LCWS2024 Industry & Sustainability Forum

Industry Session Conveners:

Tohru Takahashi (Hiroshima U.)
Jie Gao (IHEP)
Maxim Titov (CEA)
Juan Fuster (IFIC)
Nuria Catalan Lasheras (CERN)
Valery Dolgashev (SLAC)
Masakazu Yoshioka (KEK/ Iwate Prefectural U.)
Marc Winter (IJCLab)
Nobuhiro Terunuma (KEK)
Osamu Jinnouchi (Tokyo Inst. Tech.)

Sustainability Session:

Benno List (DESY)
Takayuki Saeki (KEK)
Brendon Bullard (SLAC)
Maxim Titov (CEA)

International Workshop on Future Linear Colliders (LCWS2024),
Tokyo University, Japan, July 8-11, 2024

Industrial Forums at the Linear Collider Workshops

ECFA LC2016 (Santander, Spain): June 2016

https://agenda.linearcollider.org/event/7014/sessions/3895/#20160601

LCWS2016 (Morioka, Japan): Dec. 2016

https://agenda.linearcollider.org/event/7371/sessions/4305/#20161206

LCWS2017 (Strasbourg, France): Oct. 2017

https://agenda.linearcollider.org/event/7645/sessions/4537/#20171025

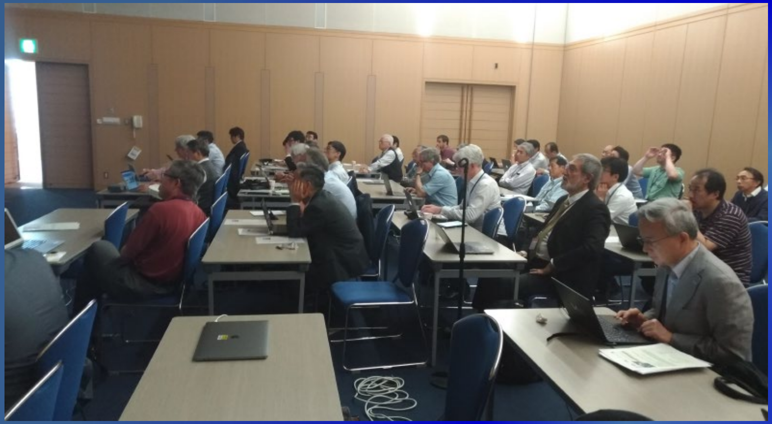
Among participants:

ZANON, RI, THALES, ALSYOM, INEUSTAR, AAA, Piges, AMICI, … CLIC-related industries

Industrial Forums at the Linear Collider Workshops

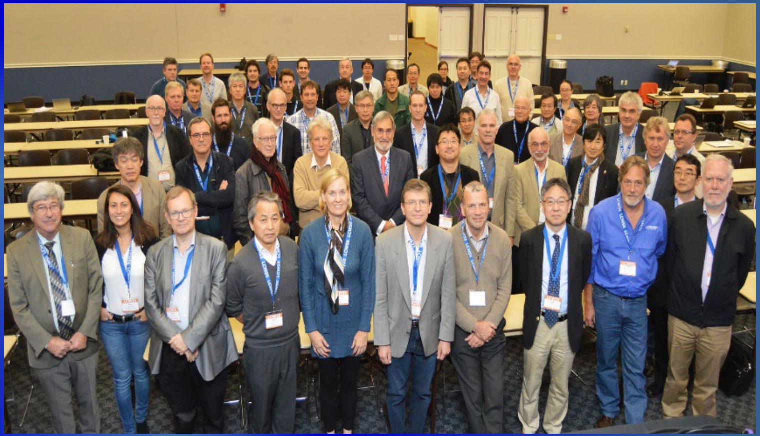
ALCW2018 (Kyushu, Japan): May 2018

https://agenda.linearcollider.org/event/7826/sessions/4652/#20180529



LCWS2018 (Arlington, USA): Oct. 2018

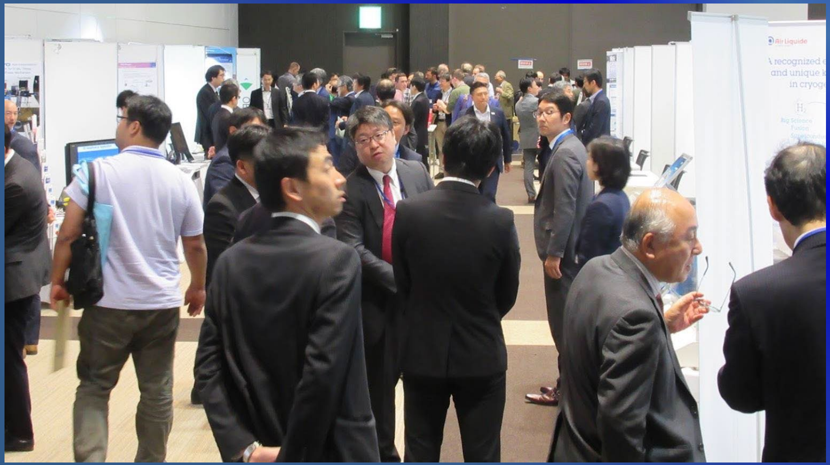
https://agenda.linearcollider.org/event/7889



LCWS2019 (Sendai, Japan): Oct. 2019

https://agenda.linearcollider.org/event/8217

Session + Exhibition (~ 100 companies)



LCWS2021 (Europe, Online): Mar. 2021

https://indico.cern.ch/event/995633/sessions/387855/#20210316

LCWS2023 @SLAC: International Workshop on Future Linear Colliders (May 15-19, 2023)

The 2023 International Workshop on Future Linear Colliders (LCWS2023) will take place on May 15-19, 2023, SLAC, USA. The program will feature ILC progress in Japan, and the establishment of the International Technology Network (ITN) as the prominent topic, to review the progress in accelerator design, detector developments and physics studies. The progress of the CLIC studies within the same areas will also be covered and most sessions and topics will be common. The ILC project in Japan and CLIC project at CERN are also the central elements of the recently approved EU / EAJADE (Europe-America-Japan Accelerator Development and Exchange) program. Emerging new linear collider concept, C^3, will be also presented. More details about the workshop program may be found at the conference website: https://indico.slac.stanford.edu/event/7467. As a part of the LCWS2023 Symposium, we are pleased to announce the following special events:

Industrial Forum on Accelerator Technologies and Advanced Instrumentation for Future Linear Colliders

Date: 16 May 2023, 13:00 – 15:00 (PDT, US)

Indico link: https://indico.slac.stanford.edu/event/7467/sessions/441/#20230516

The goal of the event is to strengthen international cooperation between academia and industrial partners involved in the development of advanced accelerator technologies and instrumentation techniques. The forum will be devoted to the industrial aspects of future Linear Colliders, which offers an opportunity to valorise and highlight the expertise and innovation capabilities of national laboratories and their related industrial partners.

13:00-13:15 Introduction to Industry and Sustainability Forum – Session Conveners
13:15-13:35 Japan - AAA activity - Takahashi Tohru (Hiroshima Univ./AAA, Japan)
13:35-13:55 US Office of Accelerator R&D and Production (ARDAP) – Ginsburg Camille (Deputy Director of ARDAP, USA)
13:55-14:15 Advances in Spanish Science Industry – Fernandez Erik (INEUSTAR, Spain)
14:15-14:35 Development of C-band RF infrastructure and initial experiments at RadiaBeam - Murokh Alex (Radiabeam, USA)
14:35-14:45 Experience in participating in the development of an electron-driven positron source as a company in the Tohoku region – Kondo Masahiko (Kondo Equipment Corporation, Japan)
14:45-14:55 Development of Nb3Sn SRF cavity using electroplating method – Takahashi Ryo (Akita Chemical Industry Co., Ltd, Japan)
15:00-15:30 Coffee Break

Sustainability Forum for Future Linear Colliders

The environmental credentials of future colliders are increasingly in the spotlight, because of their size and complexity, and will be under scrutiny for their impact on the climate. Therefore, sustainability has become a prioritized goal in the design, planning and implementation of future accelerators; approaches to improved sustainability range from overall system design, optimization of subsystems and key components, to operational concepts. A direct quantification of the ecological footprint, be it greenhouse gas emissions during construction and operation, or consumption of problematic materials, is currently performed only sporadically, mostly through translation of electricity consumption into equivalent CO2 emissions.

