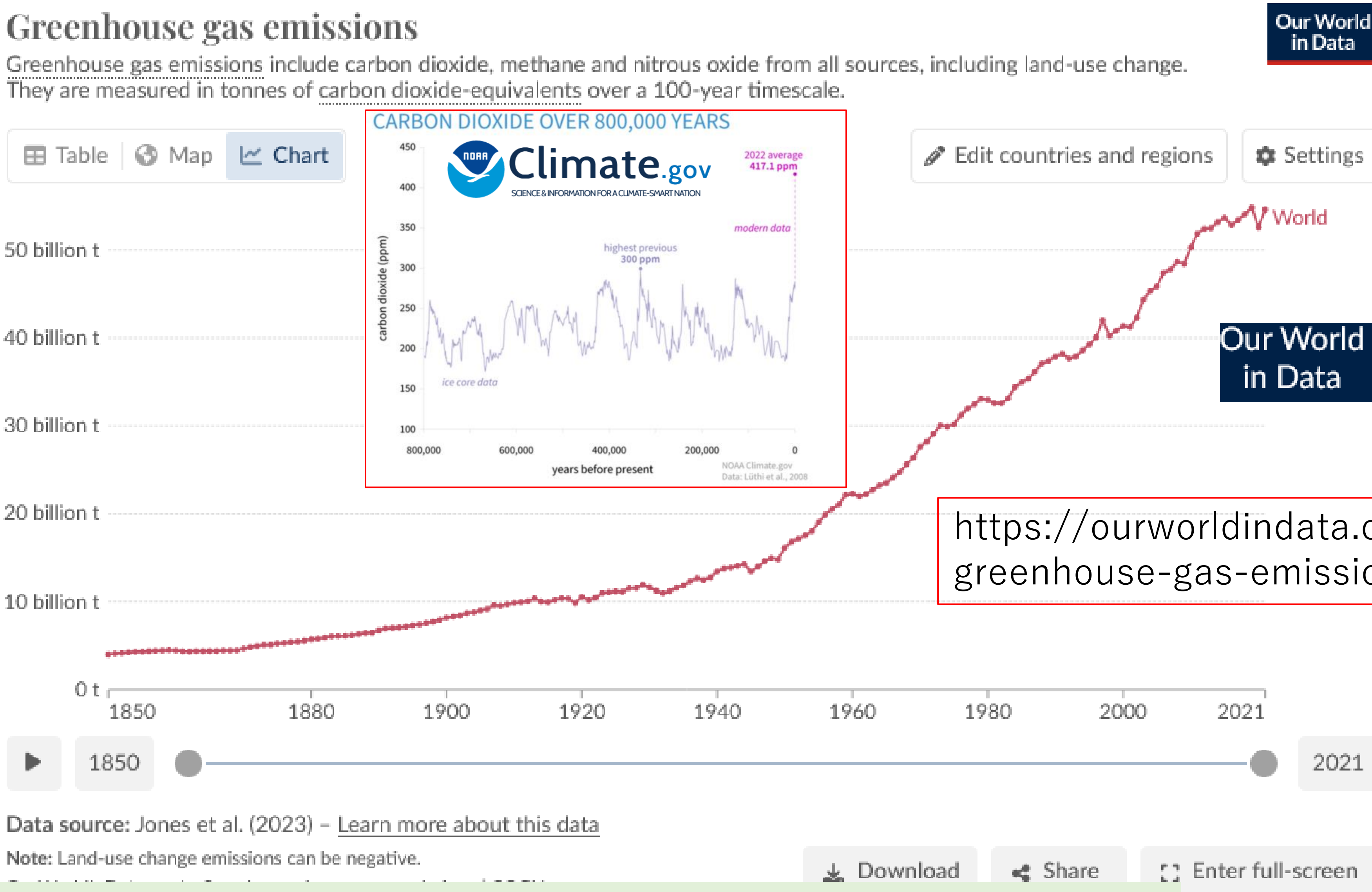
IAS Program on High Energy Physics (HEP 2024)

Th-AP02	10:30 - 11:00	**Break**	
		Chair: Maxim TITOV (CEA Saclay, Irfu)	
		Title	**Speaker**
	11:00	Green ILC **[Zoom]**	Masakazu YOSHIOKA (KEK)
	11:30 **11:45**	CO_2 Reduction Optimization with Future Colliders Design, Construction and Operation	Dou WANG (IHEP)
	12:00	Energy Recover and Reuse Technology Studies for Large Green Accelerators	Rui GE (IHEP)

I would like to thank the organizers for the opportunity to make this presentation!
Please forgive me for having to participate remotely for health reasons.
I retired from KEK 12 years ago and am now based in Morioka, Iwate Prefecture, working with Iwate University and Iwate Prefectural University to realize the ILC in Iwate Prefecture.
This presentation is not by KEK, but by activities based in the Iwate area..

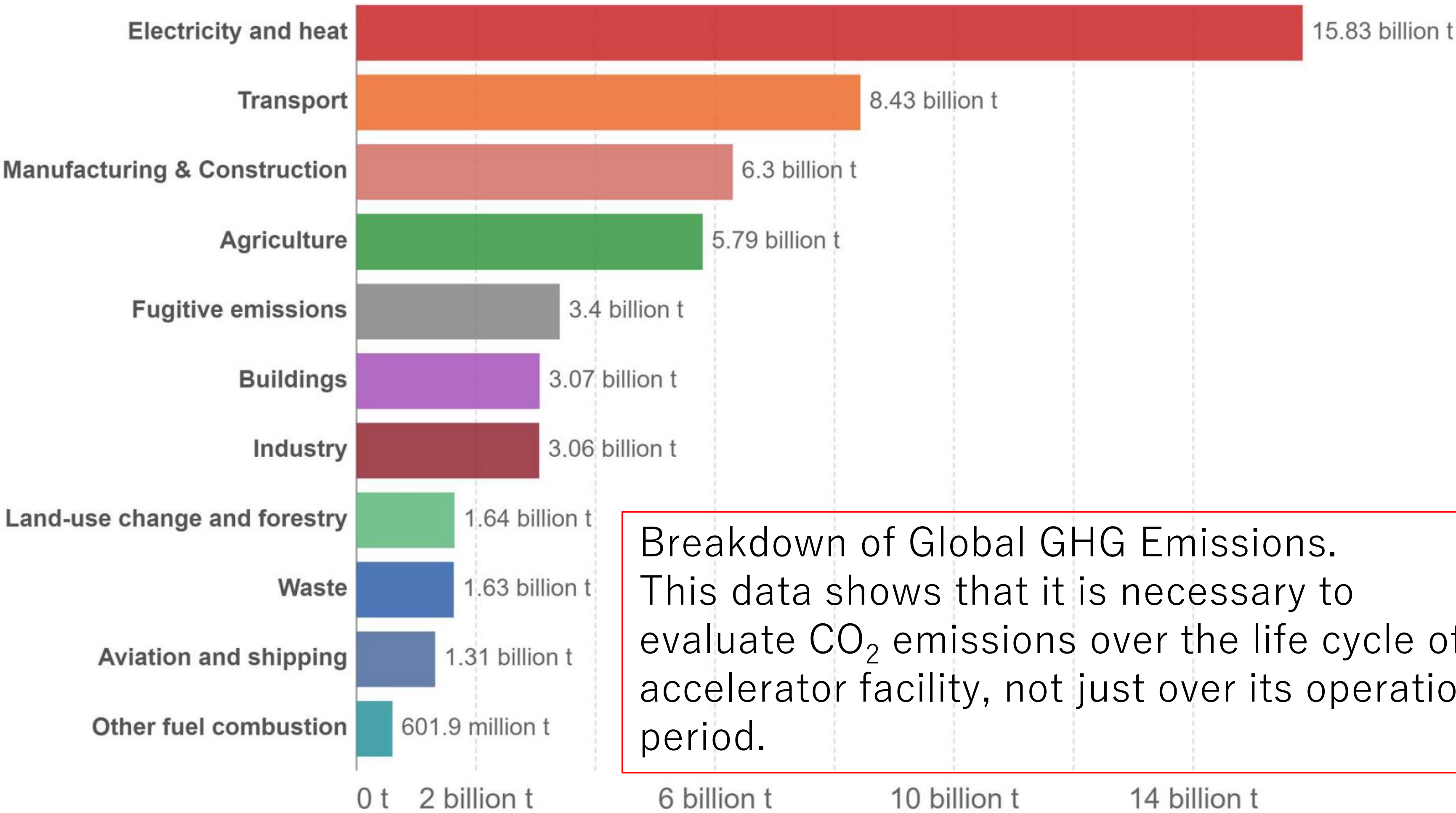
1. Prologue: Global Warming, ILC Timeline & Features, Sustainable Accelerator Facility
2. The International Workshop on Sustainability in Future Accelerators in Morioka, Iwate
3. Epilogue: ILC and GX create new technologies and give back to society



https://ourworldindata.org/greenhouse-gas-emissions

Let me clarify my understandings.

1. The earth is currently warming due to natural cycles (Milankovitch cycle).
2. Global greenhouse gases are accelerating this trend.
3. Scientists must work to stop it.
4. Accelerator facilities are no exception.



Breakdown of Global GHG Emissions.
This data shows that it is necessary to evaluate CO_2 emissions over the life cycle of an accelerator facility, not just over its operational period.

