EAJADE
WSFA
2023

Summary of the WSFA2023 "EAJADE Workshop on the Sustainability of Future Accelerators"

Karsten Büßer, Thomas Schörner
EAJADE MDI/CFS Workshop
KEK, 29 September 2023

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

EAJADE Europe-America-Japan Accelerator Development Exchange Programme

DESY.

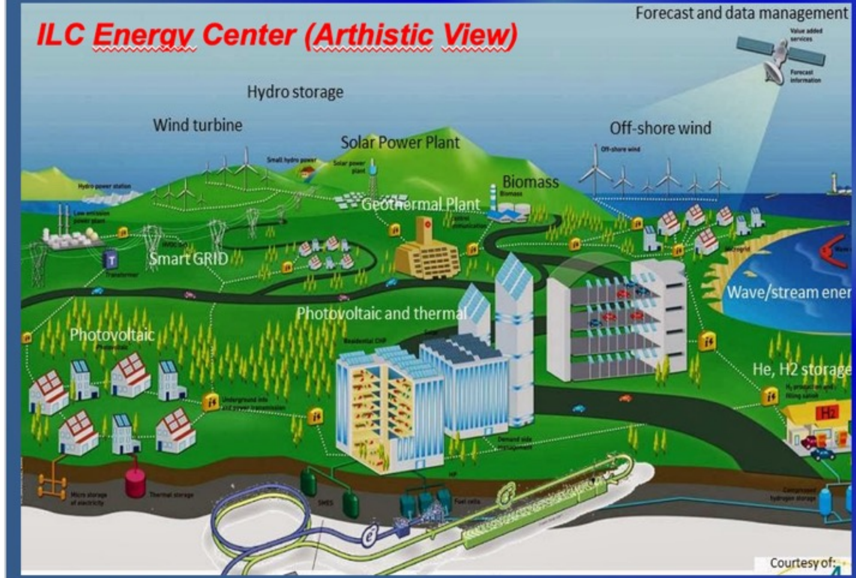
2014 → 2023

E-JADE
Europe -Japan Accelerator Development Exchange Programme

EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

Introduction to EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023) & EAJADE Work Package 4

Benno List (DESY)
Steinar Stapnes (CERN)
Maxim Titov (CEA Saclay/CERN)



International Workshop
Sustainability in Future Accel
Morioka, Japan, Sep. 25 - 27

Local Organizing Committee:

Satomi Fujisaki (Iwate University, Japan)
Kiyotomo Kawagoe (Kyushu University, Japan)
Masao Kuriki (Hiroshima University, Japan)
Shinya Narita (Iwate University, Japan) – Chair
Aiko Shoji (Iwate University, Japan)
Tohru Takahashi (Hiroshima University, Japan)
Tohru Takeshita (Shinshu University, Japan)
Satoru Yamashita (Iwate Prefectural Univ., Japan

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

International Program Committee:

Phil Burrows (University of Oxford, UK)
Benno List (DESY Hamburg, Germany)
Shin Michizono (KEK, Japan)
Takayuki Saeki (KEK, Japan)
Tomoyuki Sanuki (Tohoku University, Japan)
Steinar Stapnes (CERN, Switzerland)
Thomas Schoerner (DESY Hamburg, Germany)
Nobuhiro Terunuma (KEK, Japan)
Maxim Titov (CEA Saclay / IRFU, France)
Marc Winter (IJCLab, France)
Masakazu Yoshioka (Iwate University, Japan)

Outline of the Workshop

Four blocks (presented here in different order than in workshop)

- Large-scale research facilities and sustainability / life cycle assessments (LCA)
- Sustainable accelerator technologies
- Horizon-Europe and national sustainability-supporting programmes
- 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

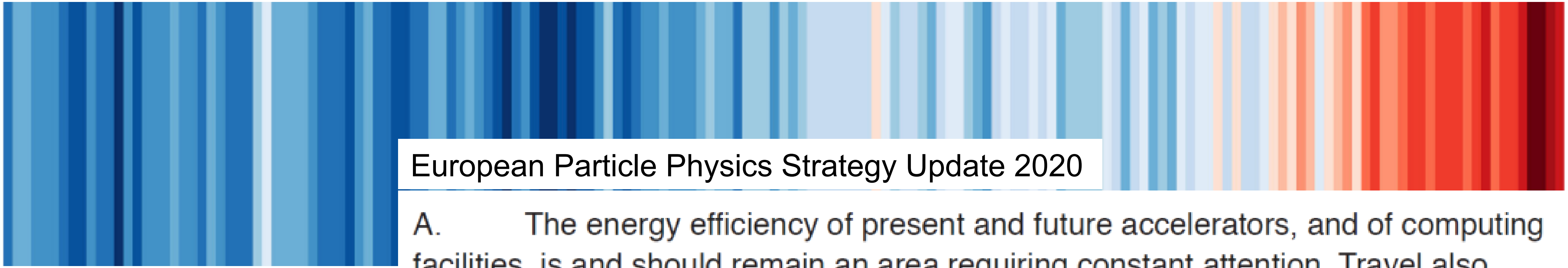
THANK YOU
to Organizers!

Large-Scale Infrastructures
Construction, Operation, Lifecycle Assessment

- Objective Assessment of Sustainability Aspects of New Large Infrastructures: B. Heinemann

- Experience from ESS on Green Facilities: A. Sunesson
- PETRA IV and Sustainability: A. Klumpp (cancelled)
- A Life Cycle Assessment of the CLIC and ILC Linear Collider Feasibility Studies: S. Evans
- The ISIS-II Neutron And Muon Source Life Cycle Assessment: An Introduction: H. Wakeling
- The HElmholtz LInear ACcelerator HELIAC : W. Barth
- CERN Accelerates Sustainability: R. Losito
- Optimisation of the FCC Power Consumption and Next Steps for Sustainability Studies¶: J.-P. Burnet
- A Sustainability Roadmap for C3: B. Bullard
- A Sustainability Outlook for CLIC / ILC: S. Stapnes

Sustainability: Assessment of New Large Infrastructures



European Particle Physics Strategy Update 2020

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.***

Jim Clarke, Beate Heineman

EAJADE Workshop on Susta

Establishing a Working Group on "Sustainability Assessment of Accelerators"

- The LDG decided last week to form 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
  - LDG = European Lab Directors Group, chaired by Dave Newbold
- This group will effectively define for 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

Charge to the Working Group (I)

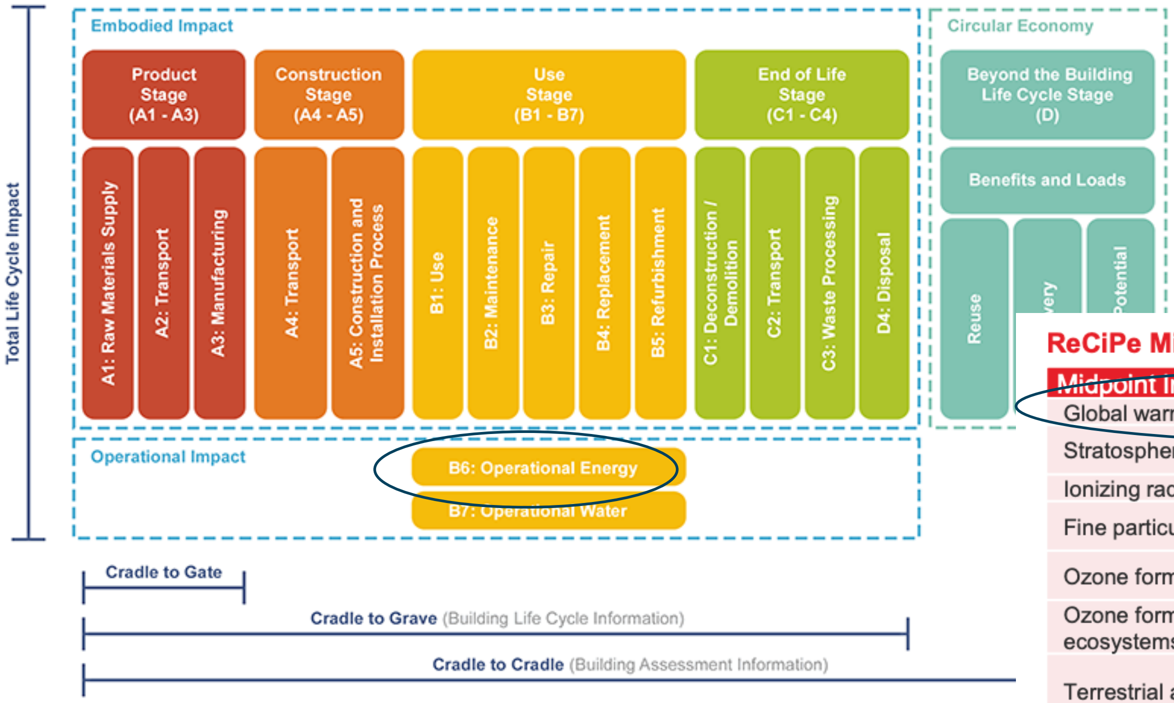
This working group is asked to develop guidelines and a minimum set of key indicators pertaining to the methodology and scope of the reporting of sustainability aspects for future HEP projects:

- Define key indicators to be reported, such as peak (or instantaneous?), lifetime- and performance specific (per luminosity) energy consumption, lifetime- and specific Global Warming Potential (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.

- Other aspects to be added if necessary
- Final report by end of 2024 – in time to serve as input to european strategy update?

Context for R&D – and collaborations – I

- Optimize with respect to:
- Energy reach, luminosities, experimental conditions
- Facility size and schedule
- Costs and Power
- Environmental Impact and Sustainability (we are learning what this means)



"Not enough to look at operation power and guess the CO2 from this power in ~2050 in your favourite country"

ReCiPe Midpoint (H) 2016 Impact Categories

Midpoint Impact Categories	Abbr.	Unit
Global warming	GWP	kg CO_2 eq
Stratospheric ozone depletion	ODP	kg CFC-11 eq
Ionizing radiation	IRP	kBq Co-60 eq
Fine particulate matter formation	PMFP	kg PM2.5 eq
Ozone formation, Human health	HOFP	kg NOx eq
Ozone formation, Terrestrial ecosystems	EOFP	kg NOx eq
Terrestrial acidification	TAP	kg SO_2 eq
Freshwater eutrophication	FEP	kg P eq
Marine eutrophication	MEP	kg N eq
Terrestrial ecotoxicity	TETP	kg 1,4-DCB
Freshwater ecotoxicity	FETP	kg 1,4-DCB
Marine ecotoxicity	METP	kg 1,4-DCB
Human carcinogenic toxicity	HTPc	kg 1,4-DCB
Human non-carcinogenic toxicity	HTPnc	kg 1,4-DCB
Land use	LOP	m^2a crop eq
Mineral resource scarcity	SOP	kg Cu eq
Fossil resource scarcity	FFP	kg oil eq
Water consumption	WCP	m^3

Reference: ReCiPe Midpoint (H) 2016


ess
Experiences from ESS on Green Facilities
Anders Sunesson
ESS
Workshop on Sustainability in Future Accelerators
Mats Lindroos, Mamad Eshraqi, Kent Hedin, Marko Kalafatic
www.europeanspallationsource.se
September 26, 2023
ARUP
Life Cycle Assessment
Comparative environmental footprint for future linear colliders CLIC and ILC
The International Workshop on Sustainability in Future Accelerators 2023 | 26/09/
ARUP: *Suzanne Evans, *Jin Sasaki, Ben Castle, Yung Loo, Heleni Pantelidou, Marin Tanaka
CERN: John Osborne, Steinar Stapnes, Benno List, Liam Bromiley
KEK: Nobuhiro Terunuma, Akira Yamamoto, Tomoyuki Sanuki
(*presenters: suzanne.evans@arup.com, jin.sasaki@arup.com)
The ISIS-II Neutron & Muon Source Life Cycle Assessment:
An Introduction
Hannah Wakeling
John Adams Institute for Accelerator Science, University of Oxford
EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)
26th September 2023
UNIVERSITY OF OXFORD
Science and Technology Facilities Council
ISIS Neutron and Muon Source
A sustainable strategy for the Cool Coppe
Martin Breidenbach1, Brendon Bullard1, Emilio Nanni1, Dimitris Ntounis1,2,
1) SLAC National Accelerator Laboratory, 2) Stanford University
EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)
September 27, 2023
SLAC NATIONAL ACCELERATOR LABORATORY
C3
Stanford University
CERN Accelerates SUSTAINABILITY!
R. Losito, CERN
26 September 2023
EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)
https://indico.desy.de/event/39980/
FUTURE CIRCULAR COLLIDER
CERN
Linear colliders
Sustainability studies for LCs
Life Cycle Assessments
Steinar Stapnes
EAJADE WP4: Morioka 27.9.2023

ARUP

Life Cycle Assessment

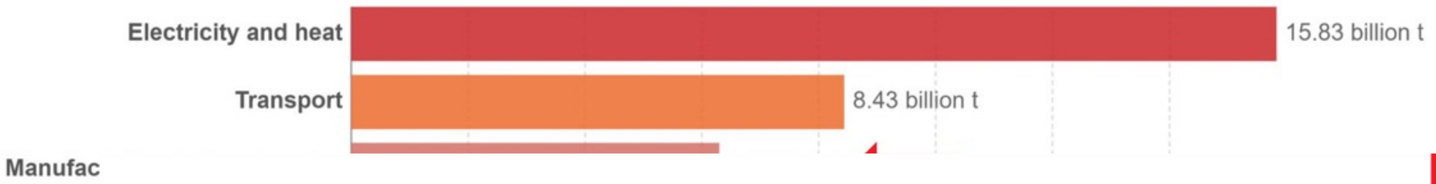
Comparative environmental footprint for future linear colliders CLIC and ILC

The International Workshop on Sustainability in Future Accelerators 2023 | 26/09/2023

ARUP: *Suzanne Evans, *Jin Sasaki, Ben Castle, Yung Loo, Heleni Pantelidou, Marin Tanaka
CERN: John Osborne, Steinar Stapnes, Benno List, Liam Bromiley
KEK: Nobuhiro Terunuma, Akira Yamamoto, Tomoyuki Sanuki

(*presenters: suzanne.evans@arup.com, jin.sasaki@arup.com)

ARUP



Global GHG Emissions (tCO_2e)

Land-us

ARUP

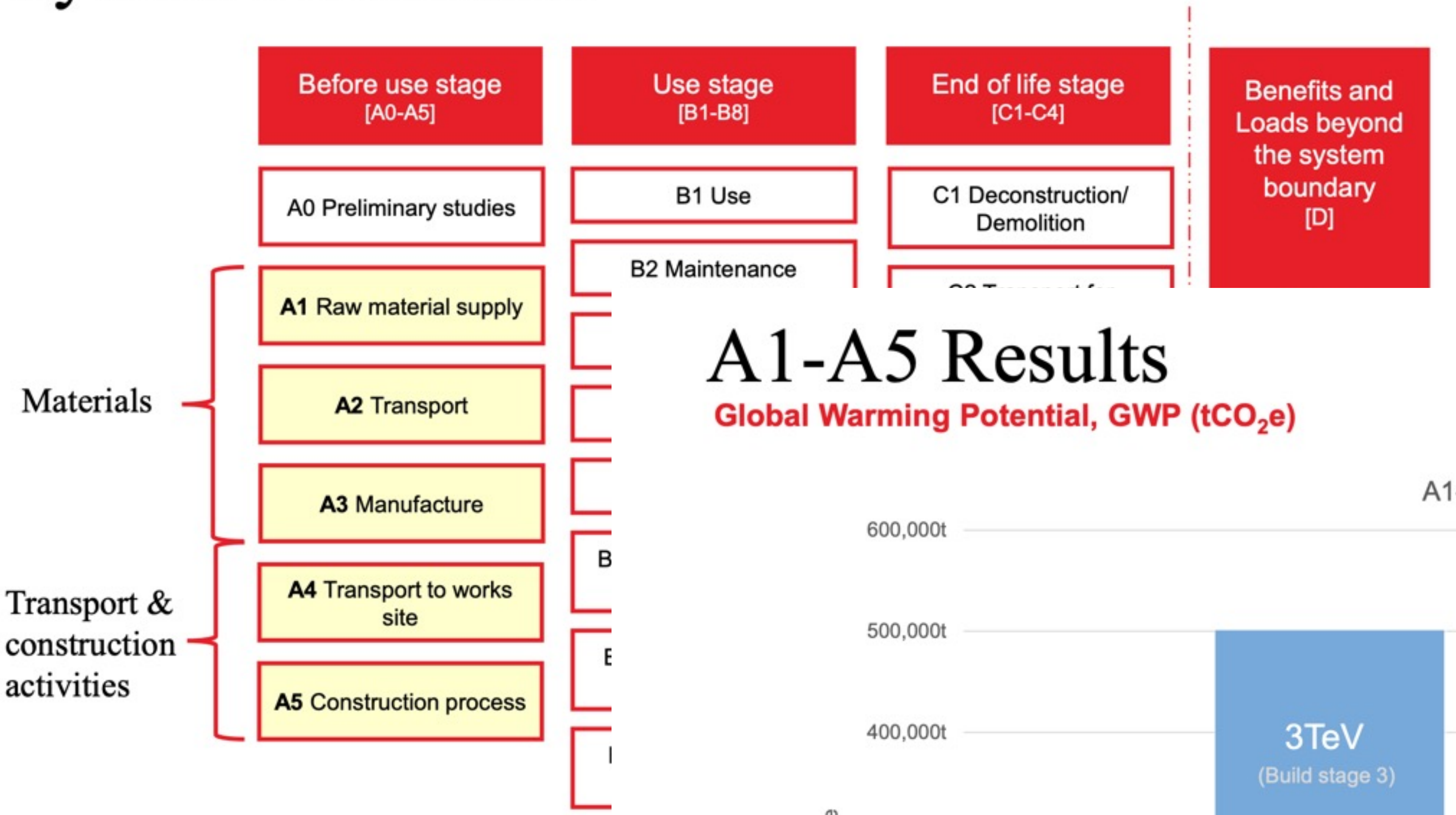
100% of projects due to be completed in **2030** or after are **net zero carbon in operation**

with at least **40% less** embodied carbon compared to current practice

2030 Breakthroughs UNFCCC

UN Breakthrough Outcomes for 2030

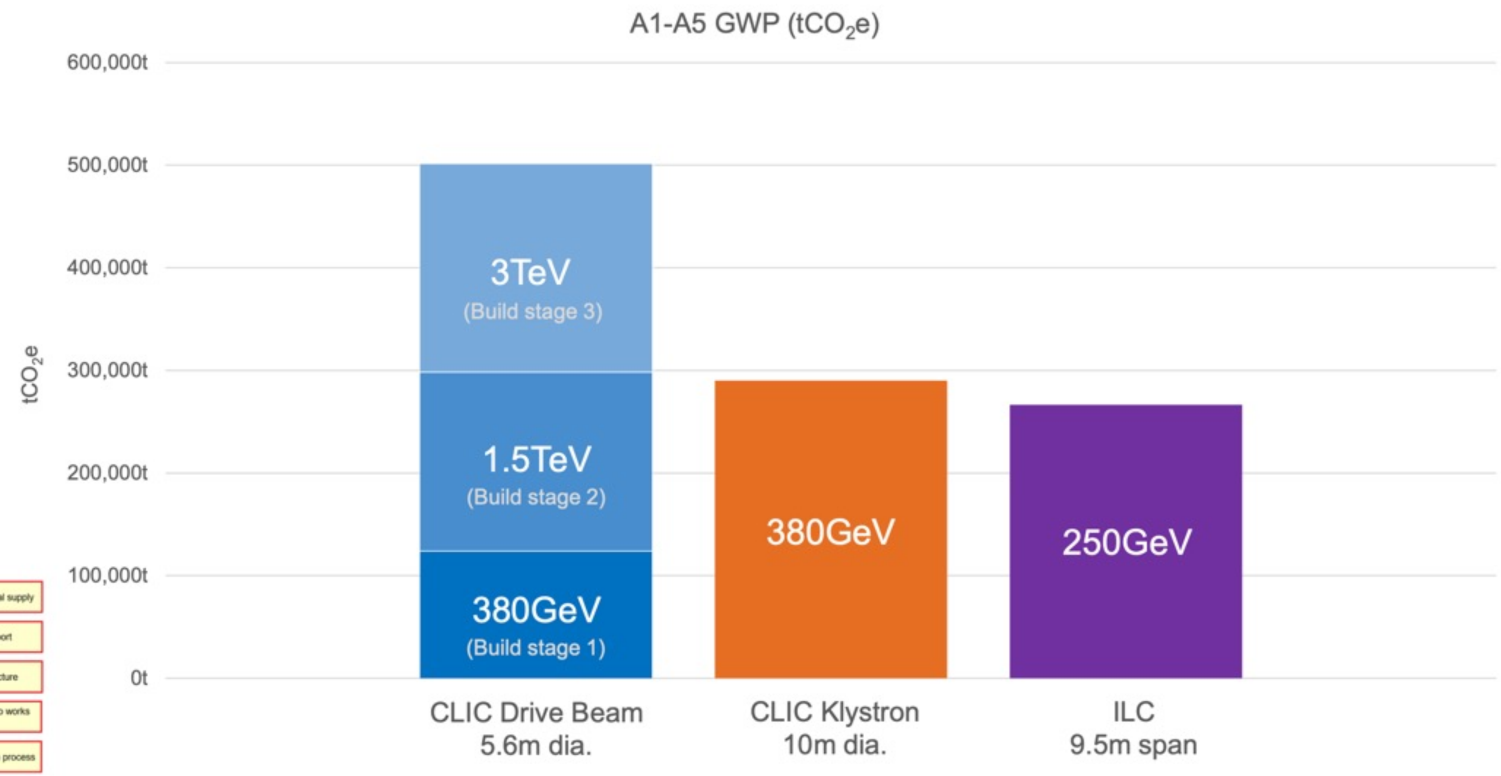
System boundaries

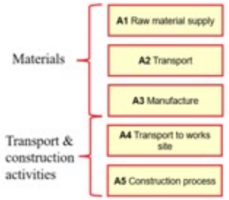


ARUP

A1-A5 Results

Global Warming Potential, GWP (tCO_2e)

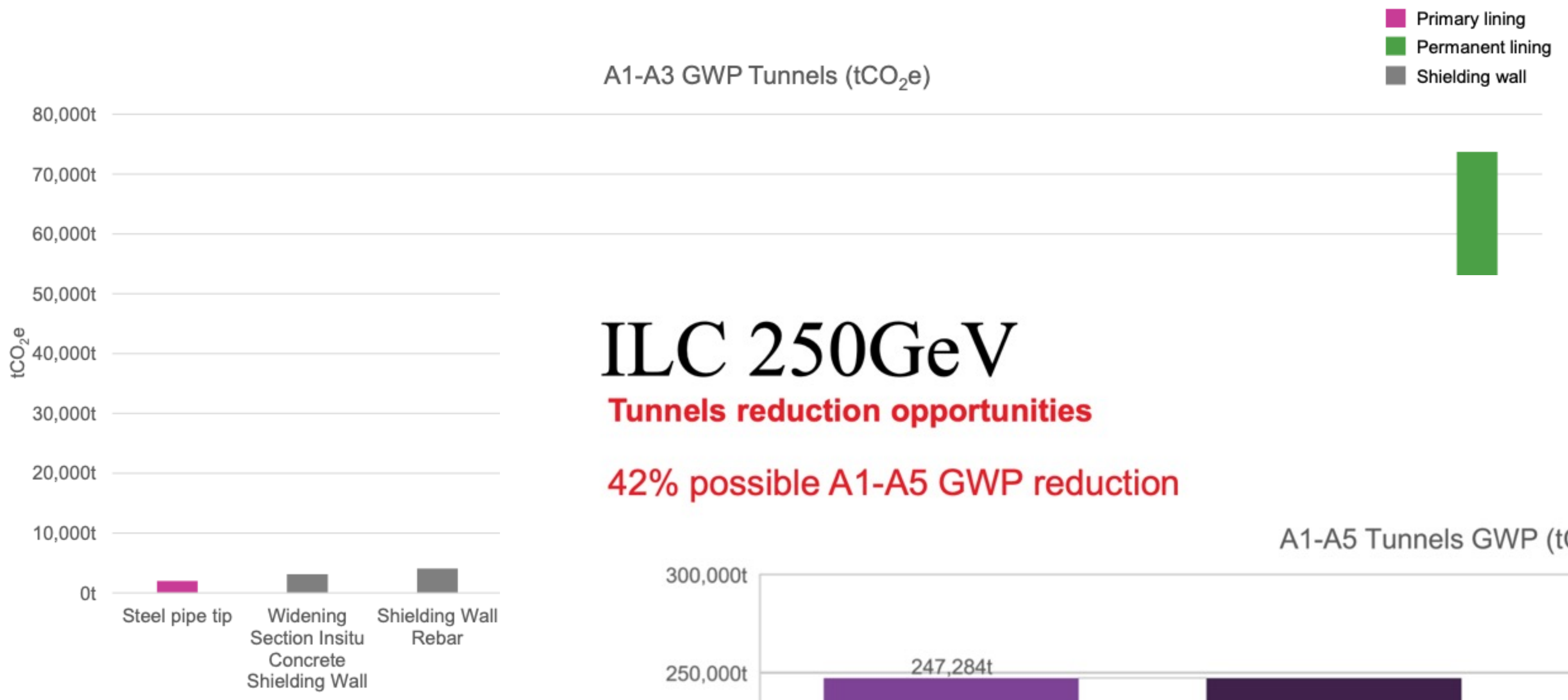




ILC 250GeV

ARUP

A1-A3 Global Warming Potential (tCO_2e)

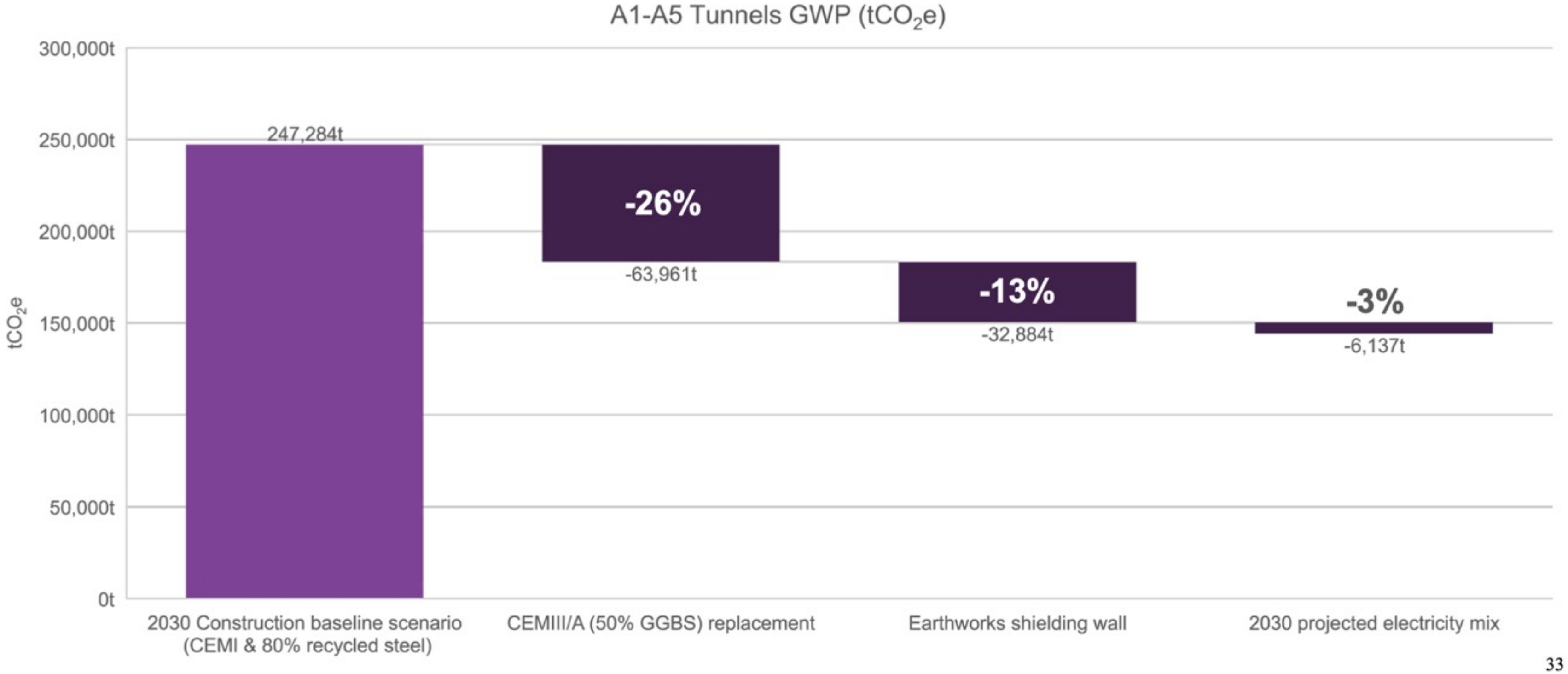


ILC 250GeV

ARUP

Tunnels reduction opportunities

42% possible A1-A5 GWP reduction



Recomm-endations

ARUP

- Consideration of low carbon concrete technologies in replacement of Portland cement.
- Replace the shielding wall in CLIC and ILC with concrete casing and earthworks fill, repurposed from tunnel excavation.
- Reduce the precast concrete segmental lining thickness for CLIC Drive Beam and Klystron. Innovations in design could reduce this further.
- Consideration of projected 2030 electricity mix at the time of construction and how this transition can be influenced.
- Consideration of steel fibre alternatives such as plant fibres and recycled rubber tyre steel fibres.
- It is recommended that the LCA is updated at key design and development milestones going forward.