This forum will highlight studies to reduce power consumption of accelerator systems, to quantify the impact of future facilities in terms of CO_2 footprint, to address smart integration of future accelerator infrastructure with the surrounding site and society (e.g. Green ILC concept), and to discuss medical and environmental applications of accelerator technologies.

Date: 16 May 2023, 15:30 – 18:00 (PDT, US)

Indico link: https://indico.slac.stanford.edu/event/7467/sessions/443/#20230516

15:30-15:50 Sustainability Studies for ILC and CLIC – Benno List (DESY, Germany)
15:50-16:10 High Efficiency Klystrons project at CERN: Status and updates – Syratchev Igor (CERN)
16:10-16:30 Linear Collider Carbon Assessments: A Life Cycle Assessment of the CLIC and ILC Linear Collider Feasibility Studies - Evans Suzanne (ARUP Group)
16:30-16:50 Green ILC Concept – Yoshioka Masakazu (Iwate University/KEK, Japan)
16:50-17:10 Permanent magnet technology for sustainable accelerators – Shepherd Ben (STFC, UK)
17:10-17:25 IHEP high efficiency, high power klystron development - Zhou Zusheng (IHEP, China)
17:25-17:35 Basic research using synchrotron radiation and commercialization of waste heat recovery technology from ILC - Mitoya Goh (Higashi Nihon Kidenkaihatsu Co., Ltd., Japan)
17:35-17:45 Town planning in the vicinity of ILC candidate site as a regional company - Kondo Masahiko (Kondo Equipment Corporation, Japan)

Accelerator: Sustainability and Applications Session

Date: 18 May 2023, 10:30 – 12:00 & 13:30 - 14:30 (PDT, US)

Indico link: https://indico.slac.stanford.edu/event/7467/sessions/450/#20230518

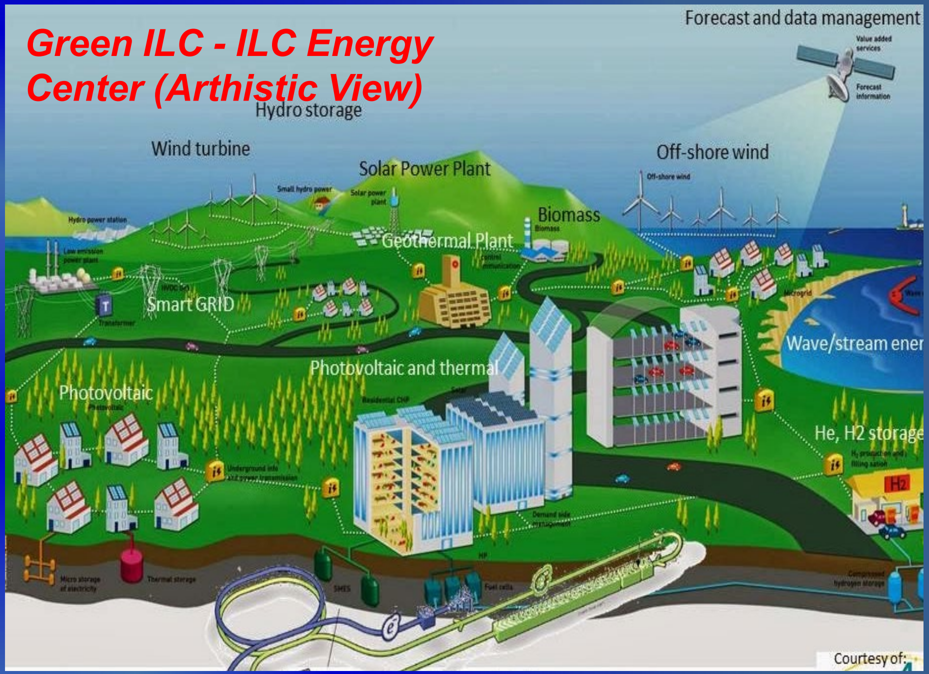
10:30-10:50 Sustainability Studies for the Cool Copper Collider- Bullard Brendon (SLAC)
10:50-11:10 Sustainability Considerations for Accelerator and Collider Facilities – Nappi Emilio (SLAC)
11:10-11:30 Strong-field QED Experiments for & at Linear Colliders – List Jenny (DESY)
11:30-11:50 High Temperature Superconducting RF cavity – Le Sage Gregory (SLAC)

13:30-13:50 Progress of High-Efficiency L-Band IOT Design for Accelerator Applications at SLAC - Othman Mohamed (SLAC)
13:50-14:10 High Efficiency, 1 MW, 1 MeV Accelerator for Environmental Applications – Shumail Muhammad (SLAC)
14:10-14:30 Applications of High Gradient Accelerator Research for Novel Medical Accelerator Technology - Snively Emma (SLAC)

EAJADE Workshop on Sustainability on Future Accelerators (WSFA2023)

MORIOKA, JAPAN, SEPTEMBER 25-27, 2023

Aiina Center, the same venue as LCWS2016, hosted by Iwate University



https://wsfa2023.huhep.org/ ; https://indico.desy.de/event/39980/

Four blocks (not limited to future Higgs Factores and to Linear Colliders):

- ***I. Large-Scale Research Facilities & Sustainability / Life Cycle Assessment(LCA)***
- ***II. Sustainable Accelerator Technologies***
- ***III. Europe-Horizon and National Sustainability-Supporting Programmes***
- ***IV. Green ILC and Local Industries***

Visit to Geothermal Power Plant in Hachimantai-city

- Novel (small) production plant (7.5 MW power generation capacity) → local electricity to power 15000 homes

3 production wells (300 C @ 2 km depth, 150C @ surface; 10% eff. depents on T, P)

Only 20 such plants are needed to power ILC

THANK YOU
to Organizers!

EU-EAJADE: Sustainability Communications

Communication @ IPAC2023 with S. Reichert, Editor at Nature Physics, responsible for accelerator physics content (May 2023)

CERN COURIER ARTICLE March/ April 2024:

Editorial *Nat. Phys.* 19, 761 (2023). https://doi.org/10.1038/s41567-023-02117-0

https://doi.org/10.1038/s41567-023-02117-0

Strive towards sustainability

Check for updates

Exacerbated by the impacts of climate change and the recent energy crisis, concentrated efforts towards more sustainable research have become matters of urgency, in particular for large-scale accelerator complexes and light sources.

Towards the end of 2022, several large-scale research infrastructures had to cut down operation time due to an increase in the cost of electricity. The Large Hadron Collider's yearly technical stop was moved up by two weeks, and the machine's operation was reduced by 20% for 2023[1]. The Elettra synchrotron in Trieste, Italy, and its free-electron laser FERMI had to halve user beam time in the first semester – a fate shared by many other light sources.

Immediate actions to alleviate the situation are limited, as long-term planning is required for large-scale facilities. Therefore, it's not surprising that sustainability – mainly in terms of reduced power consumption and carbon footprint – was an important topic at this year's International Particle Accelerator Conference.

One point towards making research facilities more sustainable is the move towards greener energy. In this regard, the SESAME light source in Allan, Jordan, is a trailblazer. The facility has its own solar power plant (pictured) and was the world's first large accelerator complex, whose power stems only from renewable energy sources. Others followed suit: the HZB in Berlin, Germany, that operates the BESSY II synchrotron secured their full electricity needs with renewable energy, saving up to 17,400 tonnes of CO_2 per year compared to 2018.

Another issue is increasing the energy efficiency of accelerator complexes. Improvements of the injectors of the Large Hadron Collider have greatly reduced the overall energy consumption; for example, a powering scheme introduced a few years ago reduced the Super Proton Synchrotron's energy consumption by 40 GWh per year. For comparison, the whole canton of Geneva consumes around 3,000 GWh per year. Similarly, by integrating the previously separate SPring-8 synchrotron with the SACLA X-ray free-electron laser in Sayo, Japan, the power consumption was reduced by five MW – roughly an electric locomotive's power output. But this is not the end of the road. With future upgrades, these and many other facilities aim to substantially reduce their energy consumption.