Our World in Data based on Climate Analysis Indicators Tool (CAIT) 2019 (Adapted)

Presentation by Suzanne Evans of ARUP, WSFA2023 in Morioka

Status and Activities of the International Development Team (IDT)

LCWS2023 at SLAC
Menlo Park, USA, 15-19 May 2023

Tatsuya Nakada
EPFL, Switzerland
Chair of the IDT Executive Board

- ILC is very attractive as a global Higgs factory;
  - Thanks to the GDE effort, ILC is technically mature and ready to proceed to construction.
  - As a global project, ILC cost is affordable.
  - ILC power consumption and environmental impact is modest.
  - ILC has a clear upgrade path to higher energies: to t.t-bar threshold, to ZHH, to ~1 TeV (and possibly beyond with technological advancement, when physics justifies).
  - ILC has been developed as a global project from its conception.

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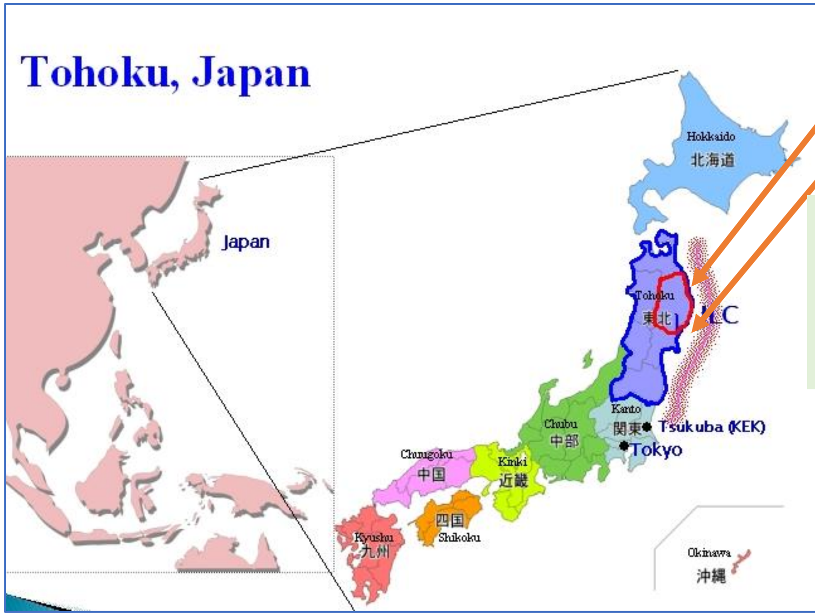
5) Overall ILC timeline

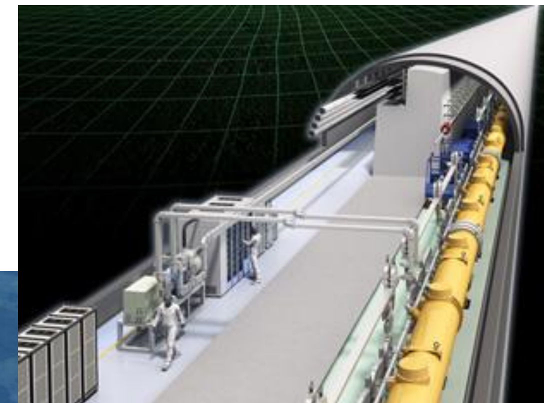
-success oriented and asuming no major incident-

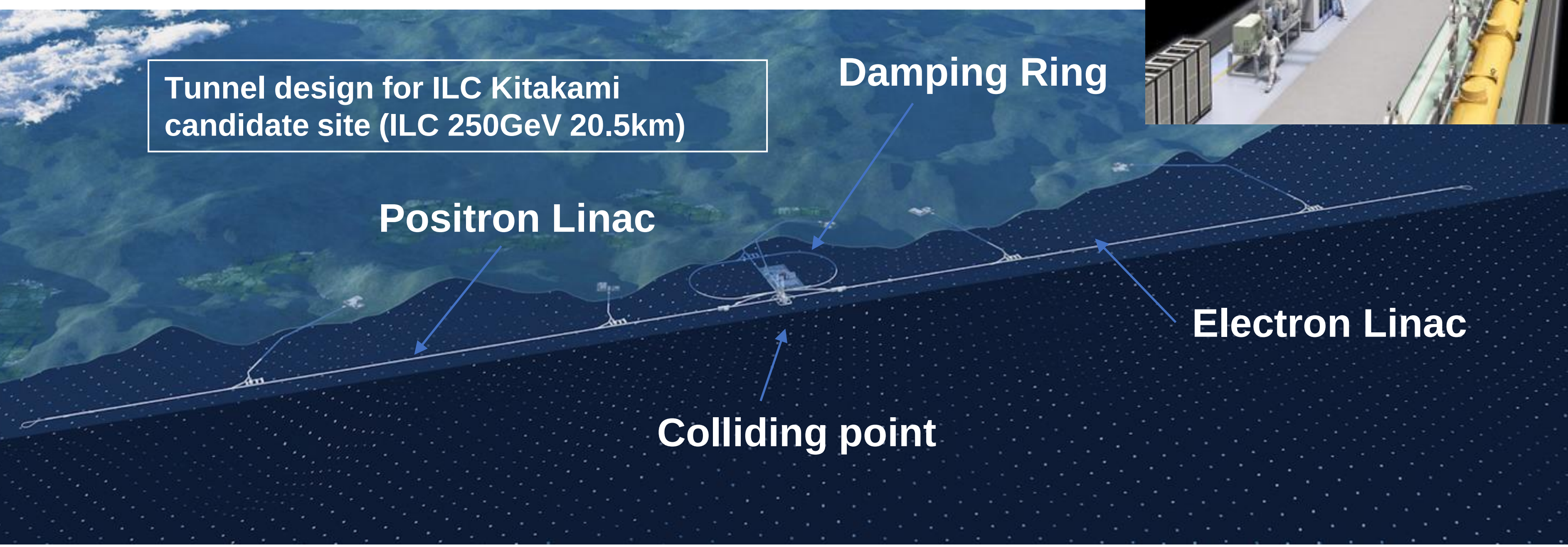
Researchers' plan: ILC construction to begin before 2030

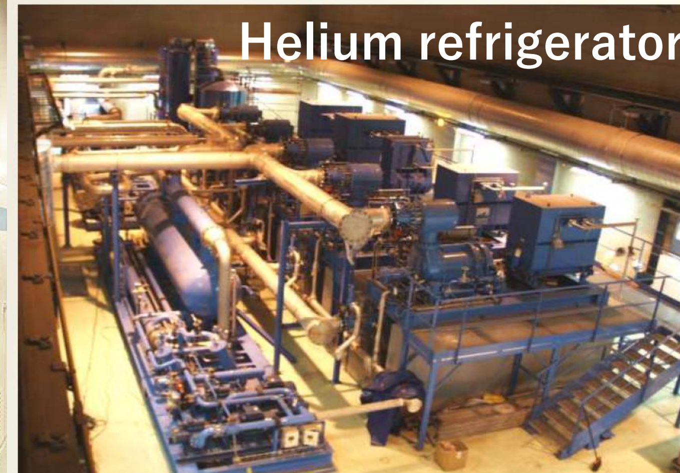


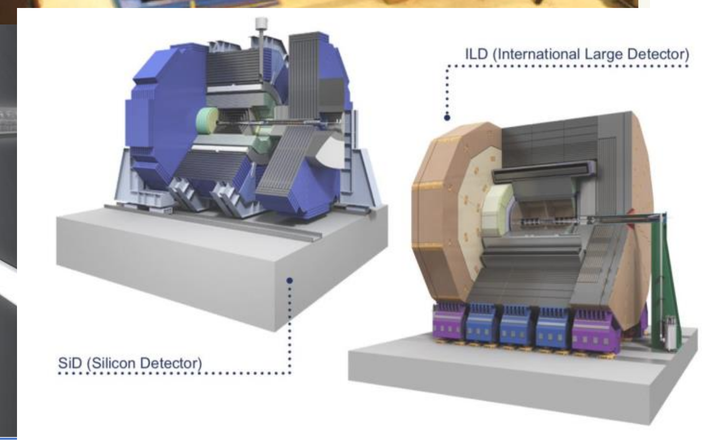
- Where is Iwate Prefecture
- Where is ILC candidate site
- What is ILC?