Experiences from ESS on Green Facilities

Anders Sunesson

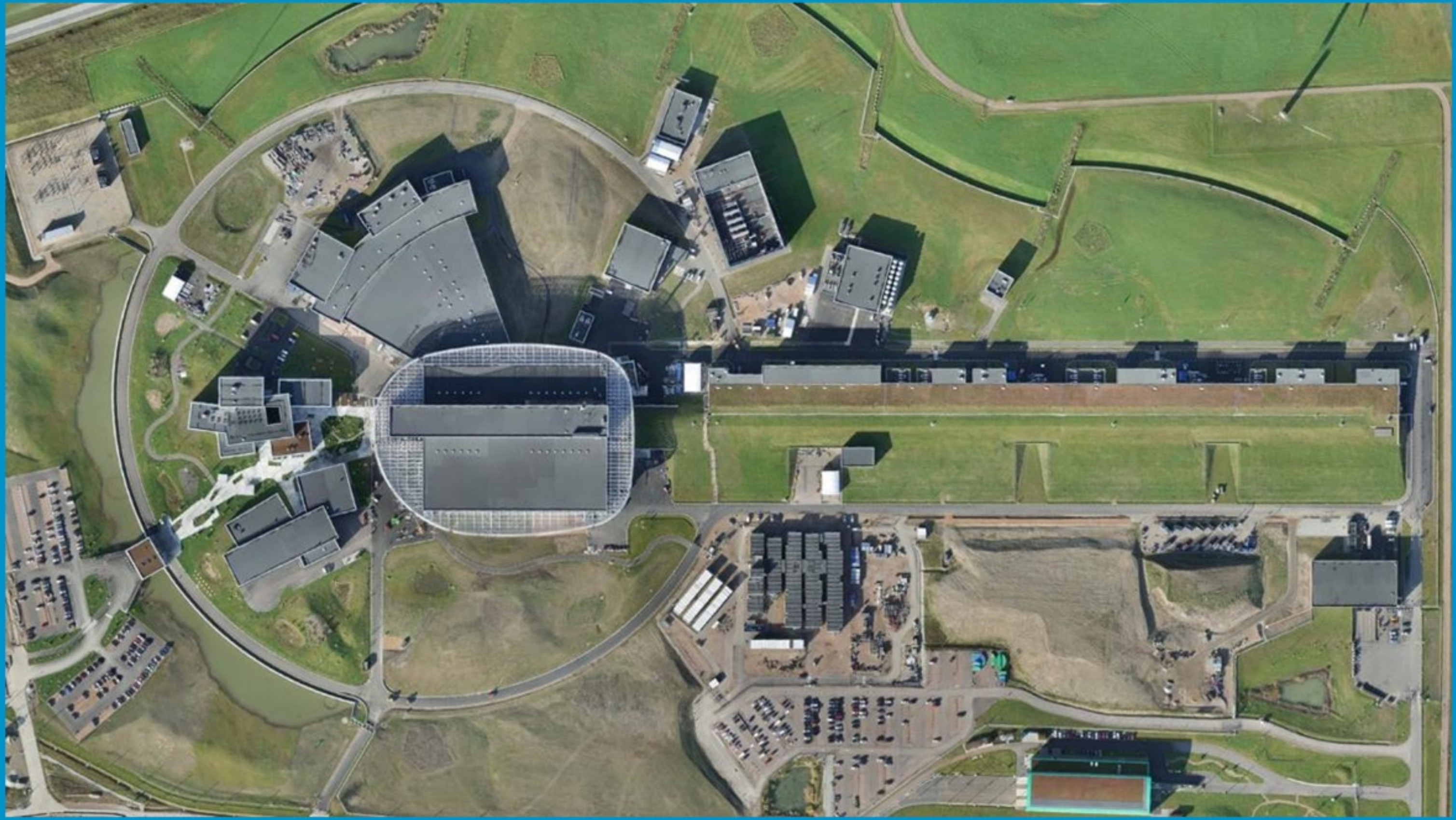
ESS

Workshop on Sustainability in Future Accelerators

Mats Lindroos, Mamad Eshraqi, Kent Hedin, Marko Kalafatic

www.europeanspallationsource.se

September 26, 2023



Overview

- ESS is planned as green facility:
  - Re-use of cooling water for district heating
  - High temperature water to i
  - Active strategy for power su
- Pioneering developments:
  - Flicker-free HV modulator to
  - Compact and cost-effective
  - Multi-beam IOT high efficien
  - Optimisation of klystron effi
- ESS active in two EU Horiz
  - iFAST (Horizon 2020) and Fle

Green ESS implementations

- Implementations:
  - Cooling water is provided in three temperature ranges: Low (ca 8 deg C), Medium, (ca 25 deg C), and High (45+ deg C), all supplies control temperature of input
  - The heated medium and high temperature water is fed to heat exchangers and heat pumps (optional) to lift the temperature to 80 deg C, and the energy is used in district heating (ESS sells the energy)
  - Heated water is also used for heating of ESS premises and for hot water, either via heat exchanger or heat pump
  - The use of heat pumps depends on the temperatures and electric power prices and the heat price
  - ESS operates procurement of electrical power according to a strategy with both variable and fixed hedges. The selling of heat is part of the strategy

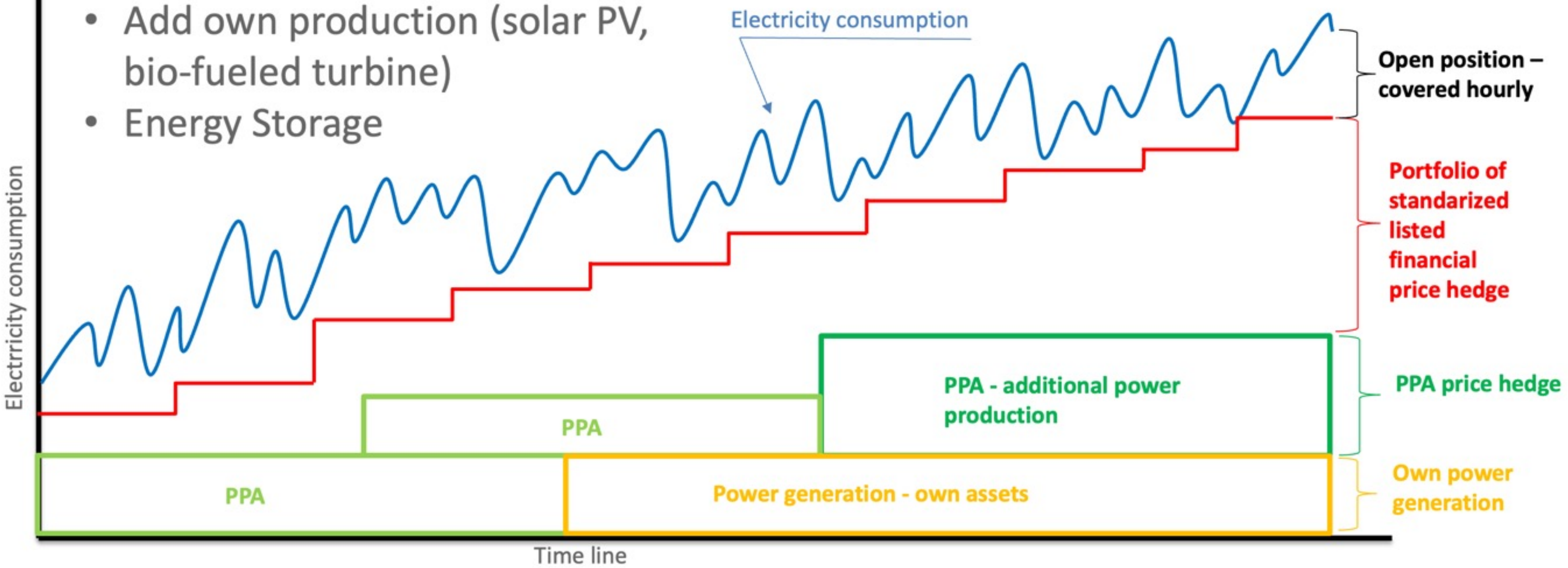
Overall Energy Strategy

Relationship between electricity/heat

Electricity provided by ESS to EON to run CPS

Possible Future Energy Strategy

- Buy directly from producer (PPA)
- Add own production (solar PV, bio-fueled turbine)
- Energy Storage



EU collaboration projects

- ESS participates in the Horizon programs iFAST and FlexRICAN
- The focus is on innovation and sustainability in accelerators – this mirrors ESS strategy of own power generation and energy storage
- In iFAST the addition of solar panels and direct powering of modulators via DC from solar panels has been studied, as well as introduction of solar panels
- In FlexRICAN flexibility in supply is the focus area, and subprojects cover areas like renewable power generation (solar panels, bio-fuel turbines,…), energy storage, optimisation of heat recovery, all to optimise power use for sustainability

iFAST, Horizon 2020 proposal No 101004730 (2020)
FlexRICAN, Horizon 2023 proposal No 101131516 (2023)

Pioneering development: Optimisation of klystron

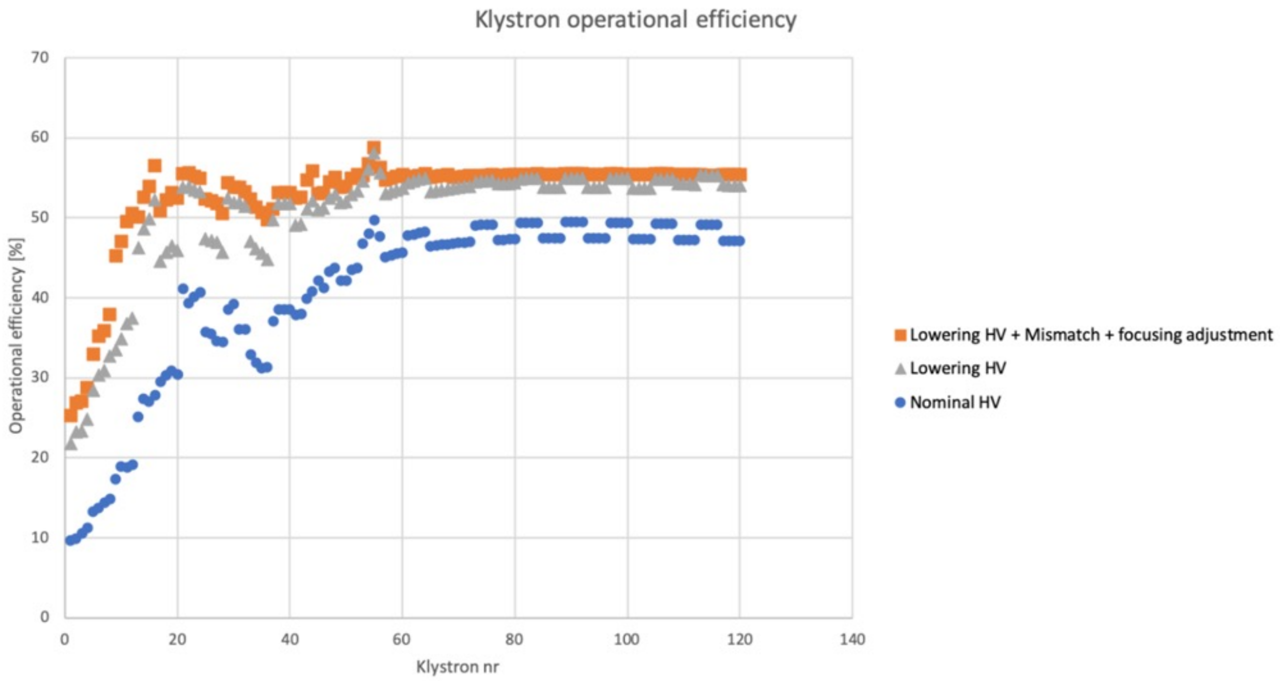
EUROPEAN SPALLATION SOURCE

- ESS employs 1,5 MW klystrons for the medium and high beta linacs
- The 1,5 MW klystrons a… 1100 kW
- Dramatic efficiency dro…
- Mitigation: mismatch t… (lower HV)
- The operational efficie… filling time consideratio…
- Success: Power savings…
- Lesson: Klystron efficie…

Klystron optimisation

EUROPEAN SPALLATION SOURCE

- Optimisations:
  - Lowering HV
  - Output mismatch
  - Focusing adjustment



Both IOT and klystron work referenced in
C. Marrelli *et al.*, “ESS RF Power Generation”, Workshop on efficient RF sources, CERN, Jul. 2022

The ISIS-II Neutron & Muon Source Life Cycle Assessment:
An Introduction

Hannah Wakeling

John Adams Institute for Accelerator Science,
University of Oxford

EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)

26th September 2023

John Adams Institute for Accelerator Science

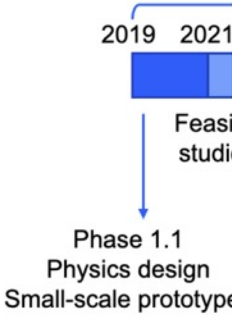
UNIVERSITY OF OXFORD

UKRI Science and Technology Facilities Council

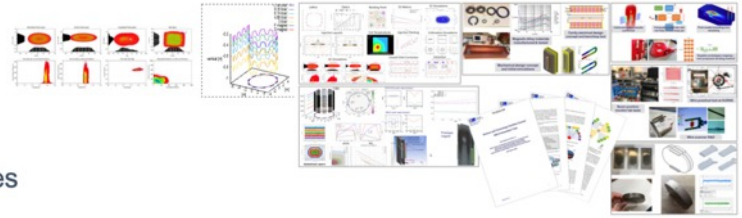
ISIS Neutron and Muon Source

The ISIS-II Project

- Currently, Europe (including the UK) is a world leader in neutron- and muon-based science.
- Over the next decades, reactor-based sources will be shut down and other sources will reach the end of their lifetimes.
- ISIS-II would be the next g



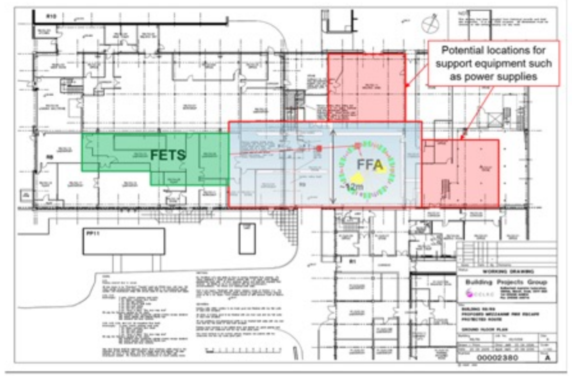
Designs and prototypes



- Environmental sustainability estimates
- High-level requirements
- Resource planning
- Targets design
- Neutronics design
- RCS and AR accelerator design
- FFA accelerator design
- Linac design
- Muon and proton irradiation solutions
- ISIS upgrade (180 MeV) feasibility
- Engineering prototypes
- Siting options and planning

ISIS-II project phase 1.2b plan

- Construction of a small FFA test ring on the end of the Front End Test Stand (FETS) at RAL in order to explore the beam dynamics fully.
- Completion of compression ring designs.
- Linear accelerator design integrated with choice of pulse compression ring.
- Completion of target, moderator and shielding design for high and low repetition rate neutron targets and a muon target.
- Production of an optimal concept design with credible initial cost estimates.



What is being done regarding ISIS-II and sustainability?

- Within STFC we have been developing a draft of high level sustainability guidelines for large accelerator facilities.
- A methodology has be
- A comparison of warm
- A full **life cycle asses** 180 MeV.

Science and Technology Facilities Council

ISIS Neutron and Muon Source

www

uk.lin

Life Cycle Assessment Software

- LCA software has benefits, and is the current focus of this analysis.
- OpenLCA, Statista and other sources have conflicting ideas of what the UK's energy mix will look like in 2050, leading to up t total environmental impact of po
- Thus, when presenting results, p (i.e. in kWh/MWh).

Science and Technology Facilities Council

ISIS Neutron and Muon Source

@isisneutronmuo

uk.linkedin.com/showca

Life Cycle Assessment of the pre-injector and LINAC to 180 MeV

Disclaimer

This work is based on multiple assumptions at various levels, with incomplete data. The assumptions made are disclosed in documentation and reasoning behind assumptions justified. The calculations will be updated continuously as information and levels of detail evolve.

- Evaluation of:
  - Construction (in development, first numbers available)
  - Operation (first numbers available)
  - Decommission (in early stages)

Science and Technology Facilities Council

ISIS Neutron and Muon Source

www.isis.stfc.ac.uk

@isisneutronmuon

uk.linkedin.com/showcase/isis-neutron-and-muon-source

Construction CO_2e impact

Transportation of chalk mound:
89 tCO_2e (V_{130m}) or 208 (V_{12}

Access and service tunnels an
5459 tCO_2e (concrete structur

Supporting buildings:
3500 (steel frame) + 785 (conc
= **4287 tCO_2e**

Tunnel & shielding:
6310 tCO_2e (concrete structur

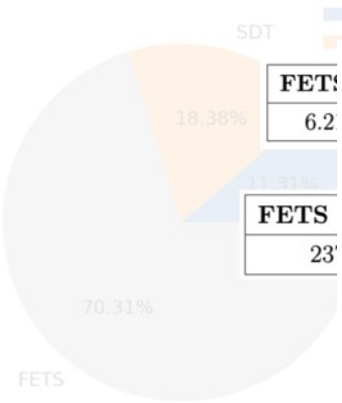
TOTAL = 16 $ktCO_2e$

Science and Technology Facilities Council
ISIS Neutron and Muon Source

www.isis.stfc.ac
@isisneutr
uk.linkedin.com/s

Operation

Cumulative CO2 emissions for the FETS(Front End Test Stand), Drift Tube (DT) and Separated Drift Tube (SDT) including SDT electromagnet power and including cooling.



FETS
6.2

FETS
23

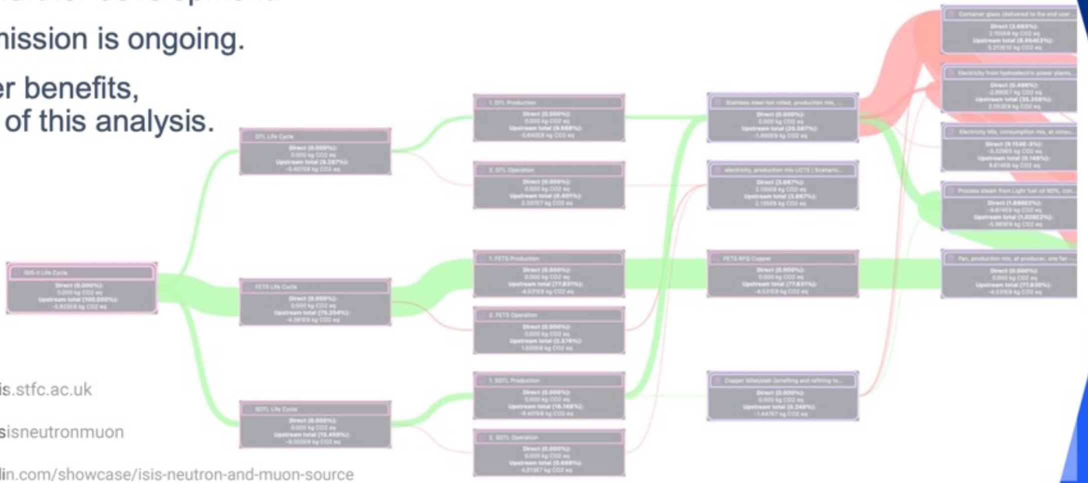
Power consumption breakdown of co

Components: 5.39x10⁸ kW

Science and Technology Facilities Council
ISIS Neutron and Muon Source

Life Cycle Assessment Conclusion (so far!)

- **Taking note that these are initial results, with further development needed**: even with highly optimistic UK 2050 power mix forecasts, concrete and steel construction impacts (16 $ktCO_2e$) do not outweigh the full lifetime electrical operation impacts (34 $ktCO_2e$).
  - This is solely through examining the GWP. Other impacts are being examined but the investigation needs further development.
- Investigation of decommission is ongoing.
- LCA software has further benefits, and is the current focus of this analysis.



Science and Technology Facilities Council
ISIS Neutron and Muon Source

www.isis.stfc.ac.uk
@isisneutronmuon
uk.linkedin.com/showcase/isis-neutron-and-muon-source

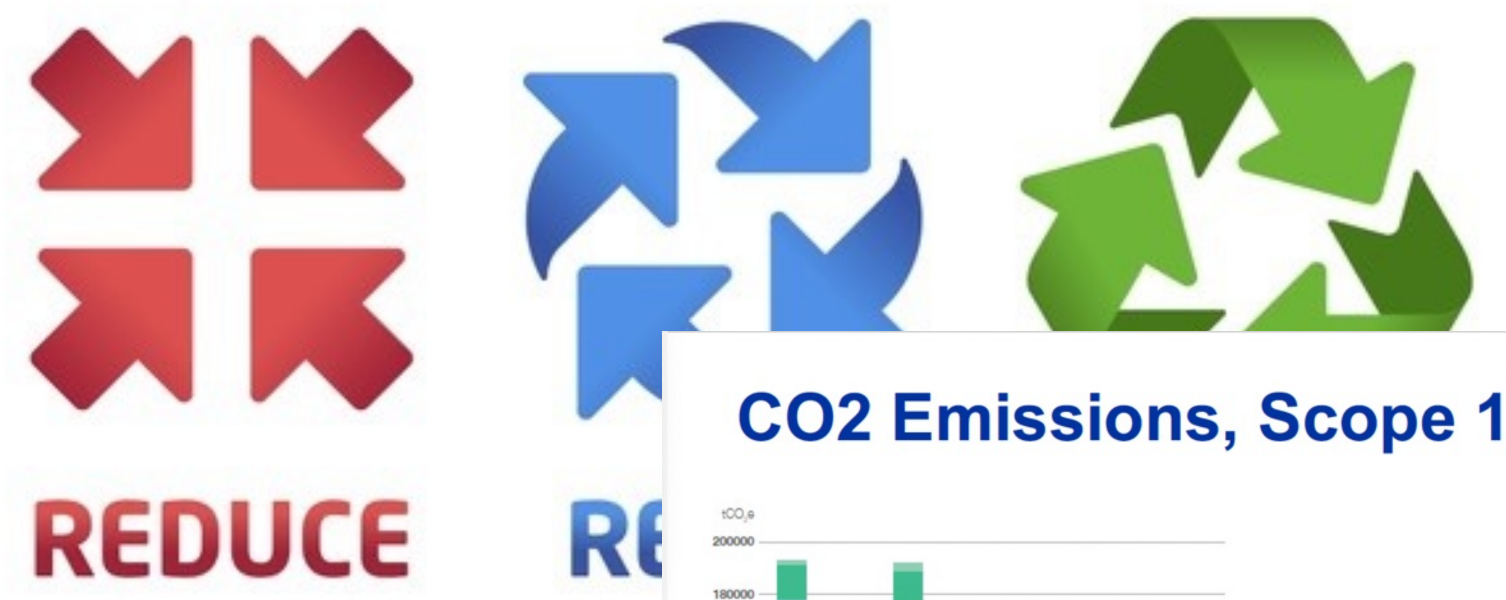
CERN Accelerates SUSTAINABILITY!

R. Losito, CERN

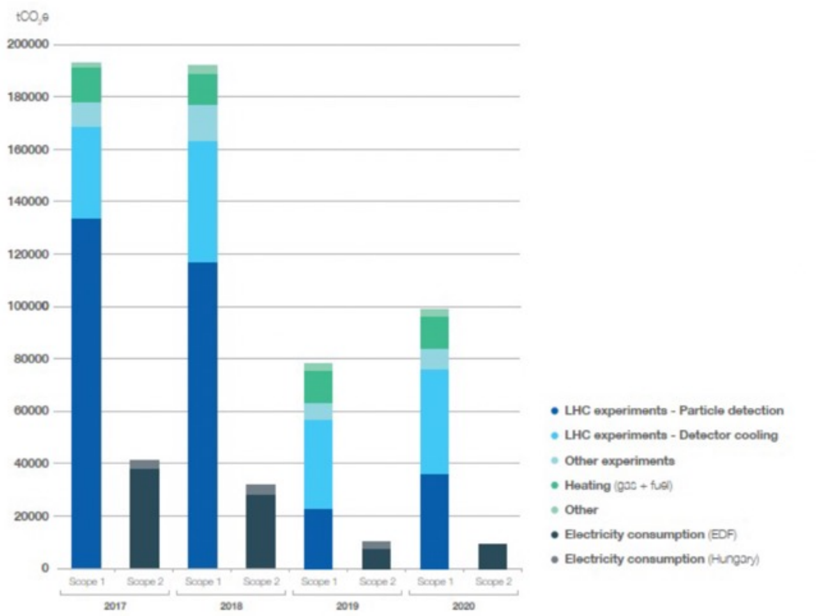
26 September 2023

EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)

https://indico.desy.de/event/39980/



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%...*

Area needed to generate 1.3 TWh/y

(no contingency, no distribution, no storage…)

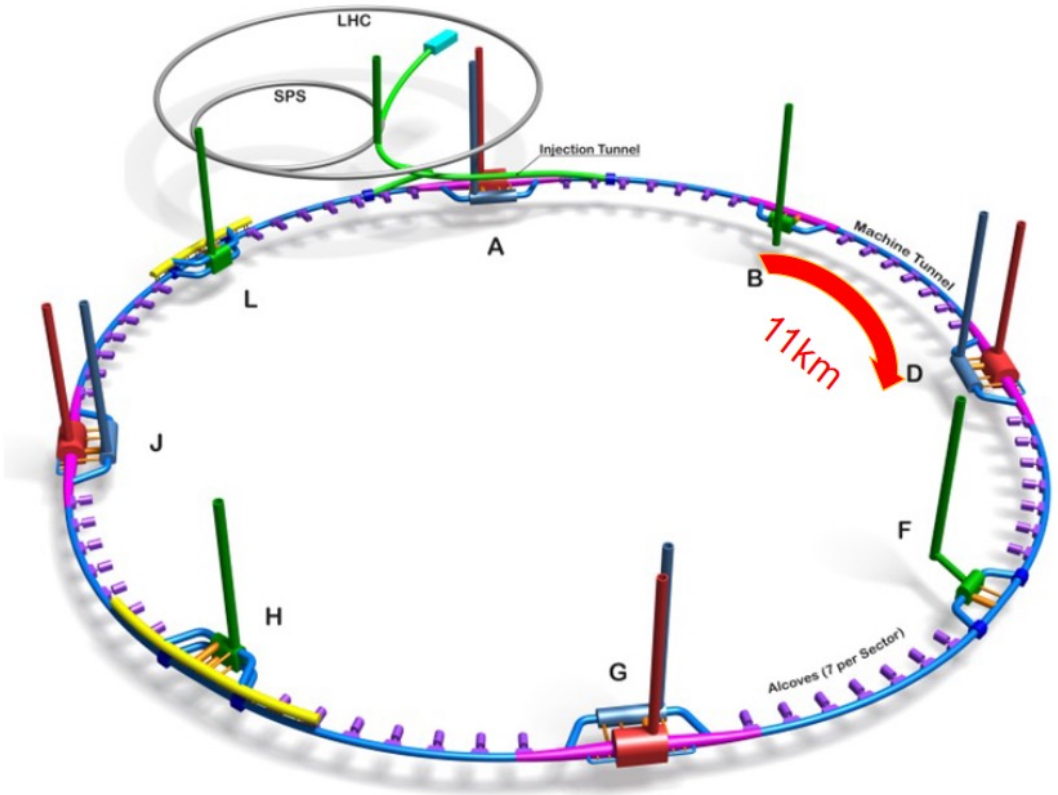
How can we procure CO_2 free energy?

