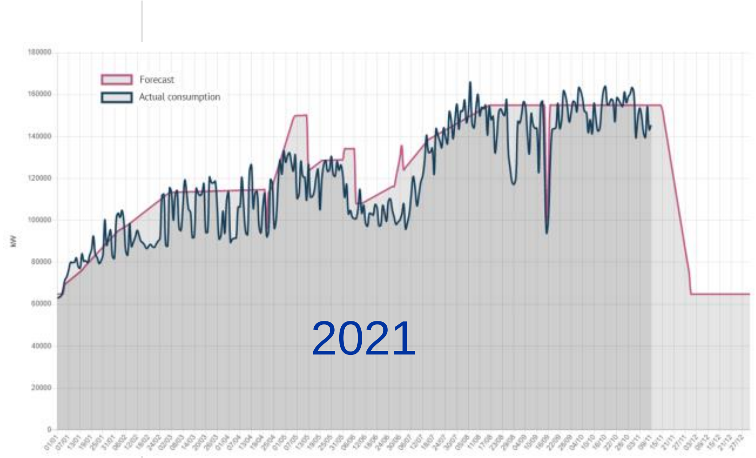
2nd version, integrated in **Web-Energy** tool to combine forecasts & measures







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.

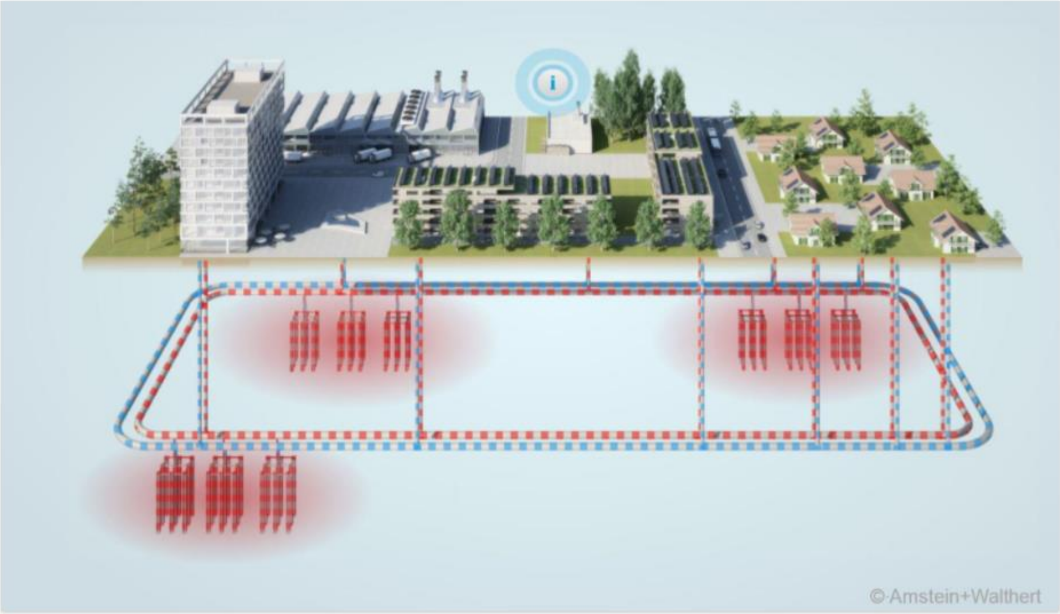
LHCCool_2017-1 (1/2)

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



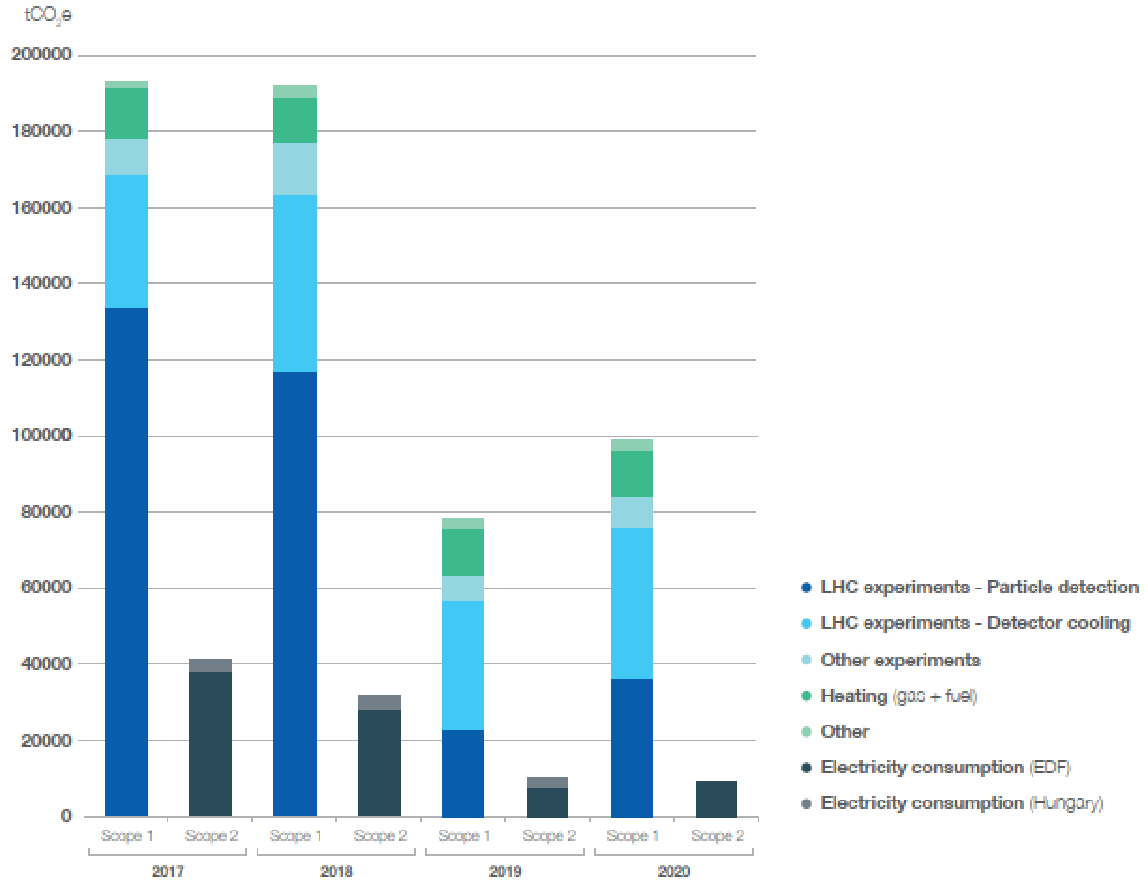
Des sondes géothermiques implantées dans le sol sous le nouveau quartier (les 9 « grappes » rouges sur l'image) permettent de stocker de la chaleur.

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 neighbourhs)

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%...*

Will we have renewables before 2050?

Solar

Pictures not at the same scale…

Centrale de Verbois Solar III

(16’000 m²)

EHN1

(18’000 m²)

Some numbers (credit: www2.sig-ge.ch)

Chiffres clés

1 MW de puissance totale

16'000 m2
de surface au sol occupée par les panneaux, soit la surface de deux terrains de football