The ILC is an eco-friendly accelerator based on a superconducting RF technology that is power efficient and sustainable

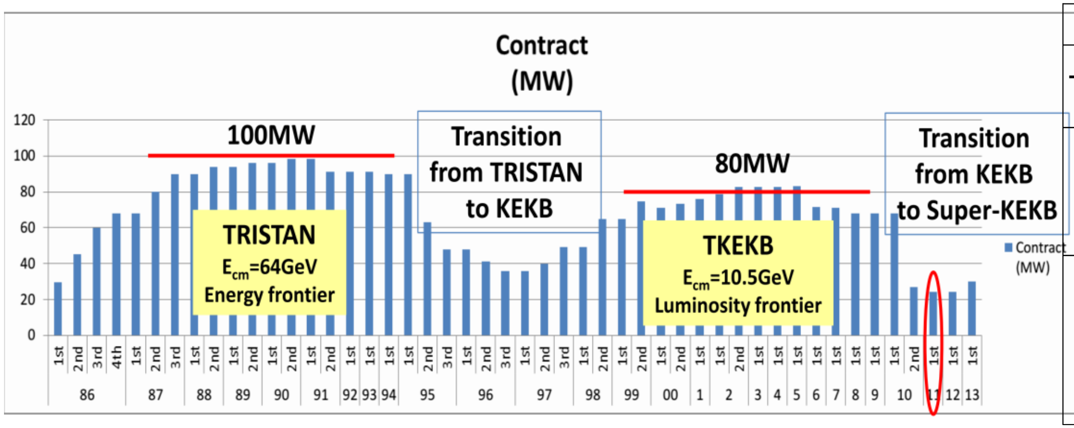






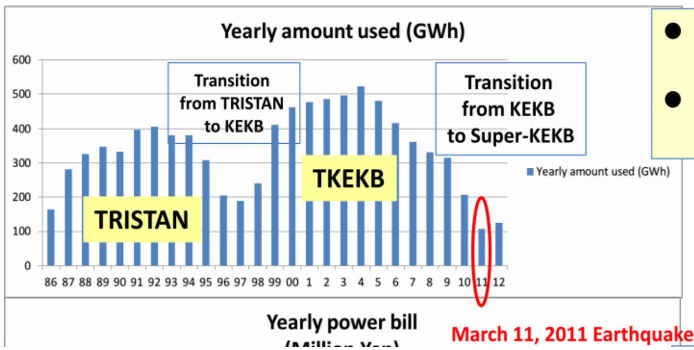


- Accelerators are electric power-loading facilities and their construction uses a lot of concrete and steal.
- Reducing life-cycle global GHG emissions from construction to decommissioning of accelerator facilities is an important issue.



	Peak(MW)	TWh/year	Feature
TRISTAN	100MW	0.4	Energy Frontier 64 GeV in 1986
KEKB	80MW	0.5	Luminosity Frontier (Factory Machine at 10.5 GeV) 2.11 E34 /cm^2/s in 2009
ILC	130MW	0.7	Energy and Luminosity Frontier 250 GeV (Higgs Factory) 2.7 E34 /cm2/s with 5 Hz operation and pol. e^-

March 11, 2011 Earthquake



- **Contract (Peak Power Demand):**
  TRISTAN = 1.15 KEKB
- **Yearly amount usage:**
  TRISTAN = 0.8 KEKB

- The table above shows how energy-efficient the ILC is.
- Super-KEKB, currently in operation at KEK, is also an eco-friendly design (nanobeam scheme) and achieves twice the luminosity at half the current of KEKB.

- These figures show data from when I was in charge of power contracts at KEK during TRISTAN and KEKB operation.
- In a large accelerator facility, the contracted power is in the 100MW class, and the annual power consumption exceeds 0.5TWh/year.
- In the case of the ILC, the contracted power is approximately 130 MW, and the annual power consumption is expected to be about 0.7 TWh, depending on the operating hours.

Accelerator researchers are making following four efforts to achieve sustainable accelerator facilities (In case of Japan for 3 and 4).
All efforts are made in collaboration with industry and will eventually have to be returned to society.

① Increasing the power efficiency and performance of accelerator components.

② Electricity used by accelerators should be provided by sustainable power sources instead of fossil fuels, and effective local use of the waste heat energy emitted from the accelerator.

③ To this end, we will help to increase the amount of sustainable electricity in the region and create regional energy management business using waste heat.

④ Cooperate to increase Green Carbon (from forests), Blue Carbon (from seaweed), and White Carbon (CO_2 fixation by increasing wooden buildings) in the region to increase CO_2 absorption.

1. Prologue: Global Warming, ILC Timeline & Features, Sustainable Accelerator Facility

2. **The International Workshop on Sustainability in Future Accelerators in Morioka, Iwate**

3. Epilogue: ILC and GX create new technologies and give back to society

- Green ILC work should be conducted under international collaboration.
- A compact international workshop with 57 participants (35 from Japan and 22 from overseas) held in Morioka, Japan, for three days from September 25, 2023, played an important role in understanding the current situation and creating a vision for the future.
- I will show here some of the highlights of this workshop and a few of Japan's policies and contributions.

Workshop Highlights

1. According to Suzanne Evans of ARUP, CO_2 emissions during ILC construction will be 250 kilotons.
2. According to Steiner Stapnes of CERN, the CERN electricity future plan in 2050 is 50% nuclear (5 g/kWh CO_2 emissions) and 50% renewable (20 g/kWh CO_2 emissions) => total: 12.5 g/kWh => 1 TWh/year = 12.5 kilotons of CO_2 emissions.
3. I could get global perspectives inspired by Anders Sunesson (ESS) and Steiner Stapnes (CERN)
    1. Nordic countries already meet 2050 EU Targets
    2. Electricity and CO_2 emissions around the world

5. Japan is an island nation, so it is necessary to create its own closed scenario. Therefore, Japan and EU have very different scenarios for achieving carbon neutrality.
    - Japan reduces fossil fuel use but cannot reduce to zero, so it offsets by increasing CO_2 absorption by forests (Green Carbon) and seaweed (Blue Carbon) and CO_2 fixation by constructing wooden buildings (White Carbon)
    - Japan is blessed with renewable biomass and also is working on low-carbon technologies in concrete and steel making by indistries.

According to Suzanne Evans of ARUP, CO_2 emissions during ILC construction will be 250 kilotons.

ARUP

Life Cycle Assessment

Comparative environmental footprint for future linear colliders CLIC and ILC

Final Report
July 2023

CERN
KEK-JAPAN

- **A methodology for calculating life cycle CO_2 emissions has been completed.**
- **The CLIC and ILC cases were evaluated in detail.**
- **Future reductions are also proposed.**

Contents

Authors: Suzanne Evans, Ben Castle
Contributors: Yung Loo, Heleni Pantelidou, Jin Sasaki, Fragkoulis Kanavaris

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Executive summary

Approach

This report evaluates the Life Cycle Assessment (LCA) of the construction of the Compact Linear Collider (CLIC) and the International Linear Collider (ILC). This study has considered the underground facilities construction, covering tunnels, caverns and access shafts only, for the following configuration options:

1. **CLIC Drive Beam**, 5.6m internal diameter, Geneva (380GeV, 1.5TeV and 3TeV)
2. **CLIC Klystron**, 10m internal diameter, Geneva (380GeV)
3. **ILC**, arched 9.5m span, Tohoku Region Japan (250GeV)

The LCA follows the ISO 14040/44 methodology and was carried out using Simapro 9.4.0.2. The ReCiPe Midpoint (H) 2016 method was used to estimate the environmental impacts across 18 impact categories.

A1-A5 Global Warming Potential (GWP) hotspots have been evaluated and possible reduction opportunities have been identified.

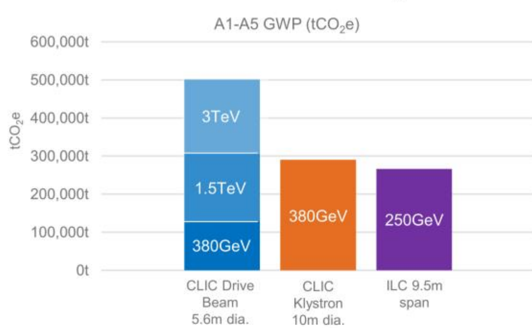
The approach and evaluation has been undertaken in close collaboration with CLIC and ILC teams from CERN and KEK.

A1-A5 Outcomes

A1-A5 considers material, transport and construction environmental impacts only. The A1-A5 GWP (tCO_2e) values are detailed below and constitute a baseline GWP for the current design of the CLIC and ILC.

CLIC Klystron 380GeV and ILC 250GeV have similar A1-A5 GWP of approximately 0.3 $MtCO_2e$. The CLIC Klystron 380GeV has approximately 2 times the A1-A5 GWP than CLIC Drive Beam 380GeV which is due to the increase in cross section of the main linear accelerator tunnel and the shielding wall. The increase in GWP across the 3 CLIC Drive Beam build stages is a direct function of the increase in tunnel length per increased energy levels.

The options have been evaluated as tunnels, shafts and caverns. The tunnels is the largest A1-A5 GWP contributor across all CLIC and ILC options.



Recommendations

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

- Consider the use of low carbon concrete technologies
- Reduce the precast concrete segmental lining thickness for CLIC Drive Beam and Klystron options as this can have a significant impact on embodied carbon reduction of the tunnels.
- Replace the shielding wall in CLIC Klystron and ILC with concrete casing and earthworks fill, repurposed from tunnel excavation. This is to be confirmed with CERN and KEK upon shielding wall requirements for experiments.

These reduction opportunities demonstrate a possible 40% embodied carbon reduction for CLIC and ILC, in line with the UN Breakthrough Outcomes for 2030.

In addition, consider the steel manufacturing process as well as SFRC alternatives such as plant fibres and recycled tyre steel fibres that are lower cost and environmental impact. More generally, consider partnering with suppliers that are committed to low carbon solutions.

It is recommended to adopt carbon management principles in accordance with PAS2080:2023 to maximise the carbon reduction potential in the development of these projects and integrate carbon reduction into decision-making driving design, construction and operation of the colliders.