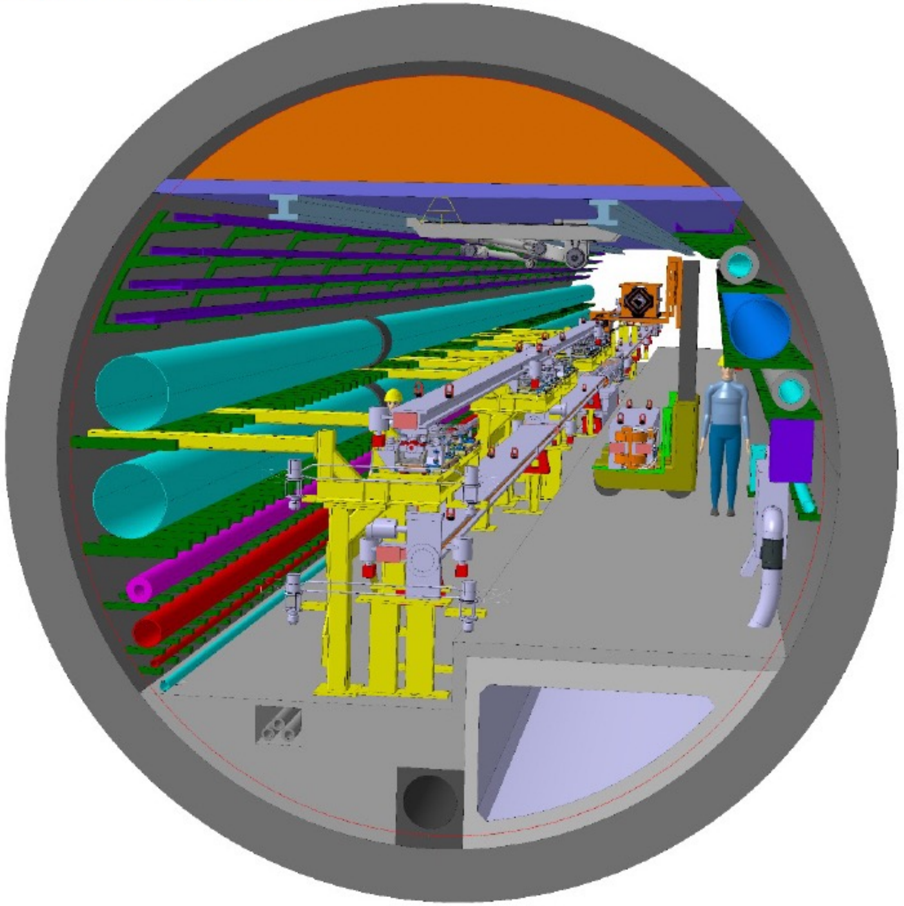
- **We already do!!!**
- 80% of our energy comes from French Nuclear, the rest is purchased on the market through EDF and reflects the standard mix of French energy.
- The EU is establishing a new policy that aims at encouraging the investment in renewables, targeting at the same time stability for the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

FUTURE CIRCULAR COLLIDER

A very large machine

8 Arcs of 11km, full of magnets, pipes, cables…





91km tunnel, 230m underground, 12 shafts, 8 access points

FCC as a sustainable accelerator

From R. Losito, Sustainable Accelerators (Panel), LHC Chamonix Workshop 2023

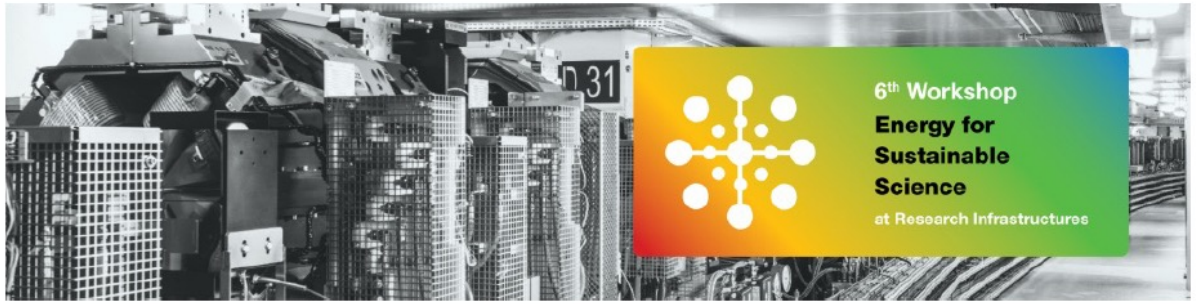
A sustainable accelerator needs to **minimize its impact** on

- Environment (Energy, CO_2 and water footprint, emissions, waste etc…)
- availability of resources (e.g. minimization of materials extracted)

While **maximizing the value** returned to society:

- Serious and valuable Scientific programme
- Generation of knowledge and transfer of Technology
- Training of students, professionals, Teachers…
- Social Justice

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



All powered by electricity

Power demand estimation by operation mode

Reduced by 9% compared to 2022

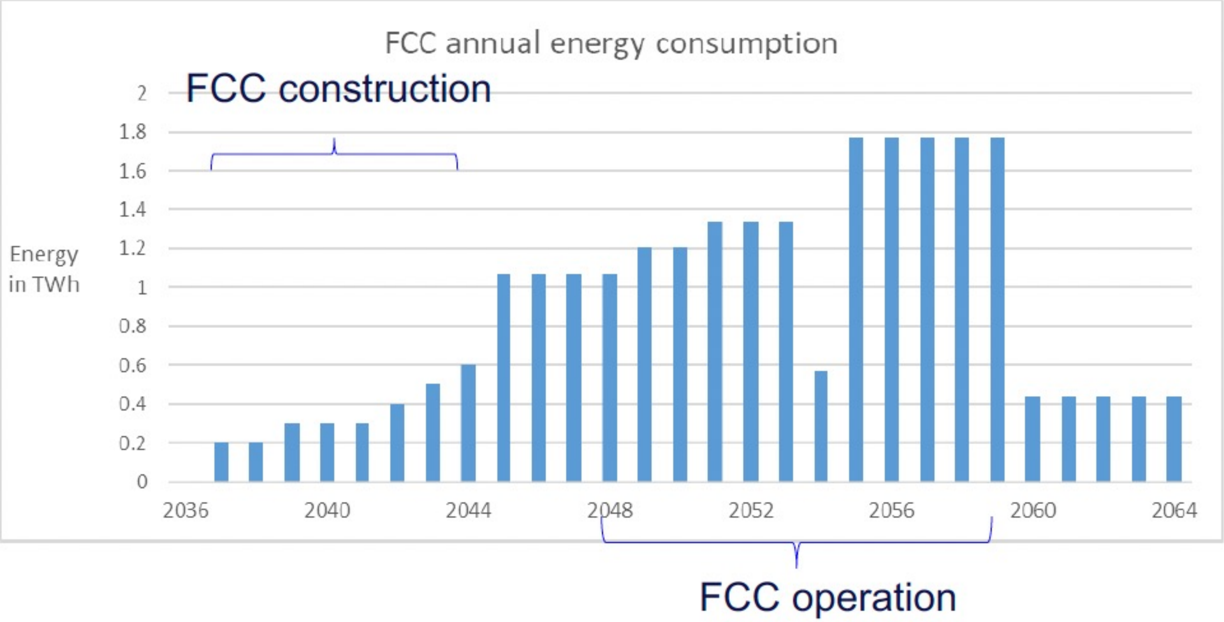
2023		Z	W	H	TT
Beam energy (GeV)		45.6	80	120	182.5
Magnet current		25%	44%	66%	100%
Power ratio		6%	19%	43%	100%
PRF EL (MW)	Storage	146	146	146	146
PRFb EL (MW)	Booster	2	2	2	2
Pcryo (MW)	Storage	1.2	11.5	11.5	27.6
Pcryo (MW)	Booster	0.35	0.80	1.50	7.40
Pcv (MW)	all	25	26	28	33
PEL magnets (MW)	Stroage	6	17	39	89
PEL magnets (MW)	Booster	1	3	5	11
Experiments (MW)	Pt A & G	10	10	10	10
Data centers (MW)	Pt A & G	4	4	4	4
General services (MW)		26	26	26	26
Power during beam operation (MW)		**222**	**247**	**273**	**357**

FCC electricity consumption 2036 - 2065

Electricity for FCC

First consumption started with construction, then commissioning and operation.
Based on runs (beam operation) and long shutdowns (maintenance and upgrade).

FCC operation is foreseen to be in the range of 20TWh over 15 years (<400 ktonCO2e) ≈ 2 years of LHC detectors operation



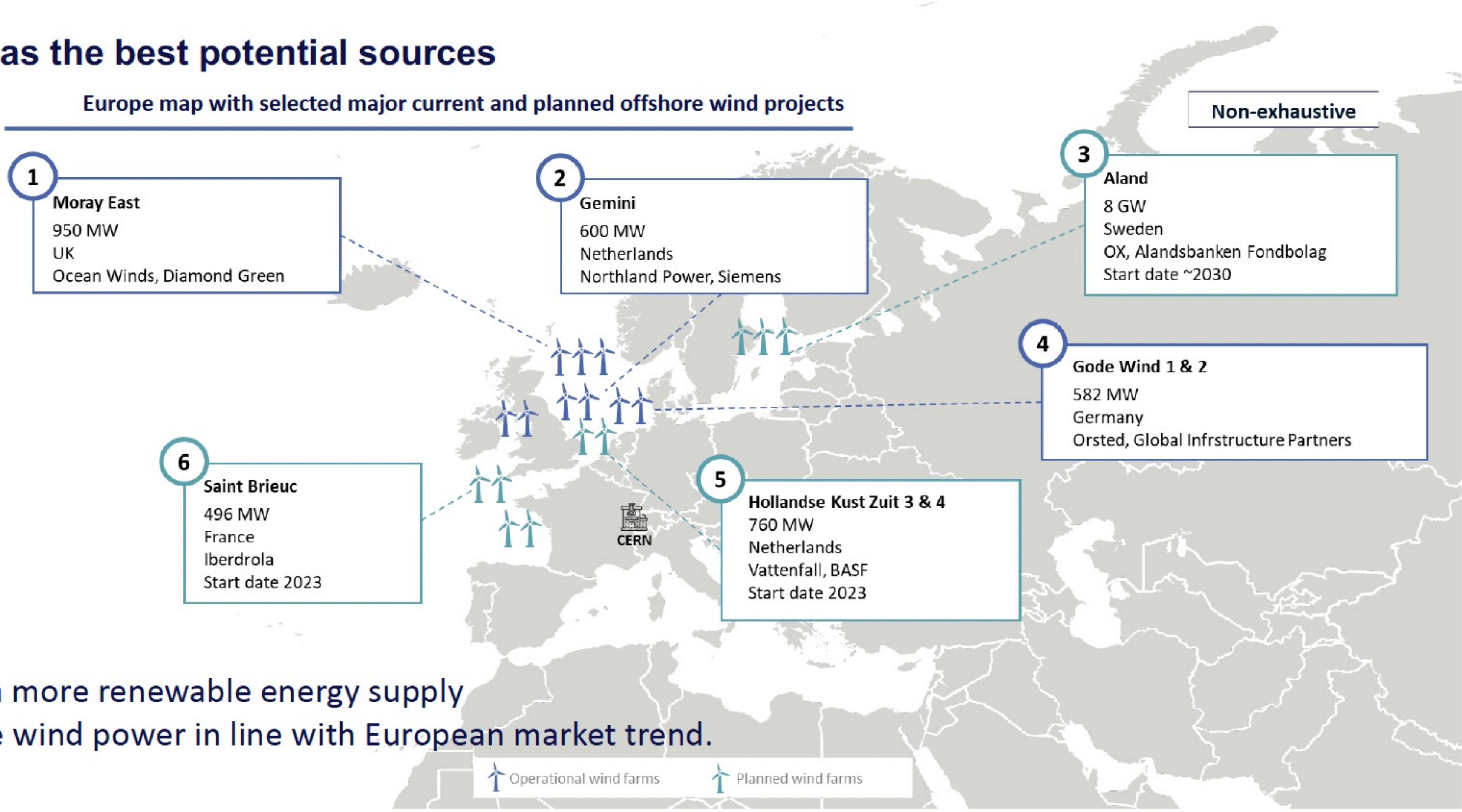
From CERN annual report (2018 LHC in operation)
CERN's total amount of greenhouse gas emissions, those produced directly by the Organization, was 192 100 tonnes of CO2 equivalent, tCO2e, in 2018, 92% of which is related to the activities of the large LHC experiments.

CERN's total amount of indirect greenhouse gas emissions, those due to CERN's electricity consumption, was 31 700 tCO2e in 2018.

CERN environment report (2017-2018)

FCC renewable energy supply

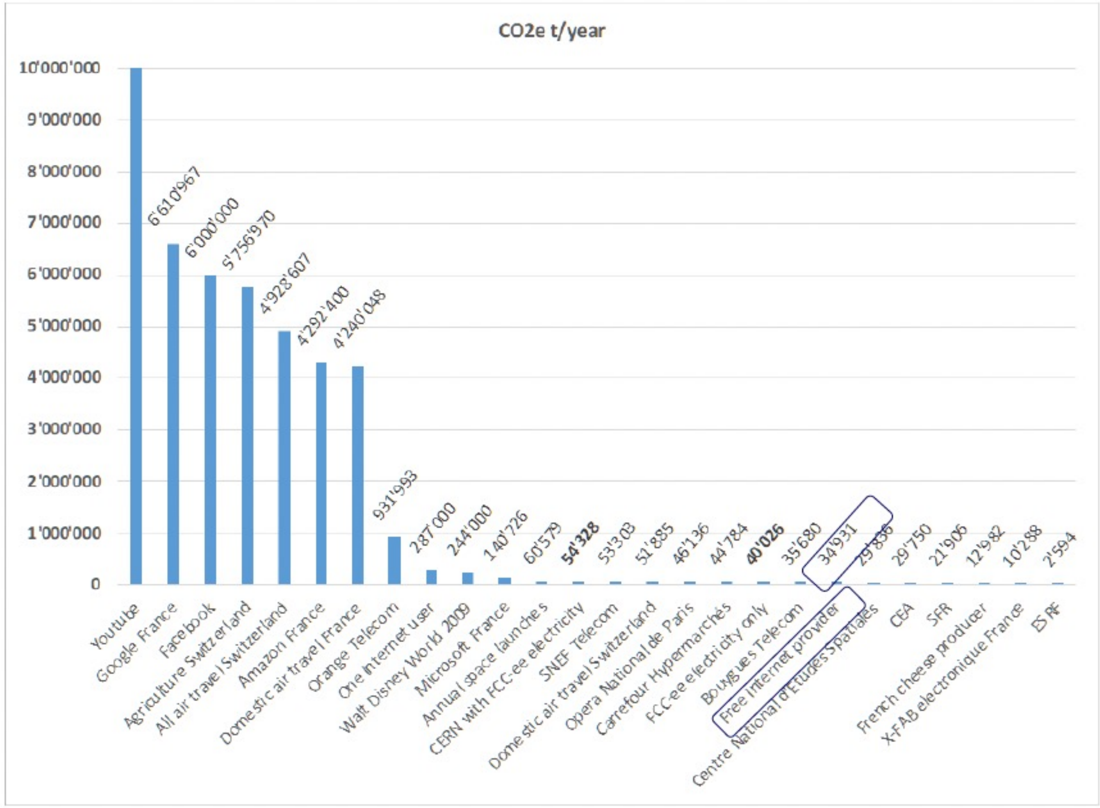
Offshore wind farms as the best potential sources



CERN is moving forward to a more renewable energy supply
FCC target = 80% of offshore wind power in line with European market trend.

FCC electricity indirect emissions

Carbon footprint of selected organisations put in relation to CERN with an FCC programme



For max power, Ttbar operation, 2TWh/y

Typical person-related carbon footprint values

Consumer	**CO2e**
CO2e footprint for each taxpayer contributing to CERN with the FCC per year	**106 g**
CO2e footprint for each taxpayer contributing to the FCC only per year	**78 g**
Boiling 1 water kettle	34 g
1 email with attachment	10 g
1 hour of Youtube usage per viewer	164 g
1 hour of Netflix usage per viewer	983 g
1 hour of Facebook interaction per user	16 g
1 hour of TikTok operation per user	328 g

FCC renewable energy supply feasibility analysis

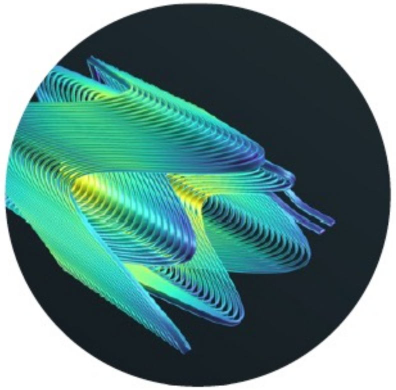
Design for sustainability

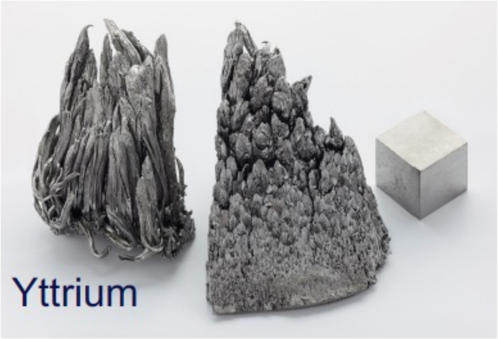
Opportunities for reduction of carbon impact

The project is still in the conceptual phase.
Looking for significant opportunities for whole-life carbon impact reduction.

- Life Cycle Assessment for civil engineering, including MATEX (excavated materials)
- Life Cycle Assessment for technical infrastructures
- Life Cycle Assessment for Accelerators

Example,
Life cycle Assessment for classical quadrupole magnets and superconducting HTS magnets (as proposed at FCC week 2023).
Rare-Earth Elements + rare-gases, is it more sustainable?





Copper, 4kgCO2/kg
Helium, 587kgCO2/l
RRE, 170kgCO2/kg

A sustainable strategy for the Cool Copper Collider

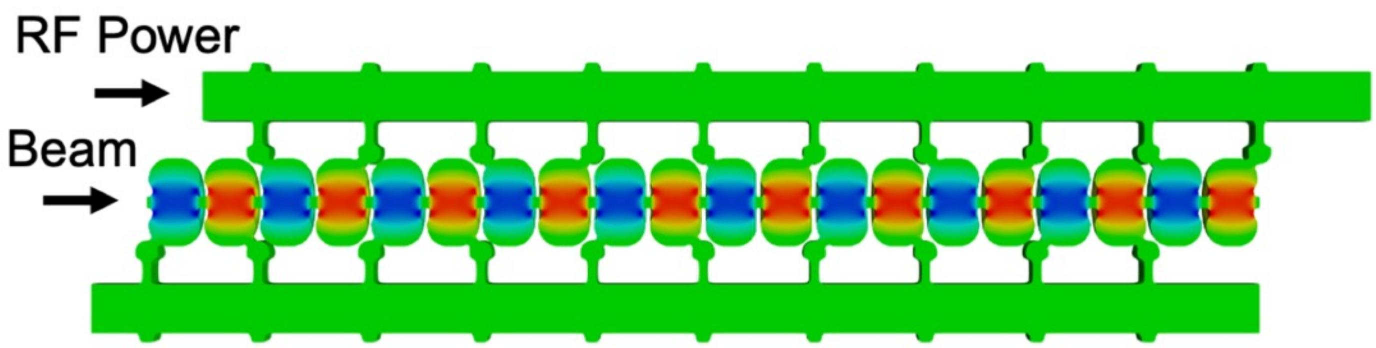
Martin Breidenbach[1], Brendon Bullard[1], Emilio Nanni[1], Dimitris Ntounis[1,2], Caterina Vernieri[1,2]
1) SLAC National Accelerator Laboratory, 2) Stanford University

EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)
September 27, 2023

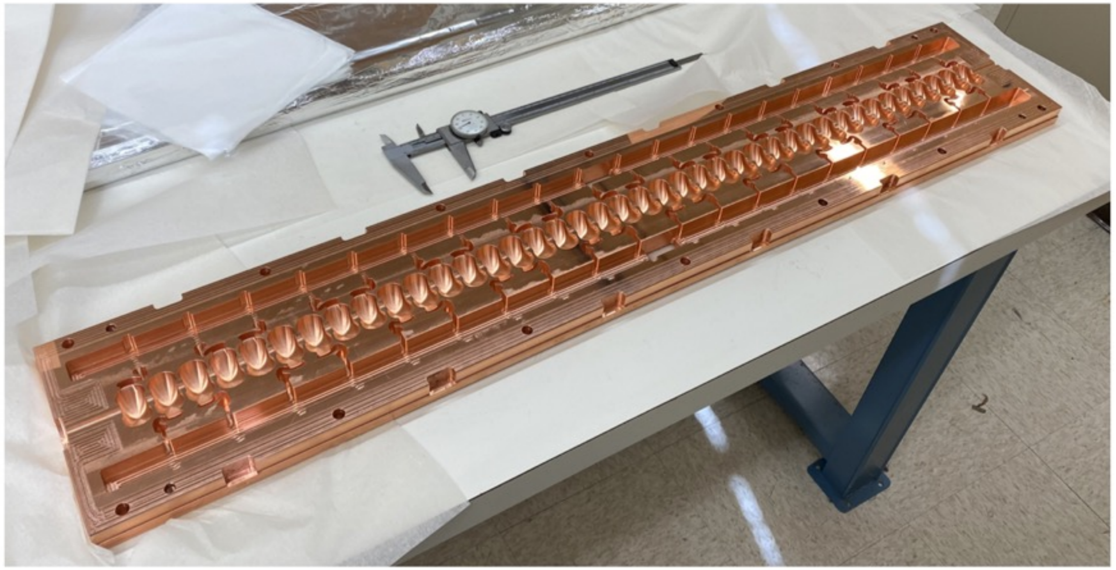
SLAC NATIONAL ACCELERATOR LABORATORY
C^3
Stanford University
U.S. DEPARTMENT OF ENERGY

A compact accelerator

- The Cool Copper Collider (C^3) is a linear e^+e^- collider concept with a compact 7-8 km footprint
- Cavity geometry is optimized to minimize surface fields → low breakdown rates at high gradients
  - Small iris between cavities minimizes coupling, fundamental RF does not propagate along the beam line
    - Solution: power distributed to each cavity from a common RF manifold
    - C^3 structures are machined in halves using modern CNC milling from slabs of copper
- Operation at 77 K with LN_2 reduces breakdown rate by 2 orders of magnitude w.r.t. room temp



Electric field magnitude for equal power from RF manifold



PRAB, (2020), 092001, 23(9) JINST, (2023), P07053, 18(07)

C^3 Excavation models

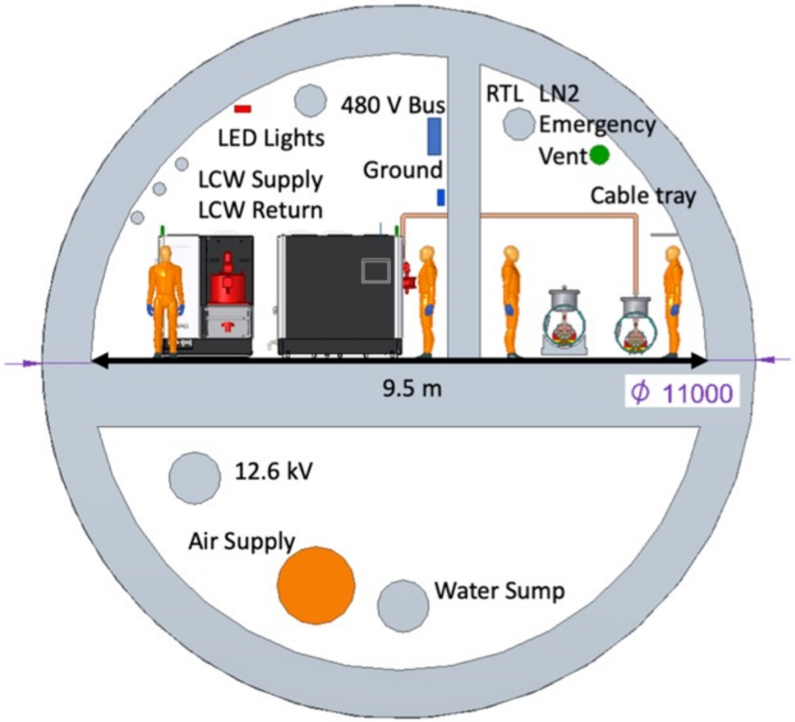
Bored tunnel

Total of 600k m^3 total excavation, 225k m^3 concrete

- 200k m^3 of excavation comes from tunnel volume, concretes include all site requirements
- Emissions estimated using Snowmass report parameters

Releases ~60 kton CO_2 from concrete

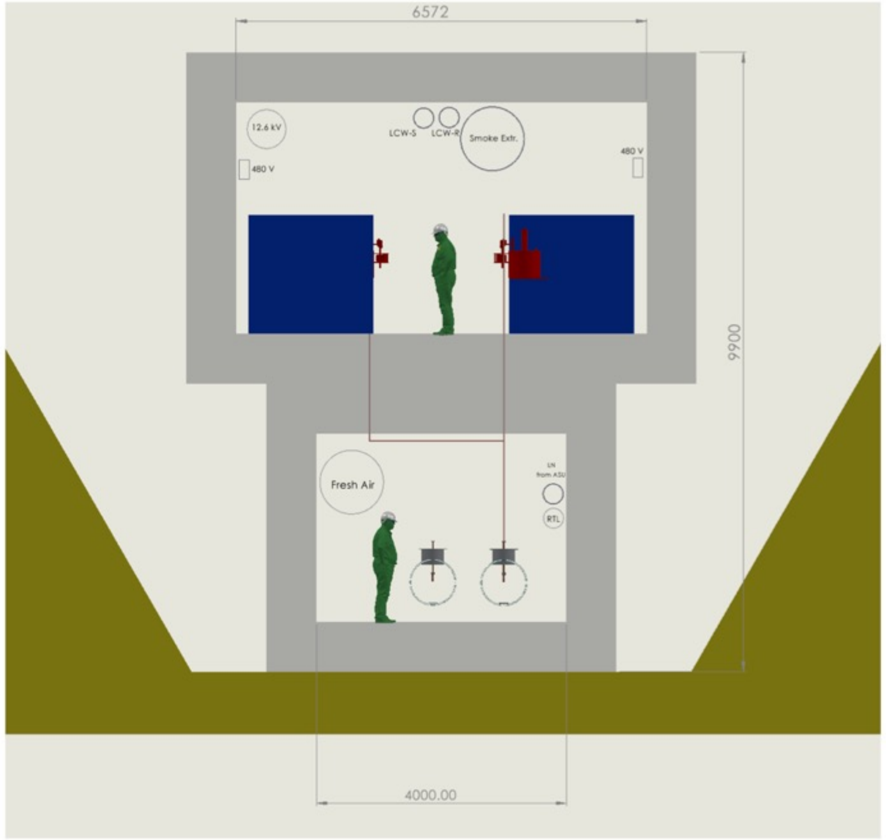
Double it to account for top-down vs. bottom-up **(120 kton CO_2)**