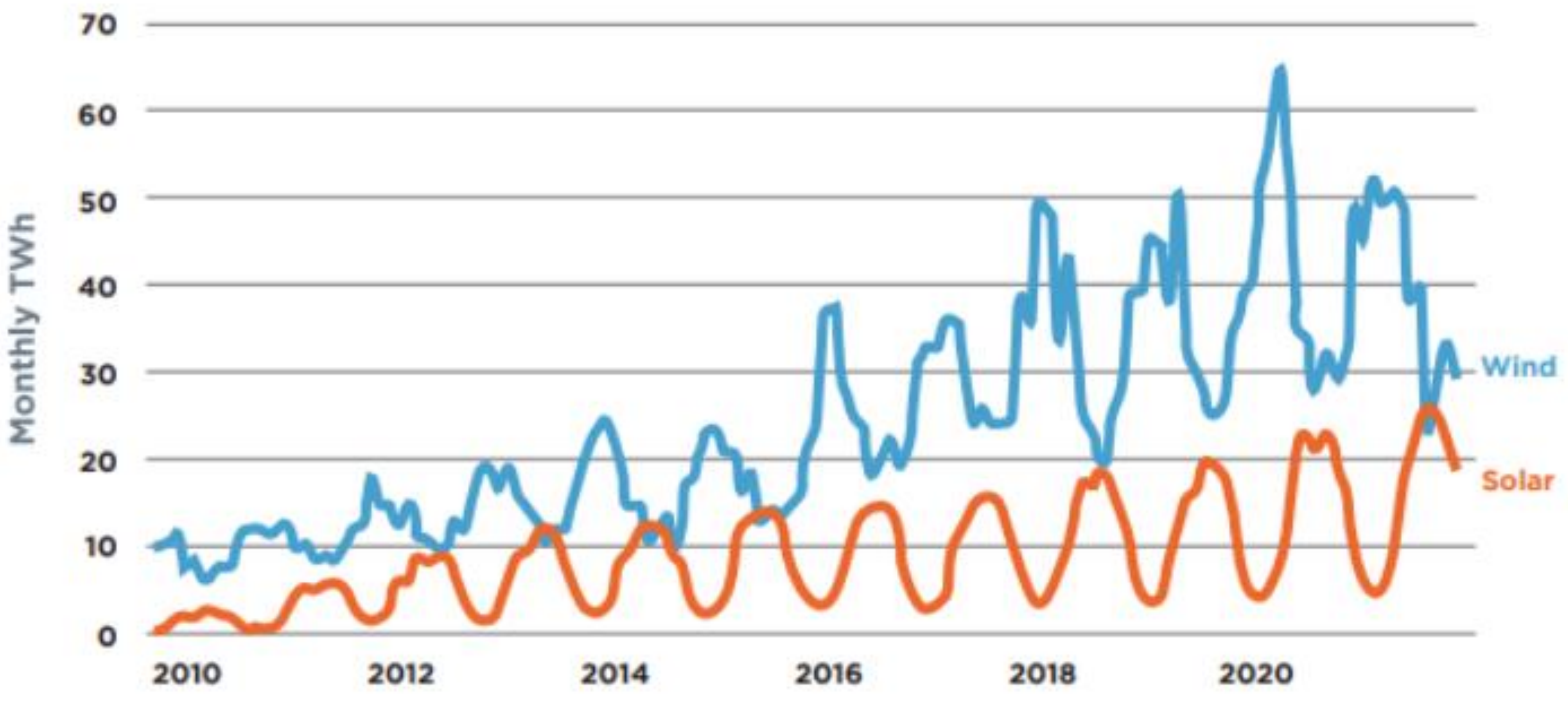
1 GWh
de production par an

300
foyers genevois dont la consommation est couverte par cette production

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

CURRENT GRID / ENERGY SYSTEM CANNOT OPERATE WITHOUT CARBON

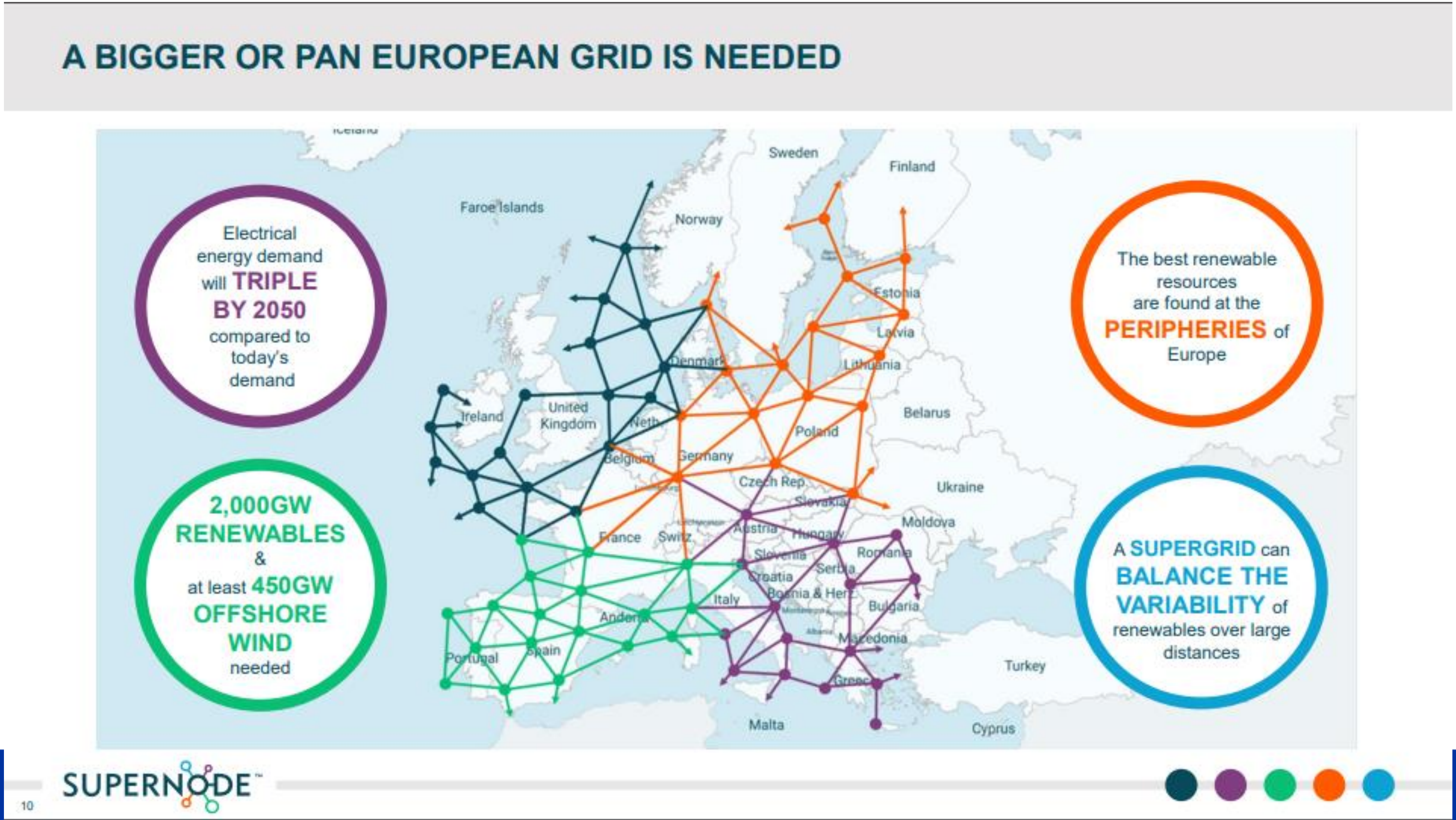
- There are little or no offshore grids.
- Fossil fuel supply lines (ships & pipelines) need to stop.
- DC transmission is better for long distance than AC.

ELECTRIFICATION POWERED BY RENEWABLES IS THE MOST EFFICIENT WAY TO DECARBONISE

SUPERNODE™

7

Why don’t we aim at more than 10%?



CERN contribution…

Superconductivity for sustainability: a new superconducting li… High-Luminosity LHC

A flexible cryostat and the first series of high-temperature magnesium diboride cables will form an innovative electr… HL-LHC inner triplet magnets

3 MARCH, 2023 | By Chetna Krishna

A novel, flexible cryostat, colloquially known as the "python", composed of 19 high-temperature magnesium diboride superconducting cables that can carry 120 kA. (Image: CERN)

World Today News

Home | News | Business | Entertainment | Health

SuperNode and CERN join forces to develop innovative insulation for superconducting cables

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.

- 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)

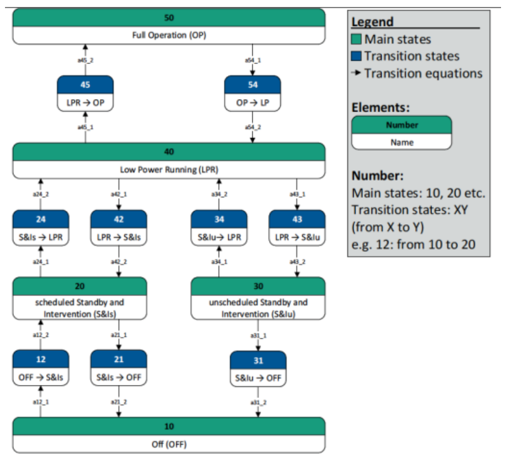
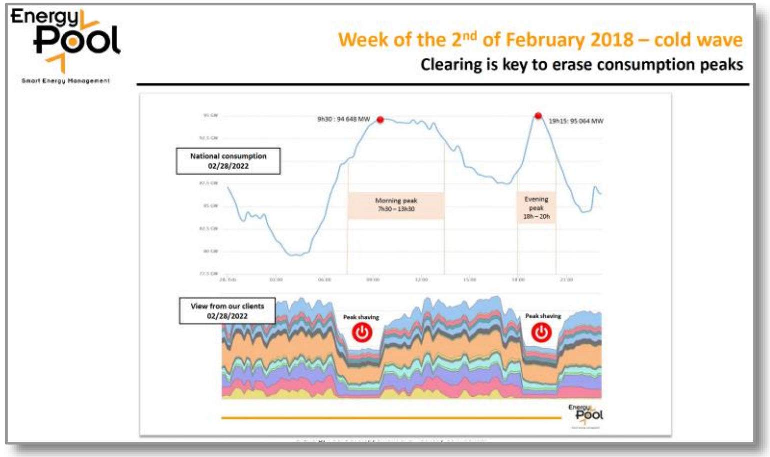


Figure 1-1: Schematic representation of the finite state machine

(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**

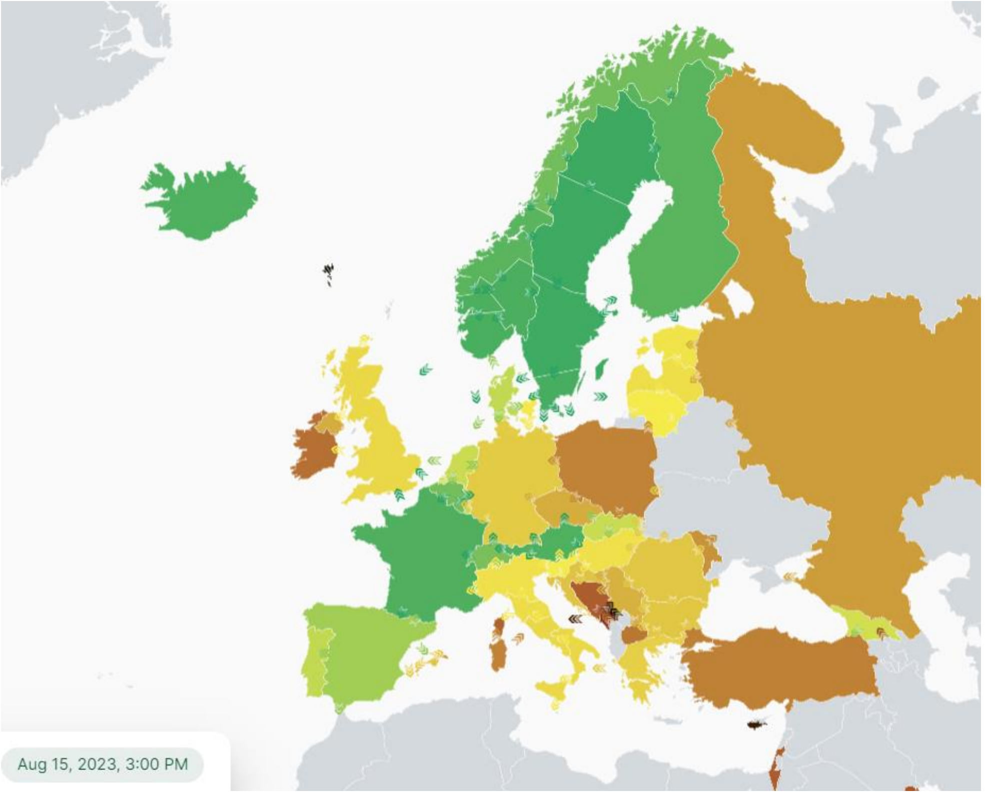


C. Gaunand, B. Remenyi: *Introduction to Demand Side Flexibility*
ESSRI Workshop 2022 https://indico.esrf.fr/event/2/contributions/94/

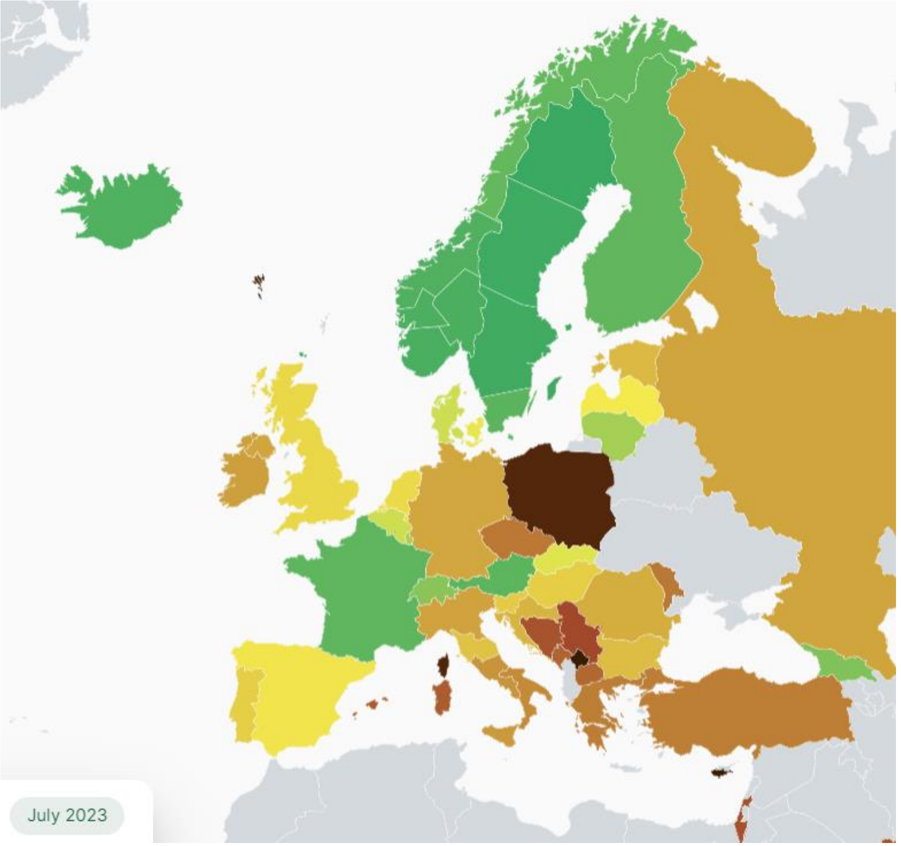
How can we procure CO_2 “free” energy?

https://app.electricitymaps.com/map

24 h (15 August)



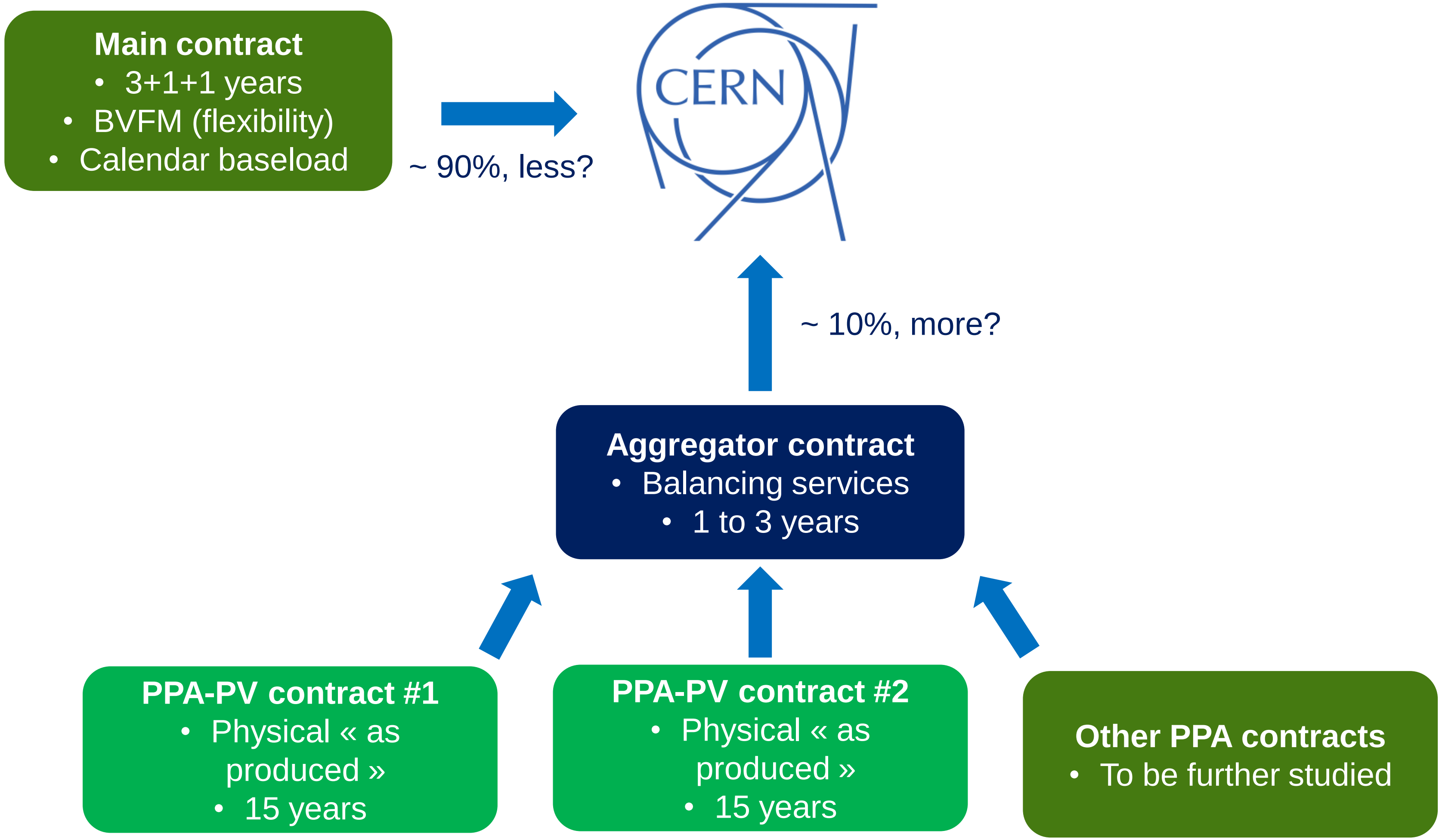
12 months



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.
- Cost-wise, at present we are “protected” by the ARENH mechanism (~42 €/MWh)
- In the future (2026?) Nuclear Energy will go at market prices ☹
- 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