Linear colliders
Sustainability studies for LCs
Life Cycle Assessments

Steinar Stapnes

EAJADE WP4: Morioka 27.9.2023

Sustainability during operation

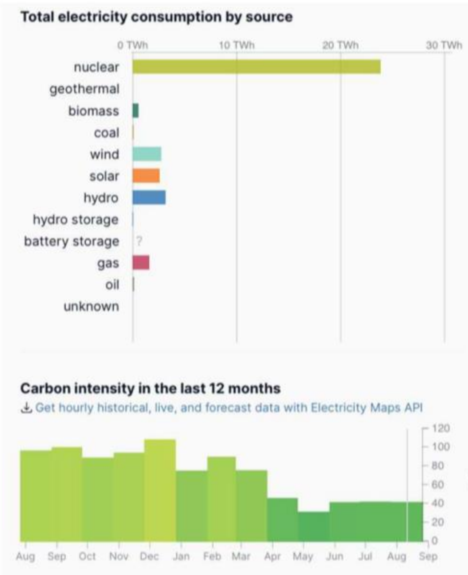
- Operation costs dominated by energy (and personnel, not discussed in the following)
- Reducing power use, and costs of power, will be crucial. Other consumables (gas, liquids, travels …) during operation need to be well justified. Align to future energy markets, green and more renewables, make sure we can be flexible customer and deal with grid stability/quality.
- 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).
- Provided we can run on green mixtures (PPA example at CERN, also (hopefully) built fully into the green ILC concept) we can also contractually chose green options. LCs are very suited for this (variable power load).

A rough estimate, assuming ~50% nuclear and ~50% renewables (as wind/sun/hydro):

1 TWh annually equals ~12.5 ktons CO2 equiv. annually

(note: this is factor ~3 below the current French summer month average)

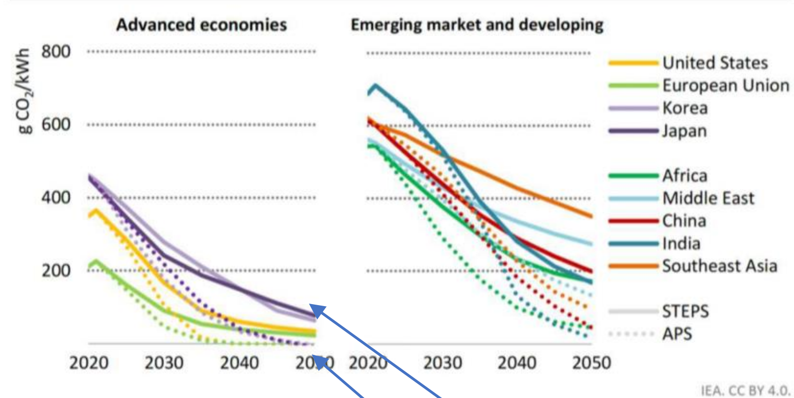
From energy to CO2 – in 2040-50



From: https://app.electricitymaps.com/zone/FR

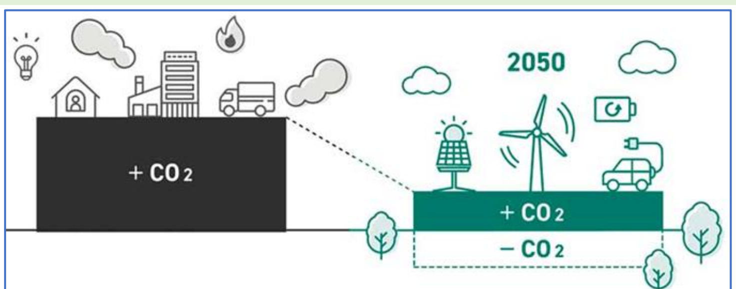
Contains also g/kWh per source

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



ectricity generation varies widely today, but all regions see a decline in
d many have declared net zero emissions ambitions by around 2050

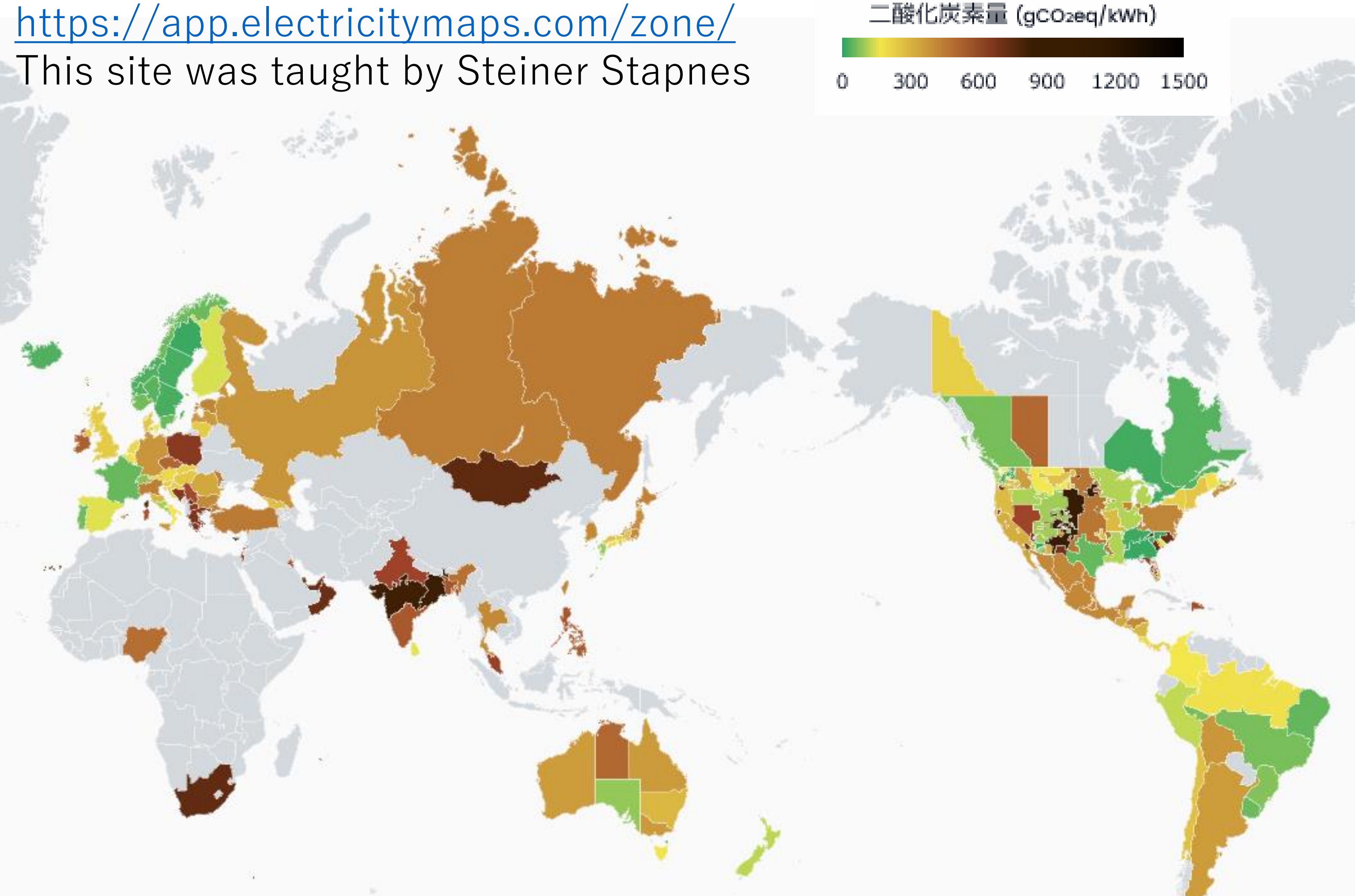
- Japan is an island nation and must be a closed scenario in one country.
- Offset" scenario is reasonable because Japan cannot go fossil fuel free by 2050 and is rich in renewable biomass.



By 2050
Japan: 480g ⇒ 100g
EU: 220g ⇒ almost zero

https://app.electricitymaps.com/zone/

This site was taught by Steiner Stapnes



World Map of CO_2 Emissions/kWh: The greener the better, the darker the worse

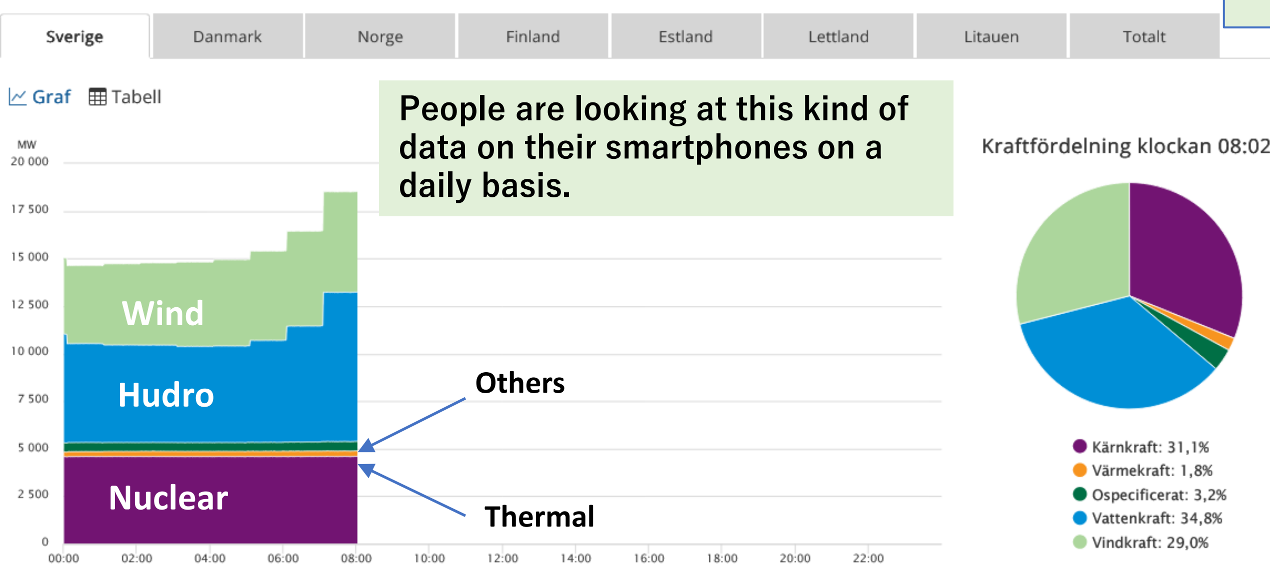
Data not AVAILABLE for gray countries or regions