Cut and cover

Preferred option for reduced construction costs and emissions (but not required)

- Much of the displaced earth is pushed on top (shielding), only ~40k m^3 must be transported away

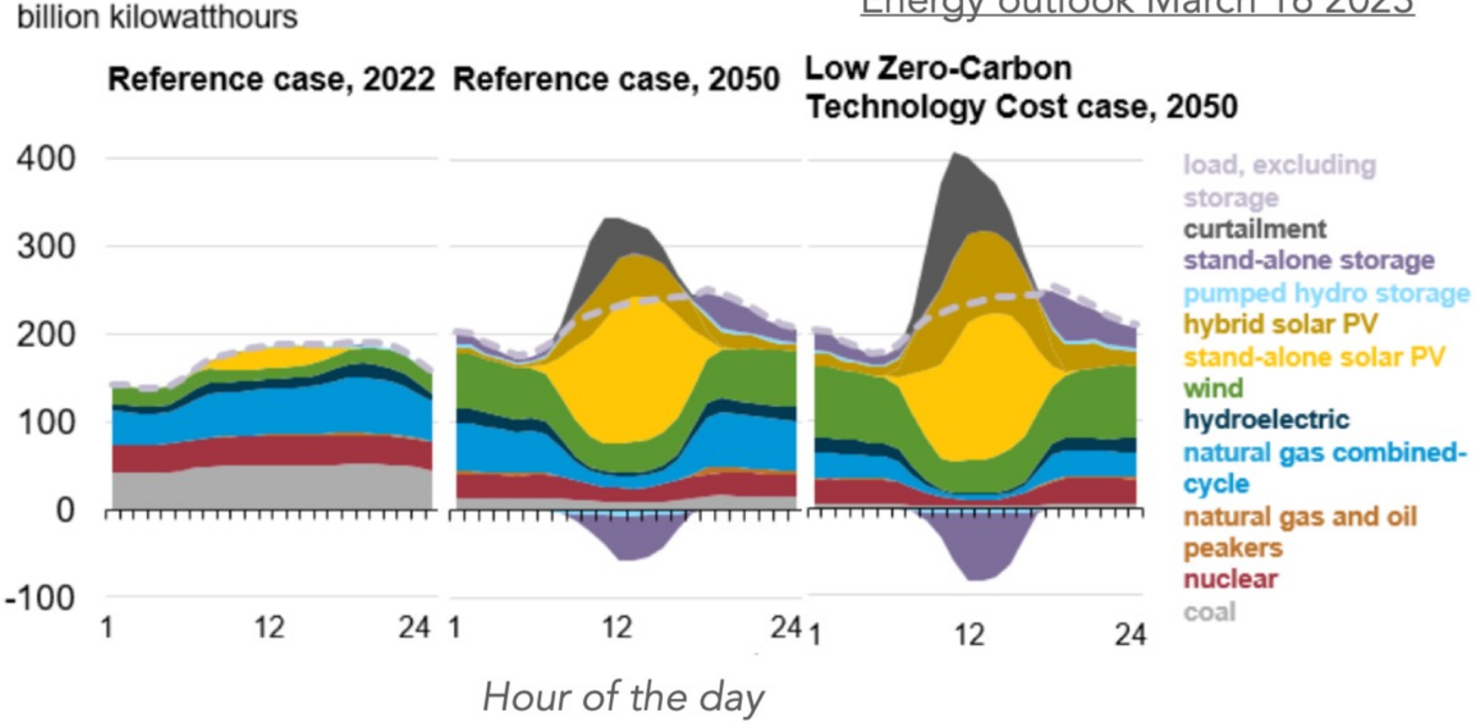


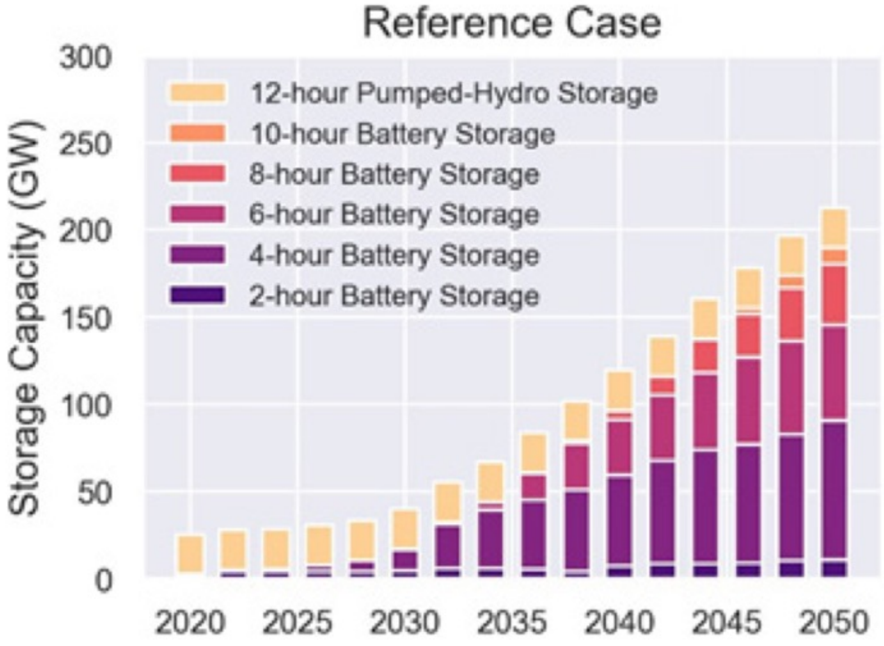
Operations emissions

Solar and wind are established technologies, the question is how to store it?

By 2040, 8 hours of energy use for C^3 at 150 MW **is < 1% of grid capacity**

Energy outlook March 16 2023





NREL Storage Futures Study

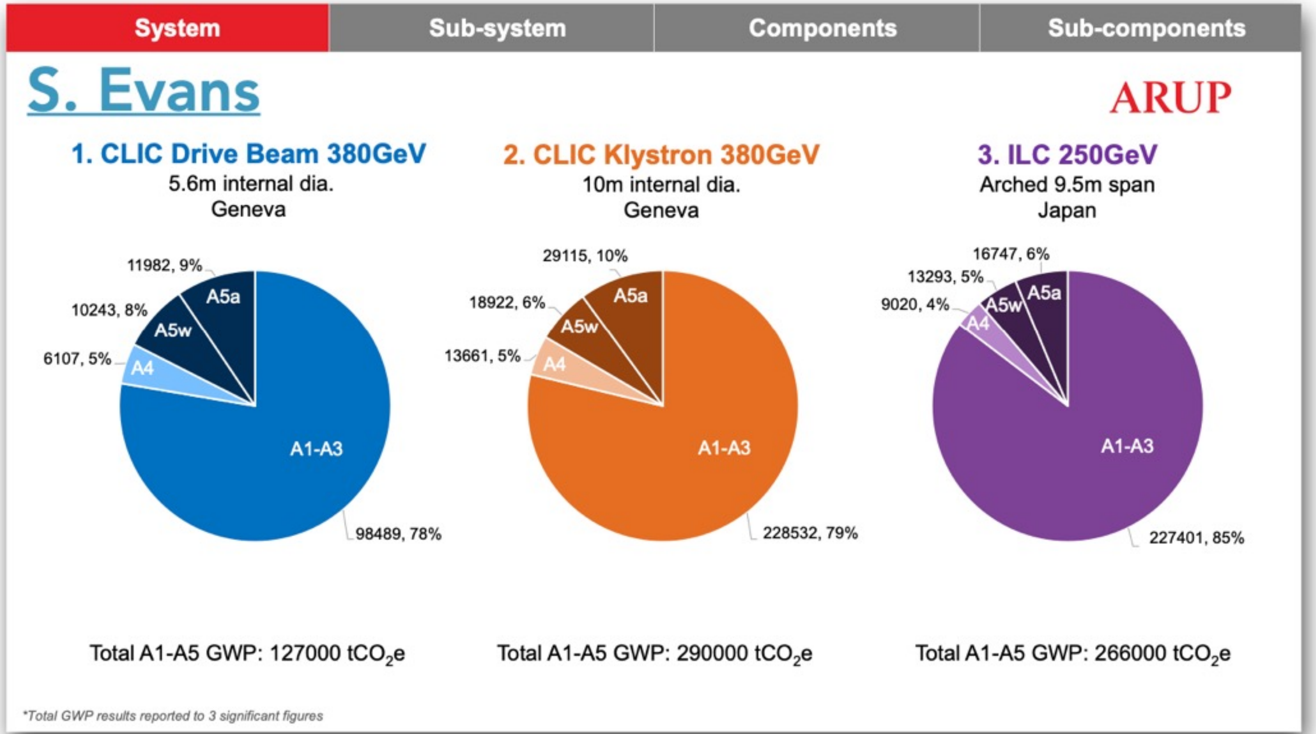
With access to renewables (e.g. dedicated solar/wind farms), we can leverage the grid to smooth energy load curve

→ ***any facility can have access to 20 gCO_2e/kWh energy with their own solution (e.g. Green ILC)***

Collider project inputs

SLAC

- ARUP analysis indicates 80% of construction emissions arise from materials (A1-A3), remaining from material transport and construction process
  - More thorough than Snowmass report - rely on it for inputs for other Higgs factory parameters!
  - Approximate global warming potential (GWP) for tunnels ~6 tn/m for CLIC/ILC, apply for circular collider concepts



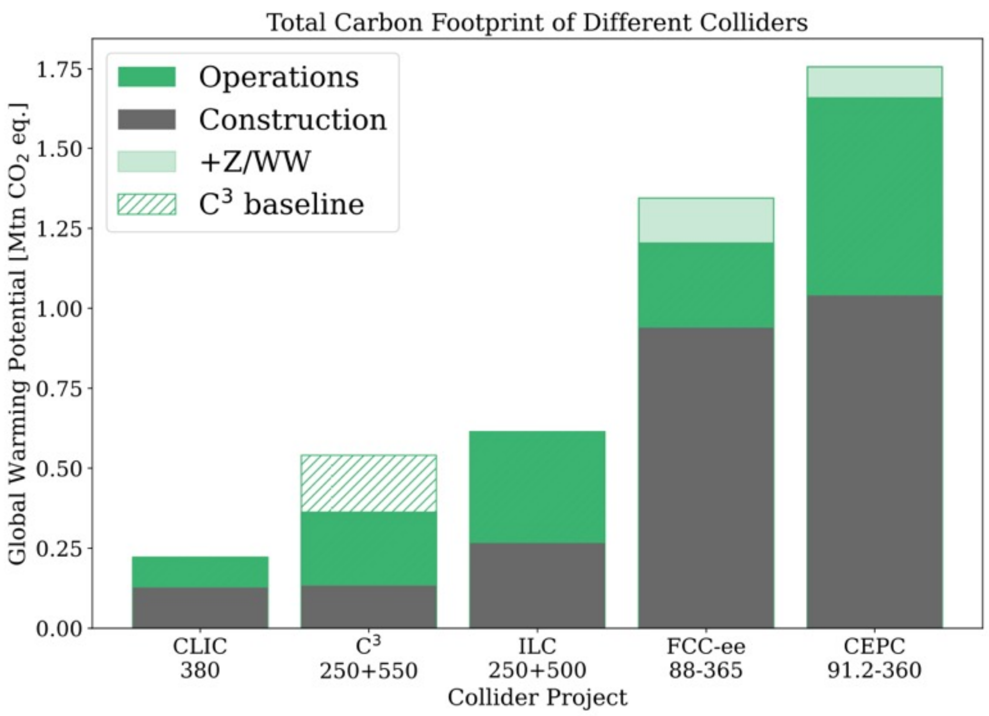
Project	Main tunnel length (km)	GWP (kton CO_2e)		
		Main tunnel	+ Other	+ A4-A5
FCC	90.6	578	751	939
CEPC	100	638	829	1040
ILC	13.3	97.6	227	270
CLIC	11.5	73.4	98	125
C³	**8.0**	**133**		**146**

Estimating +30% concrete volume for shafts, klystron gallery, caverns +25% for A4-A5 construction processes for circular colliders

For C³, estimate A4-A5 for surface site is half that for tunnel (ILC/CLIC)

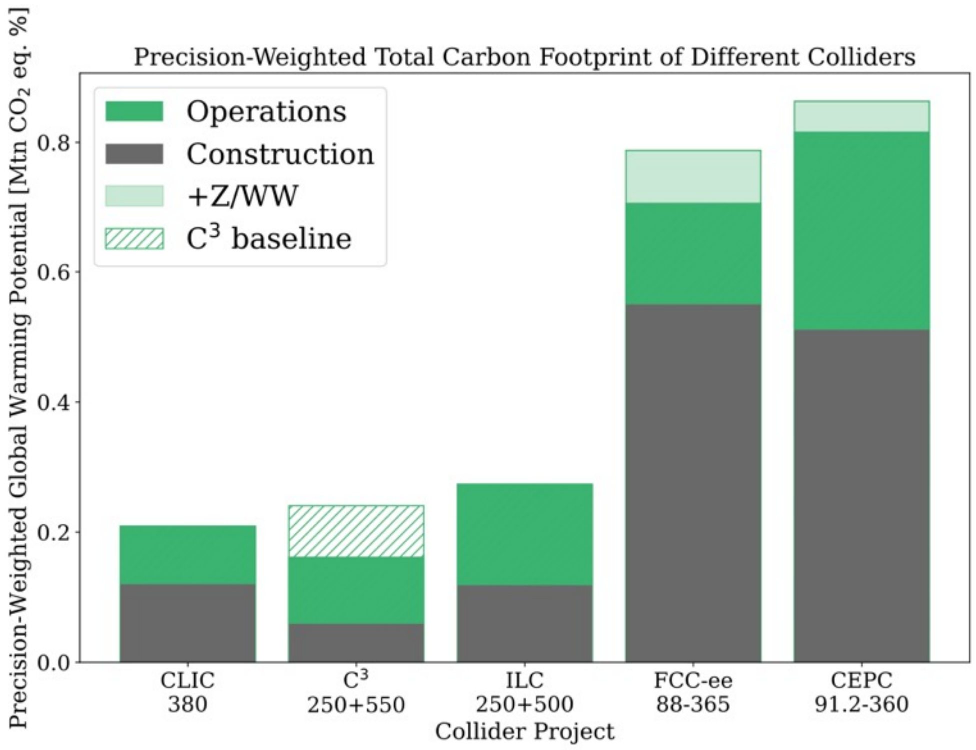
Total carbon footprint

Absolute total emissions



Impact of embodied carbon in construction materials is the driving factor of GWP

Total emissions x average coupling precision



Considering also the physics reach, linear colliders are clearly superior with optimized C^3 on top!

Linear colliders

Sustainability studies for LCs
Life Cycle Assessments

Steinar Stapnes

EAJADE WP4: Morioka 27.9.2023

Initial considerations

- Resource optimization as traditionally done for accelerators:
  - Length/complexity -> construction cost
  - Power/energy consumption -> operating costs

Traditionally we optimize for energy reach and luminosity wrt to cost and power

- Sustainability in a wider sense adds new construction and operation optimization criteria:
  - Energy use not only costs but also CO_2, embedded CO_2 in construction materials and components, rare earth usage, responsible sourcing in general for all parts, landscaping, integration in local communities, life cycle assessments including decommission and many more issues

Approaches to increase sustainability

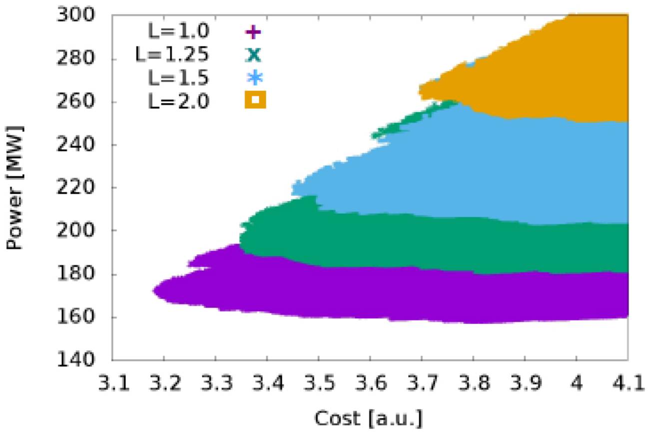
- Overall system design
  - Compact accelerator -> high gradients, high field magnets
  - Energy efficient -> low losses (wall-plug to beam)
  - Effective -> small beam sizes to maximize luminosities
  - Energy recovery concepts
  - Civil engineering including landscaping and “community” integration
- Subsystem and component design, e.g.
  - High-efficiency cavities and klystrons
  - Permanent magnets, HTS magnets
  - Heat-recovery. e.g. in tunnel linings, possibly other components
  - Responsible sourcing and material choices for all parts
- Sustainable operation concepts
  - Renewables
  - Adapt to power availability
  - Exploit energy buffering potential
  - Recover low grade energy (heat)

Good progress on the red points (was also part of our tradiational approach), initial progress/focus on the yellow/black ones

From costs and power to sustainability and life cycle assessments

1. Reduce power/energy (hand in hand with cost optimisation)
2. Operation energy use means carbon –> use the minimum energy, of the right type and at the right time, compensate
3. Life Cycle Assessments

Power optimization

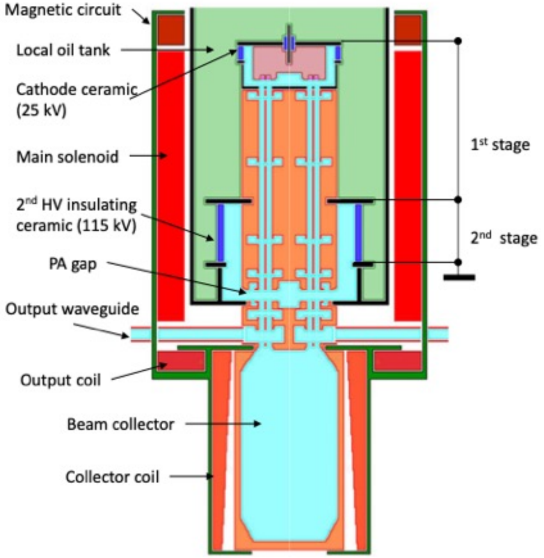


Parameter scans to find optimal parameter set, change acc. structure designs and gradients to find an optimum

The designs of CLIC, including key performance parameters as accelerating gradients, pulse lengths, bunch-charges and luminosities, have been optimised for cost and power

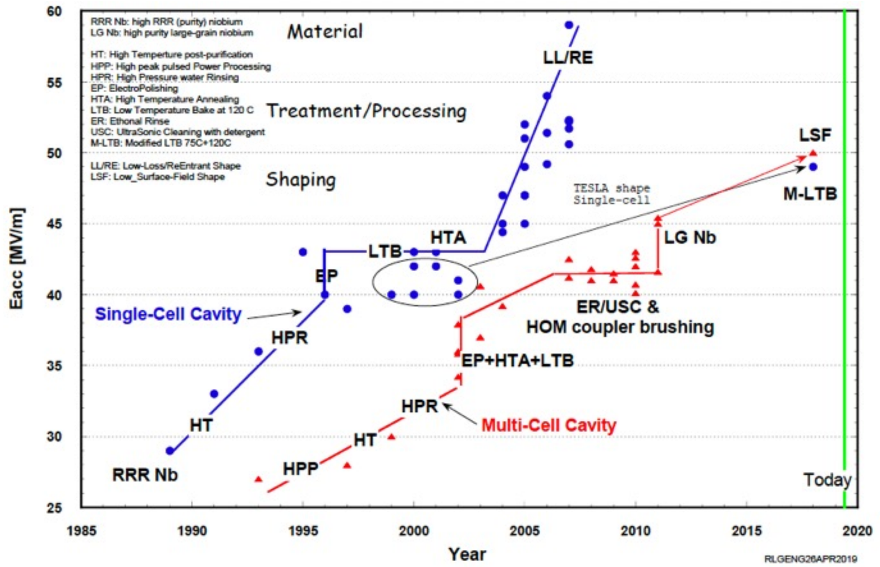
High Eff. Klystrons

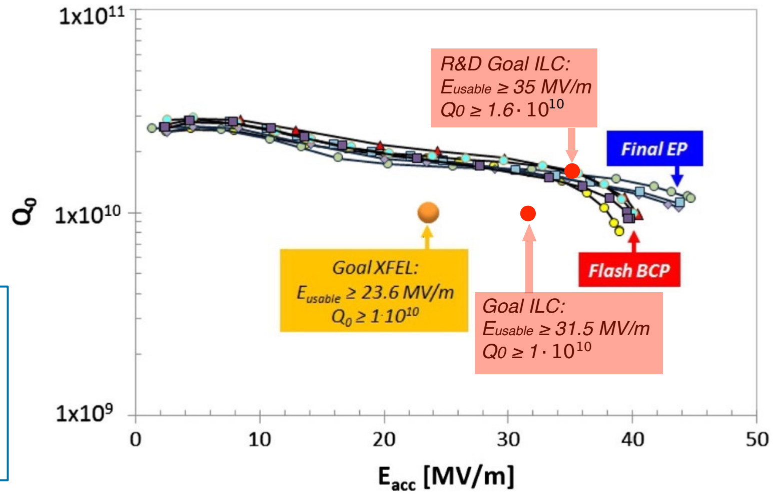
L-band, X-band (for applications / collaborators and test-stands



SRF

Surface treatment, higher gradient, improve Q0, avoid electropolishing, remove bulk niobium





Permanent magnets

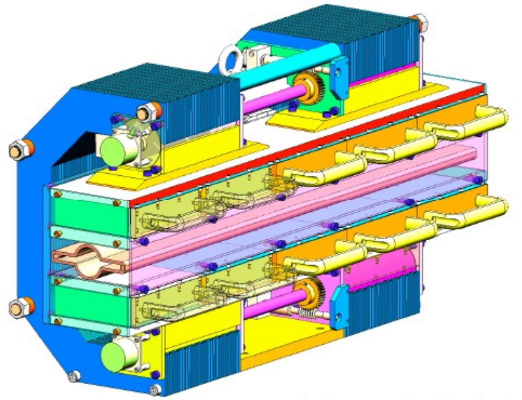


Figure 3: Overview of possible design of PM dipole for ILC damping ring.

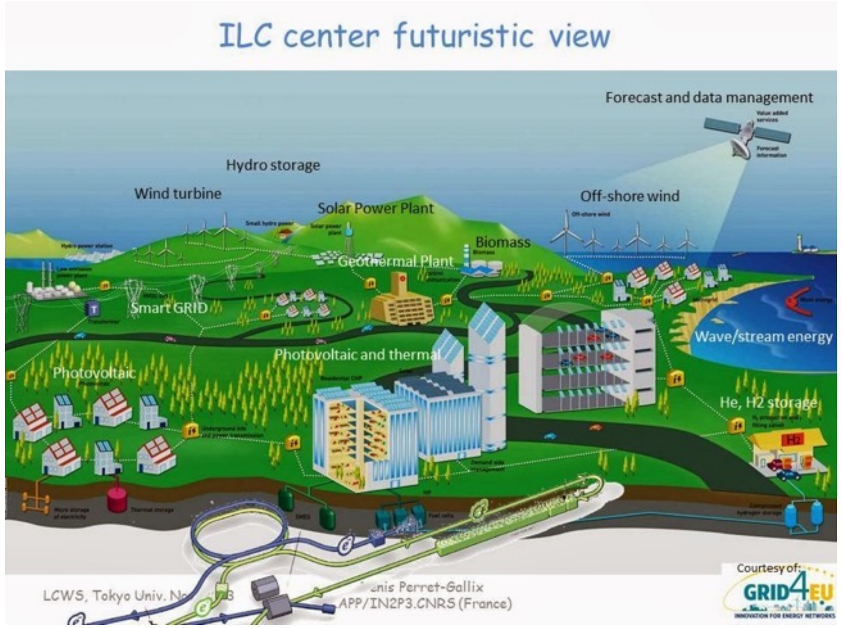
1.5 TeV CLIC power
Magnets second largest

E.g. ZEPTO project
CERN / STFC

Heat recovery
where possible

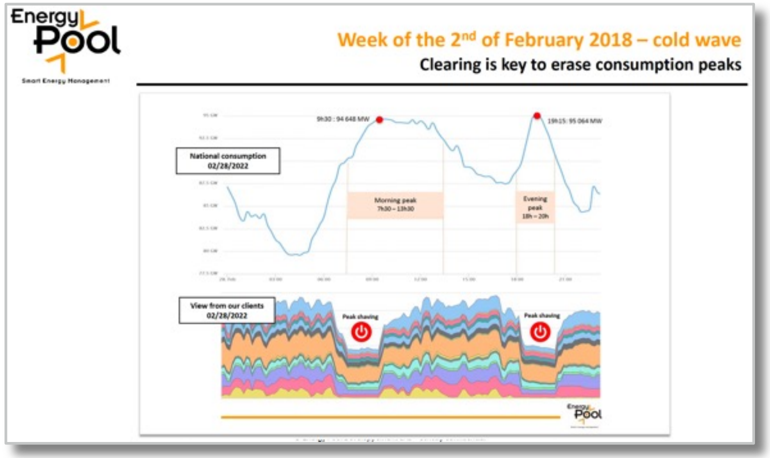
Nanobeams
reducing beam sizes
Increasing lumi

Green ILC



Running on renewables and when energy is cheap

Demand-side flexibility

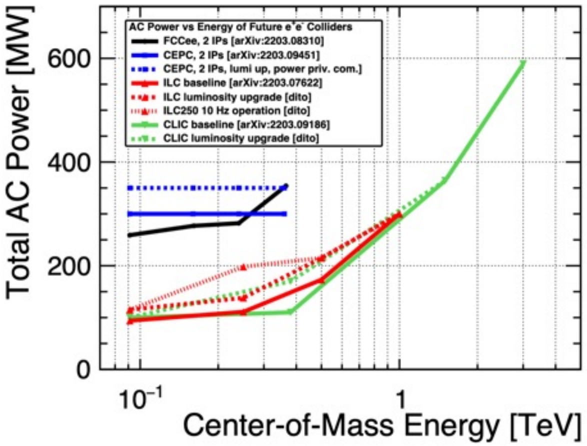


C. Gaunand, B. Remenyi: *Introduction to Demand Side Flexibility*
ESSRI Workshop 2022 https://indico.esrf.fr/event/2/contributions/94/

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.

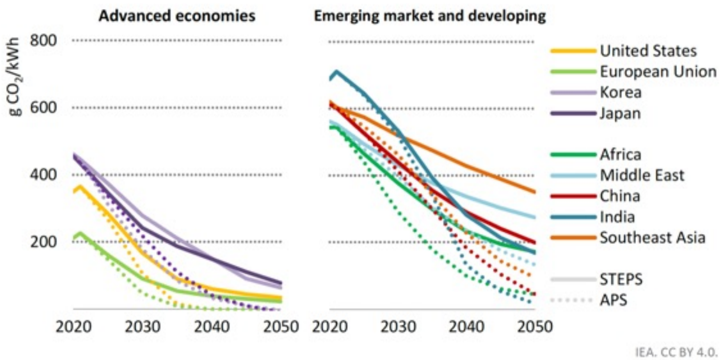
Machine choice and minimizing running power (also major cost driver)



Electricity contract design (e.g. renewables, long-term etc.)