Apart from measures directed at improving the sustainability of the research infrastructure, such as water and waste management, a few main themes concerning accelerator technology have emerged. The actual particle acceleration occurs in superconducting radiofrequency cavities. For bulk niobium, this requires operation at 2 K and thus cooling with superfluid helium. Increasing the operation temperature to around 4.5 K would result in substantial energy savings. One direction that's being explored is superconducting thin films on bulk copper for radiofrequency cavities, which also have the potential to achieve higher accelerating gradients and thus to enable more compact machines.

The bending and focusing of the accelerated particle beams relies on different magnets. For the future BESSY III synchrotron, electromagnets are estimated to amount to an annual energy consumption exceeding 5 GWh, which could be reduced by 80% by installing permanent magnets as dipole and quadrupole magnets[2]. But this does not necessarily make them a more sustainable choice. Permanent magnets often involve rare-earth elements; their mining not only has a substantial carbon footprint but also impacts the people living on the land[3].

A clever way to make linear accelerators more sustainable is through energy recovery. The idea is rather simple: instead of dumping two accelerated particle beams after colliding them, why not recover the beam energy? The principle of an energy recovery linear accelerator was first demonstrated in 1987 – enabled by superconducting radiofrequency technology. A recent experiment at the S-DALINAC machine demonstrated saving up to 87% of the consumed beam power in its main linear accelerator[4].

In the design of large-scale facilities, performance is weighted against cost. Factoring in sustainability parameters, such as CO_2 emission from energy use or the embodied CO_2, increases the level of complexity and changes the optimization. For the proposed Compact Linear Collider and the International Linear Collider, a life cycle assessment estimated the environmental footprint. Such assessments provide the accelerator community with guidelines for the planning of more sustainable large-scale projects.

Apart from considering the impacts of accelerators on climate change and making the research infrastructures more sustainable, they can contribute to sustainability as well. For example, pollutants in wastewater can be reduced through irradiation with electron beams. By switching from normal conducting to superconducting radiofrequency technology, electron beam irradiation could become more cost efficient and competitive with other treatment methods[5].

Sustainability is an all-encompassing issue, from research facilities to the code used to analyse data[6]. And it's much broader than considering electrical power consumption and carbon footprints. Striving towards sustainability requires a holistic understanding of the multiple and connected impacts on the environment – including the people that live in it.

Published online: 13 June 2023

References

1. Owens, B. *Nature* **610**, 431–432 (2022).
2. Völker, J., Dürr, V., Goslawski, P., Jankowiak, A. & Titze, M. In *Proc. IPAC22* 2763–2766 (JACoW Publishing, 2022).
3. Owen, J. R. et al. *Nat. Sustain.* **6**, 203–211 (2023).
4. Schliessmann, F. et al. *Nat. Phys.* **19**, 597–602 (2023).
5. Li, X. et al. *Nucl. Instrum. Methods Phys. Res. A* **1039**, 167093 (2022).
6. Lannelongue, L., Grealey, J. & Inouye, M. *Adv. Sci.* **8**, 2100707 (2021).

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WORKSHOP ON SUSTAINABILITY FOR FUTURE ACCELERATORS

Accelerator sustainability in focus

The world is facing a crisis of anthropogenic climate change, driven by excessive CO_2 emissions during the past 150 years. In response, the United Nations has defined goals in a race towards zero net-carbon emission. One of these goals is to ensure that all projects due to be completed by 2030 or after have a net-zero carbon operation, with a reduction in embodied carbon by at least 40% compared to current practice. At the same time, the European Union (EU), Japan and other nations have decided to become carbon neutral by around 2050.

These boundary conditions put large-scale science projects under pressure to reduce CO_2 emissions during construction, operation and potentially decommissioning. For context: given the current Fren…

M Titov

In the field *The workshop offered the …*

… ways forward, a Workshop on Sustainability for Future Accelerators (WSFA2023) took place on 25–27 September in Morioka, Japan within the framework of the recently started EU project EAJADE (Europe–America–Japan Accelerator Development and Exchange). Around 50 international experts discussed a slew of topics ranging from life-cycle assessments (LCAs) of accelerator technologies with carbon-reduction potential to funding initiatives towards sustainable accelerator R&D, and local initiatives aimed at the "green" realisation of future colliders. With the workshop being held in Japan, the proposed International Linear Collider (ILC) figured prominently as a reference project – attracting considerable attention from local media.

The general context of discussions was set by Beate Heinemann, DESY director for particle physics, on behalf of the European Laboratory Directors G…

… take on sustainability and steps towards performing LCAs. Starting with the much-cited ARUP study on linear colliders published in 2023 (edms.cern.ch/document/2917948/1), there were presentations on the ESS in Sweden, the ISIS-II neutron and muon source in the UK, the CERN sustainability forum, the Future Circular Collider, the Cool Copper Collider and other proposed colliders. Also discussed were R&D items for sustainable technologies, including CERN's High Efficiency Klystron Project, the ZEPTO permanent-magnet project, thin film-coated SRF cavities and others.

A second big block in the workshop agenda was devoted to the "greening" of future accelerators and potential local and general construction measures towards achieving this goal. The focus was on Japanese efforts around the ILC, but numerous results can be re-interpreted in a more general way. Presentations were given on the potential of concrete to turn from a massive carbon source into a carbon sink with net negative CO_2e balance (a topic with huge industrial interest), on large-scale wooden construction (e.g. for experimental halls), and on the ILC connection with the agriculture, forestry and fisheries industries to reduce CO_2 emissions and offset them by increasing CO_2 absorption. The focus was on building an energy recycling society by the ti… ILC woul…

… second, we as a community must consider the imprint our research leaves on the globe, along with as many indicators as possible. The GWP can be a beginning, but there are many other factors relating, for example, to rare-earth elements, toxicity and acidity. The LCA methodology provides the accelerator community with guidelines for the planning of more sustainable large-scale projects and needs to be further developed – including end-of-life, decommissioning and recycling steps – in an appropriate manner. Last but not least, it is clear that we need to be proactive in anticipating the changes happening in the energy markets and society with respect to sustainability-driven challenges at all levels.

Thomas Schörner *DESY*, **Steinar Stapnes** *CERN and* **Maxim Titov** *CEA Saclay.*

WSFA2023 covered wide range of topics:
from life cycle assessments (LCAs) over individual accelerator technologies with a carbon reduction potential, to funding initiatives towards sustainable accelerator R&D, and to local initiatives aimed at the "green" realisation of future colliders

EU: Europe-Horizon Sustainability-Supporting Programs

- ✓ *Innovation Fostering in Accelerator Science and Technology (I.FAST): https://ifast-project.eu*
- ✓ *Europe-America-Japan Accelerator Development Exchange Programme (EAJADE): https://www.eajade.eu/*
- ✓ *Innovate for Sustainable Accelerating Systems (iSAS): https://indico.ijclab.in2p3.fr/event/9521/*

Common iFAST / EAJADE Workshop on Sustainability
DESY Hamburg, Jan. 15-17, 2025 (tbc)

https://indico.cern.ch/event/1326603/timetable/#20240215.detailed

WP11 Overview

task 1: Sustainable Concepts for RIs: networking, workshops on selected topics
deliverable: report
1) System Efficiency of Accelerator Concepts (N.Catalan Lasheras, CERN)
2) Key Technologies and Components for High Efficiency (A.Sunesson [C.Martins], ESS)
3) Cross Linking Accelerator R&D with Industrial Approaches (P.Spiller, GSI)
4) Ecological Concepts (D. Voelker, DESY)

task 2: High Efficiency Klystron (O.Brunner CERN, THALES, ULANC)
- deliverable: industrial prototype
- replacing klystrons in LHC

... **Sources** (B.Shepherd, UKRI, DLS,
... for Diamond upgrade
... of permanent magnets, not just power consumption

iSAS Objectives – Techn...