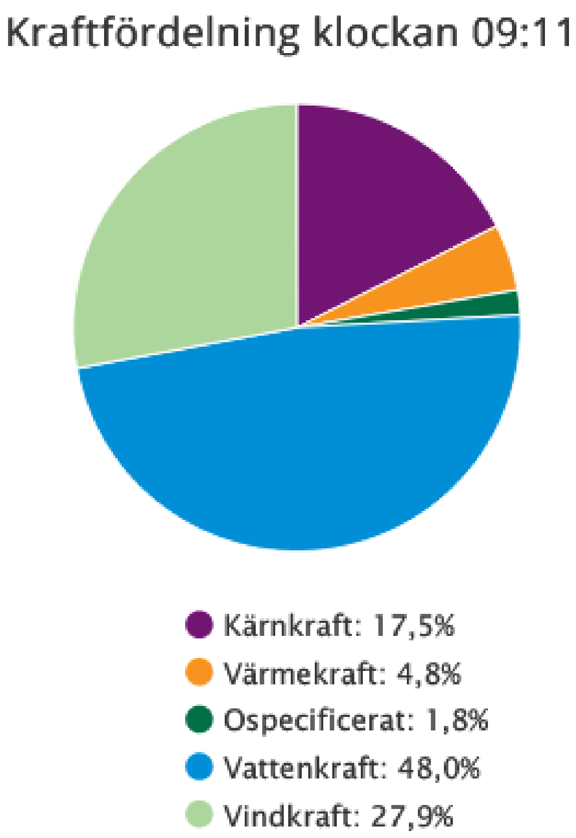
- I spoke with Anders Sunesson (ESS Institute) from Sweden.
- Sweden and Europe have liberalized their electricity markets and electricity is traded under free competition.
- Electricity networks are interconnected and power is transmitted and distributed across borders.
- The objective of the electricity market is to use integrated resources as efficiently as possible to meet the demands of electricity users.
- The public can view the following electricity statuses at any time in real time (https://www.svk.se/om-kraftsystemet/kontrollrummet/)

- This screenshot shows the situation in Sweden at 8:02, October 4. You can switch between the 7 countries.
- The lower figure shows the power flow in the seven countries.
- In Sweden, nuclear power is the base power source, hydro and wind power fluctuate according to demand.
- Hydro and thermal power adjust the overall power balance.
- Denmark: 90% wind power.
- Norway : 90% hydro.
- Finland: 51% nuclear.
- Electricity mix varies by country

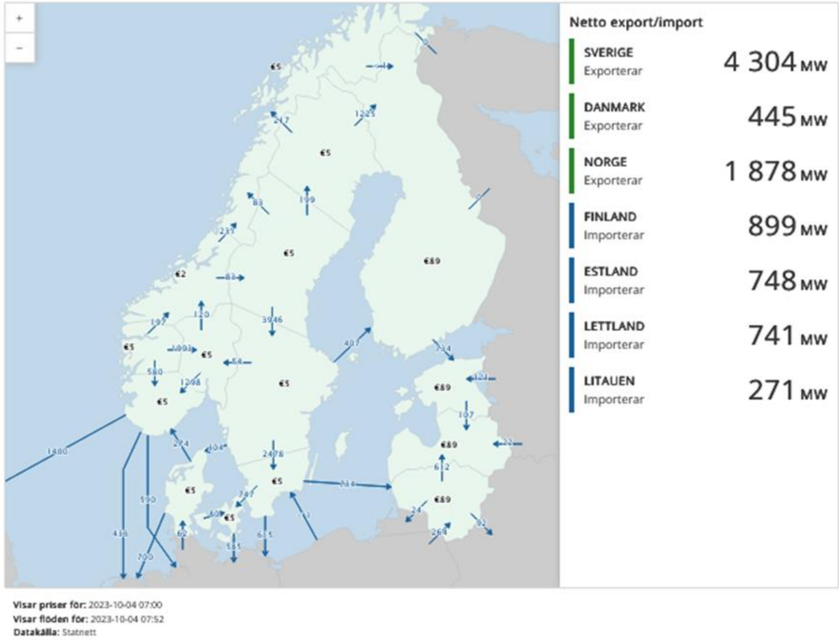
As demand for electricity increases in the morning, wind and hydroelectric power generation is increased.

People are looking at this kind of data on their smartphones on a daily basis.



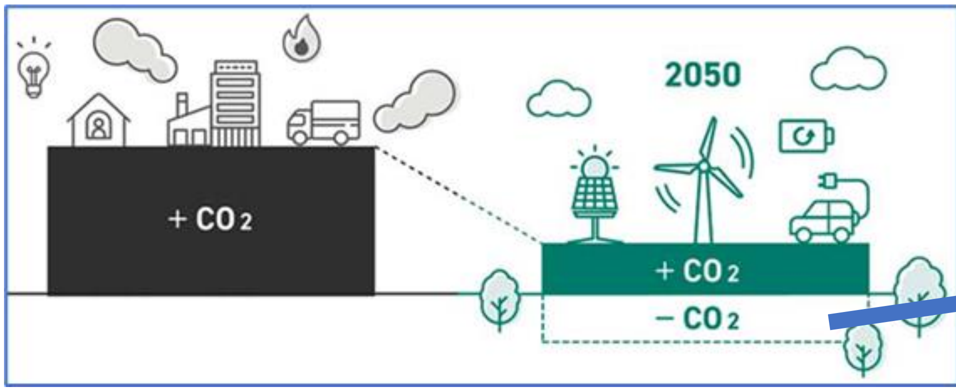


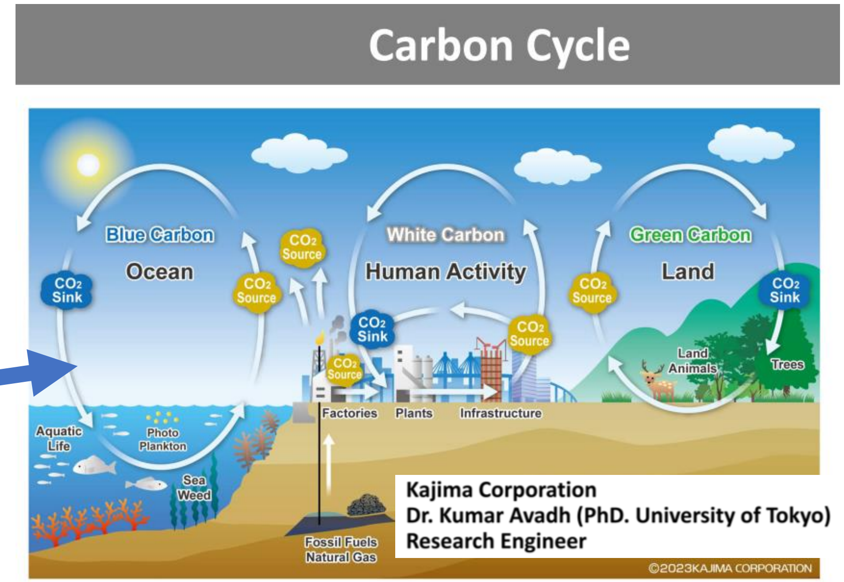
- The total for the seven countries (left graph) is
  (1) hydro,
  (2) wind,
  (3) nuclear,
  (4) thermal, and
  (5) other, in descending order.
- Thermal power is less than 5%.
- Renewable energy 75.9%, nuclear 17.5
- **Nordic countries are a good model for achieving carbon neutrality in 2050**



Finally, here are some contributions of Japanese companies to the Green ILC

Again, Japan's strategy is to reduce CO_2 emissions while simultaneously increasing and ultimately offsetting CO_2 absorption



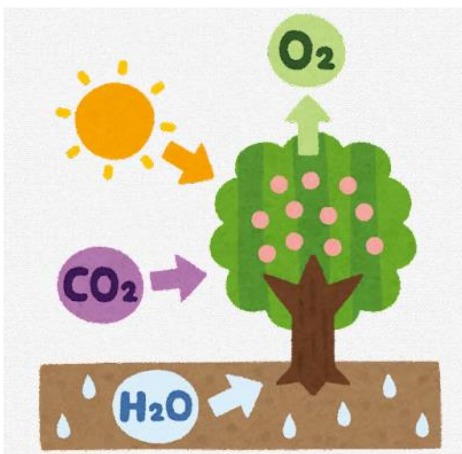


Contributions

- Green Carbon
  - ✓ H. Kikuchi, Ichinoseki City: Estimation of CO_2 absorption by forest
  - ✓ Shibata Sangyo Inc.: Sustainable forestry
- Blue Carbon: Yoshioka, Experience by Hirono-town
- White Carbon: Shelter Inc.: Large scale wooden buildings
- Negative CO_2 emission cement development: Kajima Corporation
- Waste heat utilization business using HASClay: HKK Inc.