And note CO2 / kWh will go down globallly

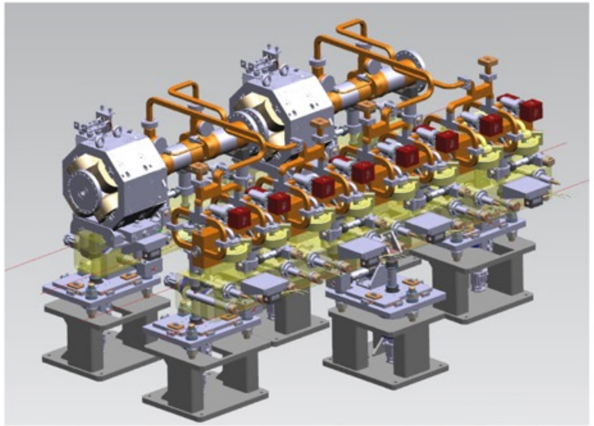
Figure 6.14 ▷ Average CO_2 intensity of electricity generation for selected regions by scenario, 2020-2050



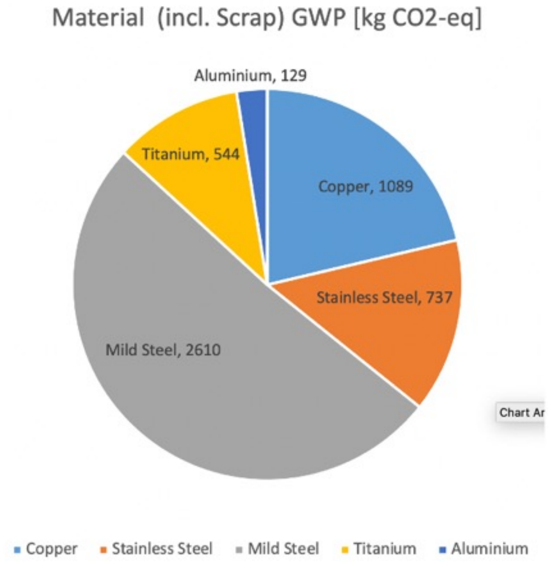
CO_2 intensity of electricity generation varies widely today, but all regions see a decline in future years and many have declared net zero emissions ambitions by around 2050

Looking at the impact of the accelerator components

- Study to estimate the Green House Gas emissions from raw materials in CLIC 2-beam module, including waveguides and supports
- ~2.5t CO2-eq / m:
  -> about half of CO2 for tunnel
- Half of CO2 impact is steel for supports
  -> optimization potential
- Services (power, cabling, cooling, ventilation) not included
- Situation in magnet-heavy sections (e.g. turn-arounds, bends, damping rings) may be different



CO2 impact of accelerator components is comparable to CO2 of main tunnel – to be studies but easily 5 kton/km



Note (yesterday's warning): What about material processed away, recycled or not ?

Sustainable Technologies

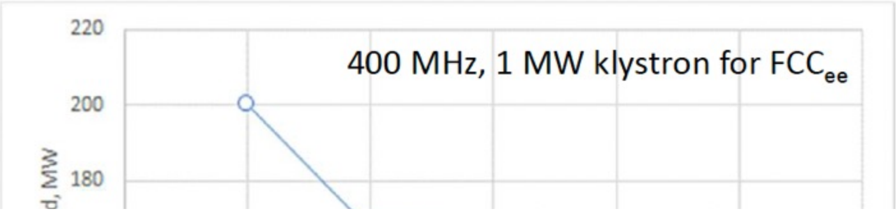
- High-Efficiency Klystrons @ CERN: I. Syratchev
- Sustainable Accelerator R&D in the UK: B. Sheperd

High Efficiency Klystrons

High Efficiency Klystrons Projects at CERN

I. Syratchev for CERN & ULAN HE klystron team

Grid power required for the large-scale HEP Accelerators.



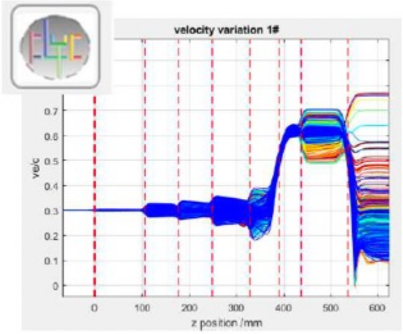
High Efficiency Klystrons

High Efficiency klystrons activity was initiated at CERN in 2014. In 2021 it was transformed into a CERN's **project.**

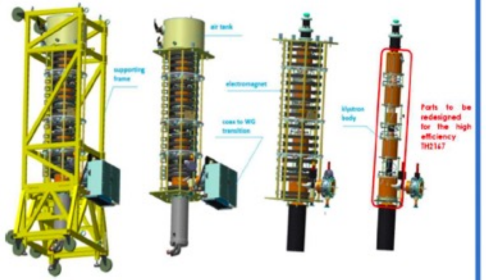
Objectives: Development, design, fabrication and testing of the new HE klystrons for application in various particle accelerators.

To operate FCC_{ee}, **100 MV** RF power is needed to ac and to compensate for th synchrotron radiation.

*100 MW, CW ~ 100 000 Microwave ovens

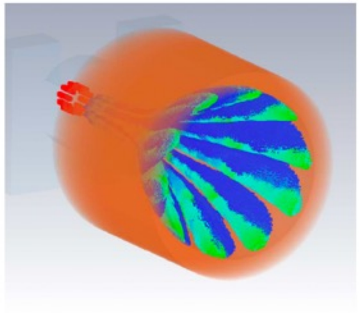


Task 1: Design & simulations
- Maintenance and distribution of the CERN made klystron code KlyC.
- High level expertise in using commercial tools like CST PIC, HFSS etc.



Task 2: HE LHC 400 MHz klystron
- Retrofit upgrade of Thales klystron (60% to 70%) in close collaboration with industry.
- **A base line option for HL-LHC.**

Selected topic

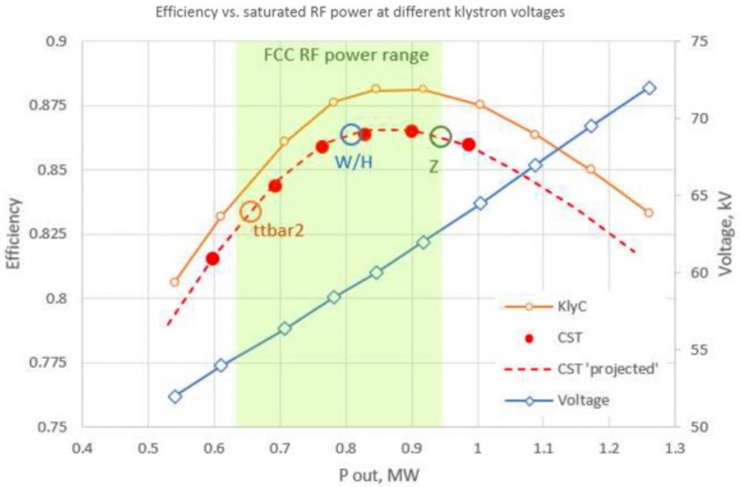


Task 3: Novel two-stage klystron technology with 80%+ RF production efficiency
- Design, fabrication and testing of the 400 MHz 1MW CW klystron for **FCC** in collaboration with industry.
- Promote this new technology towards CLIC, ILC and Muon_C.

First commercial X-band 10 MW HE (56%) klystron. CERN-Canon collaboration.

Task 4: High efficiency X-band pulsed klystrons in the power range 10-50MW
- Strong Collaboration with industry (Canon, CPI and Thales).
- Important for multiple projects (CompactLight, DEFT, EUPRAXIA etc.).
- Great show case for CERN's technology and **contribution to worldwide society.**

400 MHz HE Two-Stages MBK for FCC_{ee}. Performance summary.



Featured:

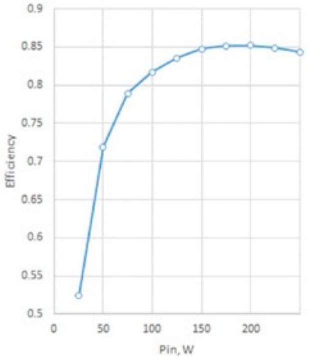
- **Very efficient**. 86% @ Z,W,H and 83% @ ttbar2.
- **Compact**. Total length <3m.
- **Low Voltage**. Up to 64kV @ 1 MW.
- **High RF power gain**. 43dB @ 1MW.
- **Broadband**. 3.5 MHz @ -1dB.
- **Robust**. Can handle mismatch up to -15dB.

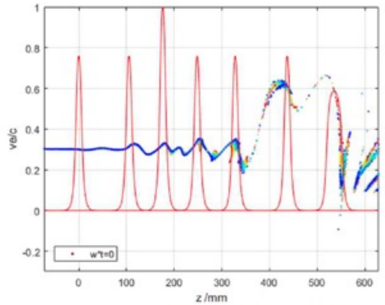
Project status @ CERN

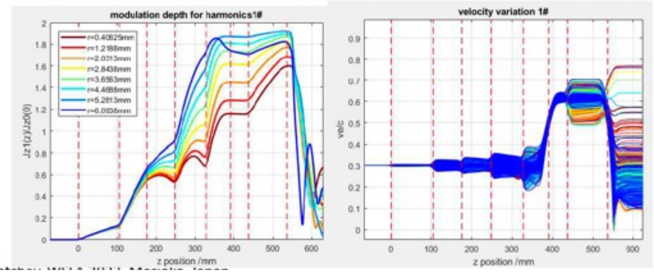
- ✓ RF circuit
- ✓ Collector
- ✓ Cathode
- ✓ Solenoid
- ✓ Special High Voltage isolated RF feedthrough (prototype).
- ❑ Integration
- ❑ Thermal/mechanical analysis

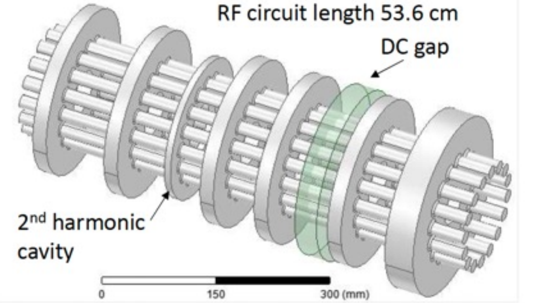
High Efficiency 10 MW, 1.3 GHz, pulsed ILC TS 15 beams MBK

Parameter	TS MBK	E37536	Unit
Operating frequency	1300	1300	MHz
Voltage at the 1st stage	25	118.8	kV
Voltage at the 2nd stage	140		
Total beam current	88	129.5	A
Number of beamlets	16	6	
Number of cavities	7	6	
Perveance at the 1st stage	1.68	0.53	μA/V^3/2
Perveance at the 2nd stage	0.105		
Output RF power	10.5	10	MW
Saturated power gain	47.2	48.2	dB
Saturated efficiency	85	65	%
Length of RF circuit	536	---	mm









High Efficiency 24 MW, 1 GHz, pulsed CLIC TS 30 beams MBK.

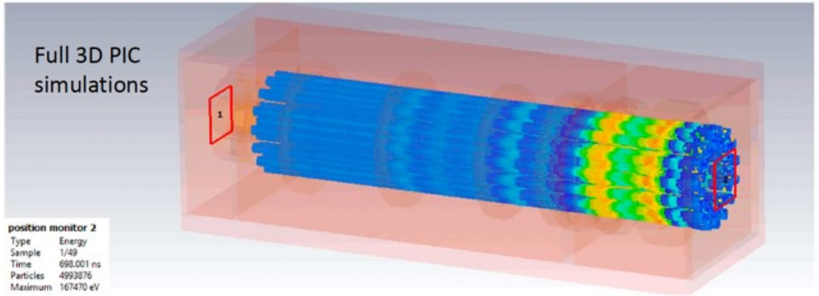
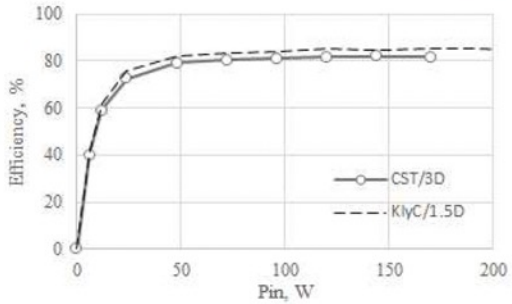
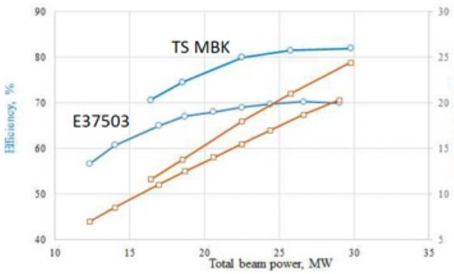


TABLE I. DESIGN AND SIMULATED PARAMETERS (CST/3D) OF THE CLIC TS MBK AND CANON MBK E3750 CATALOGUE DATA

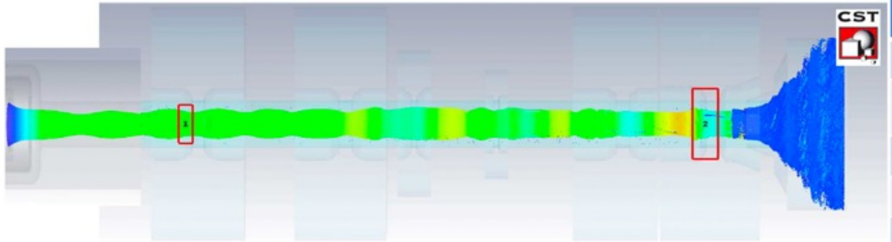
Parameter	TS MBK	E37503	Unit
Operating frequency	1000	1000	MHz
Voltage at the 1st stage	25	160	kV
Voltage at the 2nd stage	140		
Total beam current	212	180	A
Number of beamlets	30	6	
Number of cavities	6	6	
Perveance at the 1st stage	1.77	0.47	μA/V^3/2
Perveance at the 2nd stage	0.133		
Output RF power	24.1	20	MW
Saturated power gain	52	54	dB
Saturated efficiency	82	70	%
Length of RF circuit	900	1500	mm





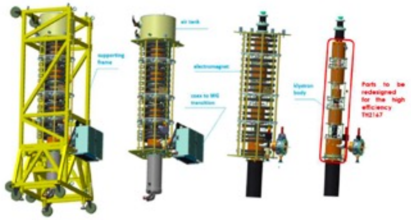
Retro-fit High Efficiency (70%) 350kW, 0.4 GHz CSM LHC klystron upgrade for HL-LHC.
(in collaboration with Thales)

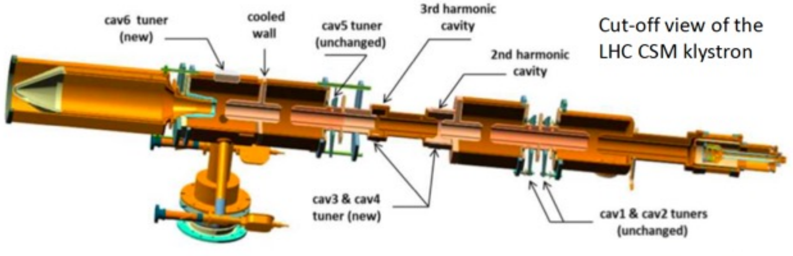
3D PIC full simulations



	LHC/CSM	LHC/Thales
Frequency, GHZ	0.4	0.4
Beam power, MW	0.5	0.5
Perveance,	0.72	0.72
RF power, MW	**0.35**	**0.30**
Efficiency, %	70	60

Re-used housing, electron gun and solenoid





Cut-off view of the LHC CSM klystron

FAT is scheduled to May 2024.

Science and Technology Facilities Council

ASTeC

Sustainable Accelerator R&D in the UK

Ben Shepherd

Accelerator Science and Technology Centre, STFC Daresbury Laboratory

The International Workshop on Sustainability in Future Accelerators

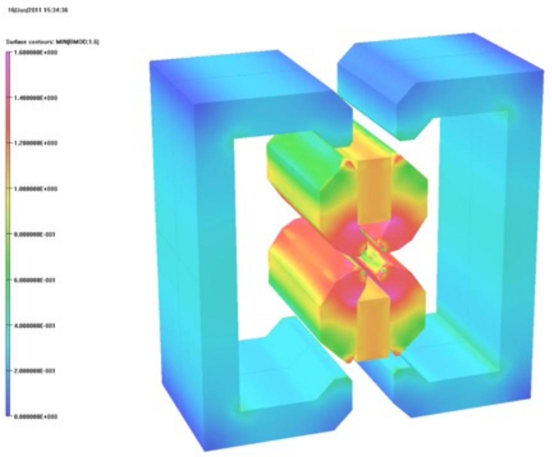
Morioka, Japan

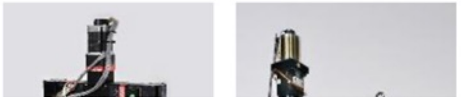
25-27 September 2023

Shepherd *et al*, IPAC2014 TUPRO113

Green Projects: ZEPTO

- **Ze**ro-**P**ower **T**unable **O**ptics
- Tunable PM quadrupole and dipole magnets to replace electromagnets
  - Large **tuning range** using motors to move PMs
  - Same **physical footprint**
  - No **energy usage** (except a tiny amount when adjusting)
  - Less **infrastructure** required (no big current cables, power supplies, cooling)
- Two prototypes built at STFC Daresbury Laboratory
  - **27 mm** aperture
  - **230 mm** length
  - **15-60 T/m, 4-35 T/m** ranges
  - Fixed poles, movable PMs
  - Simple control system with one motor



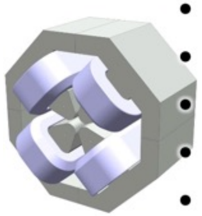


ZEPTO: comparing carbon footprints

- Electromagnetic quadrupole
- Main materials: steel, copper
- Manufacture impacts

steel 201kg | copper 52kg

- Operation costs
  - 856W at 100% excitation
  - Another 250W for cooling
  - Assume 251 days / year operation
  - 6.7 MWh / year
  - EU avg intensity 225 gCO2e/kWh



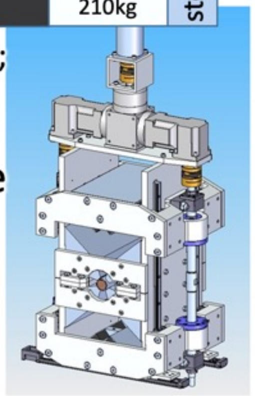
electricity 1160 $kgCO_2e$ / year | cooling 340 $kgCO_2e$ / year

- Permanent magnet quadrupole
- Main materials: steel, NdFeB, aluminium
- Manufacture impacts ($kgCO_2e$)

NdFeB 1097kg | aluminium 210kg | steel 91kg

(big uncertainties in NdFeB footprint; using recycled magnets could significantly reduce it)

- Operation costs: negligible
- "Carbon payback": 1 year



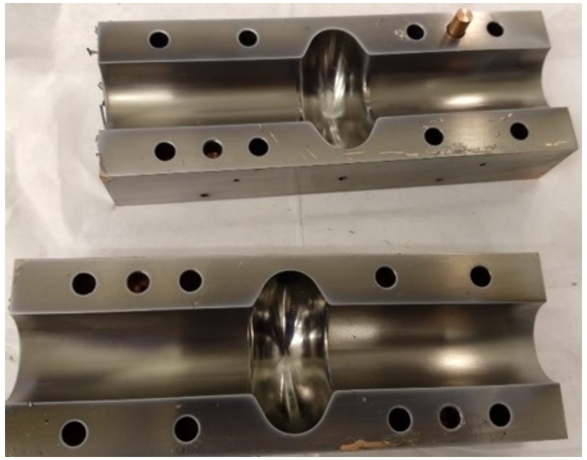
Thin Film Superconducting RF

- **Bulk niobium cavities** have been the choice for SRF for the last 50 years
- Use a considerable amount of natural material
- Performance limit of niobium has been reached
- Costly to produce
- Run at a temperature of 2 K
  - A considerable cryogenic demand and energy load

Benefits of thin films

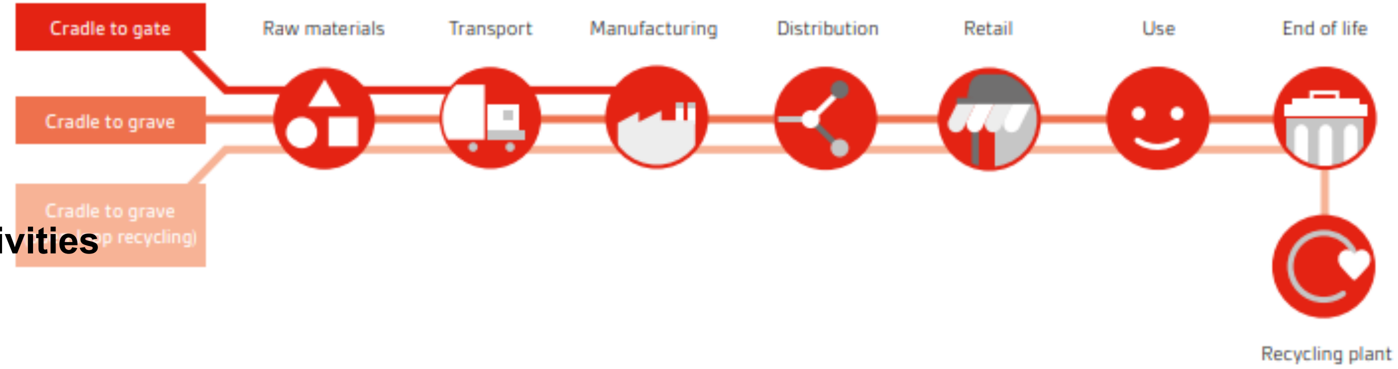
- Use a copper supporting cavity
  - Better thermal properties, cheaper material and production
- Use different superconducting materials (e.g. Nb_3Sn, NbN and MgB_2)
  - Better performing materials than Nb that can't be formed into solid cavities
- Higher operation temperature of new alloys
- Reach higher accelerating gradients

6 GHz split cavity with Nb coating

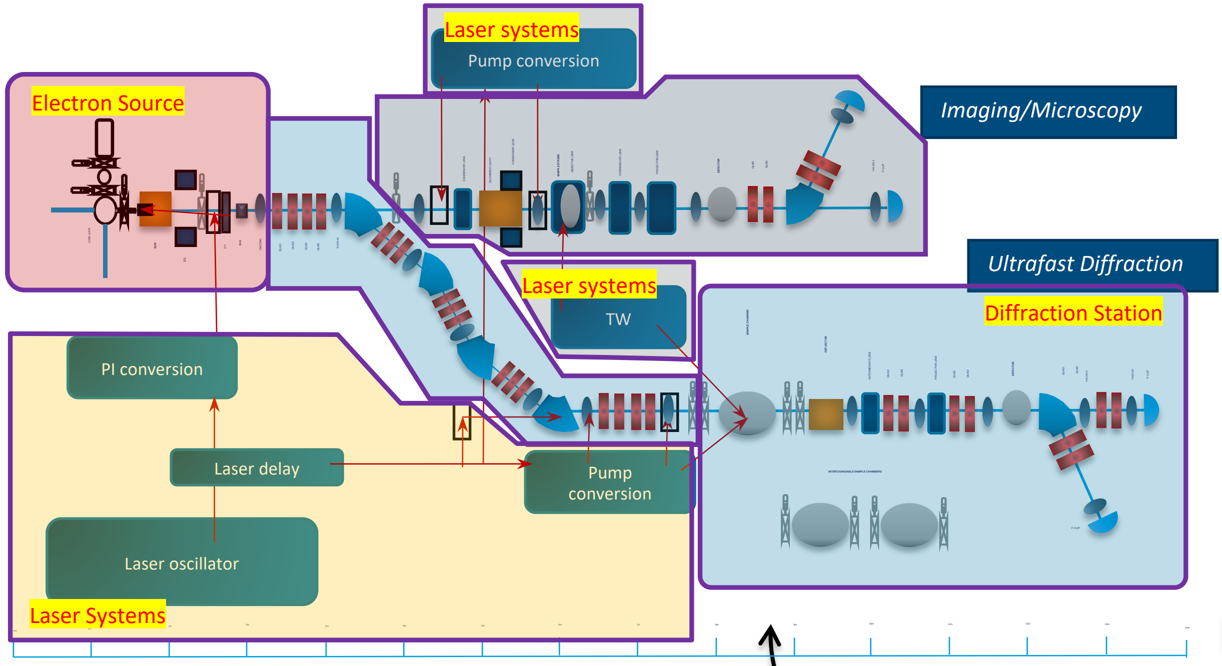


- Easy to coat with either conventional planar magnetron or in tubular geometry used for RF cavities
- Easy to inspect
- Three 6 GHz cavities have been manufactured, mechanically polished and tested at RT and T = 4.2 K
- 1st cavity Nb coated and tested at 4.2-9.5 K

Lifecycle analysis



- Detailed review of the **climate impact of accelerator activities**
- Where are the **Big Sources** of emissions?
  - **Manufacturing?** Steel / Copper / Aluminium / Concrete
  - **Operations?** Running RF and magnet systems. Cooling & AC
  - ~~**Disposal?** End of life of components –~~ not considered (yet)
- How can we **reduce these** for the biggest impact?
  - Using different materials
  - Improved efficiency
  - Smart powering schemes
- **RUEDI*** is our case study for this exercise
- Considered wider applicability for other accelerators too
- Figure of merit is **kgCO_2e** per "delivered unit"
  - Other environmental impact indicators are available (land use change, ocean acidification, eutrophication etc) so this isn't really the same as a full LCA
  - So at the end, we should have a database listing carbon emissions for components in every area
- Look at the big picture; **not** every gram of CO_2 - not a bean-counting exercise!