- **TA#1: energy-savings from RF power** – *While great strides are being made in the energy efficiency of various RF power generators, the objective of iSAS is to ensure additional impactful energy savings through coherent integration of the RF power source with smart digital control systems and with novel tuners that compensate rapidly cavity detuning from mechanical vibrations, resulting in a further reduction of power demands by up to a factor of 3.*
- **TA#2: energy-savings from cryogenics** – *While major progress is being made in reusing the heat produced in cryogenics systems, the objective of iSAS is to develop superconducting cavities that operate with high performance at 4.2 K (i.e., up to 4.5 K depending on the cryogenic overpressure) instead of 2 K, thereby reducing the grid-power to operate the cryogenic system by a factor of 3 and requiring less capital investment to build the cryogenic plant.*
- **TA#3: energy-savings from the beam** – *Significant progress has been achieved in maintaining the brightness of recirculating beams to provide high-intensity collisions to experiments, but most of the particles lose their power through radiation or in the beam dump system. The objective of iSAS is to develop dedicated power couplers for damping the so-called Higher-Order Modes (HOMs) excited by the passage of high-current beams in the superconducting cavities, enabling efficient recovery of the energy of recirculating beams back into the cavities before it is dumped, resulting in energy reduction for operating, high-energy, high-intensity accelerators by a factor ten.*

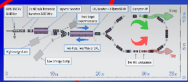
https://indico.cern.ch/event/1326603/timetable/#20240215.detailed

EAJADE WP4: Sustainable Technologies for Scientific Facilities

WP4

Task 4.1: High Efficiency & Sustainable SC cavities

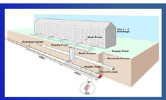
Task 4.2: High efficiency RF power amplifiers



Task 4.3: Energy Recovery Linacs

Task 4.4: Power Modulation

Task 4.5: Smart Tunneling



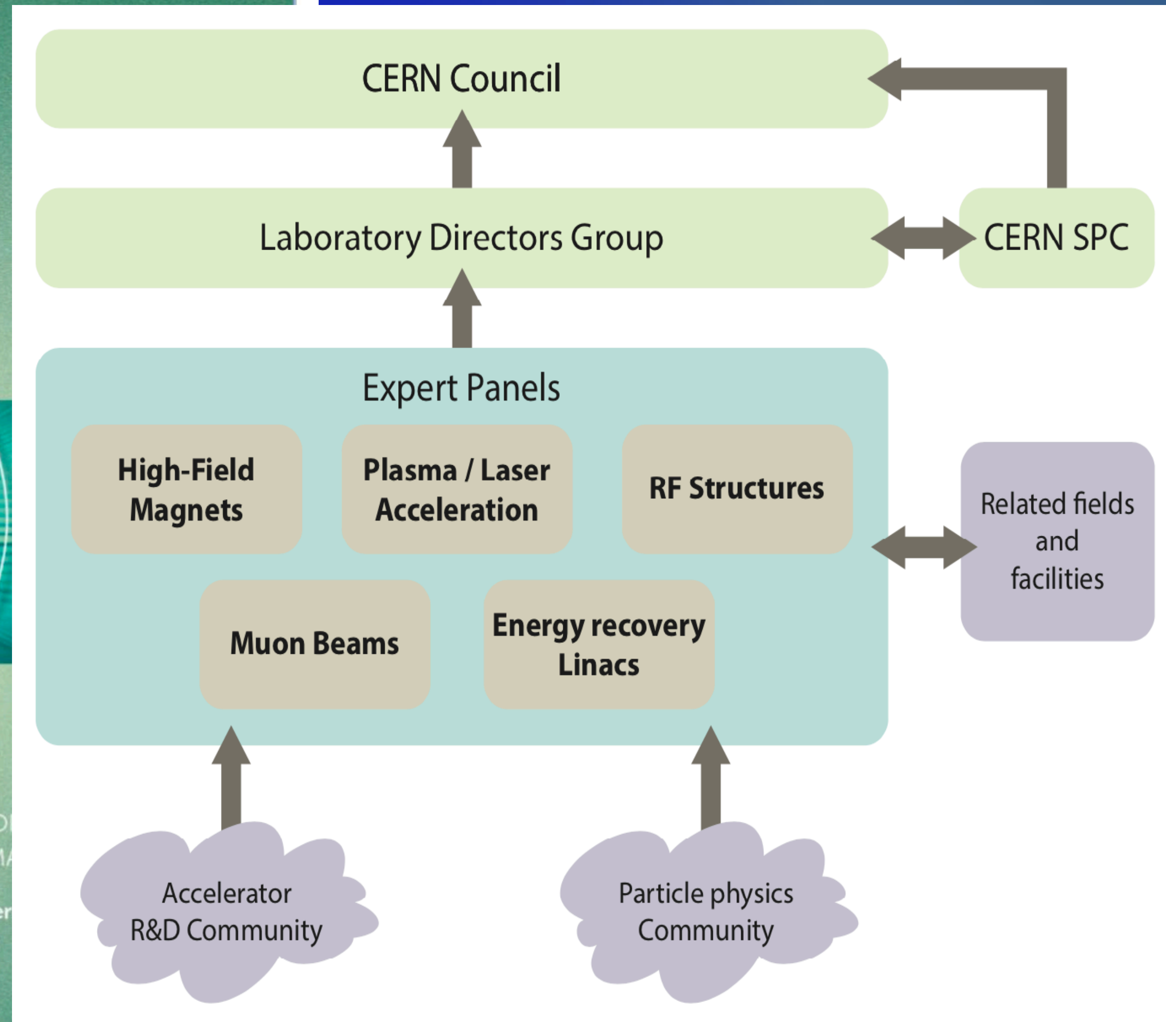
Task 4.6: "Green ILC"

Work package 4	Sustainability		Start/end month	1/48
Work package title	Sustainable technologies for scientific facilities			
Lead beneficiary	CEA			

Participating organisation short name**	CEA	CERN	DESY	CNRS	INFN		
Total person-months per participating organisation:	4	2	2	2	2		

Objectives:
- Advance technology of critical accelerator components towards more sustainability in terms of energy efficiency during manufacturing and operation and in terms of resource conservation by avoidance of harmful, toxic or otherwise unsustainable raw materials or production methods.
- Advance overall design of accelerator facilities towards better sustainability by use of sustainable energy sources, adaption of power consumption to energy availability, evaluation of energy storage potentials, re-use of waste heat, reduction or re-use of waste materials during construction and operation.
- Investigate civil engineering solutions to sustainability issues of accelerator facilities, in particular concerning construction and operation of extensive tunnels and underground caverns, and management of electricity, water, heat.
- Foster an integrated approach to sustainability by bringing together experts from engineering disciplines (mechanical, electrical, civil engineering), physicists, social and economic sciences to develop concepts for sustainable accelerators.

https://cds.cern.ch/record/2800190/files/146-138-PB.pdf



Sustainability Working Group (added to 5 LDG Expert Panels) since January 2024

Mandate / Charge of Sustainability LDG Working Group

Charge for a Working Group on "Sustainability Assessment of Accelerators" for the next European Particle Physics Strategy Update (EPPSU)

J. Clarke, B. Heinemann, M. Seidel, June 23rd 2023

Sustainability is increasingly in the focus of public discourse. Accelerator facilities, in particular for High Energy Physics, are among the largest scientific endeavors in terms of construction and energy consumption, with lifetimes spanning decades. For this reason, and as a community representing forefront research, we have a special obligation to assess and optimize sustainability. Several next generation facilities were proposed at the last EPPSU and are expected to be proposed for the next update (likely in 2026/2027).
Recently, proponents of projects have started to report on and compare projects on the basis of Green House Gas (GHG) emissions, predominantly from electric power consumption during operation, with first efforts to quantify also embodied GHG from construction. The quoted numbers differ in terms of parameters used for comparison, methodology, considered scope, and assumptions about current and future CO2 intensity e.g. of electrical power, making it difficult to compare projects impartially in terms of their sustainability. Energy consumption and construction result in GHG emissions, or rather Global Warming Potential (GWP). Other indicators such as water consumption, Helium consumption, Ozone depletion, ecotoxitity etc., habitually used in Lifecycle Assessments (LCA), may present important aspects for the environmental sustainability of specific proposals, and these should be assessed at least qualitatively.