LifeCycle mindset

LifeCycle mindset

- Future projects shall have to show compliance with the objectives of the UN Roadmap 2030 (and their successors…)
- If not for legal obligation, certainly for social acceptance...
- A key point to address is the optimization in terms of the entire lifecycle
- Construction, operation and decommissioning/disposal phases have all a relevant role
- LifeCycle Assessment (LCA) is the tool to provide figures about the impact of a project/component on the environment from all points of view (not only CO_2..)
- LCA is standardised by ISO 14040, 14044 and many others.

LifeCycle mindset

What is LCA?

LCA is a **methodology** to assess the potential **environmental impacts** of **products, systems**, or **service** at all **stages** in their **life cycle**

enviroet
Creating sustainable impact

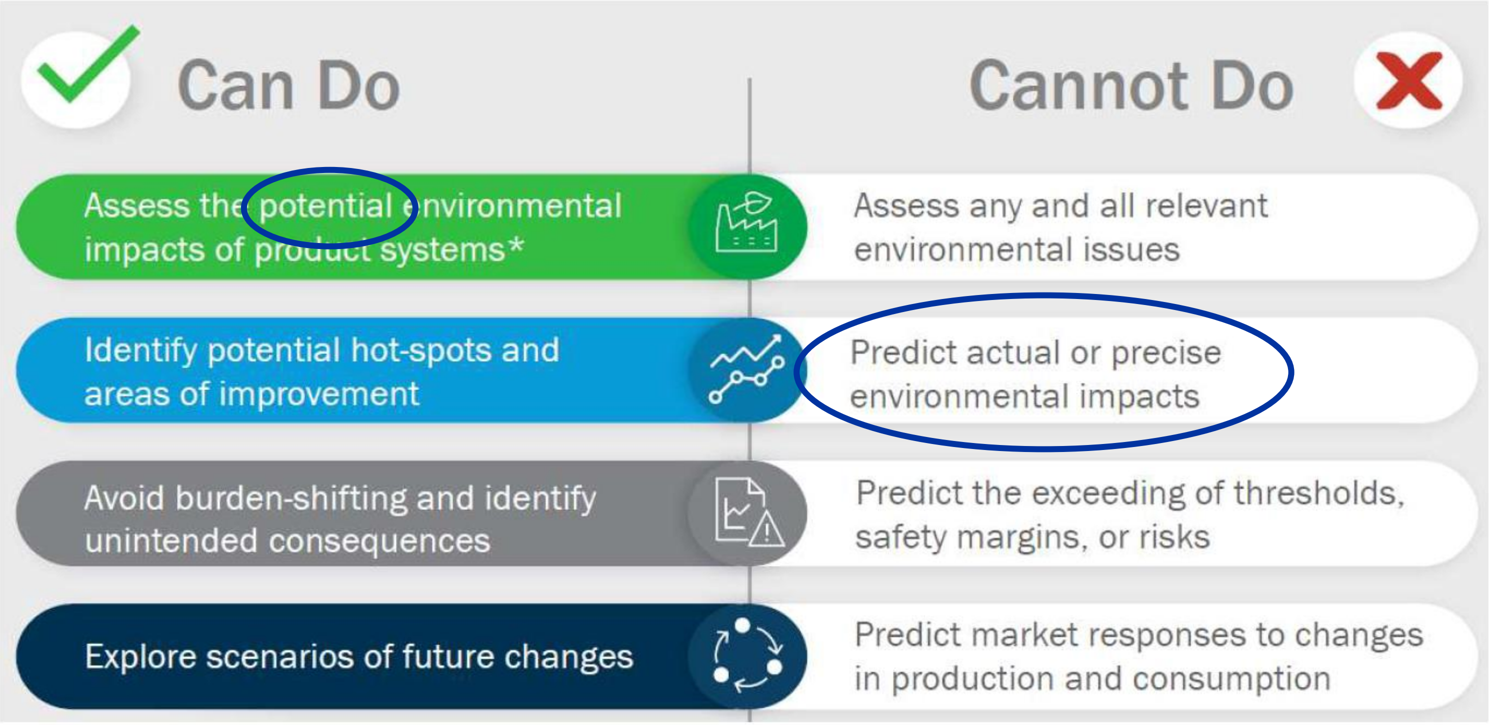
6

Courtesy Amit Lotan, Enviroet: Lifecycle assessment of an electronic board

https://indico.cern.ch/event/1278474/contributions/5370618/attachments/2637415/4563163/Methodology%20of%20LCA%20in%20the%20electronic%20industry%20-%20CERN-%2027.04.23.pdf

LifeCycle mindset

Capabilities and Limitations of LCA



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*Limited by availability of data and methodology

7

LifeCycle mindset

Phase 3: Impact assessment

Climate Change	Acidification of Land and Water Resources	Eutrophication	Formation of Photochemical Oxidants	Use of Energy and Resources
Global warming potential (GWP)	Acidification potential (AP)	Eutrophication potential (EP)	Photochemical oxidant formation potential (POFP)	1- Abiotic depletion potential (ADP Elements) 2- Abiotic depletion potential (ADP Fossil) 3- Water scarcity footprint (WSF)
*The **heat** absorbed by any **greenhouse gas** in the **atmosphere**.* *GWP-fossil* *GWP-biogenic* *GWP-land use* *GWP- Total*	*Affects **aquatic** and **terrestrial** ecosystems by changing the **acid-basic-balance***	*The **excessive** supply of **nutrients** and can apply to both **surface** waters and soils* • *Freshwater* • *Marine* • *Terrestrial*	*also known as **smog** is the **photochemical creation** of **reactive** substances (mainly **ozone**)*	*1- represents the **extraction** of **natural elements** from earth* *2- represents the **use** of **fossil-based** energy.* *3- used to **measure** the amount of **water** utilized*

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13

LifeCycle mindset

CML 2001-2016

Indicator	Unit
GWP-total	kg CO_2 eq.
GWP-fossil	kg CO_2 eq.
GWP-biogenic	kg CO_2 eq.
GWP-luluc	kg CO_2 eq.
ODP	kg CFC 11 eq.
AP	mol H+ eq.
EP-freshwater	kg P eq.
EP-freshwater	kg N eq.
EP-terrestrial	mol N eq.
POCP	kg NMVOC eq.
ADP-minerals&metals	kg Sb eq.
ADP-fossil	MJ
WDP	m3

Life Cycle Impact Assessment (LCIA) methods

CML (Used worldwide - except North America)
from the Institute of Environmental Sciences of the University of Leiden in the Netherlands. Required by the European EN 15978 and EN 15804 standards

TRACI (Used in North America)
stands for Tool for the Reduction and Assessment of Chemical and other environmental Impacts. It is a method published by the U.S. Environmental Protection Agency (US EPA)

PEF (Used worldwide - except North America)
EN15804 standard became mandatory in July 2022. Environmental Product Declaration (EPD)

ReCiPe (Used in Europe)
Developed by the Dutch research institute of RIVM (National Institute for Public Health and the Environment), Radboud University Nijmegen, Leiden University and Pré Consultants in 2008.

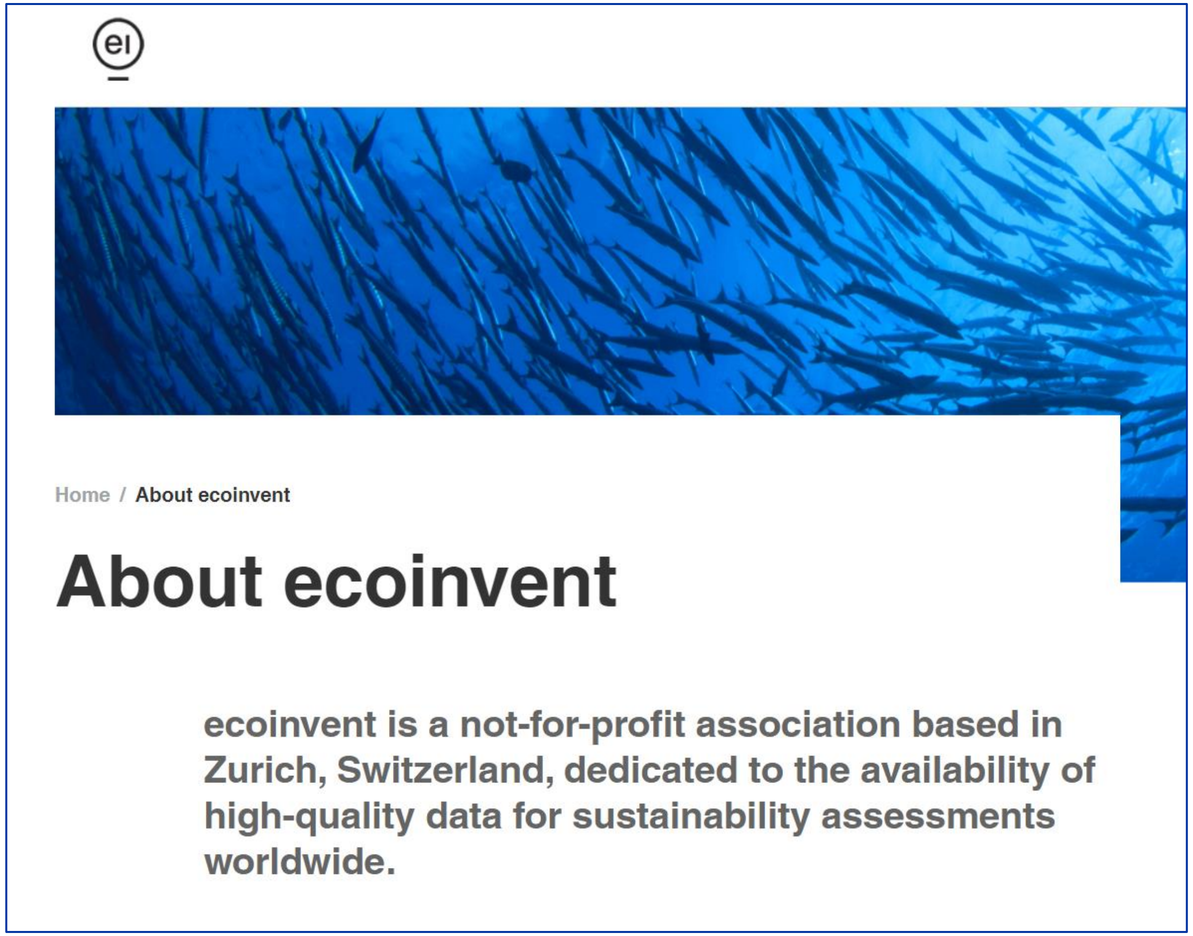
14

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…



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.