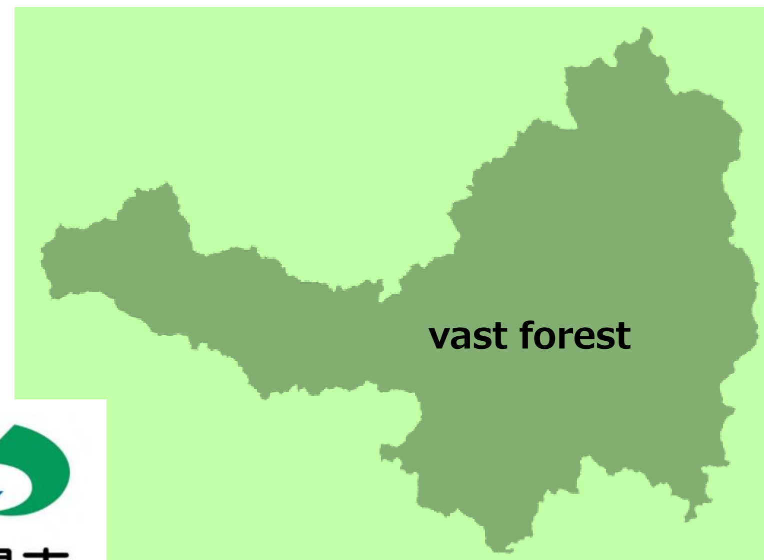
Ichinoseki City Regional Forest Policy Advisor
HIROSHI KIKUCHI

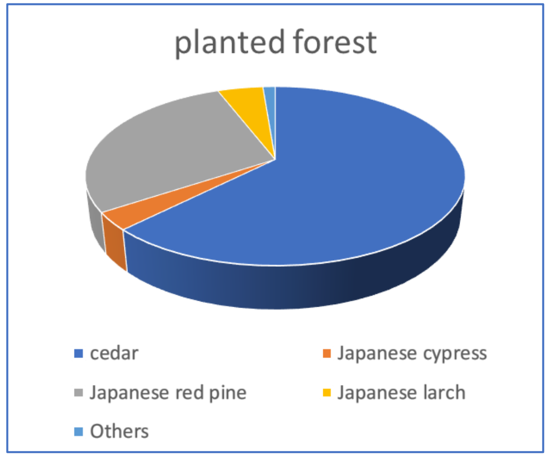
About CO_2 absorption in Ichinoseki City's forest resources

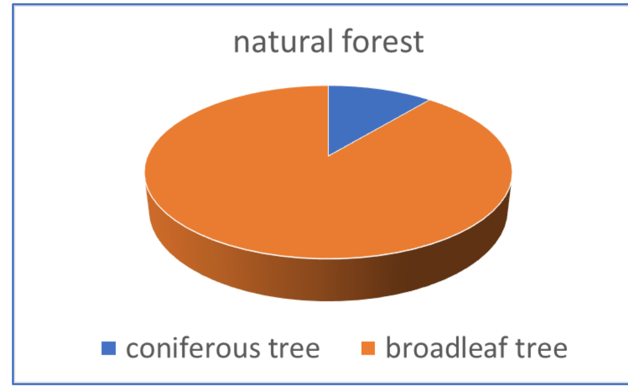


Forests are CO_2 sinks

一関市







47% Planted Forest: 31465 ha
53% Natural Forest: 34895 ha
Total 66363 ha

In planted forests, cedar is the most abundant species, followed by red pine.

Natural forests are mostly broadleaf tree.

Estimation by Hiroshi Kikuchi-san, advisor to the Ichinoseki City Agricultural Land and Forestry Department:

- The entire Ichinoseki forest absorbs 303.53 kilotons of CO_2 per year.
- The average annual CO_2 absorption per unit area is 4.57 t/year/ha.
- Japan's Forestry Agency estimates that an ideally managed artificial cedar forest can absorb 8.8 t CO_2 per hectare each year. Ichinoseki forest management has room for improvement.

- This amount, 303.53 kilotons of CO_2 per year is already sufficient to cover the total emissions of the ILC by the CO_2 emission factor, which should be so around 2040.
- Of course, it is necessary to consider the CO_2 balance of Ichinoseki City as a whole.
- Therefore, it is important to try to further reduce emissions and increase absorption.

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.

Action goals of our Shibata Sangyo members

- **Utilize the latest forestry technology**
- **Making this region thrive with the power of the forestry industry**
- **Let's create fun and happiness together!**

Blue Carbon (CO_2 absorption by seaweed in coastal areas in the town of Hirono, northern Iwate Prefecture)

CO_2 absorption by seaweed is very promising because it is slightly better than that of forests.

- Creating artificial tidal pools (4m wide and 1m deep ditches, total length 17.5 km) to create a flow of fresh seawater due to the difference in tidal range, which encourages the growth of wakame (seaweed) and kelp.
- Seaweed is eventually anchored to the seafloor as flow algae.
- 3106.5 t (CO2 equivalent) certified as J Blue Credit.
- Sea urchins (very tasty) are now abundant as a byproduct.
- J Blue Credits are blue carbon credits issued and sold by JBE (Japan Business and Economy Technology Research Association).
- JBE is composed of the National Maritime, Port and Aviation Research Institute, the Sasakawa Peace Foundation, and individual university professors.

The Challenges of Timber City

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

Shelter®

09/26/2023
Yuka Shibuya

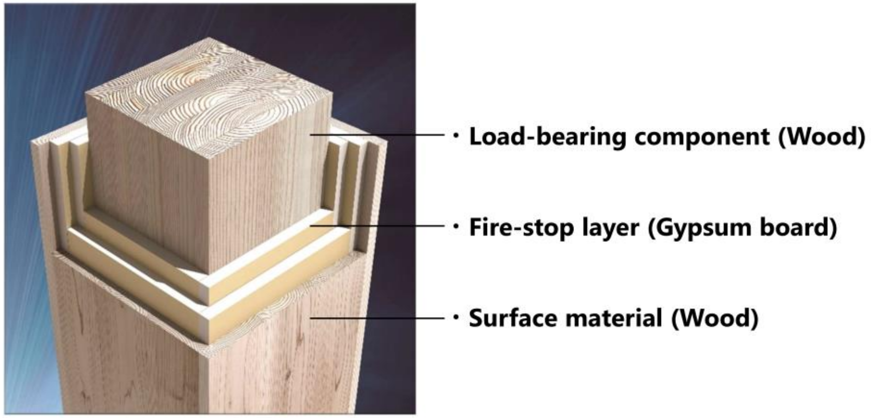
① **Seismic resistance and durability**

② **Fire resistance**

Metal Hardware Joining Method "KES System"

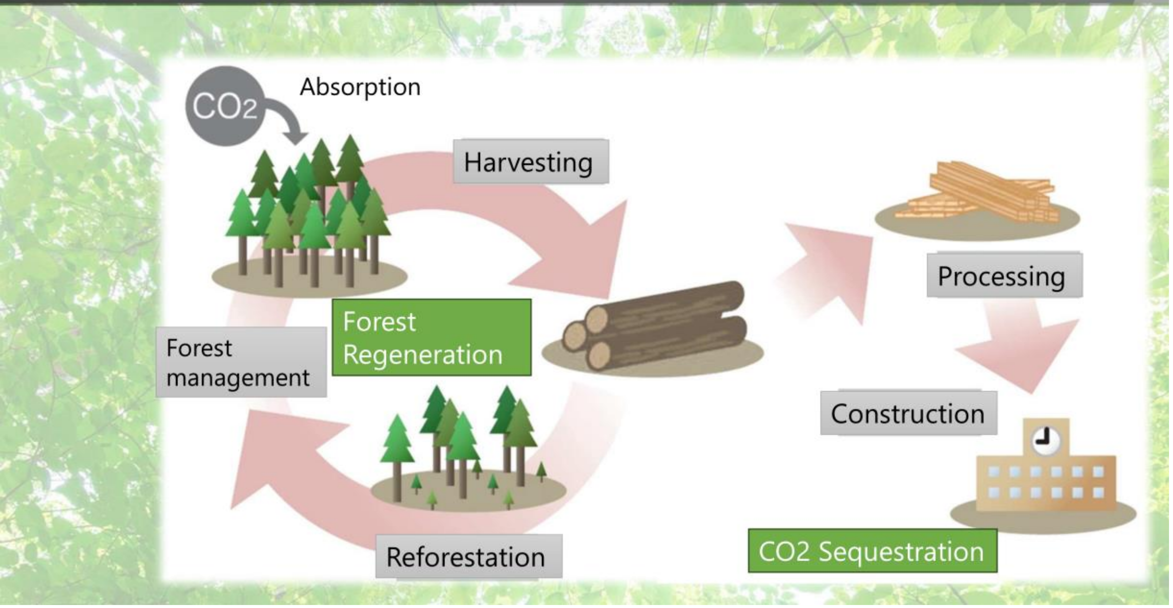
- Use of metal hardware in in the joints and connections of wooden components
- Drastic improvement in the performance of timber construction, including seismic resistance, durability, insulation, airtightness, and ease of construction.