This working group is asked to 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:

- Define key indicators to be reported, such as peak (or instantaneous?), lifetime- and performance specific (per luminosity) energy consumption, lifetime- and specific GWP including the contribution of construction. These figures should be supplemented by margins of uncertainty and possibly an assessment of the potential for improvement.
- Define the methodology and assumptions to be applied, to allow a transparent determination and comparison of these key figures across the proposals. The maturity of a proposal should be determined, for example early concept phase, CDR, TDR or TRL levels.
- Identify other high level environmental impacts that may be relevant for all or specific collider proposals.

In general, best practices determining the GWP for large projects in Europe should be followed.

The working group may comment on other aspects if deemed appropriate, for example:

- Treatment of future carbon intensity of electricity and materials: what scenarios should be assumed?
- Assessing the potential for dynamic operation of the various facilities, i.e. the ability to adapt to a fluctuating energy supply in a grid fed by renewable energy sources. This may include standby mode power consumption, recovery time to full luminosity and fraction of integrated luminosity preserved in a dynamic operation scenario.
- Treatment of regional vs global parameters: How to treat differences e.g. in carbon intensity between different host countries? (Should one compare technical merit of projects by using globally averaged carbon intensities, or site dependency by using local carbon intensity?)
- Carbon intensity / lifecycle inventory (LCI) studies of materials specific to accelerator projects: high-purity niobium, permanent magnet alloys etc.

✓ ***Definition of key indicators* to be reported**

Possible examples:

- Peak / instantaneous lifetime- & specific (per luminosity) energy consumption
- Lifetime and specific Global Warming Potential (GWP), including construction
- Include margins of uncertainty and possibly an assessment of the potential for improvement

✓ ***Definition of methodology* & assumptions to be applied for transparent determination of key figures across proposals**

- The maturity of a proposal should be determined, for example, at early concept phase, CDR, TDR levels

✓ ***Identification* of additional *high level environmental impacts* that may be relevant for all or specific collider proposals**

✓ ***Also, VERY IMPORTANT - impact on society and public appreciation of the WG report: HEP benefits and decarbonization path for the future large – scale accelerator RI's***

Some Other (More Technical) Objectives

LDG WG may comment on other aspects if deemed appropriate, for example:

- Treatment of future carbon intensity of electricity and materials:
  - what scenarios should be assumed?
- Assessing the potential for dynamic operation of the various facilities:
  - i.e. the ability to adapt to a fluctuating energy supply in a grid fed by renewables. This may include standby mode power consumption, recovery time to full luminosity and fraction of integrated luminosity per year preserved in a dynamic operation scenario.
- Treatment of regional vs global parameters:
  - how to treat differences e.g. in carbon intensity between different host countries?
- Carbon intensity / lifecycle inventory (LCI) studies of materials specific to the accelerator projects: high-purity niobium, permanent magnet alloys etc.
- How to interface with open-source LCI databases and LCA tools to potentially ease/automate the assessment for future research infrastructures
- How the recommendations for colliders can be extended to other scientific /endeavours related to HEP
- How HEP labs represented in the LDG can share/build up expertise jointly

WG Composition (Endorsed by LDG in Mar. 2024)

Panel consisting of 15 members with technical expertize in evaluation of accelerator sustainability and future collider project representatives

Ensuring broad community representation:

- *Sustainability Lab. Panels established at CERN, DESY, ESS, NIKHEF, STFC*
- *ICFA Sustainability Panel*
- *EU- Horizon Programs*
- *Future accelerator projects: FCC, ILC, CePC, CLIC/Muon, LHeC, C3*
- *Invited experts on specific topics*

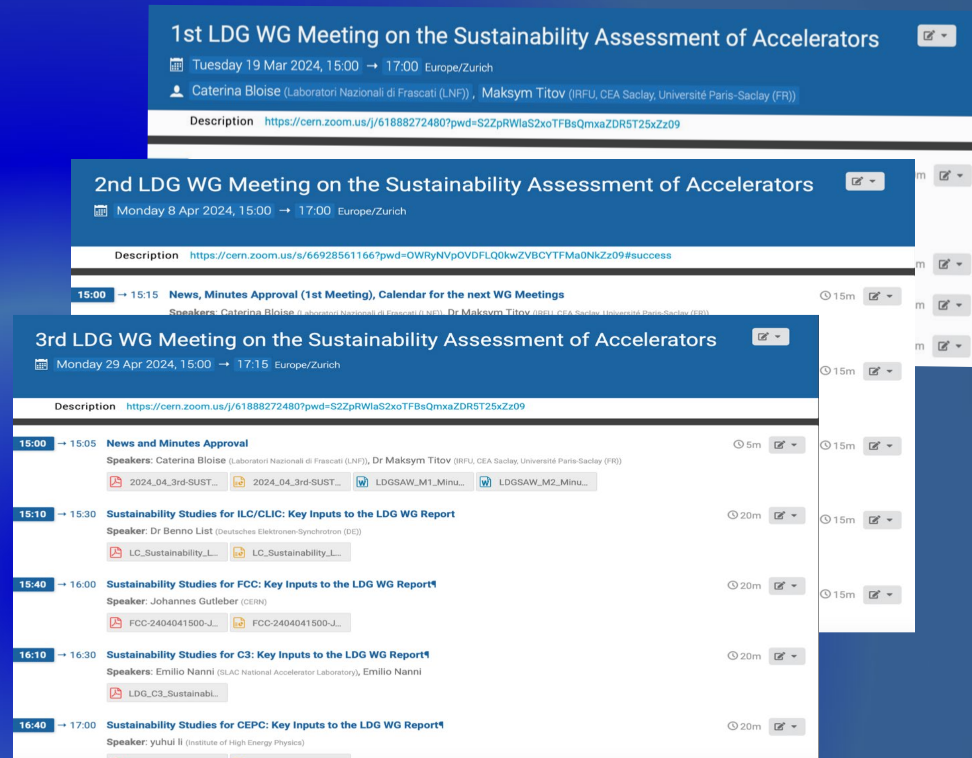
- Walib Kaabi - PERLE, EU-iSAS
- Mats Lindroos - ESS (deceased May 2, 2024)
- Roberto Losito - CERN Sust. Panel
- Ben Shepherd - STFC Sust. Task Force
- Andrea Klumpp - DESY Sust. Panel, EU-iFAST
- Hannah Wakeling - ISIS-II Neutron & Muon Source
- Patrick Koppenburg - NIKHEF Sust. Panel
- Johannes Gutleber - FCC
- Yuhui Li - CePC
- Benno List - ILC
- Emilio Nanni - ICFA Sust. Panel & C3
- Vladimir Shiltsev - LHeC
- Steinar Stapnes - CLIC & Muon collider
- Caterina Bloise - Co-Chair
- Maxim Titov - Co-Chair, EU-EAJADE

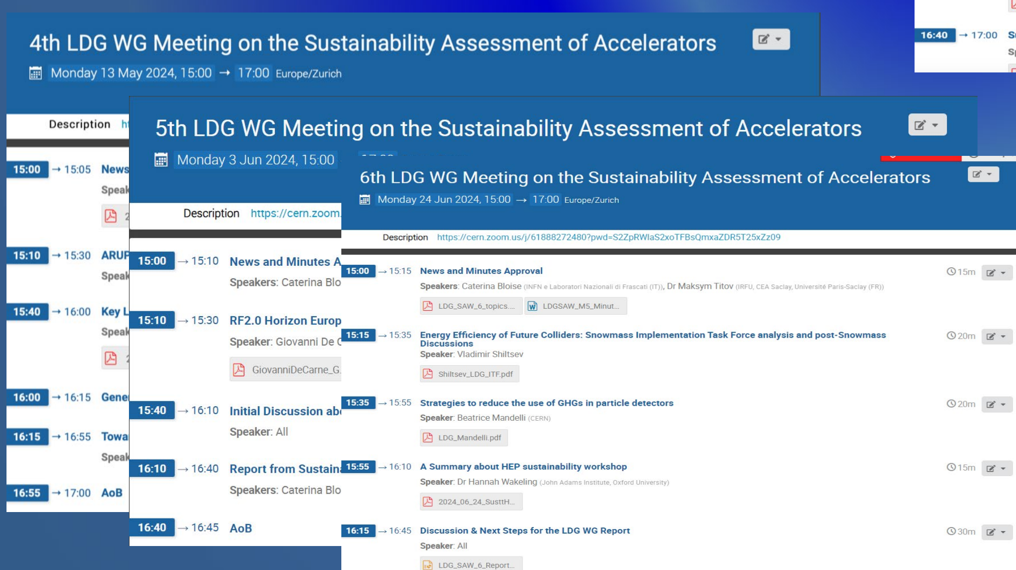
LEARN, SHARE and BUILD-UP expertise with other HEP sustainability initiatives