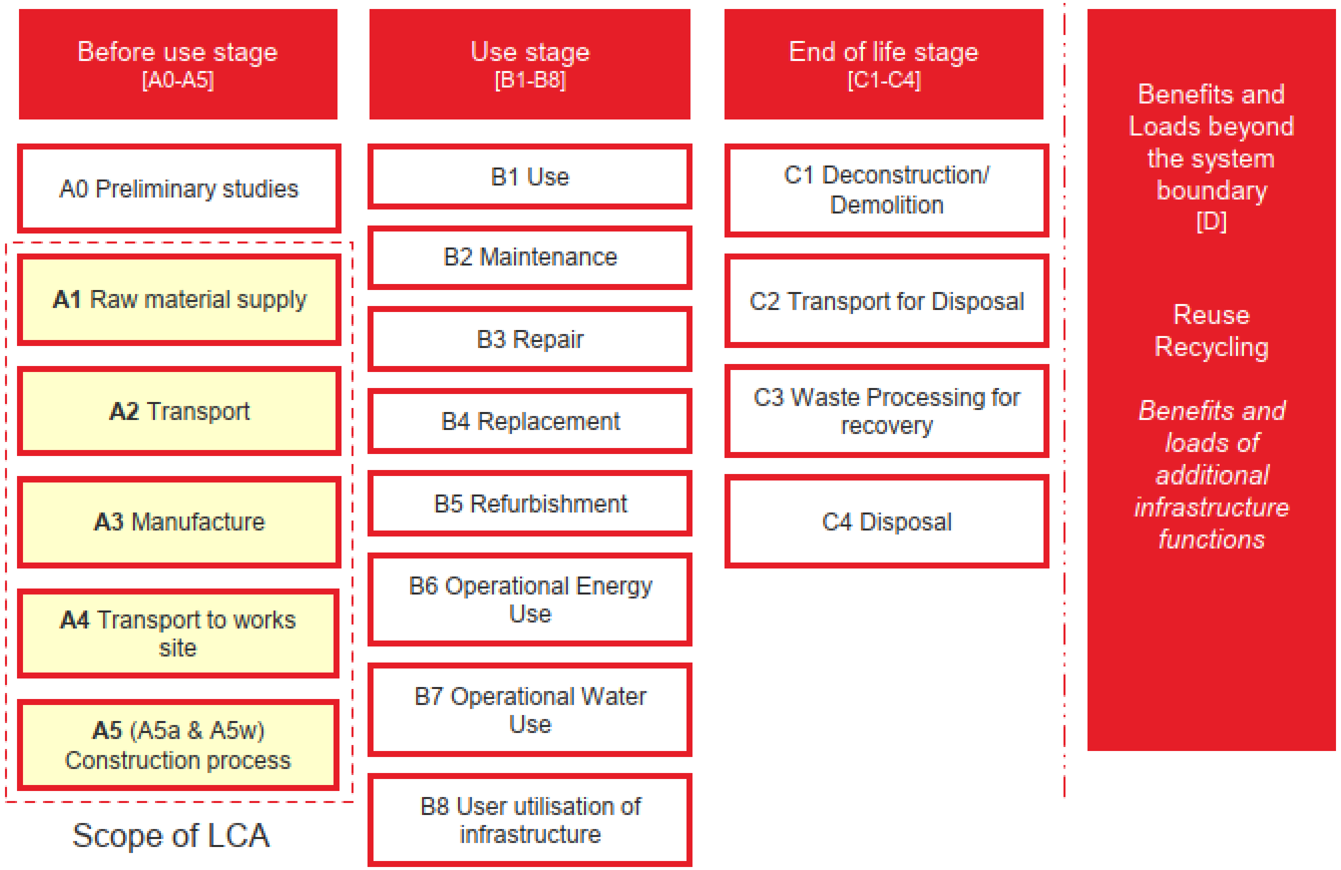
The life cycle is broken down into life cycle modules, as outlined in BS EN 17472:2022.

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

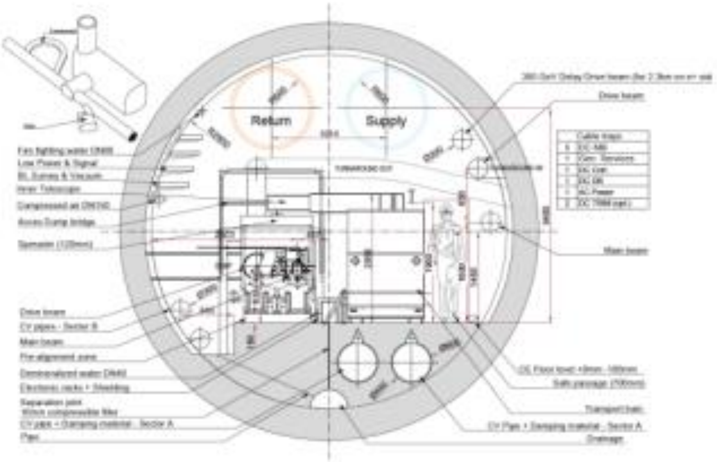
The scope of this LCA is A1-A5, which includes the raw material extraction to construction activities on site. A5 is split into A5a and A5w, construction activities and material wasted on site, respectively.

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

BS EN 17472:2022



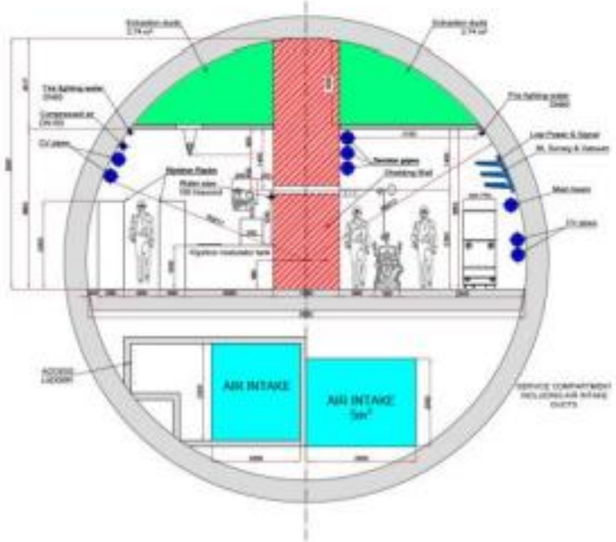
LifeCycle Assessment: CLIC & ILC



CLIC Drive beam, 5.6m dia.

Geneva

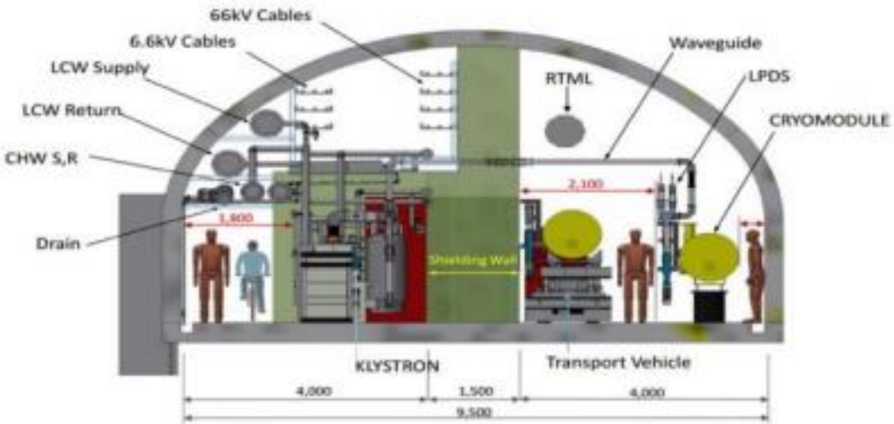
Energies: 380GeV, 1.5TeV, 3TeV.



CLIC Klystron, 10m dia.

Geneva

Energies: 380GeV

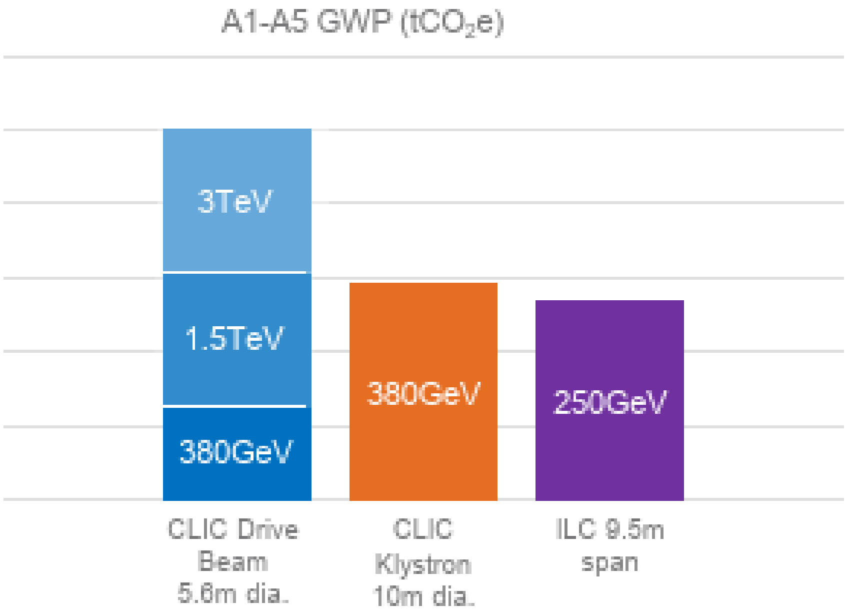


ILC, 9.5m span

Tohoku Region, Japan

Energies: 250GeV

LifeCycle Assessment: CLIC & ILC



UN Breakthrough Outcomes for 2030

For the built environment sector, the UN breakthrough outcomes for 2030 detail that 100% of projects due to be completed in 2030 or after are net zero carbon in operation, with at least 40% less embodied carbon compared to current practice. This has been set to make sure the sector is on track for 100% projects to be net zero carbon across the whole life cycle by 2050.

https://climatechampions.unfccc.int/system/breakthroughs/

- **We need to consider how to get to net zero carbon operation and 40% less impacting construction for our future projects….**

LifeCycle Assessment: CLIC & ILC

Recommendations

There is an opportunity for material and design optimisation; this includes but is not limited to:

CEMENT/CONCRETE

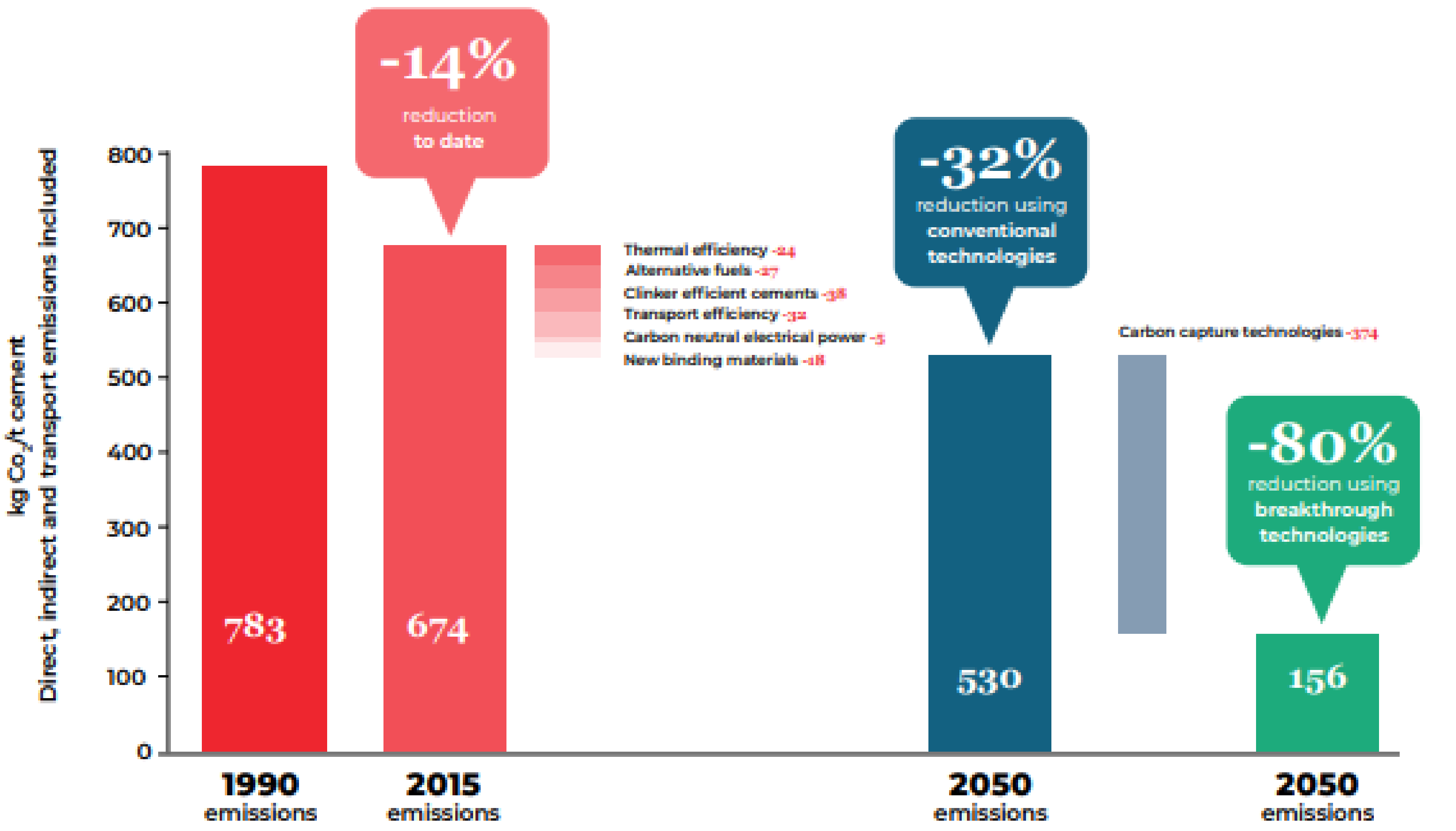
- **2030 TARGET: Over 20 cement plants with CCUS. Carbon intensity per ton of cement produced is reduced from 616 (2020 baseline) to at least 463 kg CO_2 / t cement by 2030**
- **EXAMPLES OF DELIVERY PARTNERS: CGCCA and its members, Mission Possible Partnership (MPP) – Concrete Action for Climate (CAC) – co-led by World Economic Forum & GCCA**

line with the UN Breakthrough Outcomes for 2030.