*RUEDI = Relativistic Ultrafast Electron Diffraction & Imaging
Working towards TDR now

Magnets for RUEDI

- RUEDI is an electron diffraction and imaging facility
- Needs large electron lenses (solenoids) to bring the beam to a focus
- Smaller conventional dipoles and quadrupoles needed too
- Bill of materials: primarily steel and copper

CO_2 — all magnets 1.2 tCO_2e

- Electricity usage

CO_2 — imaging lenses 7.6 tCO_2e/yr | diffraction lenses 9.5 tCO_2e/yr | others 3.3 tCO_2e/yr

Slide: Louise Cowie / Alan Wheelhouse

RF systems

- RUEDI uses normal-conducting RF
- Main power usage: klystron modulator
- RUEDI RF photoinjector: approximate energy use is **11 kW**
- Operational total for all RF systems (photoinjector, TDC, dechirper): **3.5 tCO_2e/yr**

CO_2 — electricity 3.5 tCO_2e / yr

- **Copper** and **steel** make up the largest fractions by mass of the RF system (modulators, klystrons, solid-state amplifier, LLRF units, waveguide, cavity)
- Emissions associated with raw materials:

CO_2

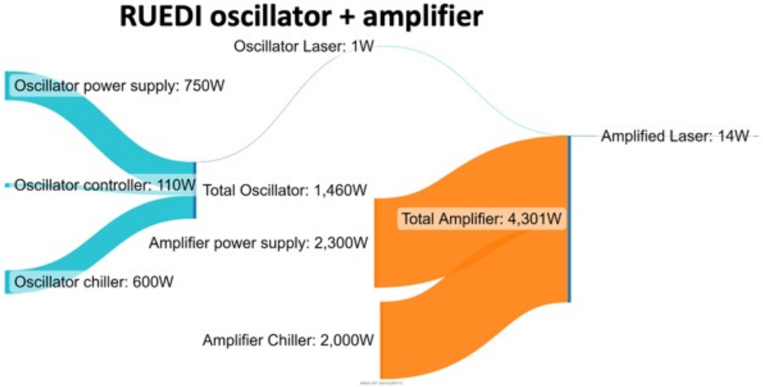
modulators 6.0 tCO_2e			others 1.5 tCO_2e
copper 2.0 tCO_2e	steel 1.7 tCO_2e	aluminium 2.6 tCO_2e	others 1.3

- Emissions from manufacturing are **not considered here** so this probably is a conservative estimate

Slide: Katie Morrow

Lasers

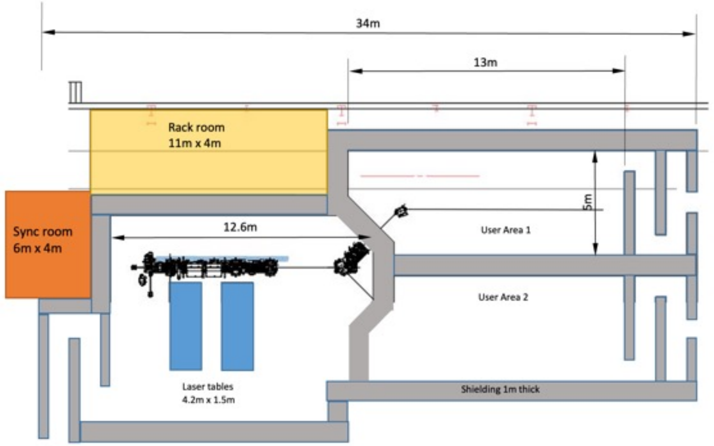
- Lasers are very power hungry due to their inefficiency
- Often lasers are used as pumps to make new lasers, compounding the inefficiency



- Altogether the oscillator + amplifier power supplies produce >8 tonnes of CO_2
- The most effective way to reduce the CO_2 emissions from the laser system is through improvements in efficiency

Slide: Hywel Owen

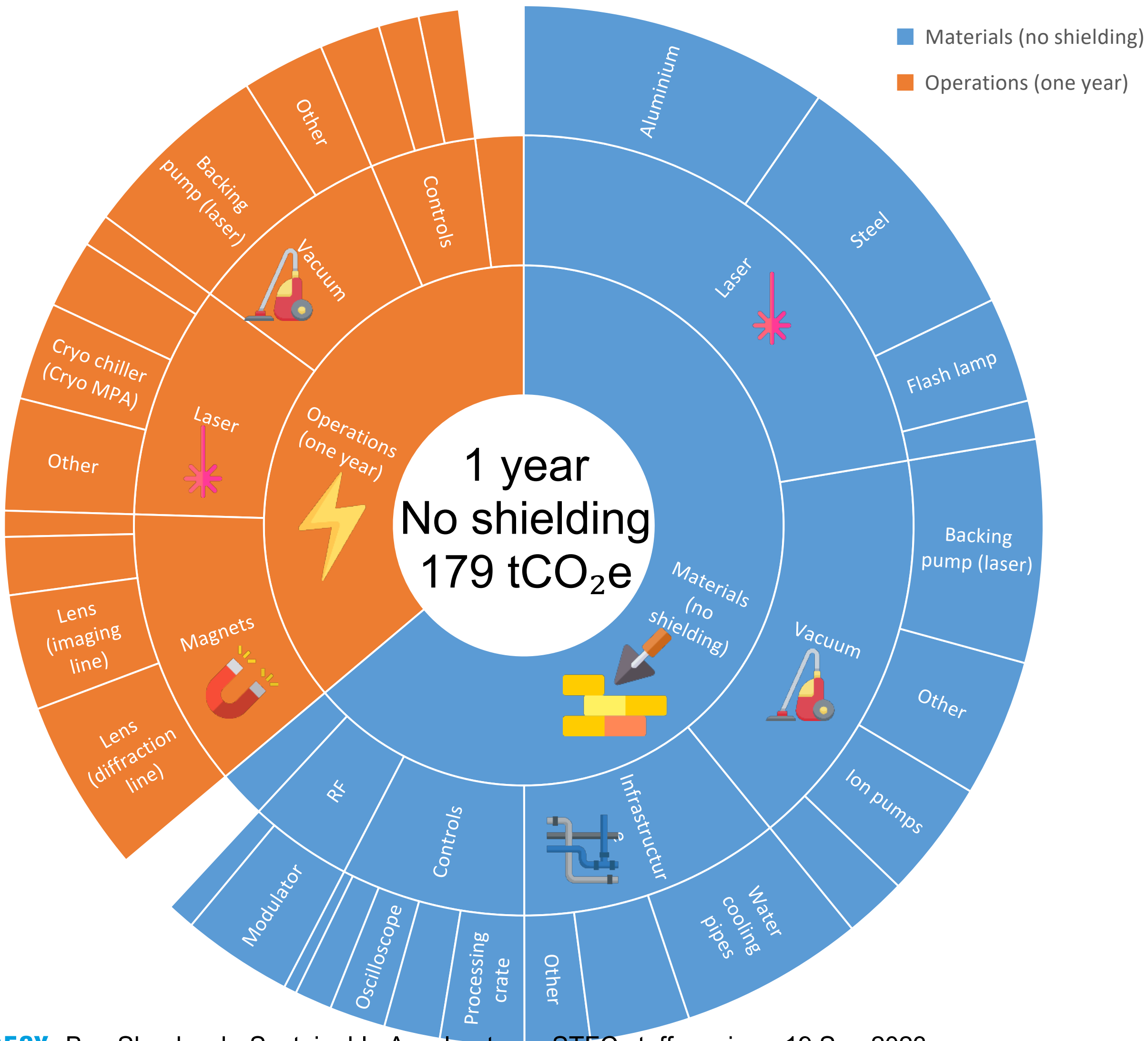
Concrete and CO_2

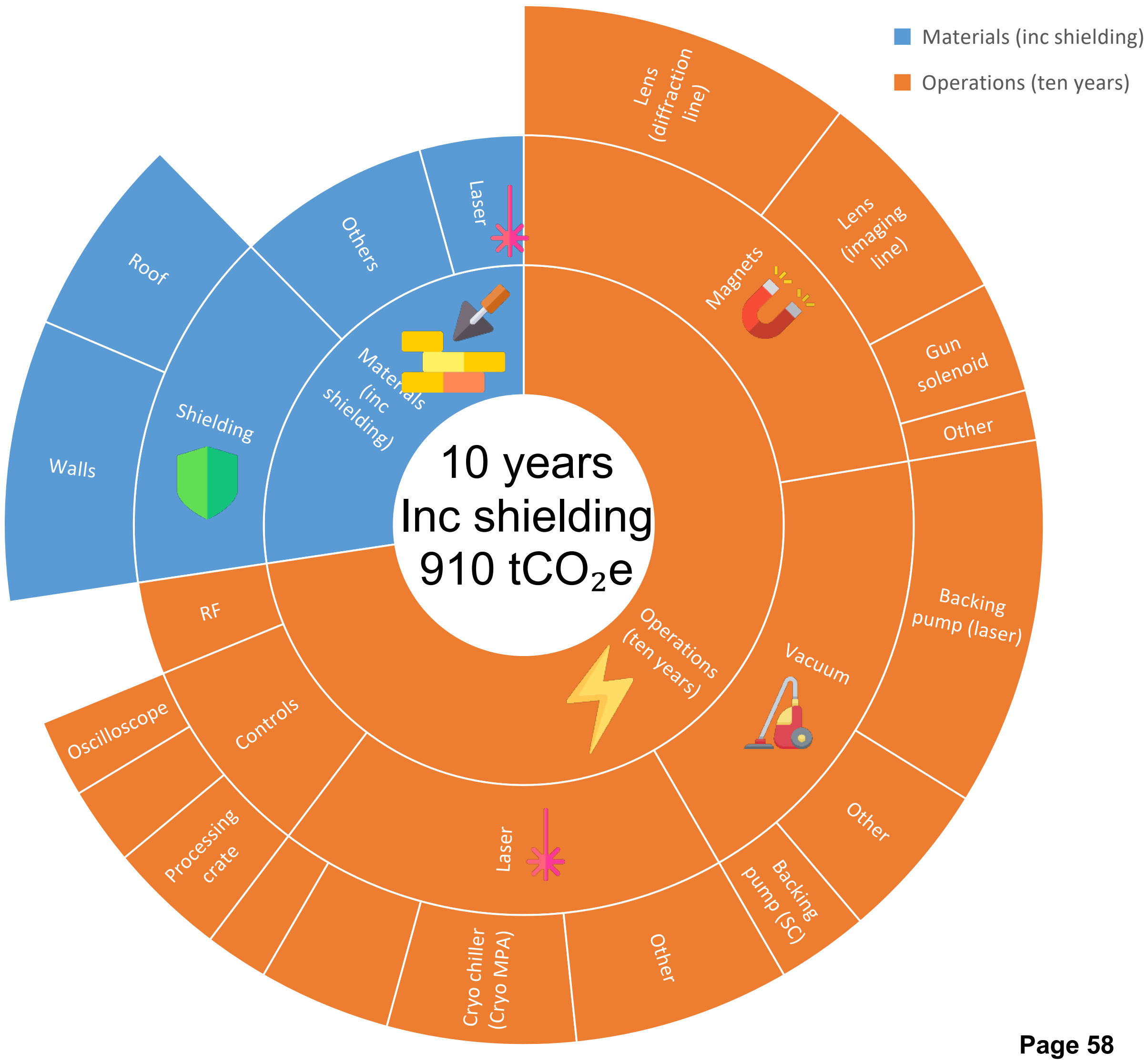


- Structural materials ('the building') and radiation shielding is a major component of nearly all particle accelerator infrastructure; these use **large quantities of concrete**
- Old 'rule of thumb' is half a project cost is accelerator, half is building
- Today's cement production accounts for 8% of global CO_2 emissions: **900 kgCO_2e/ton**
- CO2 production during cement manufacture is mainly due to clinker intermediary
- Possible mitigation strategies to be examined in sustainability report:
  - **Modular**/standardised shielding (blocks and beams), e.g. v-blocks, can be re-used/reconfigured
  - **Frame and infill** construction using (local) aggregates, earth, sand etc.
  - Replacement of clinker with **recycled materials** (fly ash, GGBS) – used in STFC EPAC project
  - **Alternative** shielding materials and combinations, e.g. for neutron shielding

RUEDI report: overall picture

Shielding: **137 tCO_2e**
Other materials: **113 tCO_2e**
Operation for 1 year: **66 tCO_2e**





Horizon-Europe & National Progammes

- **EAJADE: M. Titov**
- **iSAS: J. d'Hondt**

Note: At ESS (presentation by A. Sunesson) also programmes iFAST (addition of solar panels to power modulators) and FlexRICAN (studying flexibiility in power supply) discussed

- **Spanish Science Industry: E. Fernandez**
- **EU-Japan Regional & Cluster Cooperation Heldesk**

2014 → 2023

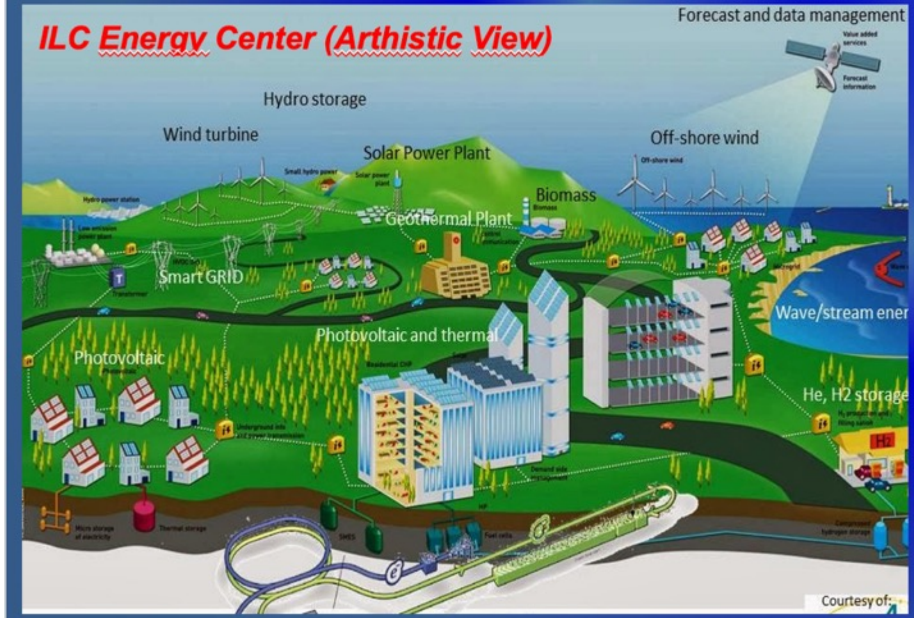
E-JADE
Europe -Japan Accelerator Development Exchange Programme

EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

Introduction to EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023) & EAJADE Work Package 4

Benno List (DESY)
Steinar Stapnes (CERN)
Maxim Titov (CEA Saclay/CERN)

International Workshop on
Sustainability in Future Accelerators,
Morioka, Japan, Sep. 25 - 27, 2023



EAJADE WP4: Sustainable Technologies for Scientific Facilities

Task 4.1 High-efficiency and sustainable SC cavities (CNRS, 2 person-months, with task 4.2): Advancement of superconducting cavity surface treatments with the goal to achieve the highest possible Q quality factors for low cryogenic losses; investigation of sustainable cavity production methods by reduction of electropolishing steps through improved heat treatment, and use of niobium raw materials with relaxed requirements on grain size and Ti content that allow more sustainable production methods. Furthermore, CEA and CNRS will collaborate with Cornell, KEK and Tohoku in the development and tests of new surface treatments for sc cavities. Also energy recovery schemes with smart RF loads will be studied.

Task 4.2 High-efficiency radio frequency power amplifiers (CNRS, 1 person-month): Investigate possibilities to improve the efficiency of radio frequency (rf) power generation by use of solid-state amplifiers to replace traditional klystrons.

Task 4.3 Energy Recovery Linacs (INFN, 2 person-months): Improve the overall energy efficiency through the implementation of novel schemes as the Energy Recovery Linacs capable of minimizing the overall AC plug power required without impacting accelerator performances. Japan hosts a leading facility in this scenario with its cERL at KEK, a compact and successful Energy-Recovery demonstrator, and we intend to join cERL team in order to deepen our understanding of operative issues and physics behind this emerging concept. INFN LASA expects this effort to largely benefit from the structured exchanges foreseen through EAJADE and moreover to be a valuable context to evaluate the possible applicability of such a machine layout to future generation of HEP colliders.

Task 4.4 Power Modulation (DESY, CERN, 2 person-months, interdisciplinary): Investigate means to make accelerators more suitable as consumers of regenerative energy sources (in particular solar and wind) by adjusting power consumption to RES energy availability. This includes e.g. operating modes with reduced power consumption, identification of internal energy buffering potentials. Improve the calculation package for power consumption in particle colliders (staging and operation scenarios)

Task 4.5 Smart Tunneling (CERN, 1 person-month, interdisciplinary): Investigate technologies to make construction and operation of accelerator tunnels more sustainable, by environmentally friendly construction methods and technological measures such as direct cooling / heat recovery from tunnel walls.

Note: MDI aspects relevant for other EAJADE WPs as well!

Task 4.6 Green ILC (CEA, 4 person-months, interdis for energy generation, distribution and storage for a green field accelerator site in Japan, with a focus on use of renewable energies and sustainable technologies (e.g. high temperature superconductor at liquid nitrogen temperature use for power transmission).

EAJADE WP4 - Sustainability

Maxim Titov

Sustainable Accelerator Construction: Q&A

- ***Operation costs dominated by energy (and personnel)***
  - Reducing power use, and costs of power, will be crucial → huge uncertainty in how the energy market, prices and price variations will be in ~2040 (ILC), ~2050 (CERN projects)
  - Carbon footprint related to energy source, relatively low already for CERN (helped by nuclear power), expected to become significantly lower towards 2050 when future accelerators are foreseen to become operational (in Europe, US and Japan).
  - Align to future energy markets, green and more renewables, make sure we can be flexible customer and deal with grid stability/quality
  - Other consumables (gas, liquids, travels, computing …) during operation need to be justified (and estimated)

- ***For carbon the construction impact might be (more) significant (also rare earths etc) than operational footprint***
  - *Construction: CE, materials, processing and assembly – not easy to calculate, very likely a/the dominating carbon source*
  - *Markets will push for reduced carbon, "responsible purchasing" crucial – construction costs likely to increase*
  - *Many other factors than a carbon life cycle assessment, rare earths, toxicity, acidity ..*
  - *Environmental studies, integration in local environment/power grids, very important (CERN generally, Green ILC)*

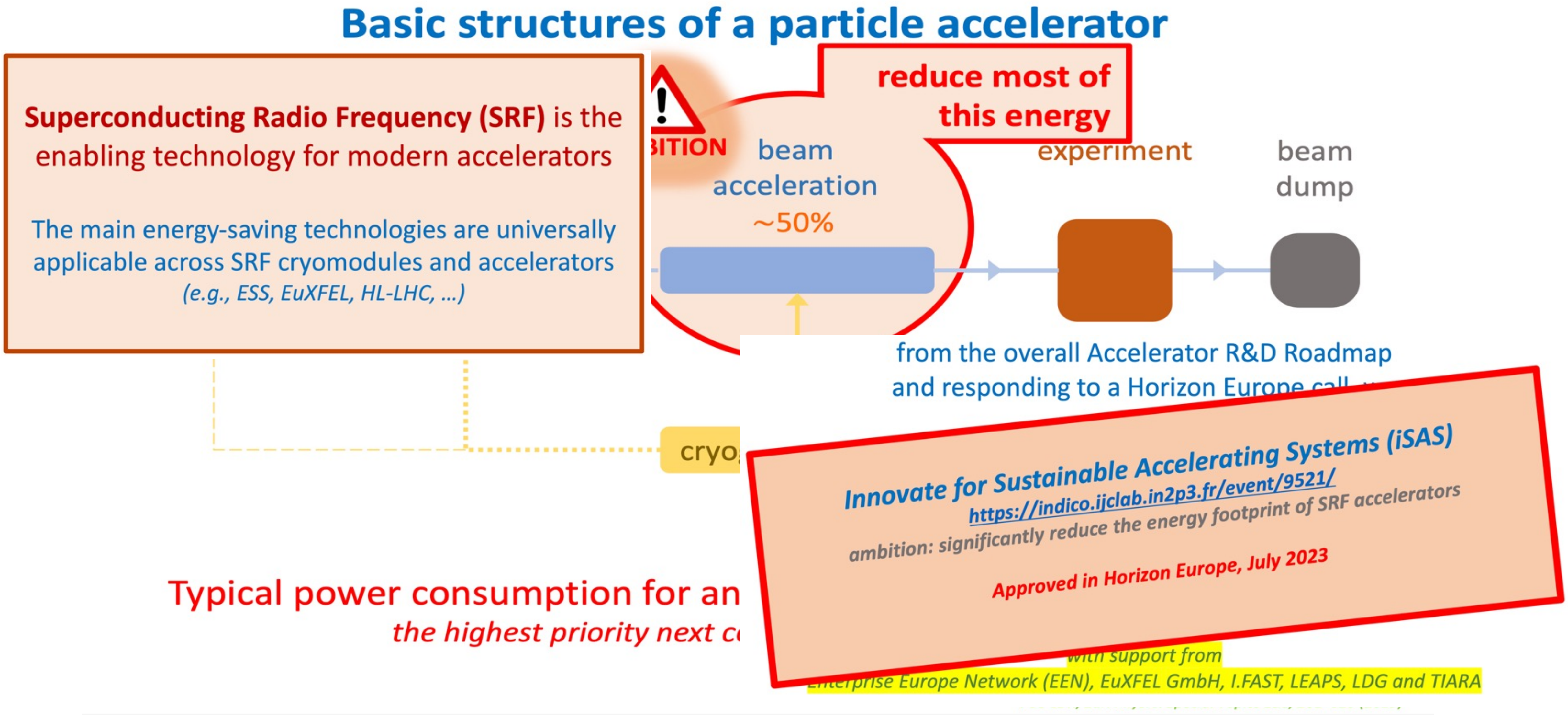
- ***Decommissioning – how do we estimate impacts ?***

European Horizon-Europe Programmes: iSAS

Jorgen d’Hondt

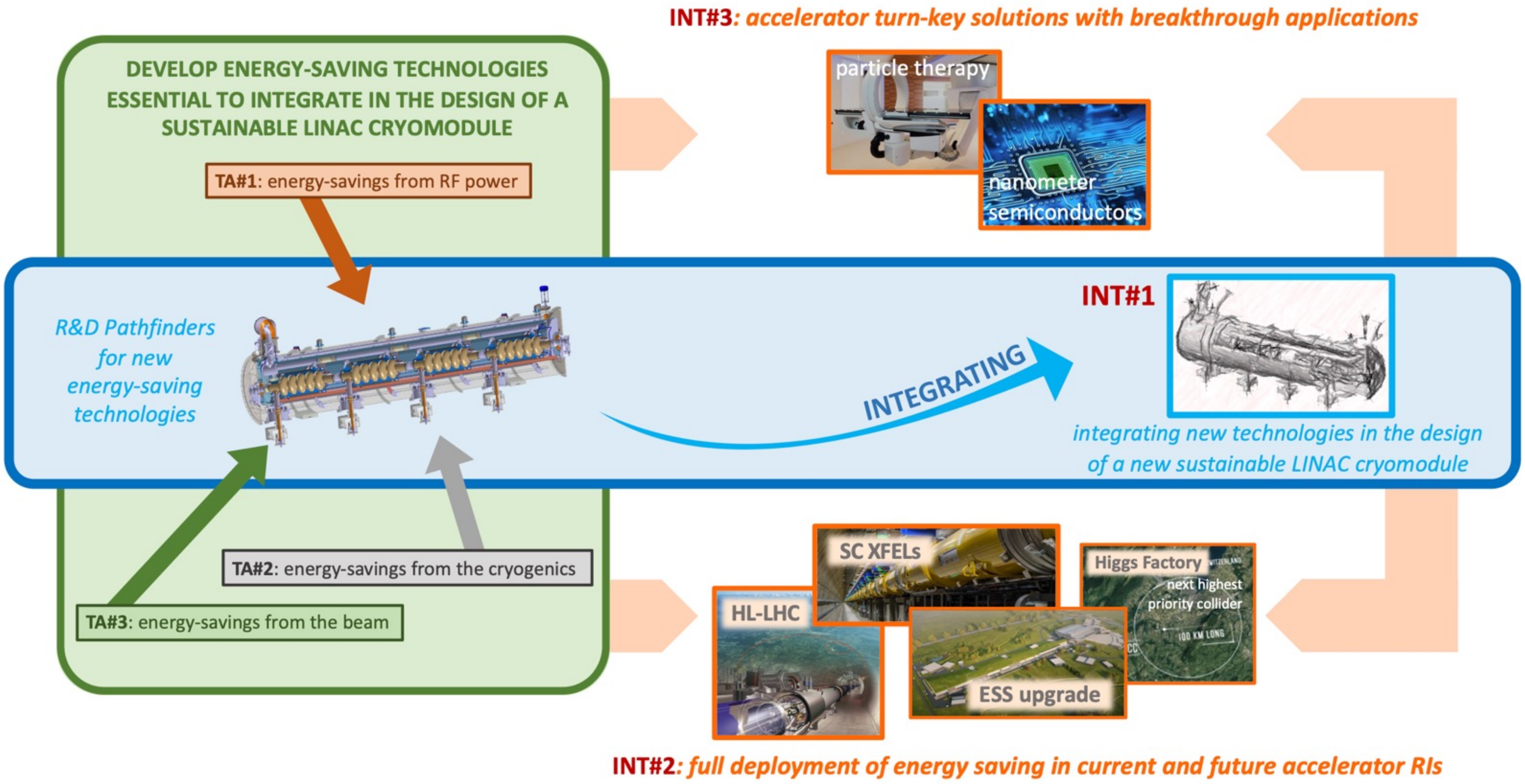
European Horizon-Europe Programmes

Jorgen d'Hondt



European Horizon-Europe Programmes

Jorgen d'Hondt



European Horizon-Europe Programmes

Jorgen d'Hondt

iSAS Objectives – *Technology Areas*

- **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.*

European Horizon-Europe Programmes

Jorgen d’Hondt

Impact of iSAS technologies on HEP e^+e^- colliders

example future e+e- Higgs Factories

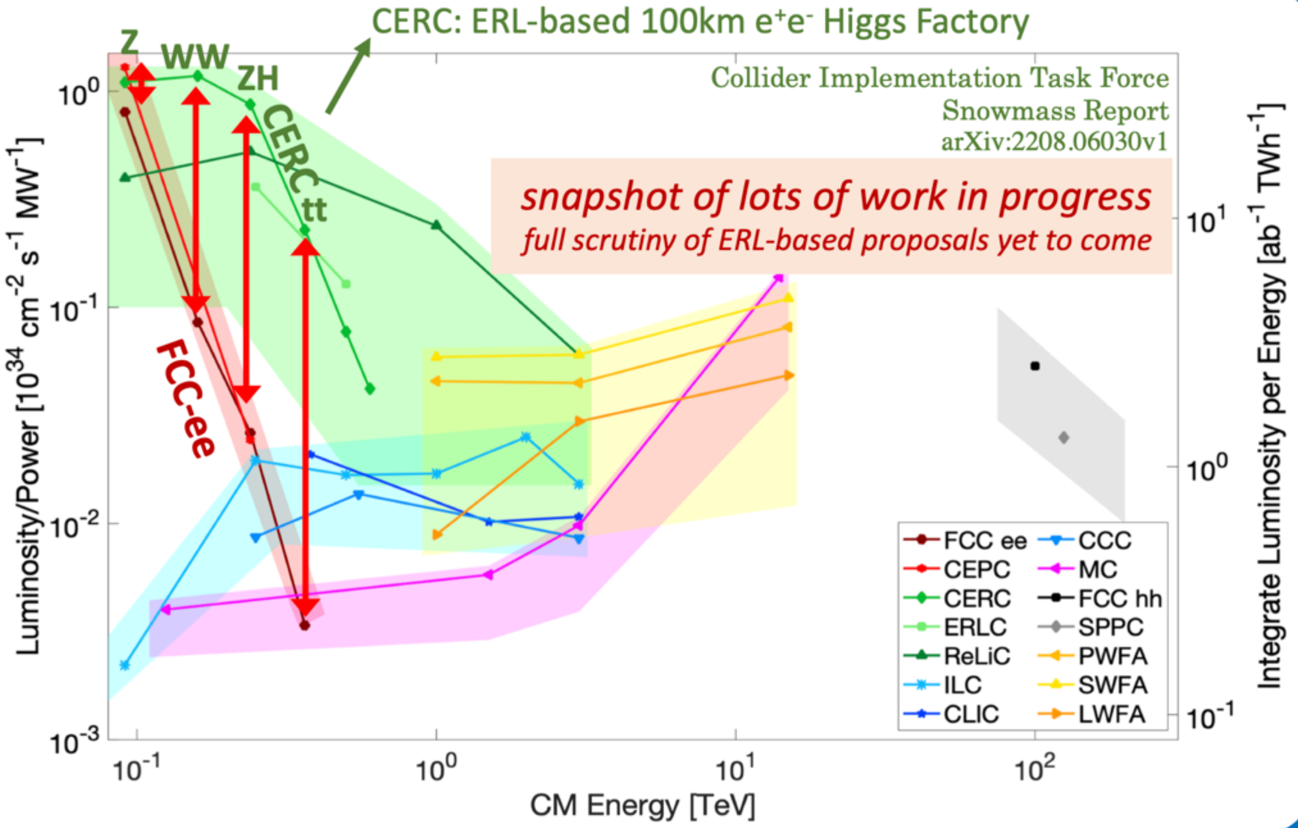
This plot suggests that with an ERL version of a Higgs Factory one might reach

x10 more Higgs bosons

or

x10 less electricity costs

NOTE: several additional challenges identified to realise these ERL-based Higgs Factories



References for CERC: PLB 804 (2020) 135394 and arXiv:2203.07358

European Horizon-Europe Programmes

Jorgen d'Hondt

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. UK Research and Innovation. HZB Helmholtz Zentrum Berlin. European Spallation Source. Lancaster University. 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)

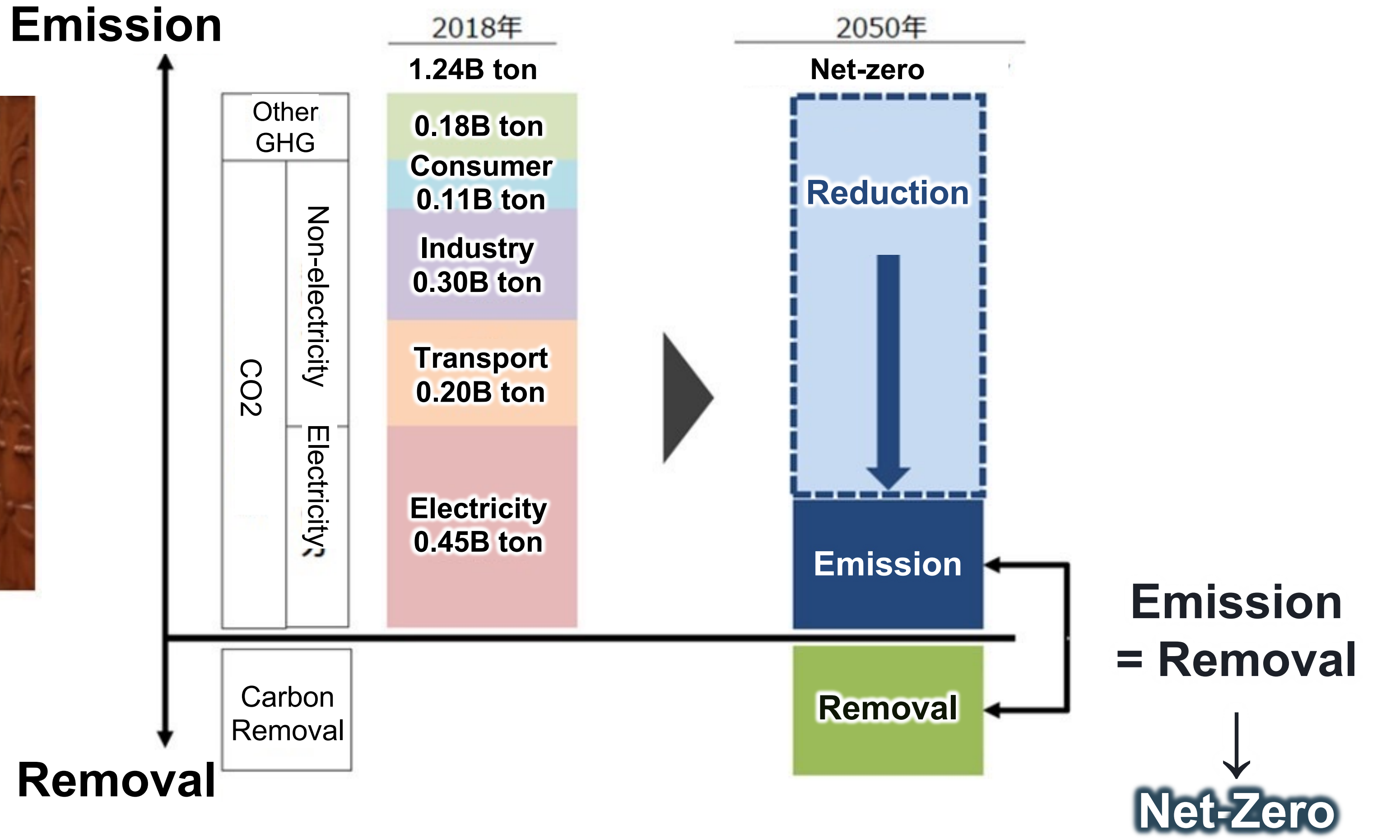
Green ILC & Japanese Industry

- Scenarios toward 2050 Carbon Neutrality in Japan and ILC: M. Yoshioka
- Efforts of Taiheiyo Cement towards Carbon Neutrality: Y. Ohgi
- The Future of Construction: Carbon-Negative Concrete for a Greener Tomorrow: K. Avadh
- Large-Scale Wooden Construction: Y. Shibuya
- Sustainable Forestry in the Tohoku region: K. Shibata
- Quantitative Evaluation of Forest CO_2 Absorption in Ichinoseki City: H. Kikuchi
- Creation of a sustainable society model utilizing IoT technology and local resources: Y. Komiya
- Commercialization of Low-Grade Waste Heat Recovery: Y. Kouno

Toward Carbon-neutral Society

- In October of 2020, the Japanese Government announced that it would realize Carbon-neutral society by 2050.