LDG Working Group Activities (6 Meetings So Far)

Broad range of topics shared:

- *Reports from the CERN and STFC Sustainability ESS, Snowmass ITF*
- *Evaluations carried out for Future Higgs Factories* (FCC, ILC, C3, CEPC)
- *On key LCA issues*
- *Invited contributions on Decarbonisation for Large RI, H.Pantelidou (ARUP), EU-Horizon Project RF2.0, G. DeCarne*
- *(KIT), Reduction of GHGs in particle detectors, B. Mandelli CERN)*





Elaboration of WG report started

✓ *Structure and basic content suggested by reports to the WG and follow-up discussions*

✓ *Draft report is expected by end of 2024*

✓ *Report as an input document to the ESPPU due by March 2025*

WG REPORT DRAFT: TOPICS and CONTENT (Preliminary)

Overleaf area for the WG report has been created

WG mandate :
Development of guidelines and a minimum set of key indicators pertaining to methodology and scope of reports on sustainability in future HEP projects

In what follows, the detailed outline and potential topics are presented:

- *not all of them can be addressed in a limited time by end of 2024*
- ***A homogeneous evaluations of all issues will probably need more time to develop and deserves a strategy to be pursued***

WG REPORT DRAFT: TOPICS and CONTENT (Preliminary)

- Foreword

- Executive Summary (for wide public) and Main Recommendations

- *Social – Economical Benefits of Particle Physics* in Relation to the UN Sustainability Development Goals (environment, economy, society):
  - Fundamental Physics Knowledge
  - Accelerator and Detector R&D (context of strategic ECFA R&D Roadmaps)
  - Education, Innovation, International Cooperation, Cultural Exchange

- Setting the *basis for sustainability of the long-term accelerator infrastructures:*
  - Best practices determining GWP for large-scale infrastructures
  - EU Policies (e.g. PNIEC, …)

- *Life-Cycle Assessment* for Future Accelerators *– Methodology and Reporting:*
  - Scope and boundary: LCA for future facilities is “a MUST”
  - Overview with unified table for accelerator sustainability parameters, esp. GWP?
  - Common approach to report and evaluate the data, assessment methodologies:
    - impact categories
    - sensitivity of the footprint to the evaluation method and related uncertainties

WG REPORT DRAFT: TOPICS and CONTENT (Preliminary)

- *Green House Gas Emissions footprint for future accelerator facilities:*

  Developing a tool and guidance for quantification could be a good recommendation for the strategy: e.g. evaluate and optimize CO2 impact in a *staged approach* at early concept phase, CDR and at TDR level over the full lifecycle

  - *civil construction:* LCA studies for accelerator infrastructure (e.g. tunnels, caverns) and Civil engineering (LCA A1-A5)
  - *accelerator construction:* carbon intensity / lifecycle inventory studies for some major accelerator components (e.g. RF and magnets); develop reference set of impact values for some commonly used accelerator materials (high-purity niobium, permanent magnet alloys etc.)
  - *accelerator operation:* Treatment of carbon intensity of electricity related to energy source - depending on future energy mixes and regions:
    - which scenarios should be assumed?
    - how to treat differences e.g. in carbon intensity between different host countries (regional vs globally averaged impacts)
    - the cost of carbon, shadow costs scenarios and associated uncertainties
  - *particle detectors:* construction, impact of detector gases, computational footprint
  - *decommissioning:* recycling and disposal of used components, site reuse; develop criteria to estimate impacts (?)

WG REPORT DRAFT: TOPICS and CONTENT (Preliminary)

- *Mitigation and Compensation Strategies, Decarbonisation and Impact Reductions:*
  - optimization of large civil & accelerator construction footprint & better/greener materials (inventory of concrete, steel, Cu, niobium)
  - responsible procurement
  - align to future energy markets & electricity provisioning

  - energy and power optimization (improving the key technologies energy efficiency and overall design) and recuperation (ERL, waste heat management, …)
  - invest in *R&D on green technologies*

  - *sustainable operational concepts:* potential for dynamic operation of the various facilities; power purchase agreements & renewable energy sources
  - *"nature-based" interventions* for carbon removal (e.g. environmental studies)
  - integration in local environment / power grids

- *Recommendations for Future Work / Optimization:*
  - additional high-level environmental impacts (e.g. rare earth, …)
  - attribution of long-lived infrastructures to projects
  - where can large accelerator labs develop new common approaches

- Summary of Evaluations

Annexes – Decarbonization Scenarios, Legislations, Standards, etc …

Life-Cycle Assessment: Targets and Issues

B. List,
H. Wakeling

optimize facility (internal); recommend improvements (Lab/FA); communicate to public (society)

LCA standards for the **assessment of future accelerator** infrastructures **are not set:**

- Common approach how to report and evaluate the data for accelerator RI's (which impact categories, treatment of CO2 intensities, attribution of impacts to long term projects);
- Common table for sustainability parameters, esp. GWP;
- ISO standards may be too rigid for accelerators to perform full LCA → "simplified LCA";
- Many LCA software available → different packages can give different results (data handling)
- LCA database is the most impactful element (global vs. local, age of database, accelerators use non-standard materials, often not available);
- Are there relevant differences in Standards / Methods (e.g. Midpoint ReCiPe 2016 (ILC) vs Endpoint EN 17472 (FCC)) that need to be addressed?

Ultimate Goal:
Collect and provide data in tabular form, provided and endorsed by the projects, for a figure as shown below

(E.g. metric to compare the carbon costs of Higgs factories, balancing physics reach, energy needs, and carbon footprint for both construction and operation)

E. Nanni, M. Breidenbach et al., PRX Energy 2, 047001

PRX ENERGY **2,** 047001 (2023)

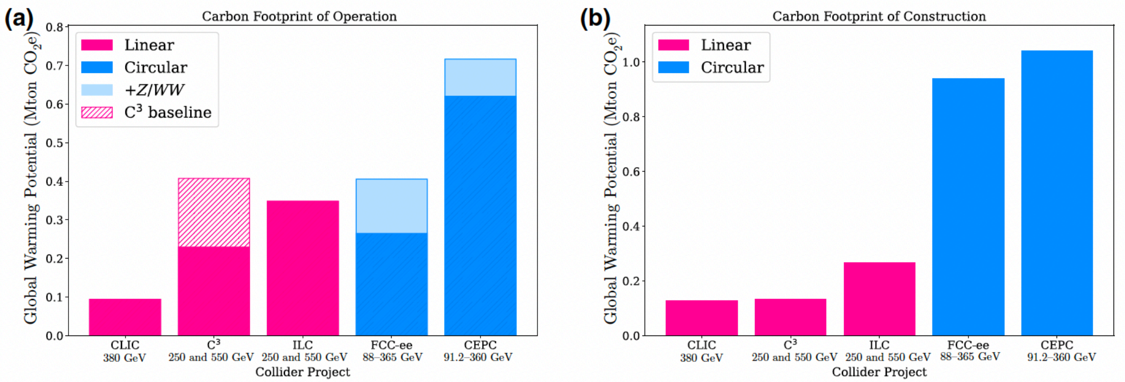


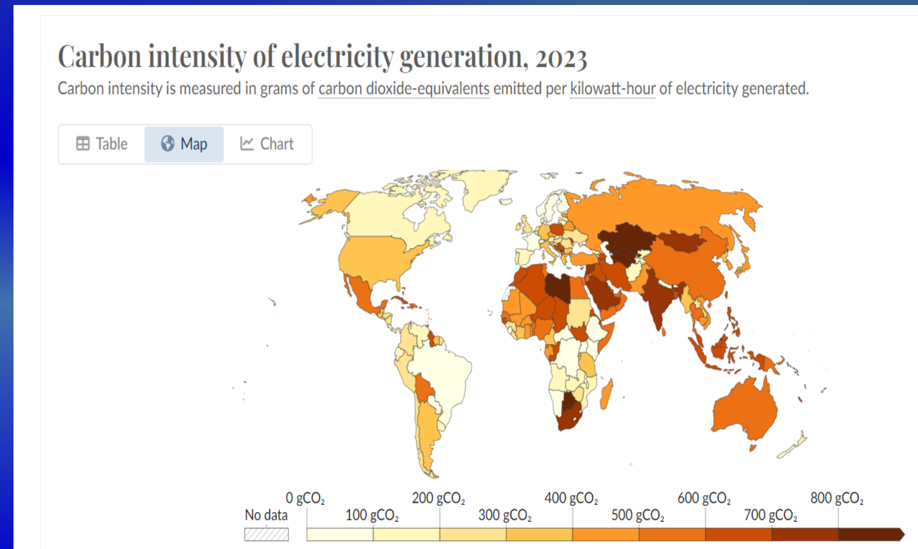
FIG. 5. Global warming potential from (a) operation and (b) construction of all collider concepts. The hashed pink component represents the additional costs of operating C^3 without power optimization, while light blue regions account for additional run modes targeting *Z* and *WW* production.