Environmentally friendly CONCRETE

•

CO_2 REDUCTION MEASURES: 2050 PERSPECTIVE



Source: ECRA and CEMBUREAU own calculations

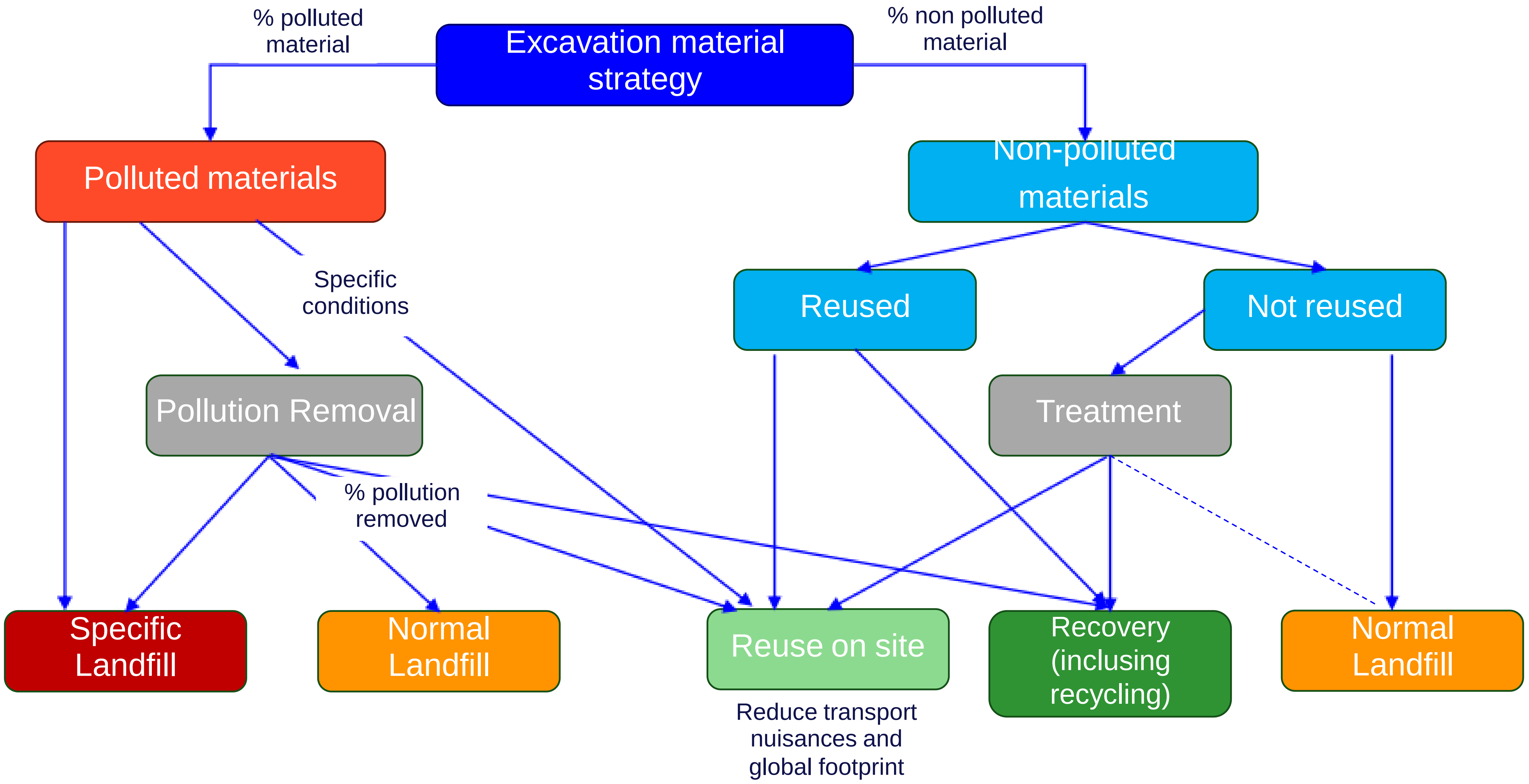
Note: Other technologies (e.g. electrical efficiency, alternative raw materials) not displayed as long term reduction potentials are severely limited

The benefits of direct air capture

Each solution, whether natural or technology-based, has its benefits. That's why it's essential that every approach works in synergy with all others if climate targets are to be achieved. Here are the benefits of direct air capture:

- **Location-independent**: CO_2 is in the air at the same concentration everywhere in the world. This means that DAC plants can be located anywhere as they do not need to be attached to an emissions source. They are only required to be placed near a renewable energy source and in a place where CO_2 can be stored.
- **Highly scalable and measurable**: Our plants are based on a modular technology design, making them highly scalable. We can also measure exactly how much CO_2 our machines capture.
- **Efficient land usage**: Our plants require less land than other techniques. E.g., on a land area of 0.42 acres, our Orca plant can remove 4,000 tons of CO_2 from the air every year, which is almost 1,000 times more effective than trees. The same land would host around 220 trees with an estimated capacity of 22kg each (source), i.e., only 4.62 tons of CO_2 per year

Approach


% polluted material
Excavation material strategy
% non polluted material
Polluted materials
Non-polluted materials
Specific conditions
Reused
Not reused
Pollution Removal
Treatment
% pollution removed
Specific Landfill
Normal Landfill
Reuse on site
Recovery (inclusing recycling)
Normal Landfill
Reduce transport nuisances and global footprint

“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.

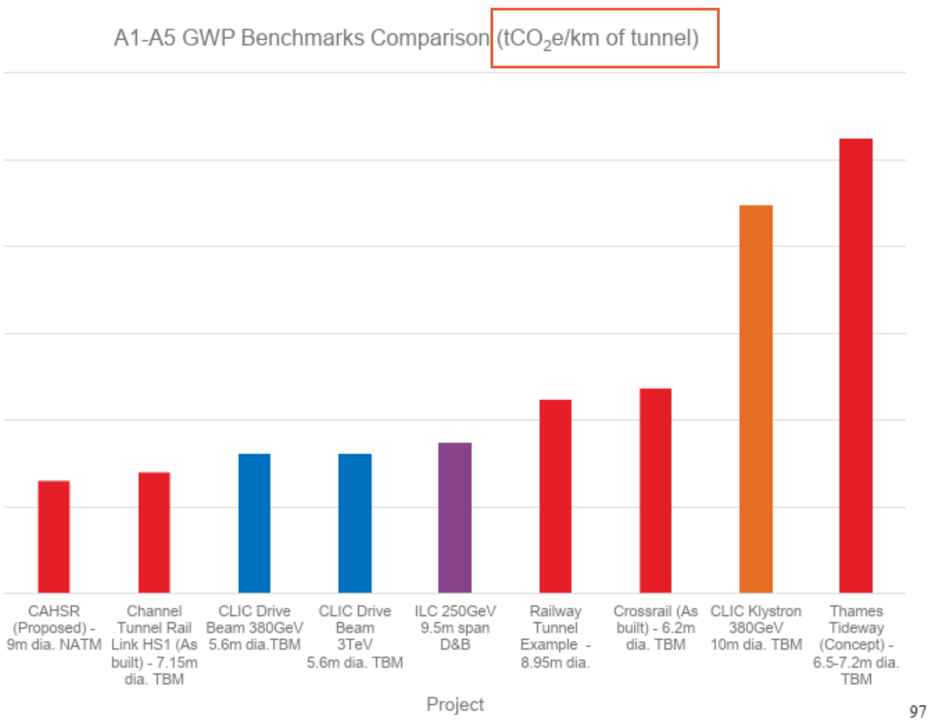
**TRL: Technology readiness level. Level 4: Technology validated in laboratory*

LifeCycle Assessment: CLIC & ILC

Methodology

The LCA follows the ISO 14040/44 methodology.

The LCA has been carried out using the LCA tool Simapro 9.4.0.2 which uses Ecoinvent 3.8 database. The ReCiPe Midpoint (H) 2016 method has been used to estimate the environmental impacts across 18 impact categories – see table to the right.



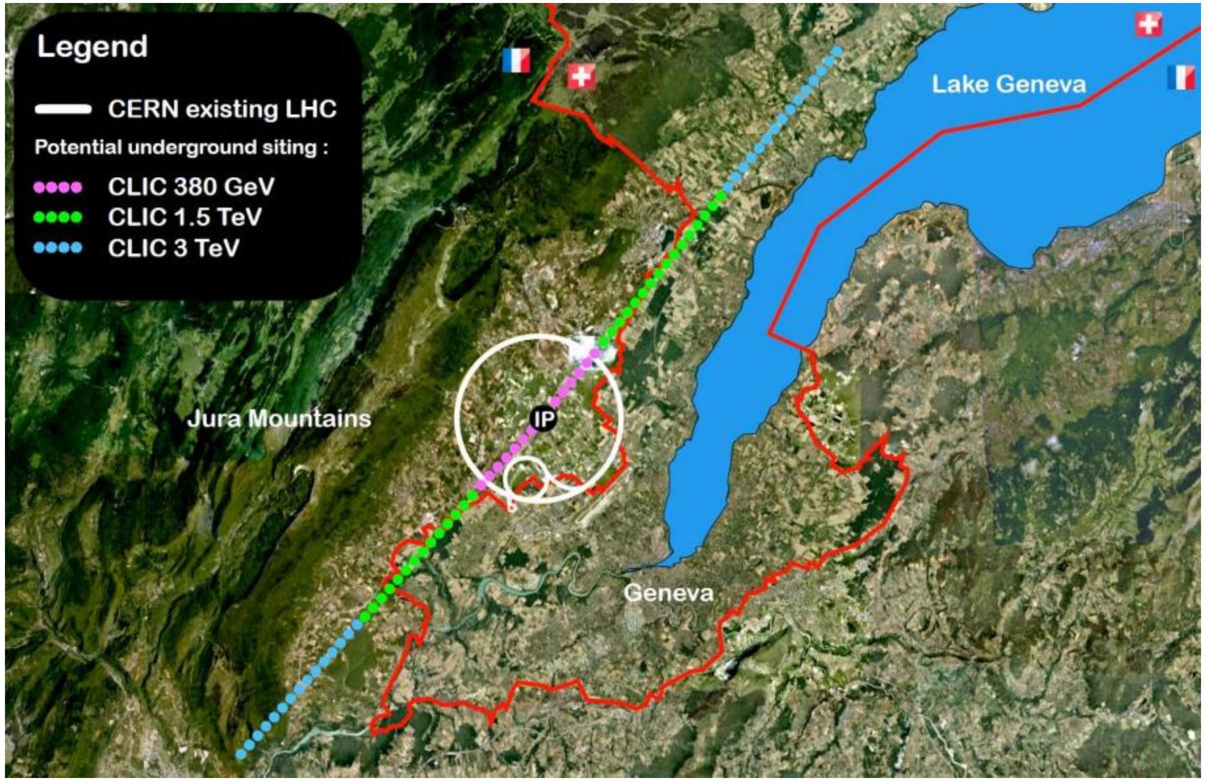
Data quality

Simapro 9.4.0.2 uses Ecoinvent 3.8 database, released in September 2021. Ecoinvent is widely recognised as the largest and most consistent LCI database. Ecoinvent validates the LCI data through ecoEditor software. Ecoinvent reviews the data through manual inspection from at least 3 experts prior to the storage of data in Ecoinvent database (Data quality guideline for the ecoinvent database version 3, 2013).