所信表明演説をする菅義偉首相（写真:つのだよしお/アフロ）



(Source: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI))

Sustainability in Future Accelerators

Scenarios toward 2050 Carbon Neutrality in Japan and ILC

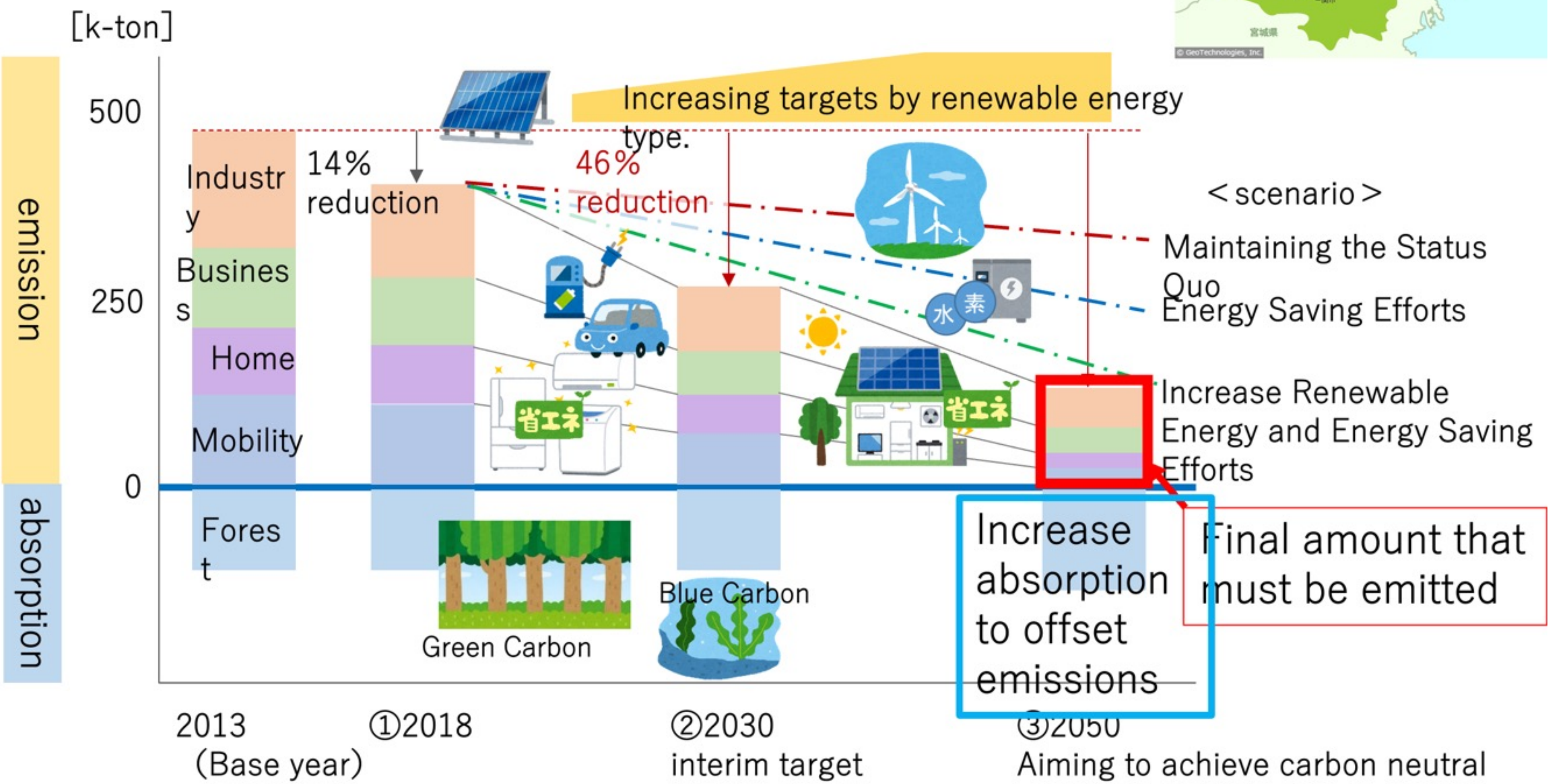
Masakazu Yoshioka（Iwate University）

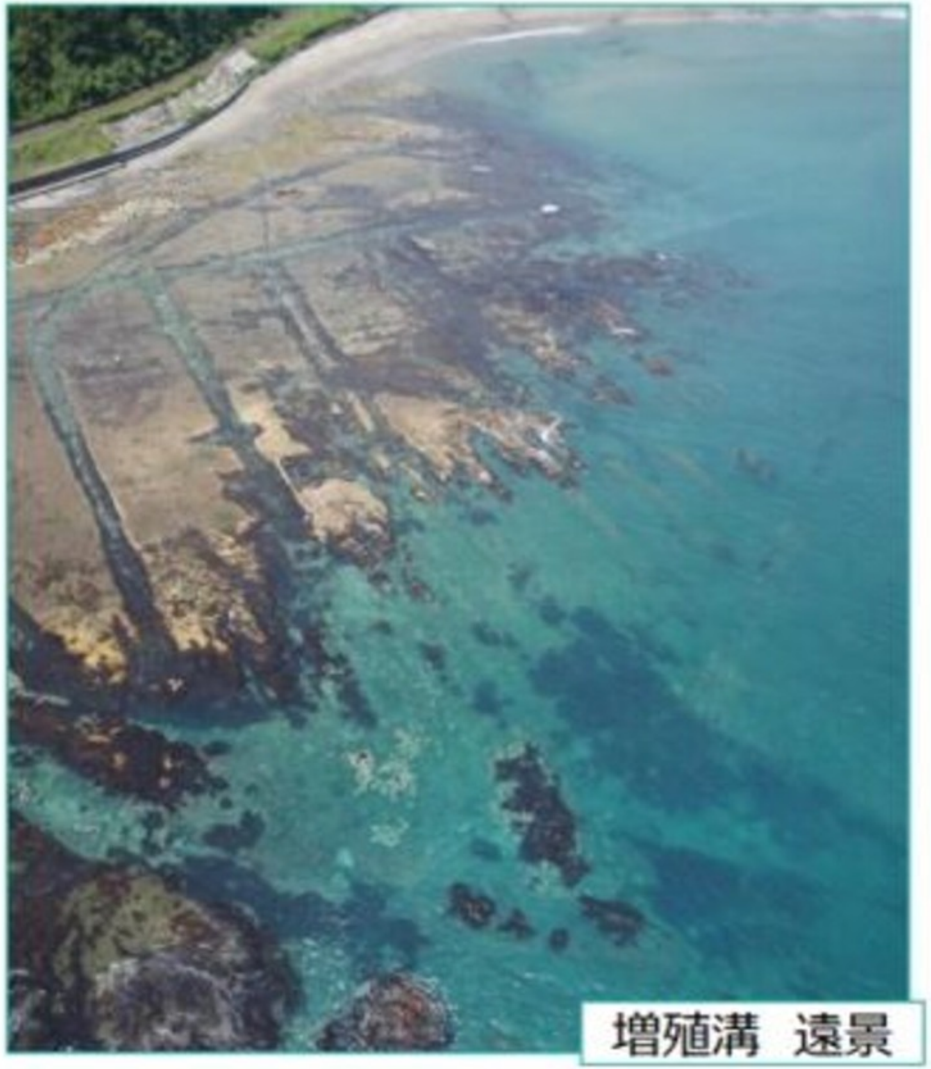
Presentation Details

1. Japanese government's 2050 carbon neutrality scenario
   ① Development of energy-saving technologies, sustainable energy use for the facilities and efficient use of energy
   ② Expand technologies for long-term carbon fixation
   ③ Increase CO_2 absorption by Green carbon and Blue Carbon
2. The Road toward Carbon Neutrality for ILC by 2050
   ① Efforts to develop energy-saving technologies at ILC facilities by researchers and effective use of waste heat emitted during operation
   ② Reduction of carbon emissions during ILC construction and use of sustainable electricity during ILC operations
   ③ Efforts to increase carbon absorption in cooperation with local communities
3. Role and correlation of 7 presentations in this session

A typical example of policy development in line with government policy is the goal of Miyako City (51,000 people, 1,259 km², Largest in area in Iwate), located on the coast of Iwate Prefecture.

- Goal: Achieve carbon neutrality by 2050 !
- To achieve this, emissions will be gradually reduced and increase green carbon (Forest) and blue carbon (Coastal Seaweed).



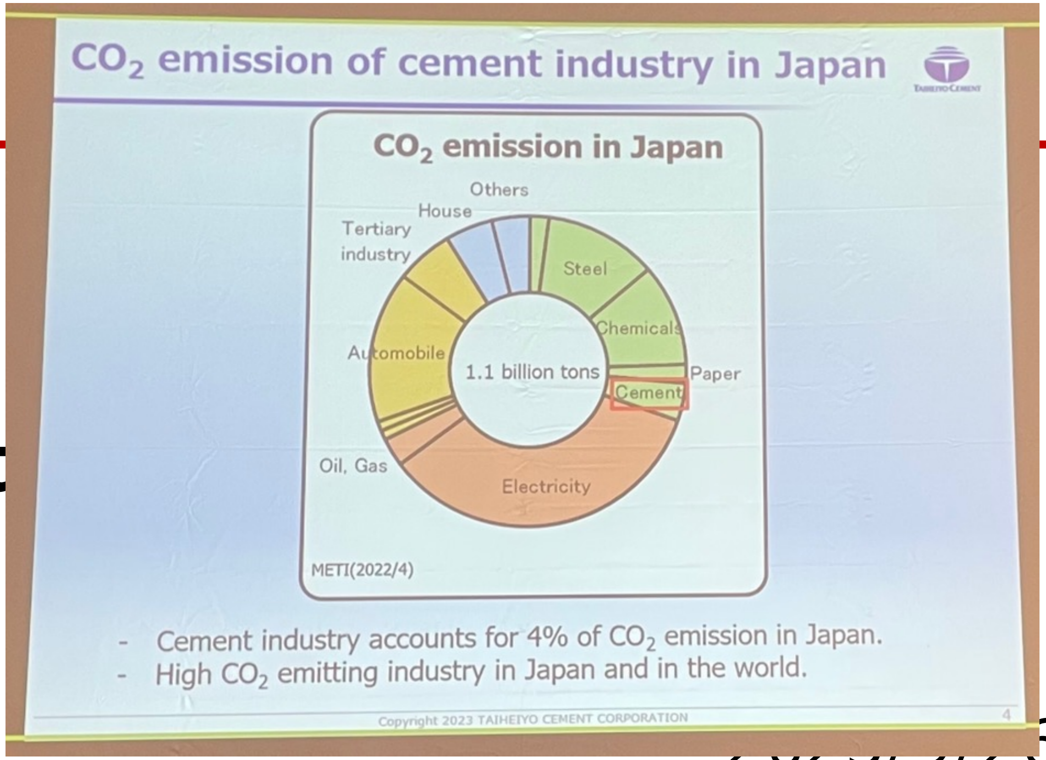


- Artificial tidal pools (4 m wide, 1 m deep trenches, 17.5 km long) are created to create a flow of fresh seawater due to the difference in tidal levels, encouraging the growth of wakame seaweed and kelp.
- Seaweed is eventually fixed to the seafloor as flow algae.3106.5 tons (CO2 equivalent) of J Blue Credits are accredited over 5 years.
- Sea urchins (very tasty) are abundant as a by-product.
- J Blue Credits are blue carbon credits issued and sold by JBE (Japanese Federation of Economic and Technical Research Associations).
- JBE is composed of the National Maritime, Port and Aviation Research Institute, the Sasakawa Peace Foundation, and university professors.

EAJADE Workshop on Sustainability in Future Accelerators (WSFA2023)

The Future of Construction: Carbon-Negative Concrete for a Greener Tomorrow

Kajima Corporation
Dr. Kumar Avadh (PhD. Universit
Research Engineer



Concrete: CO2 Emissions

Naturally Sourced

	Cement	Gravel	Sand	Water
				
CO_2 Emissions	288 kg/m^3	0 kg/m^3	0 kg/m^3	0 kg/m^3

Cement Production:

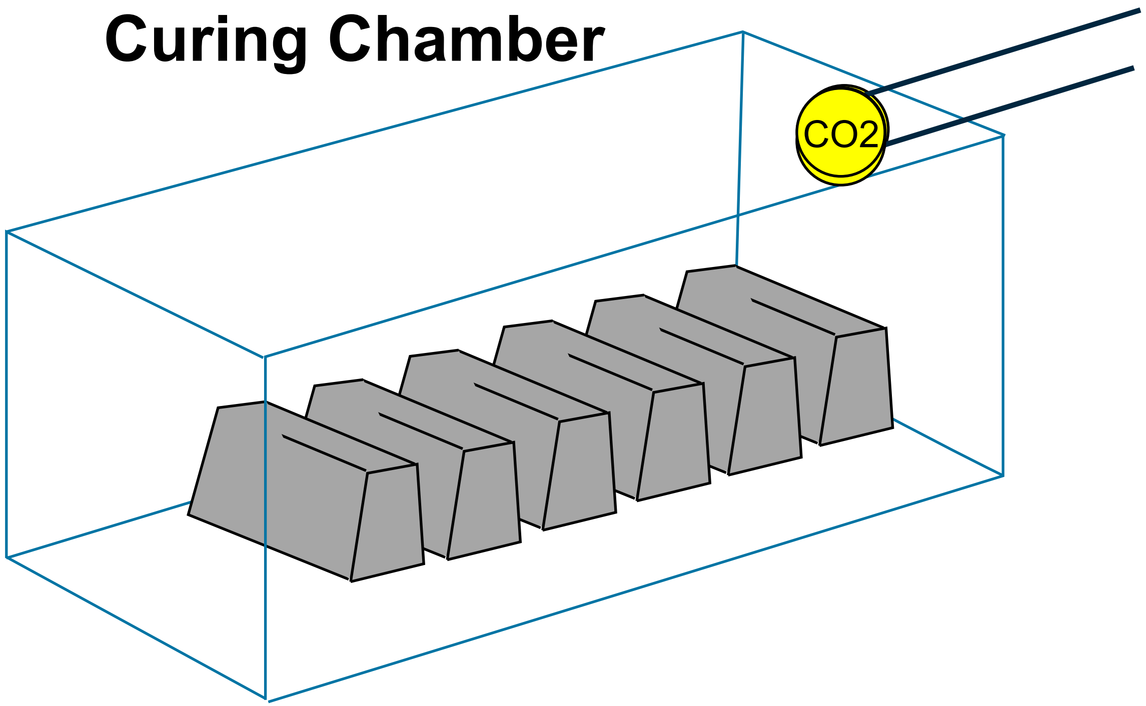
Limestone →  **Burning** → **Cement**

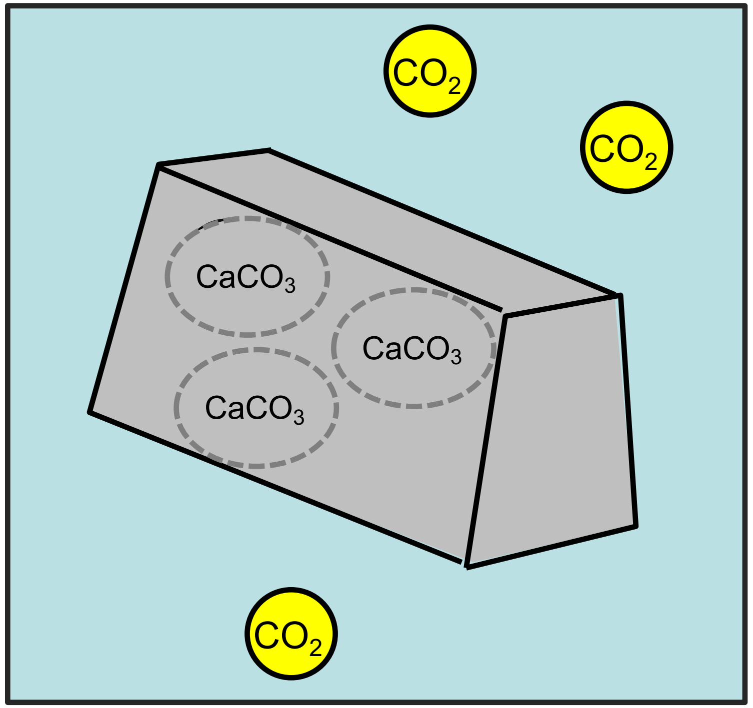
$CaCO_3$ — 1400°C — $CaO + CO_2$

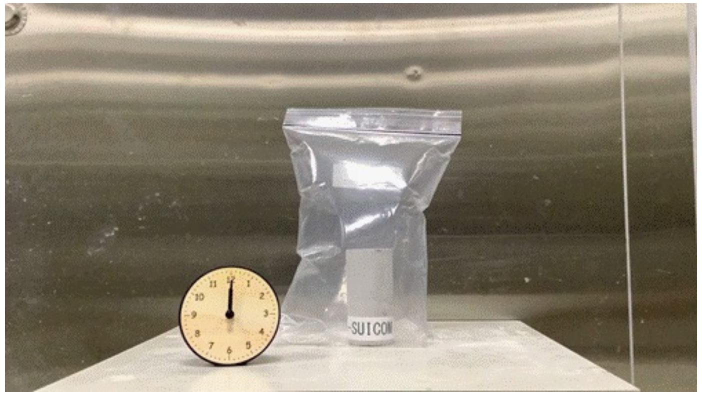
CO_2= 288kg/m^3

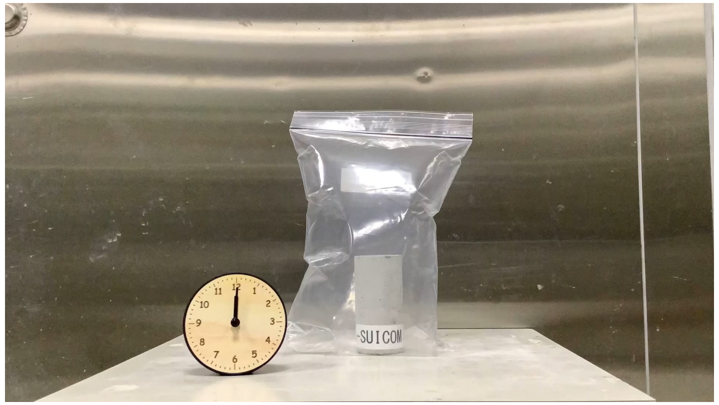
CO_2 per $1m^3$ of concrete

Carbonation Curing









Absorbing CO_2 as it hardens

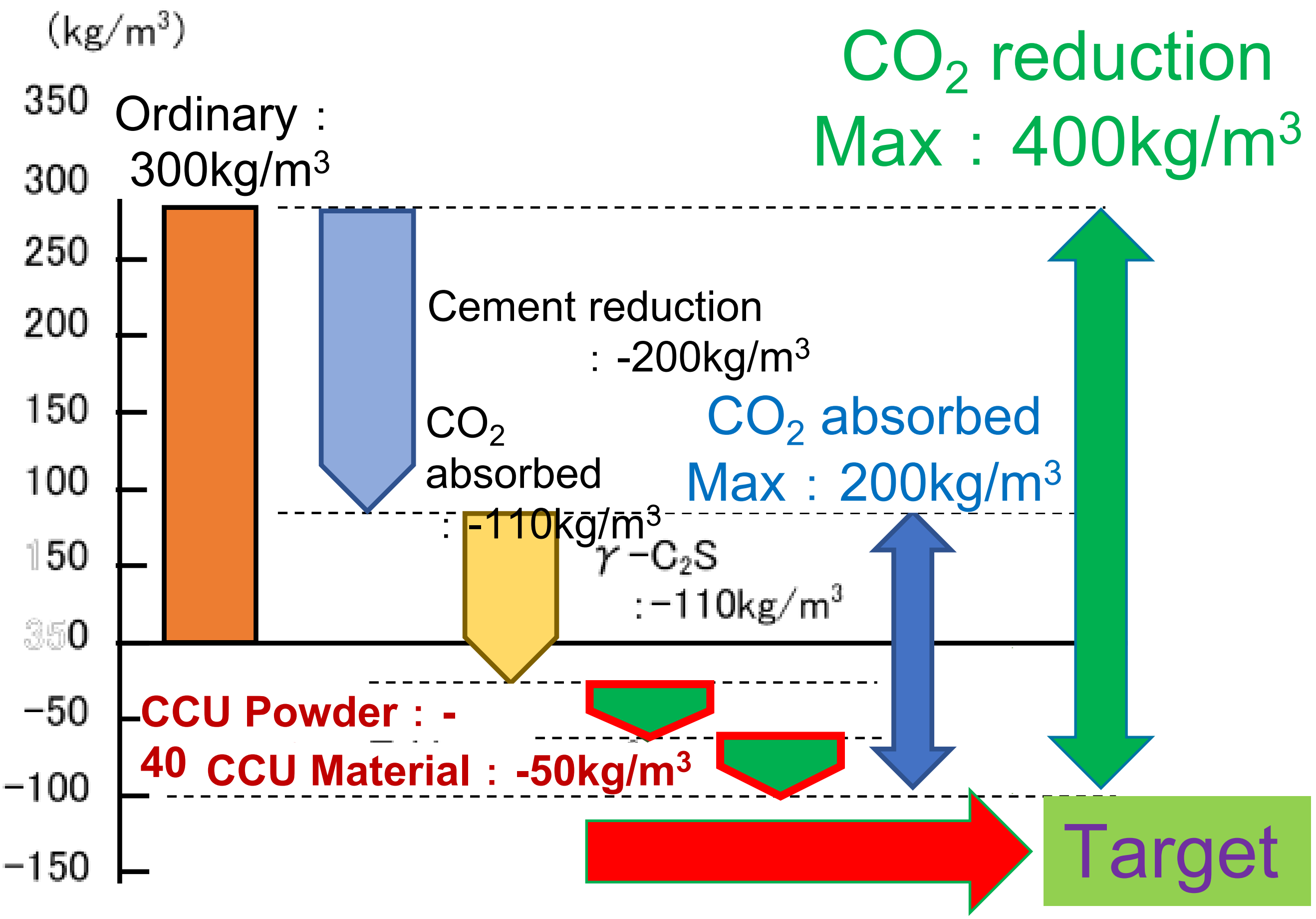
<R&D in progress> Material development

Maximizing absorption and reduction of CO_2 by using CCU materials

CO2-SUICOM® + **CCU Materials＊**

＊Materials reacted with CO_2 in advance and put into concrete

CCU: Carbon Capture and Utilization



Target of CO_2 reduction and absorption

Wooden Large-scale construction for a Greener Future: Shelter Inc.'s Initiative

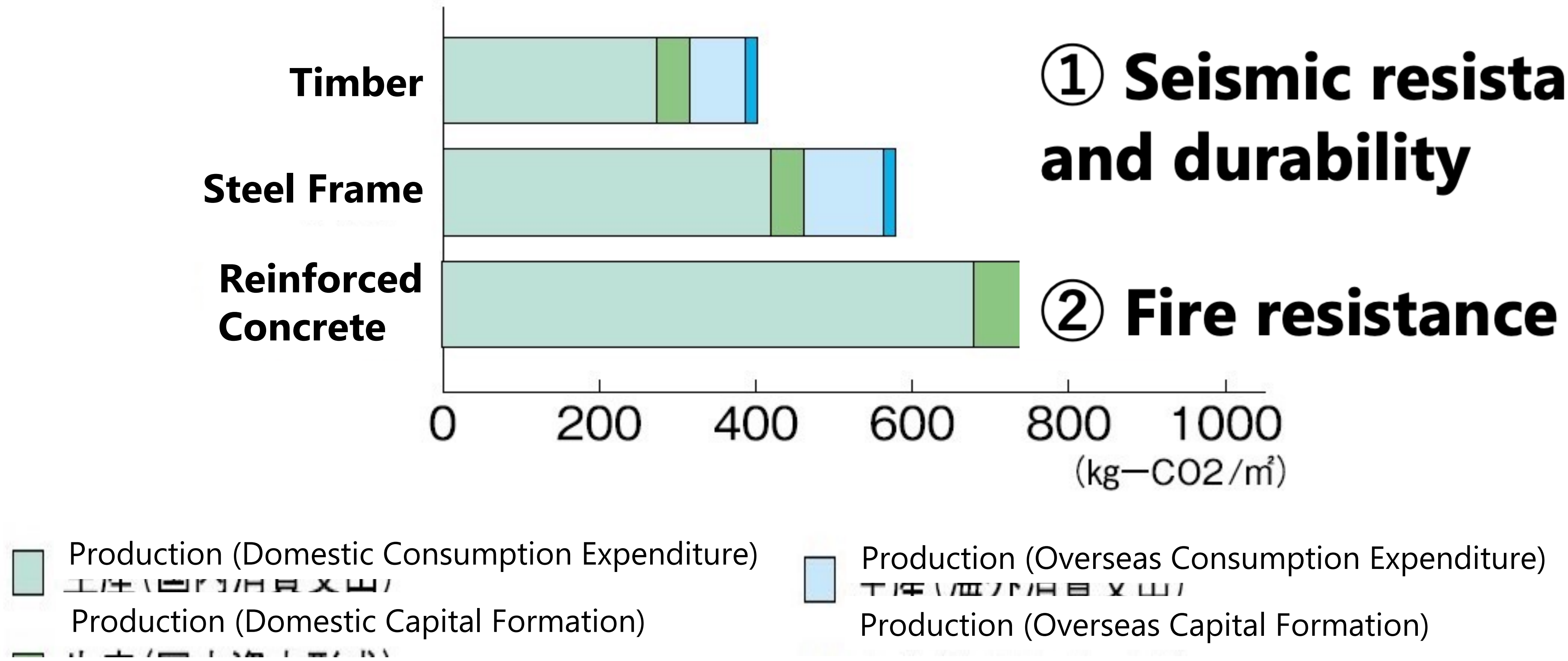
Shelter®

09/26/2023

Yuka Shibuya

Comparison of CO_2 Emissions during Construction between Timber and Other Structures