Open Questions: Regional versus Globally Averaged Impacts

- Carbon intensity of electricity production varies enormously across regions &countries
  → reference values for assumed CO2 intensity of electricity for relevant regions/labs
- Carbon intensity of materials also varies
  - Different local standards
  - Different geology, primary minerals, concentrations
  - Different carbon intensity for local energy, esp. electricity (-> copper, niobium)
- Civil construction: steel and cement mostly from local sources, adhere to local codes
- Result of LCA depends heavily on
  - Source of used materials
  - Construction and operation site
  - LCA Method: use local values or global averages

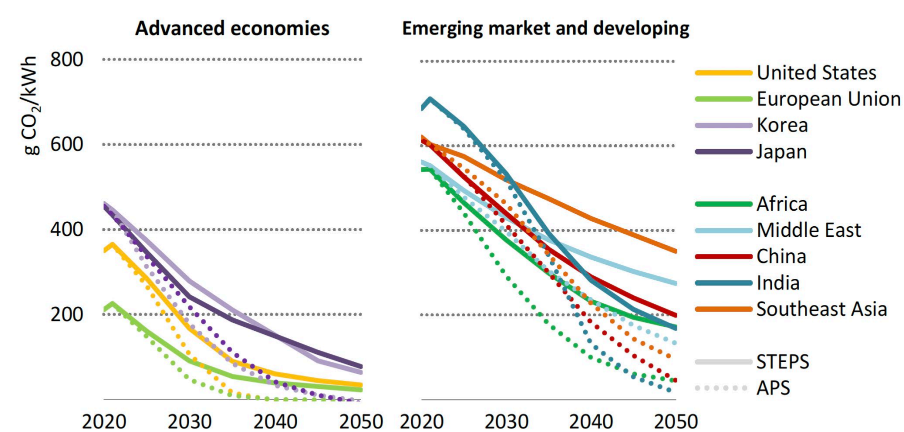
B. List

*Should one evaluate impacts using **site-specific or globally averaged impact** values?*
→ or use general LCA database and move to more local information as the project matures (for materials CO2 content) ?



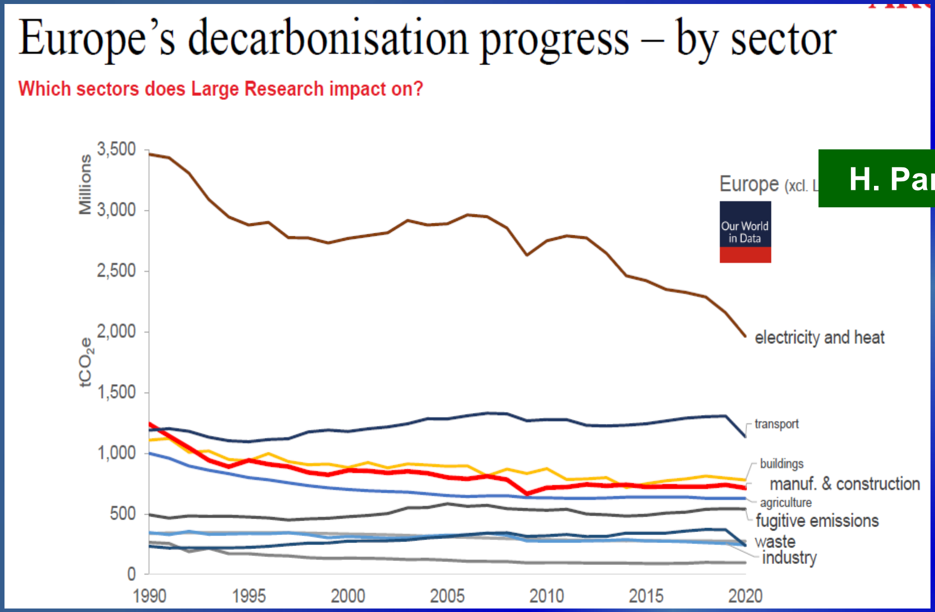
https://ourworldindata.org/grapher/carbon-intensity-electricity

Figure 6.14 ▷ Average CO_2 intensity of electricity generation for selected regions by scenario, 2020-2050