- Absolute values are only relevant to fix a reference, wrt 40% reduction needed
- The value of a joint study is to be able to compare projects using the same assumptions, same methodology and databases for LCA, in order to understand weaknesses and strengths of each configuration

SCE Technical Seminar
Lifecycle Assessments

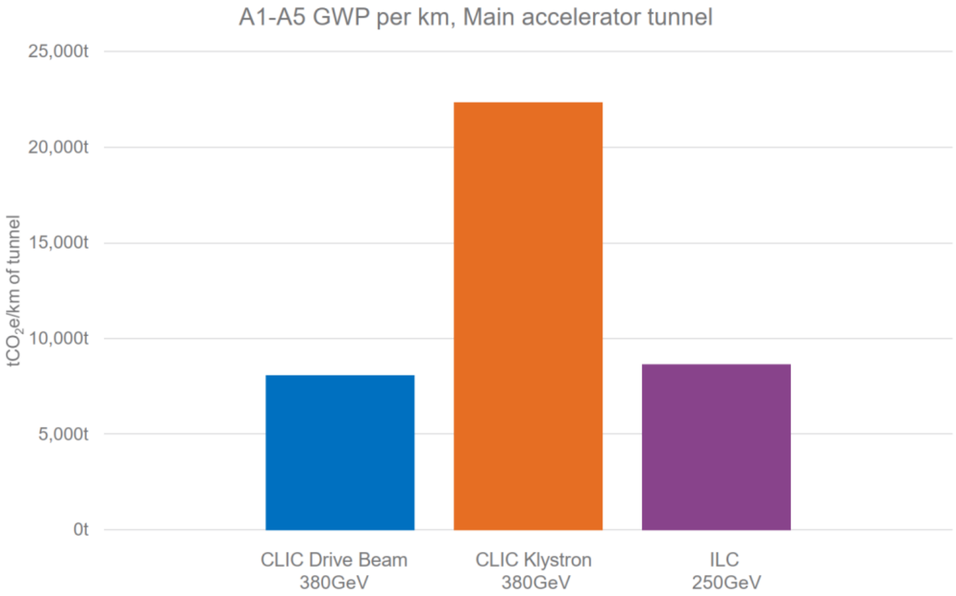
Future Projects - Linear Colliders



Introduction to Linear Colliders
Steinar Stapnes, CERN

Lifecycle Assessment of Linear Colliders
Suzanne Evans, Arup

Key topics
- Embodied CO_2
- Lifecycle assessment framework
- Construction energy consumption
- Benchmarking, comparisons to other projects
- Carbon reduction opportunities



ARUP

CERN

24th November 2023
10:30 – 12:00
Room - 30/7-018

LifeCycle Assessment: Training

- **A pilot training course has been organized for the ATS sector on Nov. 21 to 23 at CERN on how to perform lifecycle assessment of products.**

- **If successful, it may become a regular offer of the training catalogue.**

LifeCycle Assessment: Future

- **For whichever future collider, we will have to perform the LCA of all the main systems.**

- **Critical and Strategic decisions, to be taken by CERN but also within the international community, are**
  - Can/Will we compare LCAs for different projects?
  - Which methodology we will adopt
  - Which databases will we use?
  - Will the community converge on a common strategy?
  - Should we look at introducing in our plans provisions for Carbon Capture?

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

Science and Technology Facilities Council
ASTeC

Our force: New technologies, new approaches

(Incomplete collection of ongoing actions…)

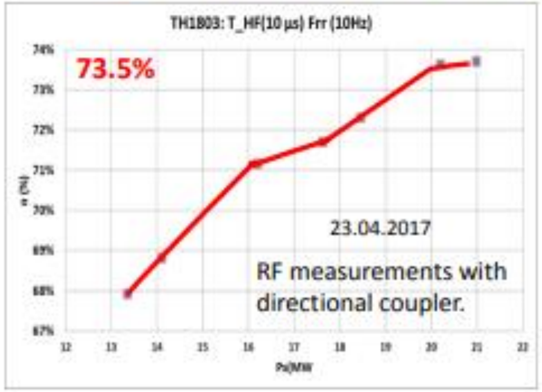
High Efficiency Klystrons

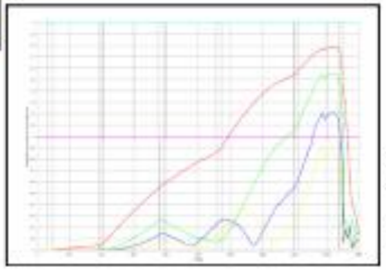
(I. Syratchev)

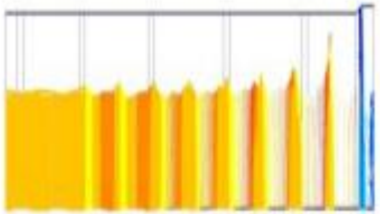
State of the art.

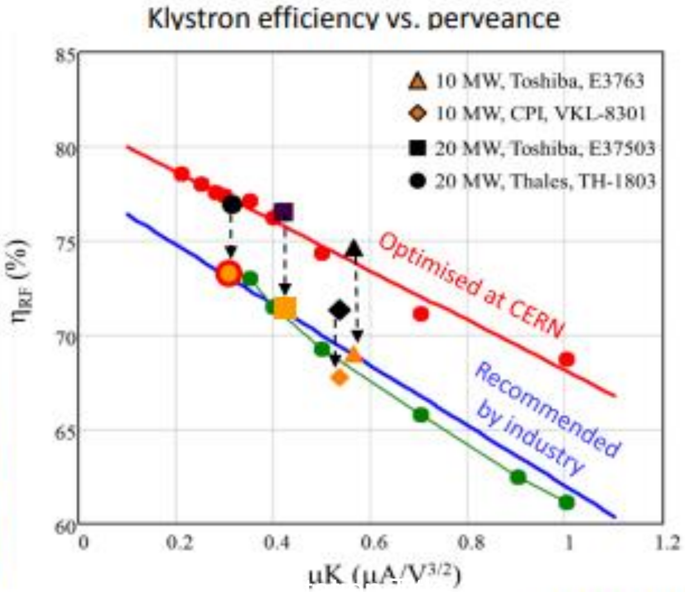
Commercial MBK (low perveance) tubes with high efficiency.

After 8 decades of development the klystron technology was considered to be saturated. The experimental results from hundred's of different devices have shown that higher efficiency is associated with lower perveance. Accounting for technological and cost reasons (μK>0.2), **the 75% efficiency was predicted to be the utmost limit.**



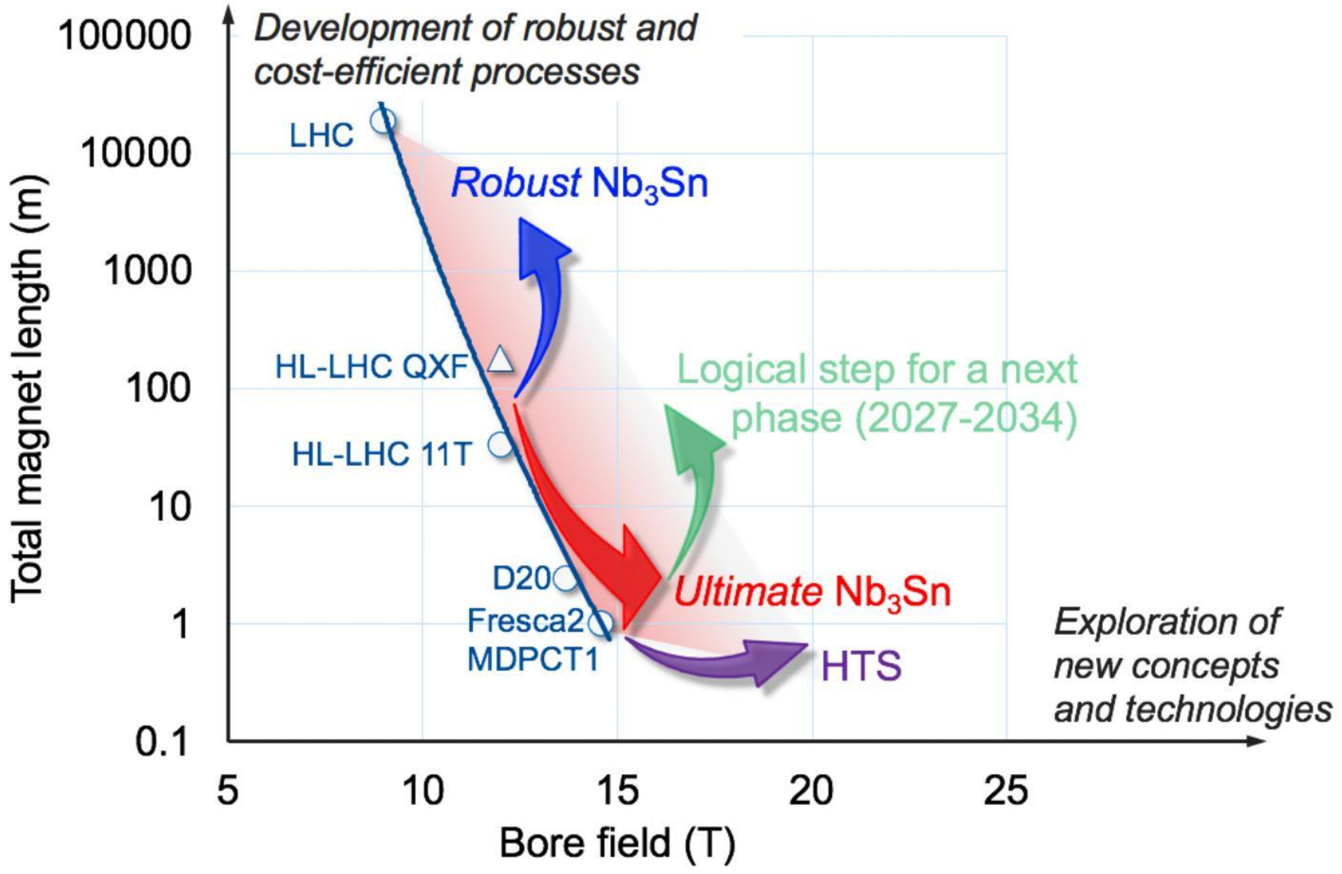






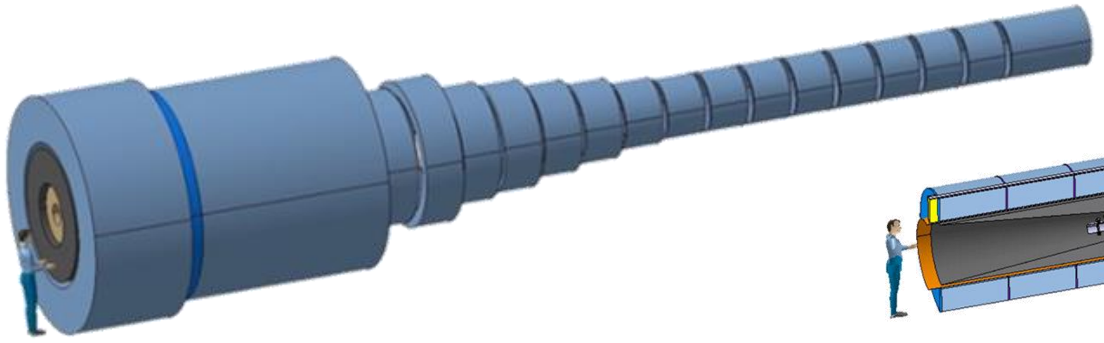
Superconductivity: High Field Magnets

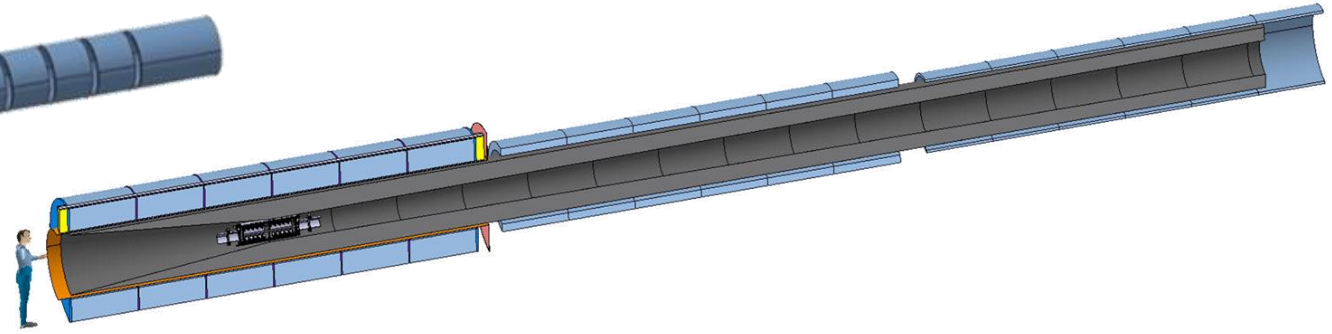
HFM
High Field Magnets



HTS is the future?