Comparison of Estimated CO_2 Emissions per Floor Area in Office Buildings by Structural Type:



① Seismic resistance and durability

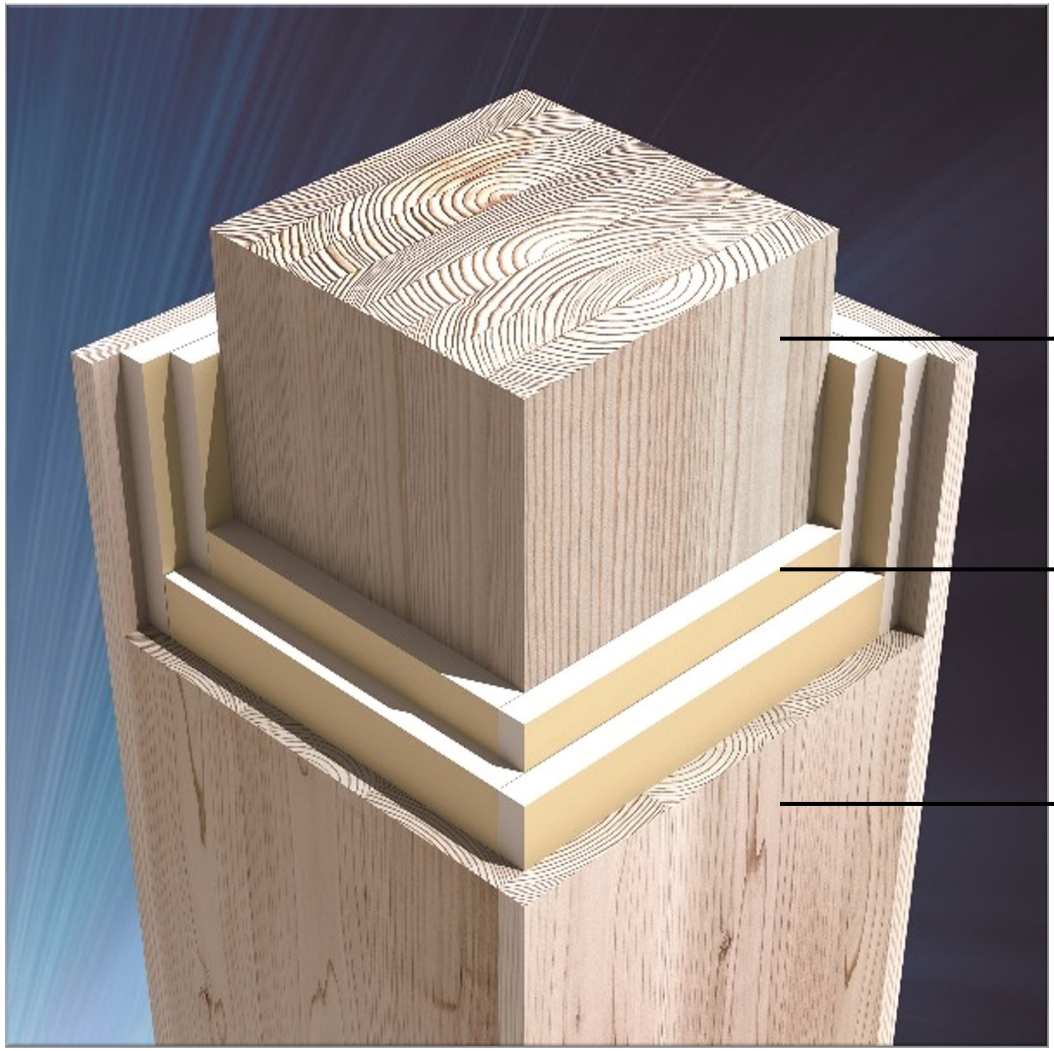
② Fire resistance

Source: Japan Housing and Wood Technology Center, a public interest foundation, "Examples of Buildings with Interior Wood Usage and Their Effects," Published in March 2022.

Seismic Resistance of the Metal Hardware Joining Method

- During the Great Hanshin Earthquake in 1995, 73 wooden houses constructed using the metal hardware joining method in the disaster-affected areas remained standing without collapsing. (The photo depicts a three-story house in the heavily affected Nada district of Kobe City.)

Wooden Fireproof Components “COOL WOOD”



- **Load-bearing component (Wood)**
- **Fire-stop layer (Gypsum board)**
- **Surface material (Wood)**

1-hour Fireproof COOL WOOD (Column)

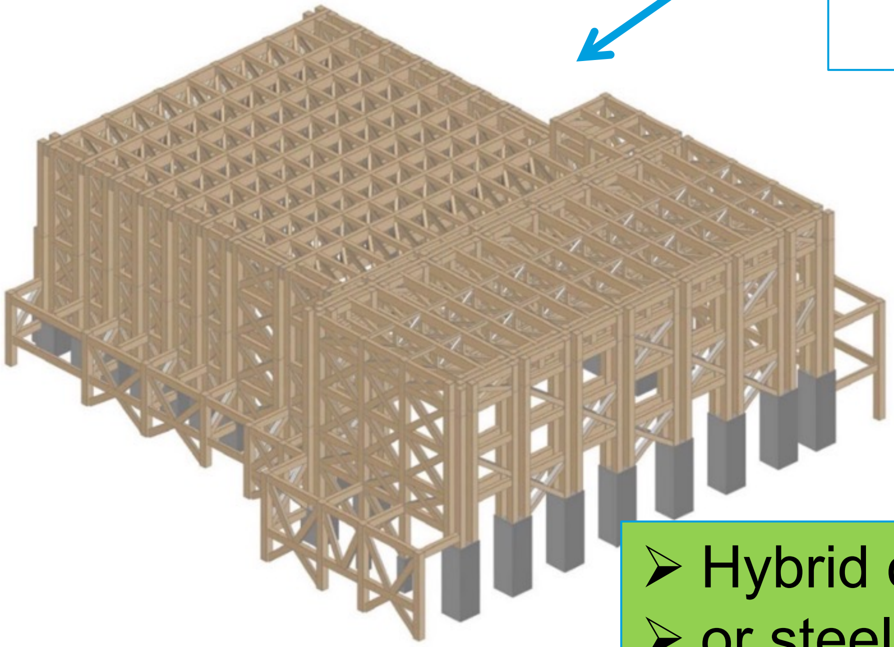
Precedents:
SLS, Swiss Light Source, PSI

\+

Shelter's experiences

↓

Adopt the KEK-ATF hall for a case study
50m × 120m ($6000m^2$)



- Hybrid of wooden and reinforced concrete
- or steel frame and RC
- Same specifications, conditions

Sustainable Forestry in the Tohoku region

~GREEN ILC IWATE~

September 26, 2023
WSFA2023@Morioka

Our Business

Tree planting
Logging

Transportation

Wood fuel
production

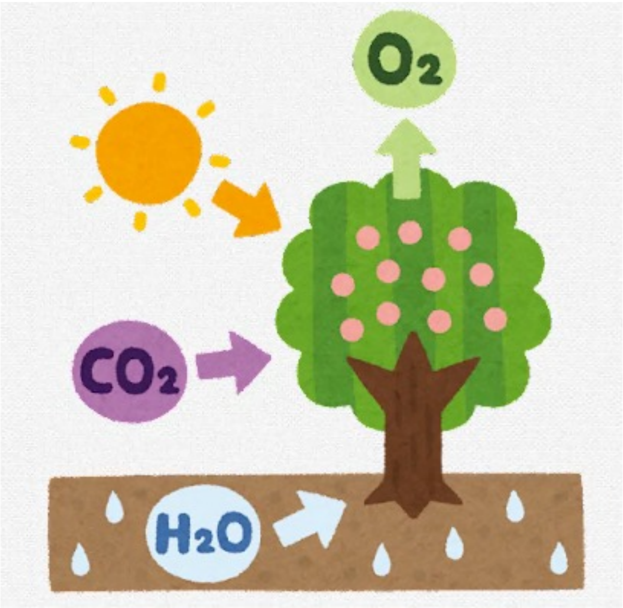
Sawing
processing

construction

Kimiya Shibata
SHIBATA INDUSTRY CO., Ltd.
Ichinohe Town in northern Iwate Prefecture

President Shibata is on a business trip to Austria, so I will make the presentation on his behalf.

About CO2 absorption in Ichinoseki City's forest resources



Forests are CO2 sinks

一関市

Ichinoseki City Regional Forest Policy Advisor
HIROSHI　KIKUCHI

Amount of CO2 absorbed and fixed in Ichinoseki public forest

Carbon (C) = Volume × Volume density × Expansion factor × (1+(Aboveground/Underground part ratio)) × Carbon content rate (0.5)

Japanese cypress			forest area(ha)	Carbon fixed amount(t)	CO2 absorption amount(t)	AnnualCO2 absorption amount(t)	Annual CO2 absorption per ha(t)
artificial forest	conifer	Cedar	19,618	2,680,553	9,837,631	109,412	5.58
		Japanese cypress	1,004	54,543	200,173	12,177	12.13
		Red pine	8,928	1,327,513	4,871,974	33,537	3.76
		Kara pine	1,521	93,234	342,172	5,999	3.94
		others	33	6,655	24,424	184	5.58
		total	31,104	4,162,498	15,276,374	161,309	5.19
	hardwood	oak	80	5,214	19,135	610	7.63
		others	281	22,508	82,605	1,594	5.67
		total	361	27,722	101,740	2,204	6.11
	Total		31,465	4,190,220	15,378,114	163,513	5.20
natural forest	conifer	Red pine	3,848	512,777	1,881,895	8,635	2.24
		others	8	1,798	6,601	34	4.25
		total	3,856	514,575	1,888,496	8,669	2.25
	hardwood	oak	26	2,427	8,907	46	1.77
		others	31,016	2,935,948	10,774,932	131,302	4.23
		total	31,042	2,938,375	10,783,839	131,348	4.23
	Total		34,898	3,452,950	12,672,335	140,017	4.01
Total			66,363	7,643,170	28,050,449	303,530	4.57

Source: Forest resource management system

Amount absorbed by private forests in Ichinoseki City	
Emissions from one human being	1,631,000
Emissions from one car	227,000
Emissions per household	80,000

Current situation of Ichinoseki City — 2022.4 to current

population	110,000
Number of registered vehicles	98000
Number of households	46,000

The amount of CO2 absorbed by Ichinoseki Municipal Forest is 303kt per year.

On the other hand, the amount emitted in 2018 was 871Kt per year.

Unfortunately, about 2.8 times the amount absorbed is emitted.

WSFA2023

Creation of a sustainable society model utilizing IoT technology and local resources

MOVIMAS

Norihiro Kodama

- Hachimantai City Hometown Ambassador
- Member of Karumai-cho Decarbonized Region Creation Council
- Representative Director, MOVIMAS Co.
- Representative Director, Hachimantai Smart Farm Co.
- Head of Takaishino Institutional Vegetable Production Association

モバイル技術で社会インフラを豊かにする。
MOVIMAS

September 26, 2023

Aims of this project: Bringing Japan's Underutilized Farmland Back to Life

Cultivated area in Japan continues to decline

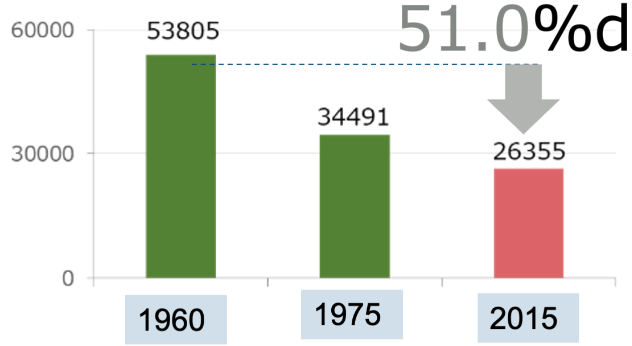
1.61 million ha decline between 1956 and 2016

※農林水産省平成28年耕地及び作付面積統計より

Japan's agricultural workforce continues to decline

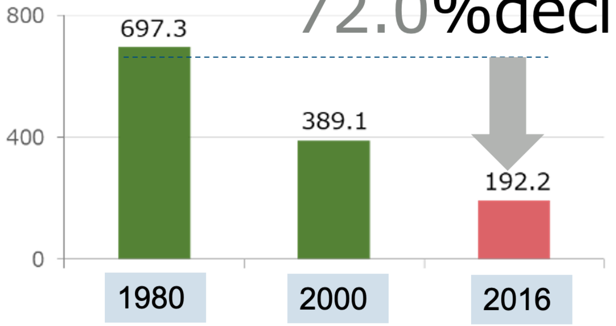
Population of Hachimantai City （人）

51.0%decline



Japan's Agricultural Employment Population

72.0%decline

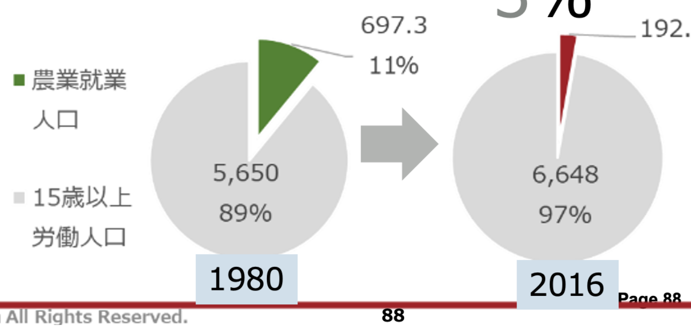


（万人）

National agricultural workforce declined from 11% (1980) to 3%(2016)

Local populations are experiencing an exodus of labor due to declining industry and a declining birthrate.

The number of people working in agriculture is also declining sharply.

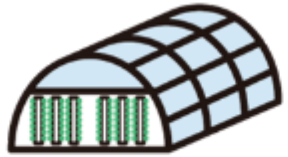


※総務省統計局　国勢調査、労働力調査より

Challenges when becoming a basil farmer

Business fund

Typical initial investment for an agricultural greenhouse without IoT is 10 million yen for 200m²



Green house

Technology

Minimum knowledge and skills to be a successful basil farmer

- ✅ Purchase of seedlings and fertilizers needed for cultivation
- ✅ Pest control necessary to maintain quality all the way through to harvest
- ✅ Technology to control temperature and humidity in the greenhouse to increase yield
- ✅ Need to develop sales channels and products before shipment

Fertilizers and seedlings

Energy

distribution in the market

Farm land

Permission or approval under the Agricultural Land Law is required to secure farmland.

regional agreement

Cultivation management using IoT technology has created new value by establishing a labor-saving and highly profitable model.

Insect infestation was controlled and quality was improved.

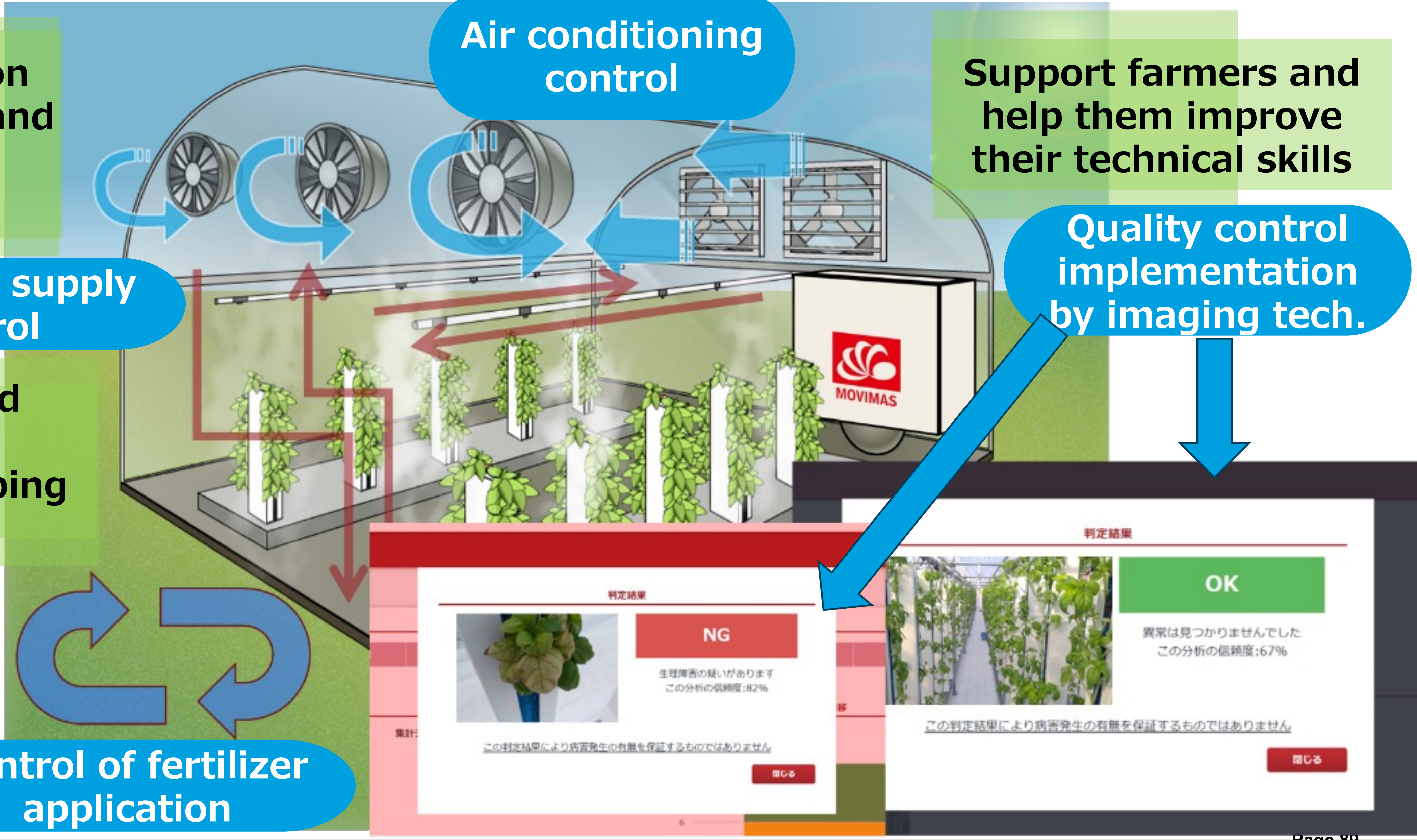
Air conditioning control

Support farmers and help them improve their technical skills

Hot water supply control

Quality control implementation by imaging tech.

Achieved lapsed cultivation and improved shipping volume.



Control of fertilizer application

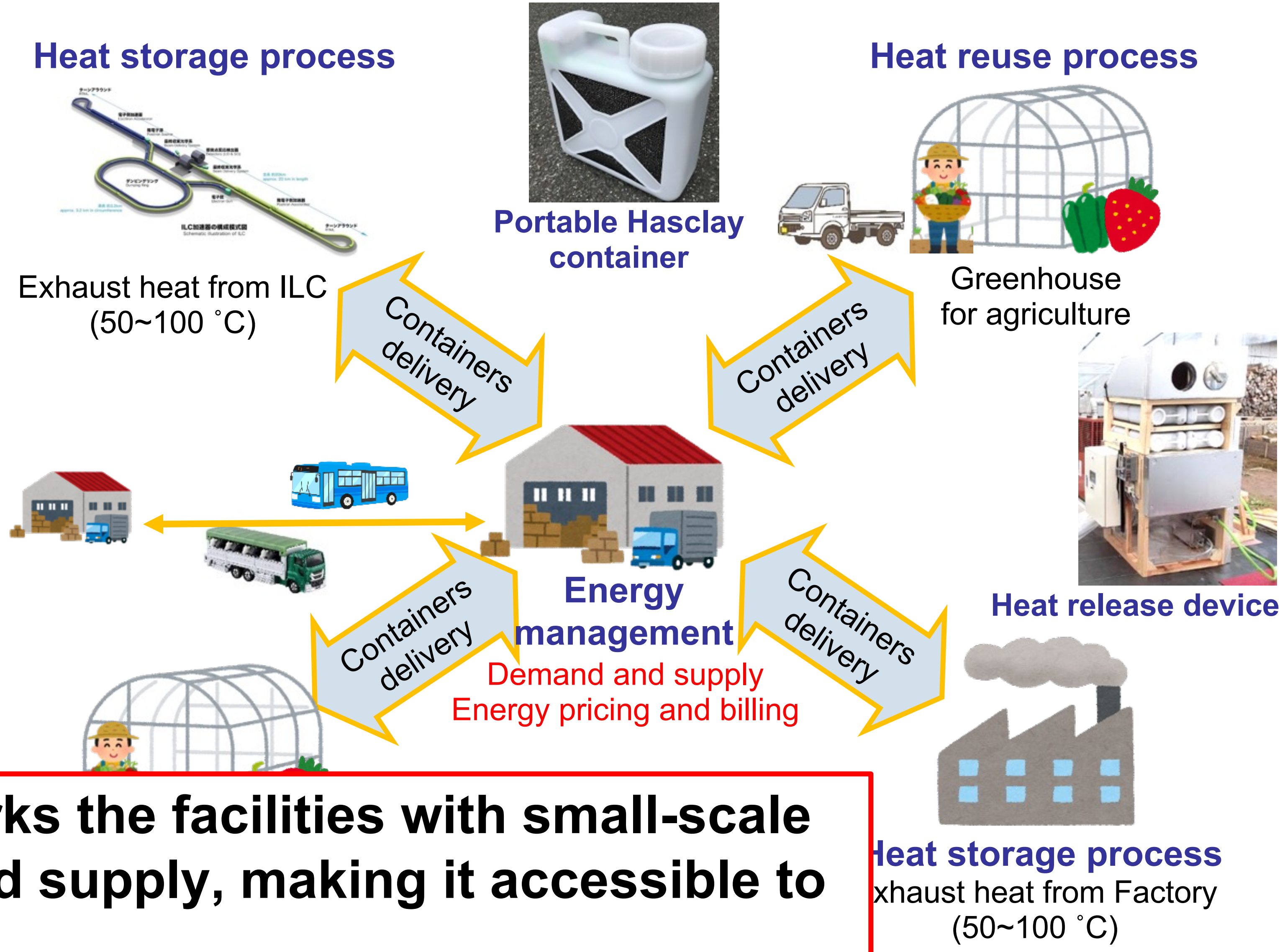
WSFA2023
Sustainability Session Ⅱ : Green ILC & Japanese Industry

Commercialization of Low-Grade waste heat recovery

Higashi-nihon **K**iden**K**aihatsu Co.,Ltd.(**HKK**)

Yuichi Kouno

Off-line Waste Heat Circulation Model



Building a system that networks the facilities with small-scale and decentralized demand and supply, making it accessible to many people.

What's HASClay ?

HASClay® is an inorganic adsorbent material composed of a composite of amorphous hydroxyl aluminum silicate (HAS) and low-crystallinity clay.

HASClay® has the ability to store heat with the principle of energy transfer by water vapor desorption.

- In particular, it has an excellent storage capacity for low-grade heat (<100 ˚C).
- It is capable of repeating the heat storage and dissipation cycle over and over again.
- By sealing the container and blocking moisture, the heat energy can be stored semi-permanently and will not ignite or deteriorate, making it safe to store.
- Off-line transport allows exhaust heat from ILC and factories to be used effectively in a wide range of fields.

The appearance of HASClay®

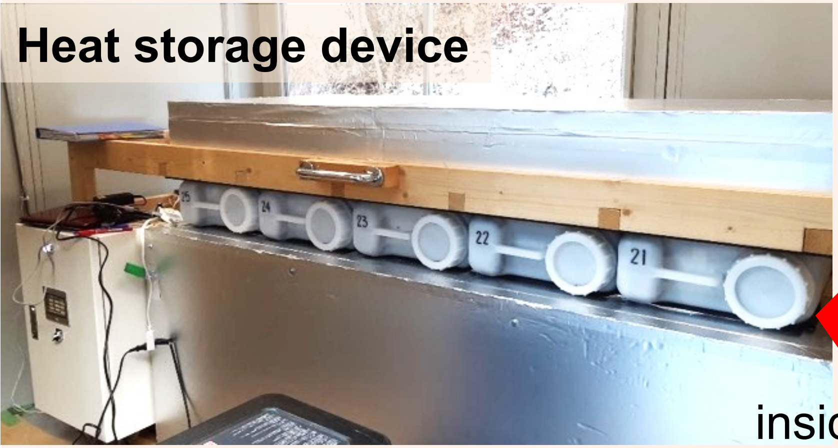
Performance of various adsorbents

Adsorbent	Heat storage ability	Heat storage capacity(kJ/L)
HASclay	**40 ˚C or more**	**567**
Modified zeolite	80 ˚C or more	439

Demonstration tests to achieve commercialization

Thermal storage process: Hot spring

Utilizing the heat of hot spring water to store (dry) HASClay

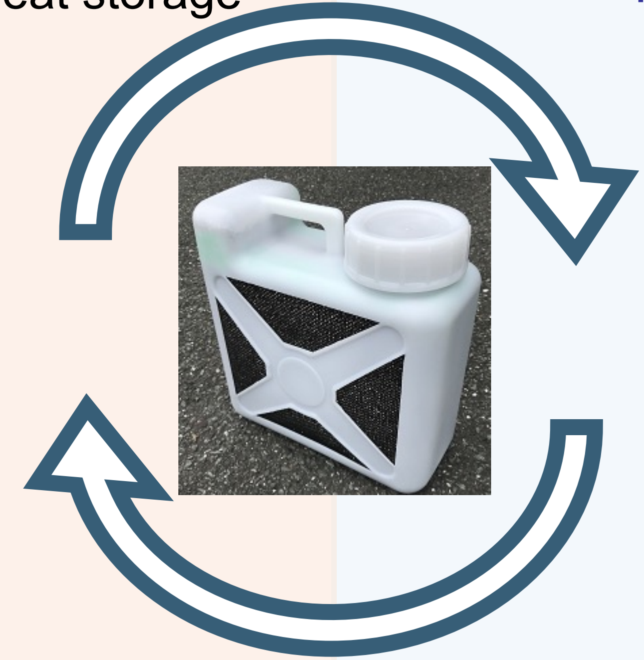


Heat storage device

inside

Panoramic view of the heat storage facility

Delivery after heat storage



Recovery and Recharging after Heat Dissipation

Heat dissipation process: Greenhouse

Utilizing HASClay for heat dissipation and using it for nighttime heating

Heat dissipation device

Strawberry cultivation greenhouse

Demonstration tests to achieve commercialization

Heat dissipation process

- 178 m^3 greenhouse located in agricultural fields in Morioka-shi
- High-elevation cultivation of strawberries using localized heating methods (made by HKK)
- Heating equipment:
  Main = Wood stove / 'Goron-ta' 23 kW
  (operates around 23:00)
  Auxiliary = A kerosene-fueled air heater 22 kW
  (operates at 10 ˚C or below)

We aim to use HASClay to heat during the night and before sunrise to reduce the consumption of kerosene used by the air heater

Heat dissipation device

8 small cases are released per cycle.
Water vapor is supplied from the bottom of the cases and adsorbed onto the HASClay, which then releases heat from the top of the device.

Thank you!

Contact

DESY. Deutsches
Elektronen-Synchrotron

www.desy.de

Thomas Schörner
DESY FH
E-Mail: *thomas.schoerner@desy.de*
Phone: +49 40 8998 3429