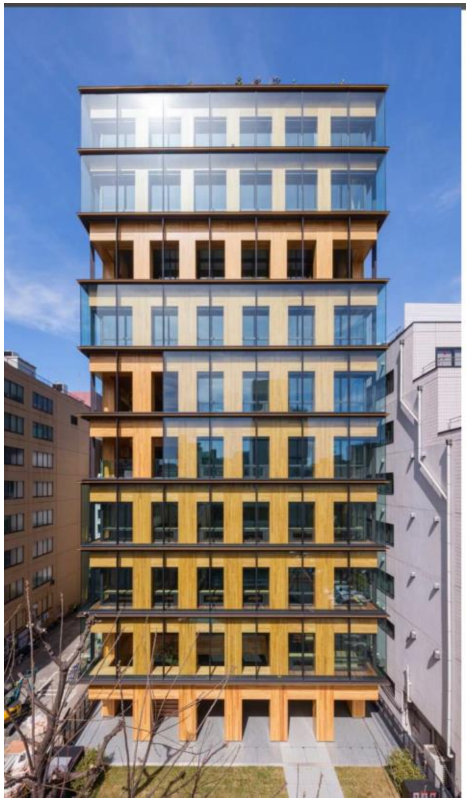
Wooden Fireproof Components "COOL WOOD"



1-hour Fireproof COOL WOOD (Column)

Creating a Forest in the City





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. University of Tokyo)
Research Engineer

KAJIMA CORPORATION

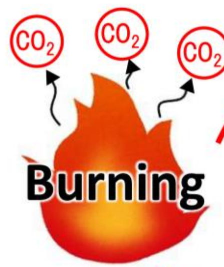
2023/9/26

Concrete: CO_2 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 → 

→ Cement

$CaCO_3$ — 1400°C — $CaO + CO_2$

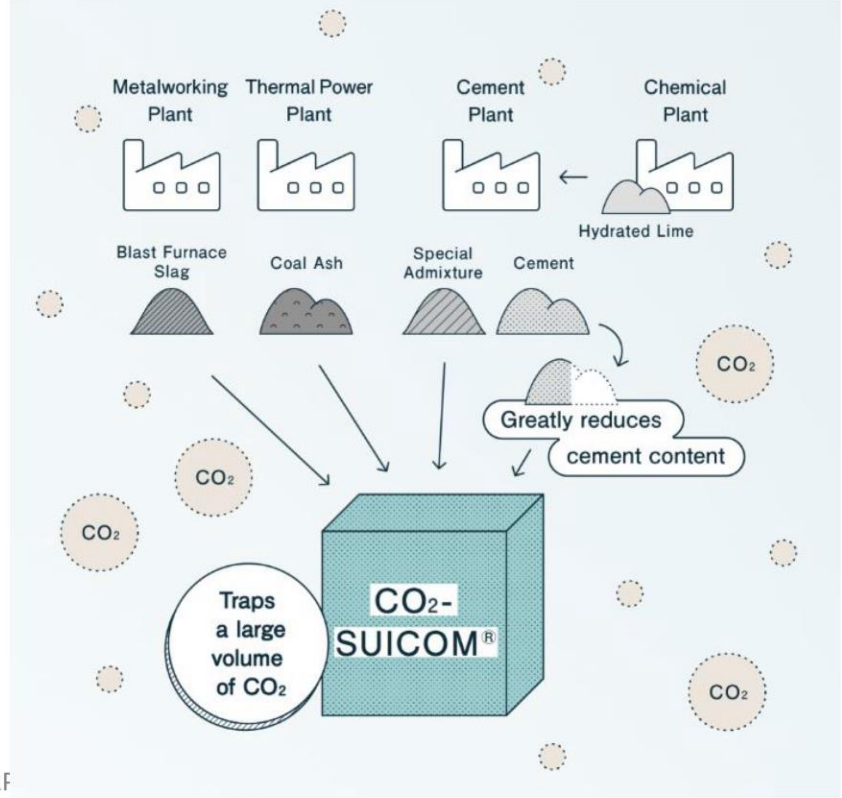
CO_2= 288kg/m^3

CO_2 per 1m^3 of concrete

CO_2-SUICOM

Storage Utilization Infrastructure by COncrete Materials

- Concrete with negative CO_2 emission in its manufacturing process
- Development started in 2008 by Kajima and 3 companies of Chugoku Electric Power, Denka, and Landes
- Available for commercial use



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

1

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.

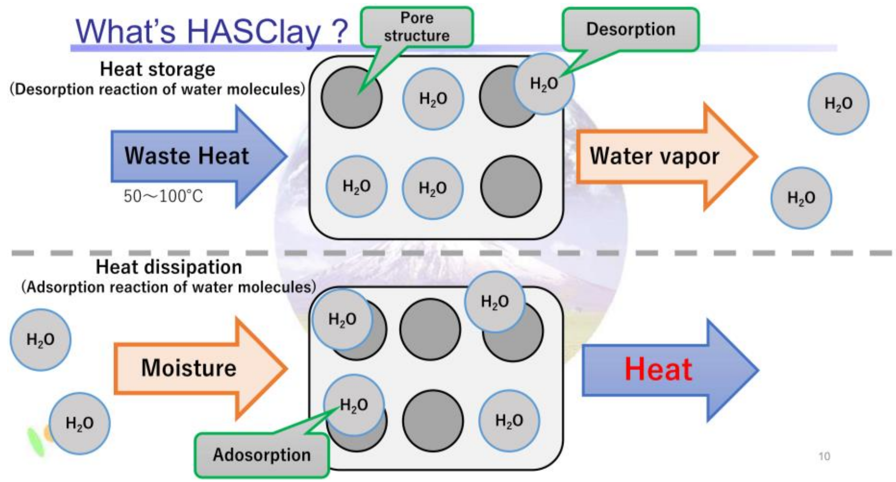
- In particular, it has an excellent storage capacity for low-grade heat (<100 ˚C).
- It is capable of repeating the heat storage and dissipation cycle over and over again.
- By sealing the container and blocking moisture, the heat energy can be stored semi-permanently and will not ignite or deteriorate, 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.