Target & Capture Solenoids for the Muon Collider





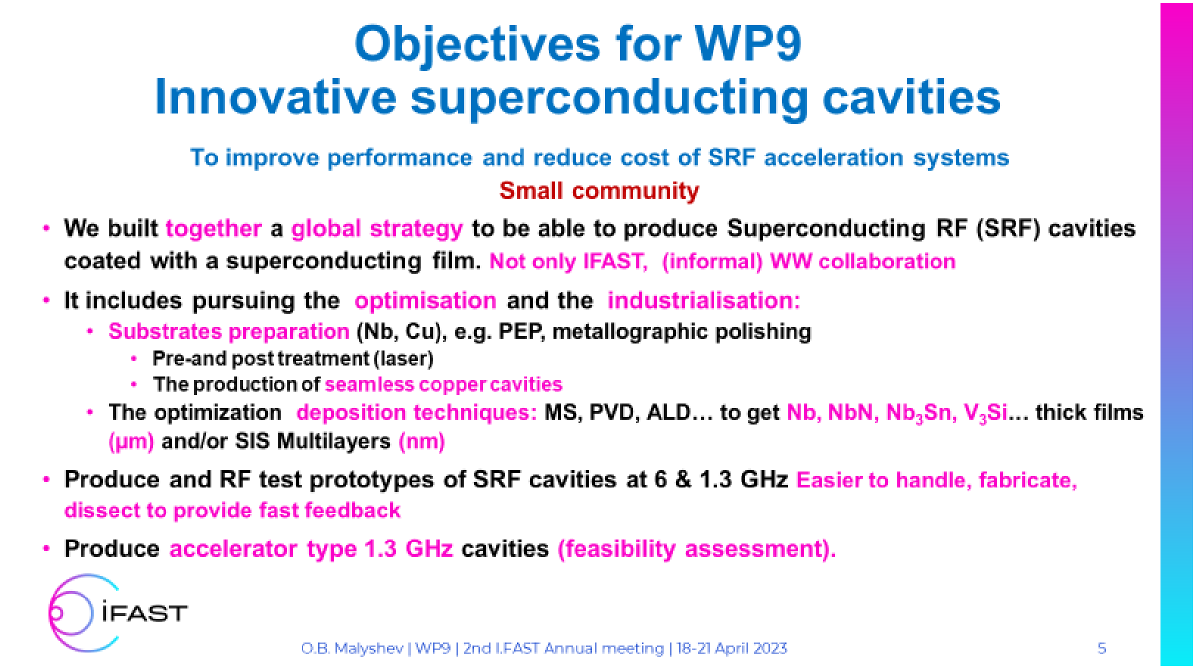
US-MAP
Proposal
(<2016)

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

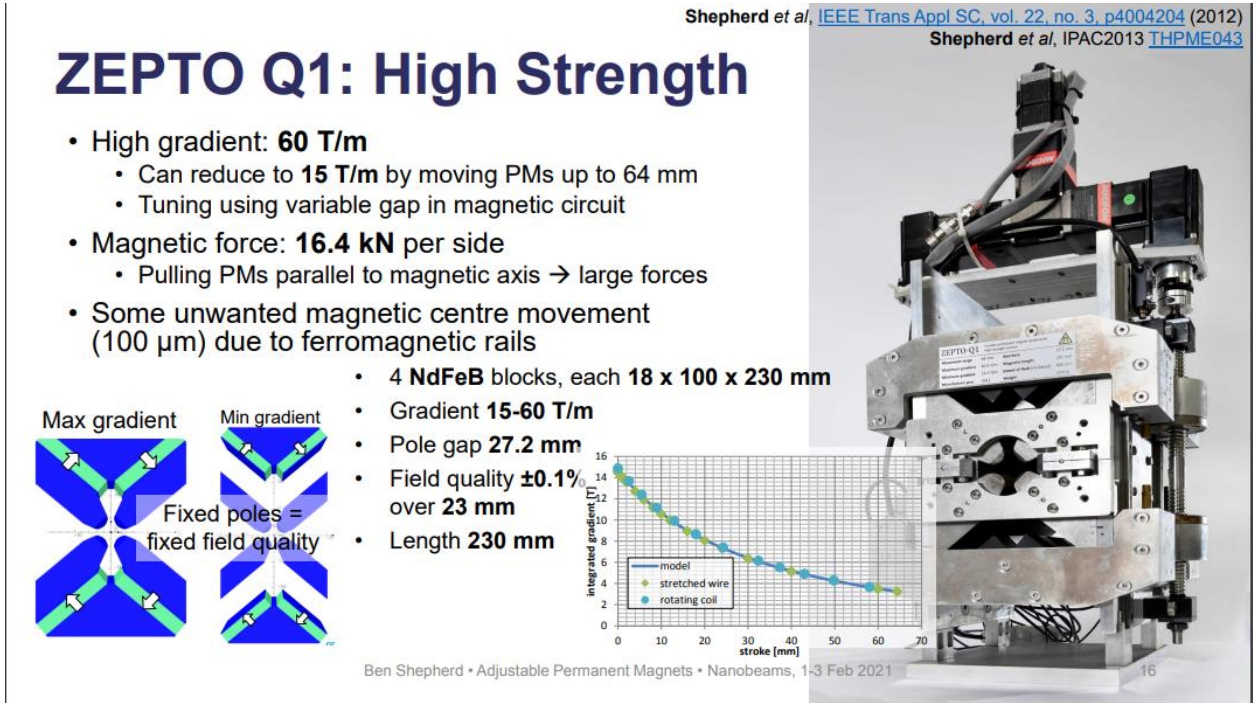
EM = 1 GJ
Top = 10…20 K
Mcoils = 110 tons
Mshield = 196 tons
P = 1 MW

IMCC
Proposal
(2023)

Superconductivity: RF



Permanent Magnets



Rare earths for permanent magnets: blessing or curse?

Although permanent magnets can significantly reduce the energy consumption of accelerators, their use of rare earths requires best practices, as discussed by experts at the latest I.FAST workshop.

13 APRIL, 2023 | By Denise Völker (DESY), Andrea Klumpp (DESY) & Mike Seidel (PSI/EPFL)

Permanent magnets require large amount of rare earths, often mined in precarious conditions for both the workers and the environment. (Credit: Sebastian Pichler/Unsplash)

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

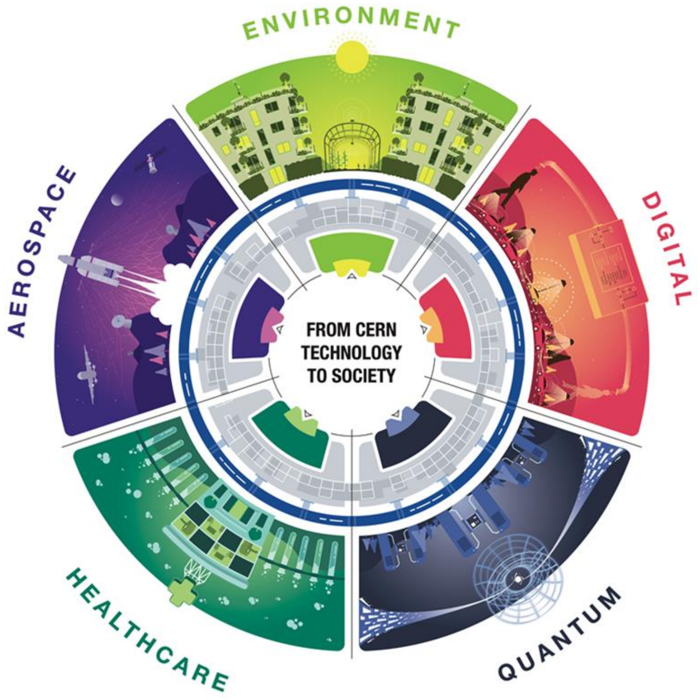
- High Level Strategy

- Call for Ideas 2022

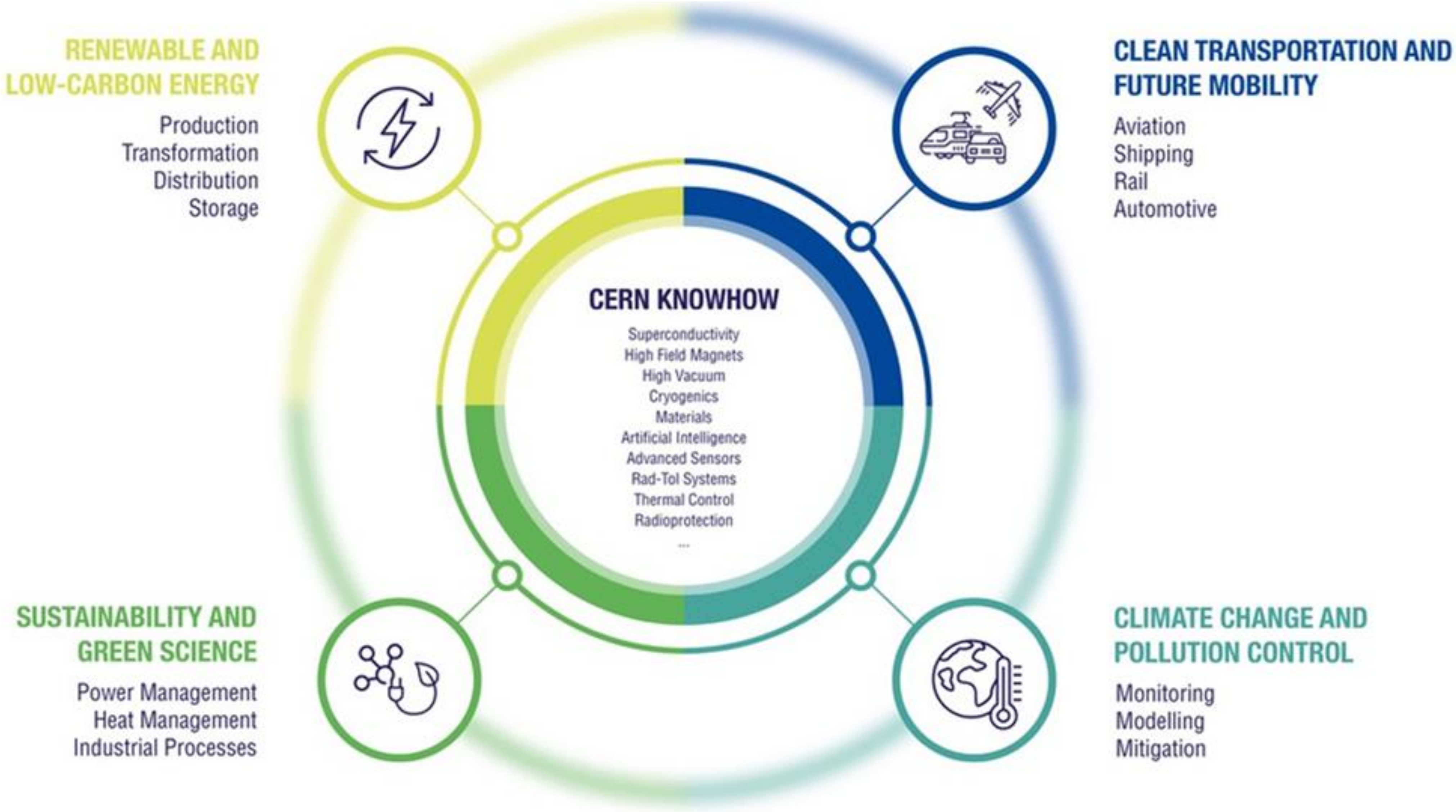
- Poles of Competence

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

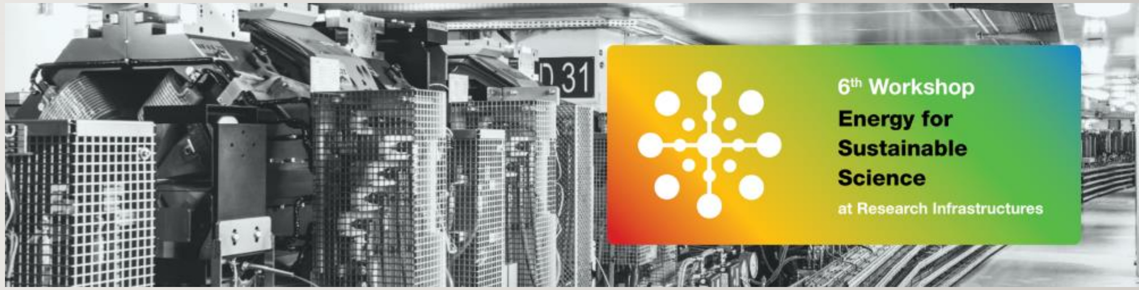
Project with **ABB** to improve energy efficiency of CERN cooling and ventilation with smart sensors and digital twins