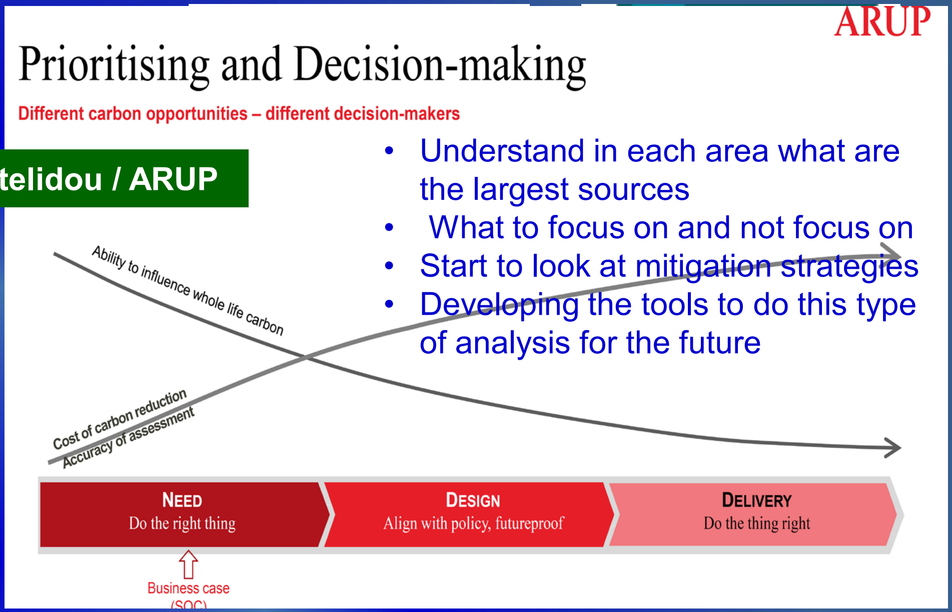


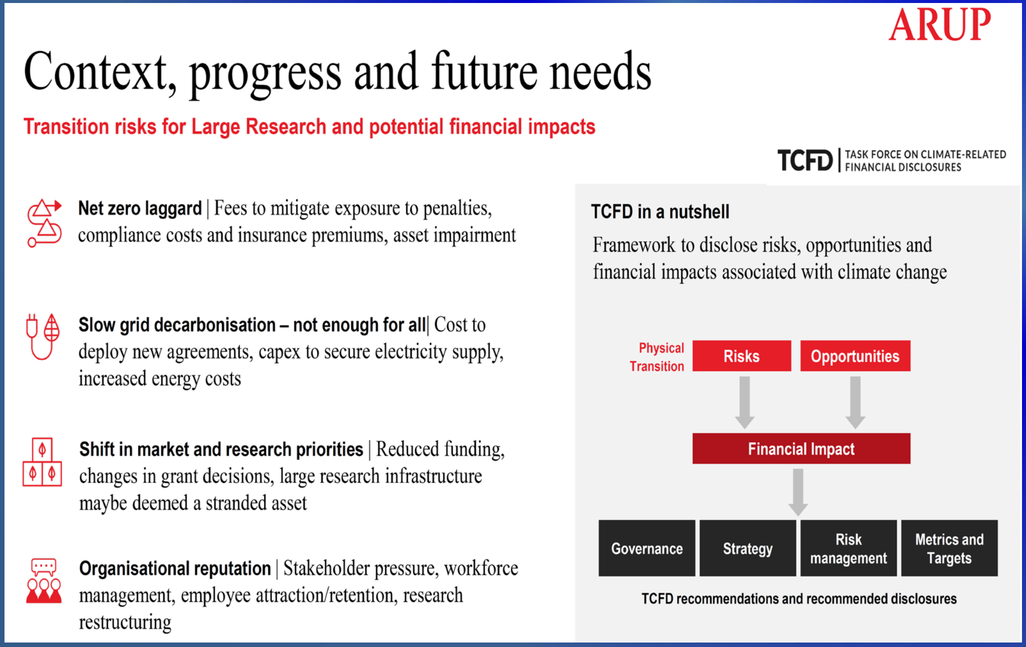
IEA (2022), World Energy Outlook 2022, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2022,

Decarbonisation and Large Research Infrastructures



H. Pantelidou / ARUP

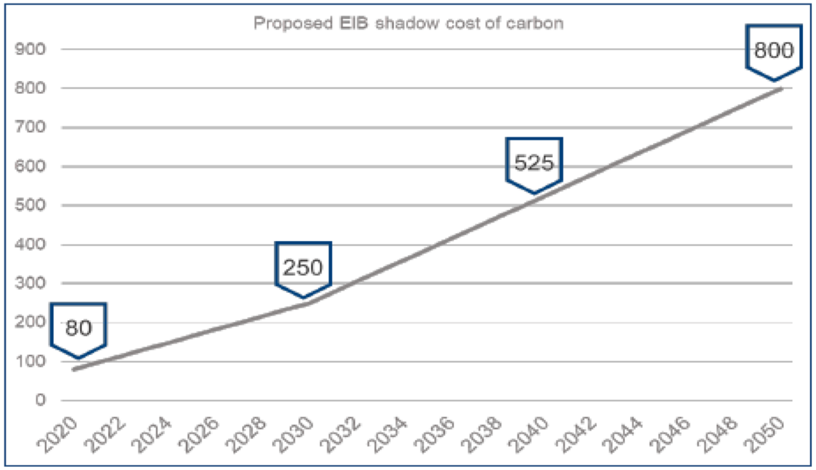




- Funding and financing landscapes are changing rapidly in Europe and beyond, which will *require addressing carbon explicitly* in the business case *for large research infrastructure*
- *Mitigation of the transition risks for RI's: this can lead to increase of costs, reduced funding – maybe* one of the future discussion topics within the WG – *start developing thinking …*

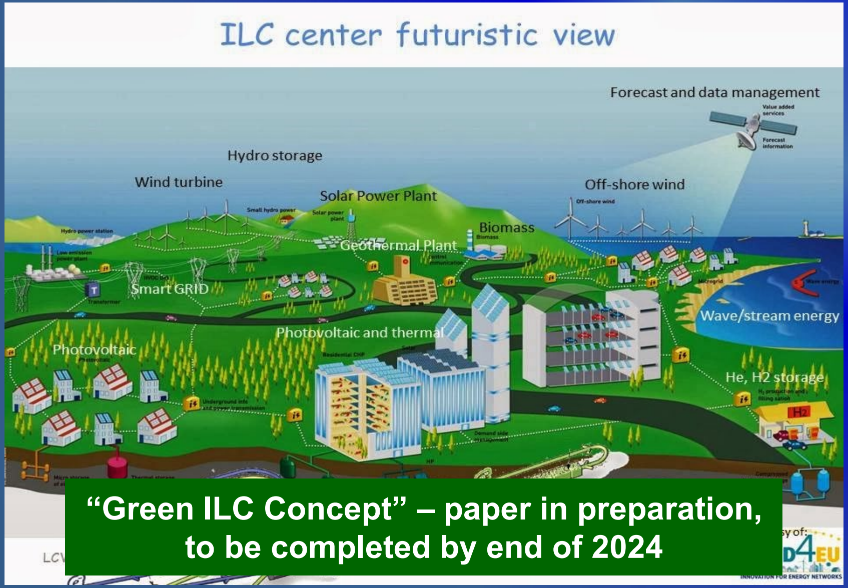
Decarbonisation: Prioritising Nature-Based Interventions

Construction of accelerator large-scale RI's has to face decarbonisation path, with the associated increase of the shadow Carbon cost over the years



https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf

- Identifying relevant initiatives to complement decarbonisation efforts:
  - *prioritising nature-based interventions within and around RI's,* integration in local environment as part of the asset management (e.g. CERN generally, Green ILC concept)
  - potential to contribute towards carbon removal through environmental enhancement



"Green ILC Concept" – paper in preparation, to be completed by end of 2024

Figure 7: A single 25 MWh energy storage unit (white containers) built from used electric car batteries, deployed for a PV energy plant in Lancaster, CA (south of Los Angeles, US) put in operate by B2U Storage Solutions in early 2023. Capacities of new systems are increasing fast. A 260 MWh[25] is by now being commissioned and today's largest systems in the range of 1 400 MWh are being extended to 3 000 MWh[26].

J. Gutleber, FCC Renewable Energy Supply Fasibility Study, https://zenodo.org/records/10023947

LCWS2024 @Tokyo: International Workshop on Future Linear Colliders (July 9, 2024)

INDUSTRY PLENARY:

13:00:00	0:20:00	Introduction and LDG working group on sustainability	Maxim Titov	CEA Saclay
13:20:00	0:15:00	AAA activities in Japan	Osamu Jinnouchi	Tokyo Institute of Technology
13:35:00	0:15:00	ILC Vanguard Initiative	Tohru Takahashi	Hiroshima University
13:50:00	0:15:00	ILC Site-Specific Activities by Tohoku ILC Project Development Center	Atsuto Suzuki	Iwate Prefectural University
14:05:00	0:15:00	Introduction of CEPC Industry Promotion Consortium (CIPC)	Jinlin GAO(FullCryo)	Fullcryo
14:20:00	0:15:00	Industrial Efforts for X-Band Accelerator Structure Fabrication (Europe)	Pedro Sanchez Morales	CERN
14:35:00	0:15:00	Inovative Public Procurement	Maite del Corte Sanz	CDTI
14:50:00	0:15:00	Spanish Science Industry update	Erik Fernandez	INEUSTAR
15:05:00	0:10:00	Significance of participating in ILC-related R&D as a regional company located near an ILC candidate site	Shinichi Takizawa	Kondo equipment

SUSTAINABILITY PLENARY:

15:45:00	0:15:00	Efforts toward a Green ILC in Japan	Masakazu Yoshioka	Iwate University
16:00:00	0:15:00	CEPC Green Accelerator Technology Development	Rui GE	IHEP, CAS
16:15:00	0:15:00	A Sustainability Strategy for the Cool Copper Collider	Brendon Bullard	SLAC
16:30:00	0:15:00	Sustainability Efforts for Present and Future Accelerator Facilities	Emilio Nanni	SLAC
16:45:00	0:15:00	Whole Life Cycle Assessment approach for linear colliders	Suzanne Evans	ARUP
17:00:00	0:15:00	Lifecycle Inventory input to an LCA for ILC and CLIC	Steffen Doebert	CERN
17:15:00	0:10:00	Need of the hour: Carbon Utilized Concrete (CUCO)	Kumar Avadh	Kajima Co.
17:25:00	0:10:00	Challenges and breakthroughs in recent RF Solid State PA design by Radial Combiner design with Initiatives for SDGs	Riichiro Kobana (R&K Company LTD)	R&K Company LTD
17:35:00	0:10:00	Commercialization and fundamental research of waste heat recovery technology using adsorption heat storage materials	Yuichi Kouno(Higashi Nihon Kiden Kaihatsu)	Higashi Nihon Kiden Kaihatsu