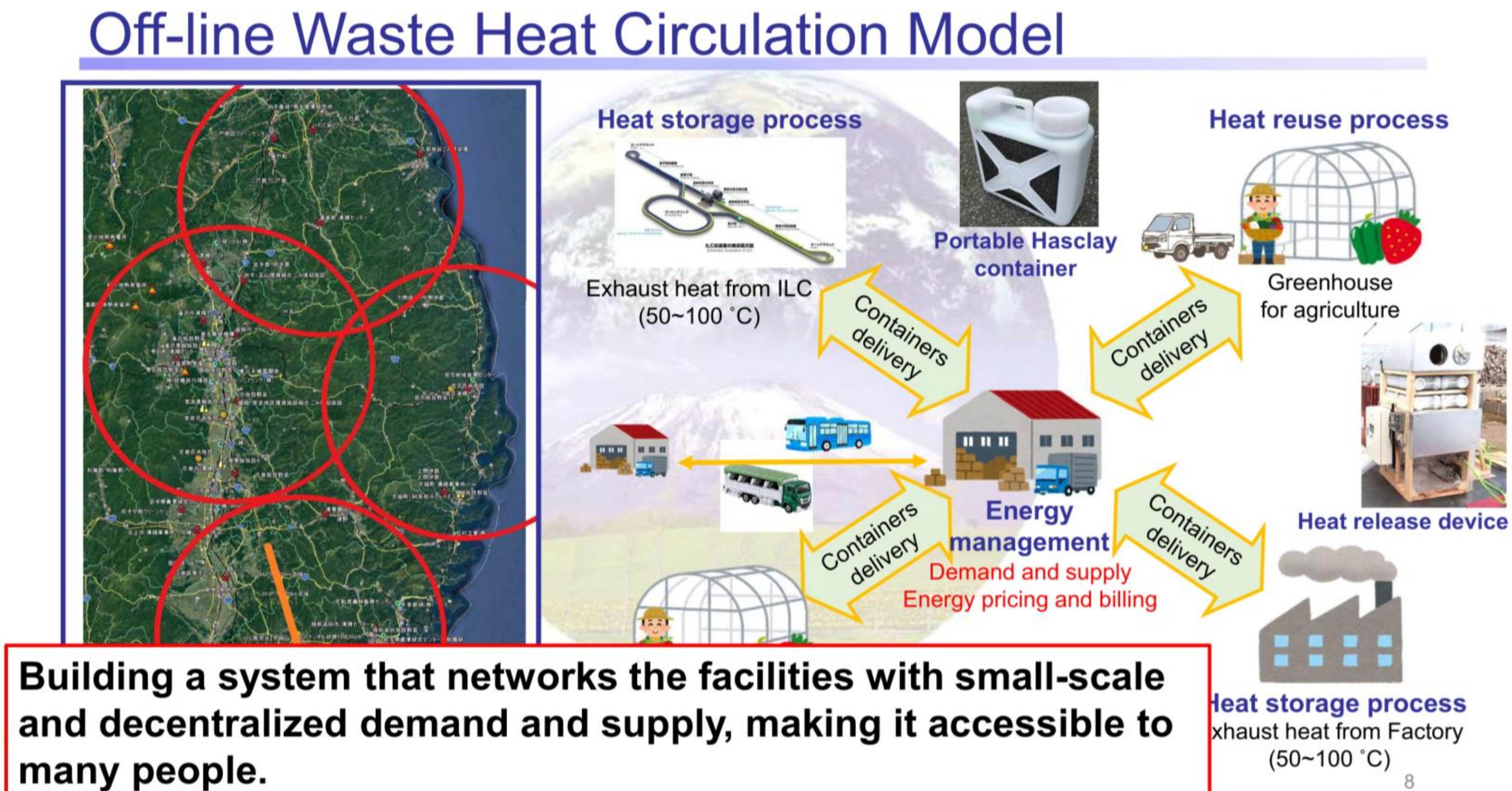

The appearance of HASClay®

Performance of various adsorbents

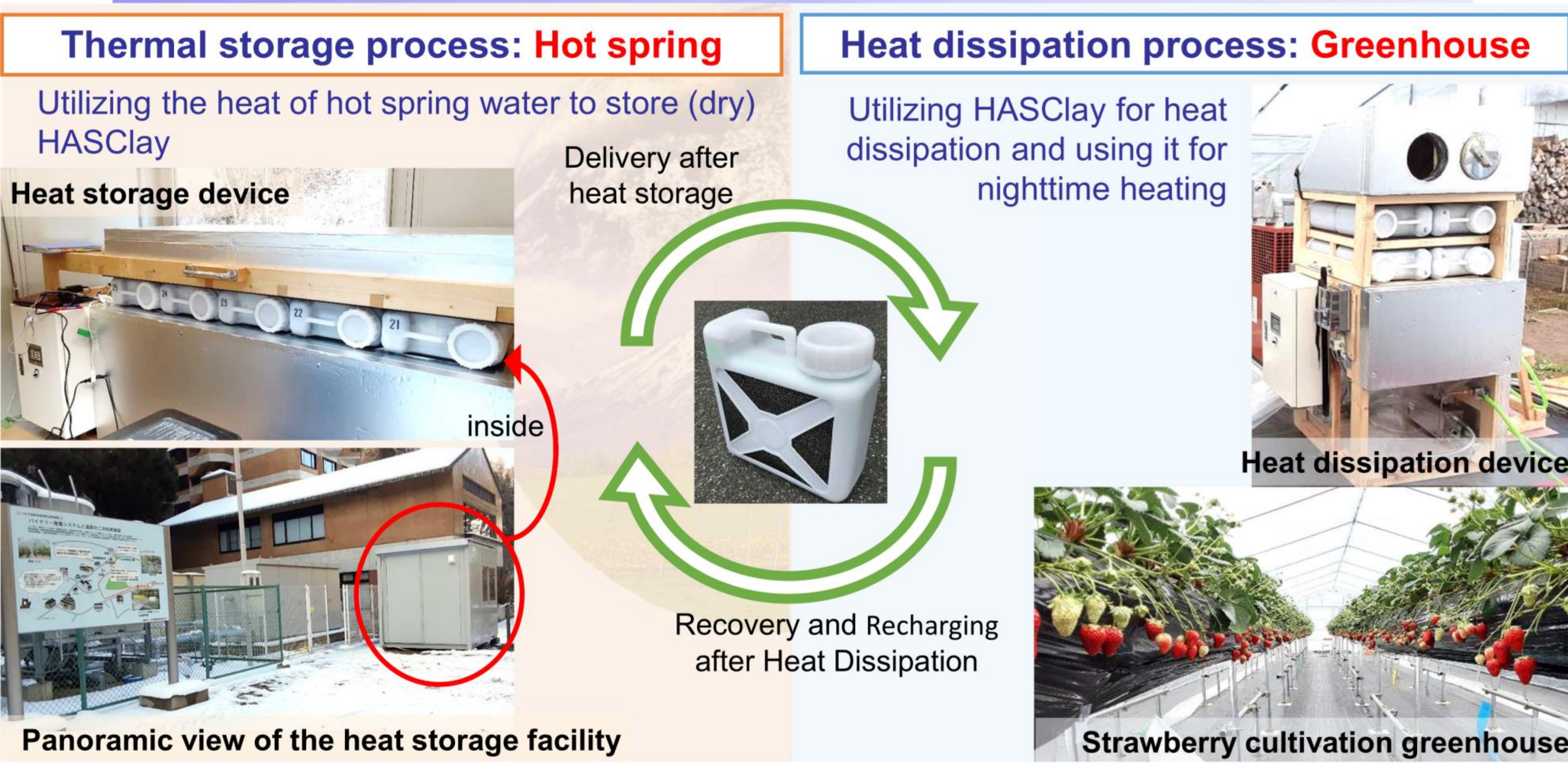
Adsorbent	Heat storage ability	Heat storage capacity(kJ/L)
HASclay	**40 ˚C or more**	**567**
Modified zeolite	80 ˚C or more	439

9


What's HASClay ?
Pore structure
Desorption
Heat storage
(Desorption reaction of water molecules)
Waste Heat
50～100°C
Water vapor
H_2O
Heat dissipation
(Adsorption reaction of water molecules)
Moisture
Heat
Adosorption
10


Off-line Waste Heat Circulation Model
Heat storage process
Exhaust heat from ILC
(50~100 ˚C)
Portable Hasclay container
Heat reuse process
Greenhouse
for agriculture
Containers delivery
Containers delivery
Energy management
Demand and supply
Energy pricing and billing
Containers delivery
Containers delivery
Heat release device
Heat storage process
Exhaust heat from Factory
(50~100 ˚C)
Building a system that networks the facilities with small-scale and decentralized demand and supply, making it accessible to many people.
8

Demonstration tests to achieve commercialization



Green ILC Summary

- ILC Lab (will be established in near future, hopefully) should make further effort to advance energy-saving technologies.
- On the other hand, as a region with a candidate site, we will continue our efforts to realize a sustainable society by the time construction of the “ILC in Japan” begins.
- To this end, we will make efforts to deepen cooperation between the ILC and local primary industries (agriculture, forestry, and fisheries).
- Furthermore, we will use the technology of the ILC waste heat recovery project to build a regional thermal energy circulation system.

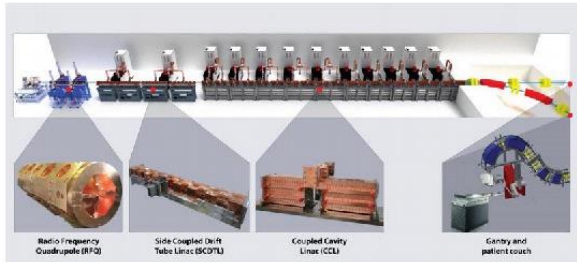
1. Prologue: Global Warming, ILC Timeline & Features, Sustainable Accelerator Facility

2. The International Workshop on Sustainability in Future Accelerators in Morioka, Iwate

3. **Epilogue: ILC and GX create new technologies and give back to society**

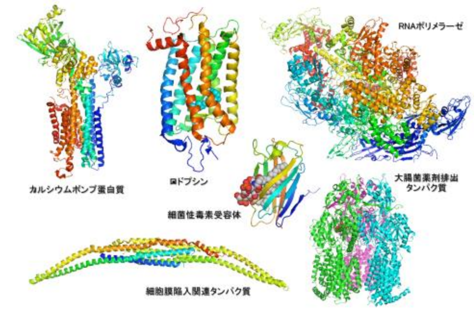
- Accelerators are the product of the synthesis of a wide field of science and technology.
- Conversely, advances in accelerator science have led to innovations in a wide range of fields of science and technology.　Followings are past examples.

Information Management Innovation WWW CERN



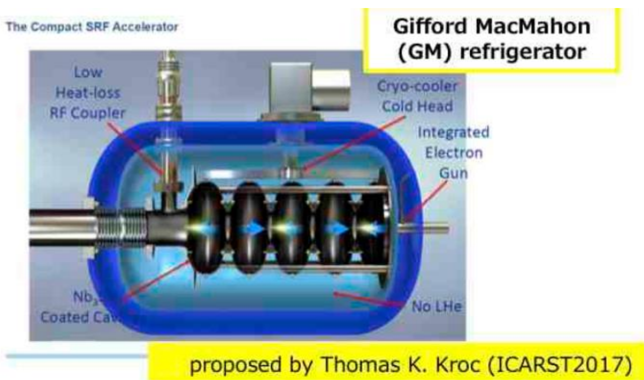
Innovative Cancer Therapy System with Linear Accelerator, CERN/ADAMS

Japan's newest synchrotron radiation facility, Nanoterasu, expected to play an active role in drug design.



Innovations in Structural Biology at Spring-8

ILC ✕ GX ⇨ Create new technologies and industries



Let me give you just one example of the impact of **ILC x GX** on society.

- ILC researchers are studying the use of Nb_3Sn alloys to further improve the performance of superconducting accelerator cavities in order to improve energy efficiency at the ILC.
- If successful, a high-power compact electron linac could be realized, which would have applications in many fields such as drug discovery, environmental pollution control, and shortening the life of nuclear waste.

Thank you for your attention