ABB

International Context

ESSRI WORKSHOP IN GRENOBLE , SEPT. 22

https://indico.esrf.fr/event/2/



- Several key messages
  - Energy and Water management is a priority for all Facilities
  - Some facilities are starting to work on LifeCycle assessment
  - Storage rings looking at massive use of permanent magnets
  - Data centers more and more efficient
  - Awareness about necessity of High Efficiency High Power Sources
  - Operation follows availability of sustainable energy

ICFA Panel on Sustainable Accelerators and Colliders

Status, July 16, 2023

- **Panel members:**
  - **Europe:** Mike Seidel (PSI, Switzerland), Andreas Hoppe (DESY, Germany), Jerome Schwindling (CEA/IRFU, France), Ruggero Ricci (LNF, Italy), Peter McIntosh (STFC, UK), Roberto Losito (CERN, Switzerland)
  - **Asia:** Takayuki Saeki (KEK, Japan), Yuhui Li (IHEP, China), Hiroki Okuno (Riken, Japan), Gwo-Huei Luo (NSRRC, Taiwan), Eugene Levichev (BINP, Russia)
  - **America:** John Byrd (ANL, USA), Soren Prestemon (LBNL, USA), Thomas Roser (BNL, USA), Andrew Hutton (JLAB, USA), Robert Laxdal (TRIUMF, Canada), Vladimir Shiltsev (FNAL, USA), Emilio Nanni (SLAC, USA)
- **Mandate:**
  - Assess and promote developments on energy efficient and sustainable accelerator concepts, technologies, and strategies for operation, and assess and promote the use of accelerators for the development of Carbon-neutral energy sources. The panel will formulate recommendations on R&D and support ICFA with networking across the laboratories and communications. The membership will ensure a broad regional participation and coverage of accelerator technologies and concepts, relevant in the context of energy consumption and production.
- Many laboratories are expanding their use of Carbon-neutral energy sources. Whereas this is a highly welcome development it does not replace or obviate the need for increased energy efficiency and reduced energy consumption, which is the focus of this panel.

iFAST 2nd Annual Meeting, April 19, 2023

Mike Seidel, PSI/EPFL

Brookhaven National Laboratory

European Commission

English | Search

Research and innovation

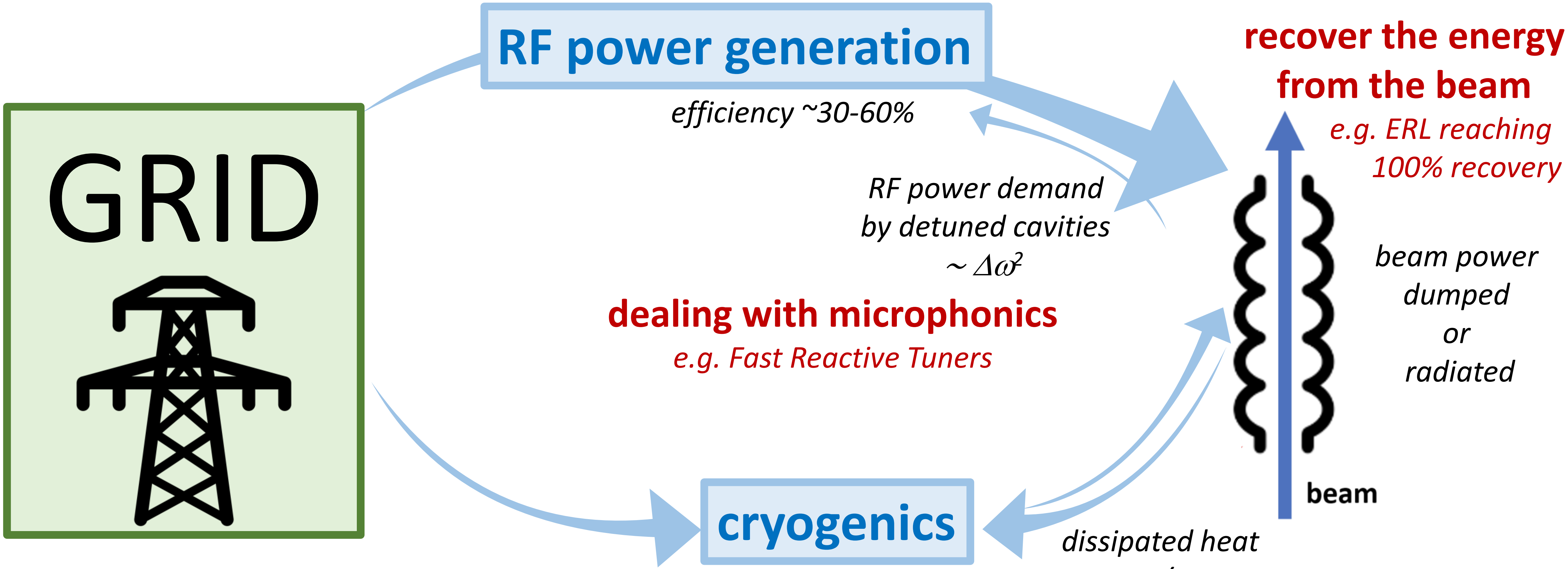
HORIZON-INFRA-2023-TECH-01-01

the new iSAS project	RESEARCH FACILITY 2.0
Courtesy J. Van D'Hondt, A. Stocchi	Courtesy G. De Carne, J.P Burnet
Approved in July '23	Approved in July '23

From Grid to Beam

improve amplifier efficiency

e.g. solid state amplifiers for oscillating power demands



dissipated heat
$\sim 1/Q_0$

performance
$\sim (300K – T) / T$

mitigation with novel technologies

operate cavities at higher T & improve Q_0 of cavities

e.g. Nb_3Sn from 2K to 4.4K ➔ 3x less cooling power needed

iSAS organisation

Spread over 4 years: ~1000 person-months of researchers and ~12.6M EUR

(of which 5M EUR is requested to Horizon Europe)

DESY.

INFN

UKRI UK Research and Innovation

HZB Helmholtz Zentrum Berlin

ess EUROPEAN SPALLATION SOURCE

Lancaster University

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

cea

VUB VRIJE UNIVERSITEIT BRUSSEL

cnrs

IJCLab Irène Joliot-Curie

CERN

+ industrial companies: *ACS Accelerators and Cryogenic Systems* (France), *RI Research Instruments GmbH* (Germany), *Cryoelectra GmbH* (Germany), *TFE Thin Film equipment srl* (Italy), *Zanon Research* (Italy), *EuclidTechLab* (USA)

Approach to sustainability at DESY

A sustainable accelerator and high research performance? How can we manage it?

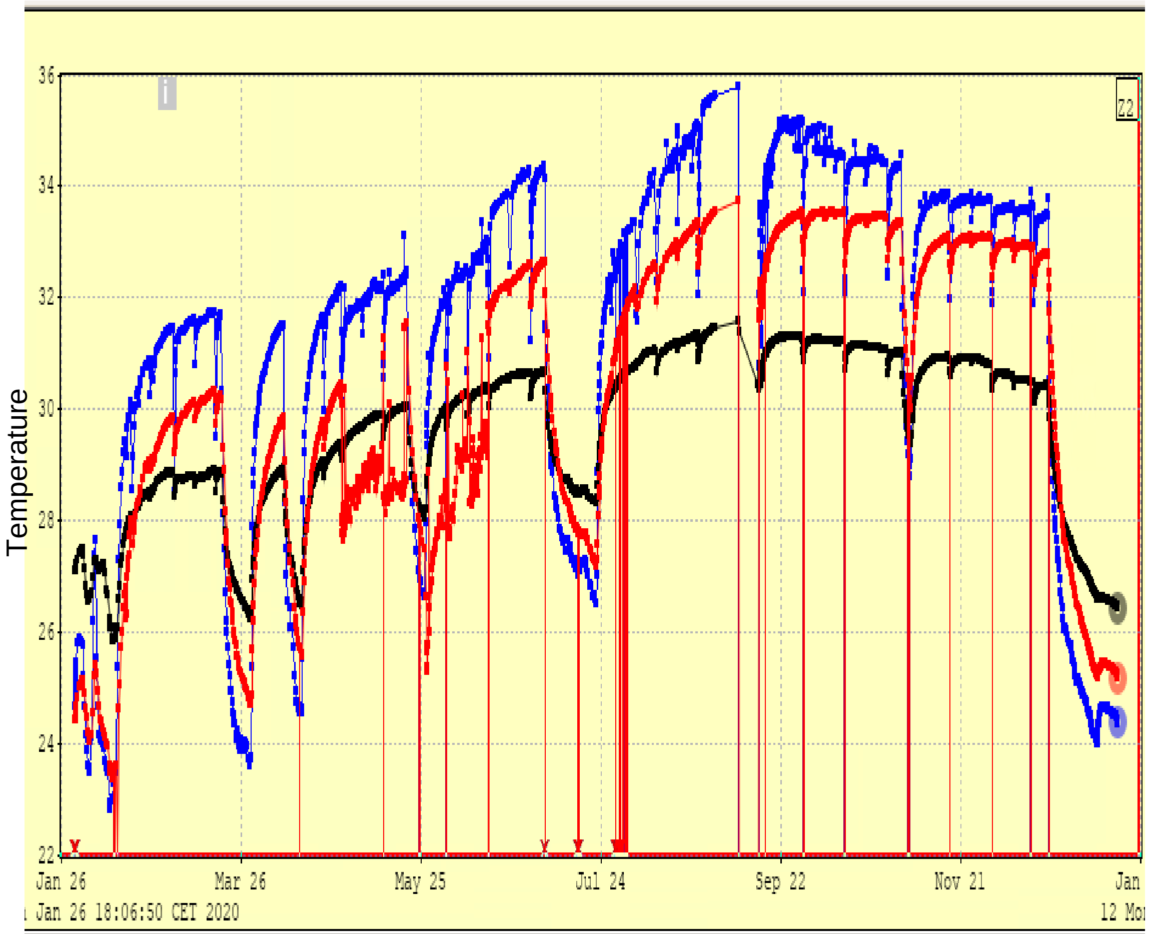
Concepts and first steps taken

Andrea Klumpp

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Tunnel Temperature PETRA III

Heated and unheated sections



Black curve, 26º – 31º C: Concrete floor, OR59, air temperature regulated (30º C)
Red curve, 23º – 34º C: Concrete floor, SOR87, air temperature unregulated
Blue curve, 23º – 36º C: Air temperature, SOR85, air temperature unregulated

Tunnel Climatization today:

- air (25º C) blown in every 300/600 m
- cooling water inlet: 25º C

Temperature over one year

- Temperature difference between positions **up to 5°C**
- operating schedule of PETRA clearly visible
- summer and winter time visible

|Temp.Calc.Kickoff| PETRA IV
WP 1.12 - Michael Bieler

Conclusions

- Sustainability will be one of the drivers for the design and the approval of future colliders
- UN Roadmap gives us the direction. Some of the goal are mandatory in the host states, more will become…
- CERN and in general the HEP community is engaged since at least 10 years to build and operate new accelerators responsibly: we are in good shape for the future!
- LCA (LifeCycle Assessment) is an essential tool to understand where are the weaknesses in a project. It's NOT a tool to calculate precisely the CO_2 footprint
- The community has to agree on common tools to be able to compare different projects (LDG Working group on sustainable accelerators)

Conclusions

- **We should keep in mind that whatever (low) impact we will have on the environment and Earth resources, we have to convince that the outcome is worth to society**

  - Solid and attractive physics case
  - 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**

Challenge or Opportunity ?

Credit: oppnest.com