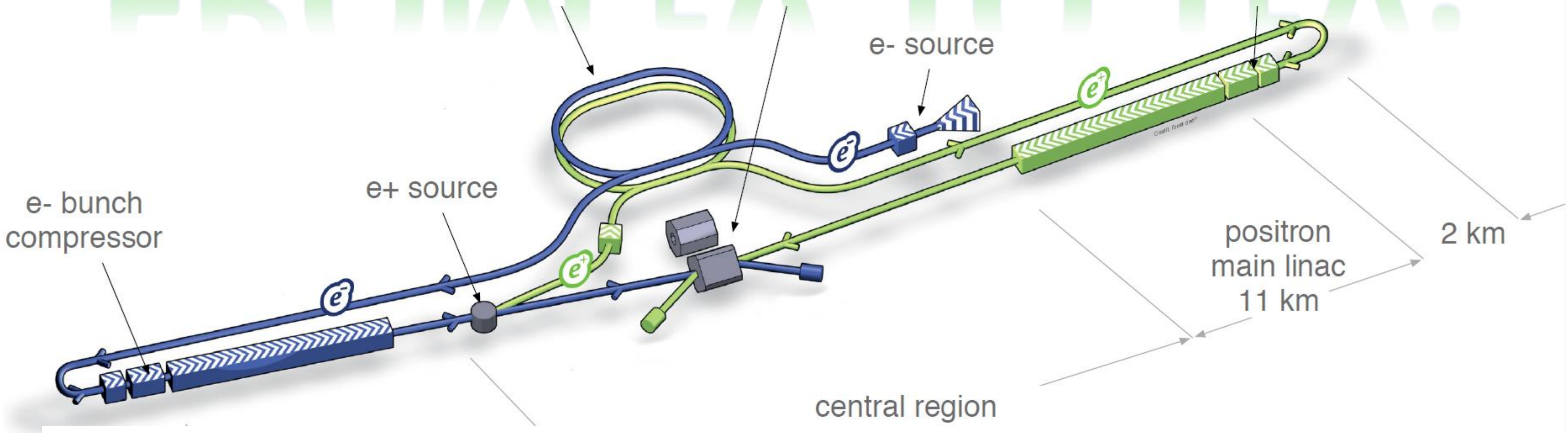
ILC: an amazing energy transformer

FROM eV TO TeV:



THE GREEN ILC

Denis Perret-Gallix
LAPP/IN2P3.CNRS (France)

Overview

- ILC and the society
- ILC Energy Budget requirement
- Green Energies for ILC
- Global organization for a Green ILC
- Conclusions

ILC and the society

- ILC: the first Global Fundamental Science project, as such it will:
  - Attract worldwide attention: a unique showroom for physics and basic research
  - Host a large number of experts from various fields in an open science framework

- ILC: a large power consumer
  - 1.2 TWh (500 GeV) 20% of a nuclear reactor, ~ a large city
  - "Only" for fundamental science
  - In an energy/global warming/financial crisis in the world and in Japan

Energy for colliders

CERN at peak 180 MW, total one year 1.2 TWh ~ 140 MW average (24/7)

"82% accelerators, 12% experiments,
3% computer center, 3% campus infrastructure.
About 1 TWh gets dissipated in cooling towers"

(H.J.Burckhart et al. IPAC2013)

Compared to Geneva canton (500,000 residents):
Total energy 11.4 TWh/year, 25% goes to electricity (2009)

- CERN is 10% of Geneva total energy
- 40% of Geneva electrical power, equivalent to consumption of 200,000 p
- Electricity bill: 40-50€/MWh … still 3 times cheaper that mine … ☹

For 1.2 TWh -> 50-60 M€/year

Energy for ILC (rough estimates)

- e+e- Linac RF, Magnets, Cryo plants: 164MW @500GeV – 300MW @1TeV (TDR)
- Experiment ~ 5 MW (one of the LHC experiments)
- Computing ~ 4 MW (estimated from CERN)
- Buildings ~ 4 MW (estimated from CERN)

Very similar to CERN consumption let's take 180 MW (peak) and 1.2 TWh/year

"A primary voltage of 275 kV was assumed for the site."
"The power capacity is designed to be 300MW and space is reserved for an additional 200MW for the future 1TeV upgrade." ILC TDR Vol. 3-1 → 500 MW

180 - 320 MW 1.2 - 2.2% of Tohoku region (15 GW) ~ Morioka (300,000)
500 Gev BL 1 TeV 18 - 32% of Iwate prefecture (ILC location)

- 135€/MWh 2011 in Japan for industry (OECD 2013 report)

Yearly electricity running cost ~ 160 M€ (500 GeV BL)
Even if 50% rebate for very large users → 80 M€/year

Denis Perret-Gallix
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Energy for Sustainable Science

23-25 October 2013

CERN

2nd Workshop
Energy for Sustainable Science
at Research Infrastructures

- Campus and building management
- Co-generation
- Computing energy management
- Energy efficiency of the facilities
- Energy management, quality, storage
- Energy management technologies developed in Research Facilities
- Waste heat recovery

CERN

EUROPEAN SPALLATION SOURCE

ERF European Association of National Research Facilities Open to International Access

Linear Collider WS

Tokyo Nov. 15 2013

A. Suzuki (KEK DG)

Energy Management in Japan, Consequences for Research Infrastructures

Masakazu Yoshioka (KEK)

1. Electric power supply in Japan, before and after March 11, 2011 earthquake
   - High efficiency and “almost” environmental pollution-free electricity generators can save Japan, and contribute to reduce global CO_2 problem
2. KEK Electricity contract as an example of large-scale RIs
3. Accelerator design by considering optimization of luminosity/electricity demand
   - Example: Super-KEKB
   - ILC
4. Accelerator component design by considering high power-efficiency
   - Klystron
   - Availability based on MTBF and MTTR
5. Summary

ILC: an amazing energy transformer

FROM eV TO TeV:

THE GREEN ILC

2nd Energy for Sustainable Sciences, CERN Oct 2013

Denis Perret-Gallix LAPP/IN2P3.CNRS (France)

1

Energy Management at KEK, Strategy on Energy Management, Efficiency, Sustainability

Atsuto Suzuki (KEK)

INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

Green ILC

- Energy saving and improving efficiency (J. Fujimoto @LCWS)
  - Better component efficiency: klystron, cryocooler (see M. Yoshioka*)
- Energy Recovery
  - Beam energy and beam dump heat recovery (See A. Suzuki*)
  - Heat recovery from cooling system (Sterling engines and heat pumps, thermoelectricity, osmosis, …)
- Production: Developing Sustainable energies for ILC
  - How to adapt the ILC component power requirements to the various energy sources distinctive features (DC (PV) supply for cryo and RF, variability, …)
  - How to build energy storage to cope with ILC running conditions (liquid helium, SMES(Sc Magnetic Energy Storage), Flywheel energy storage, hydrogen, batteries, hydro, compressed air, ….
  - What is the best mix to cover ILC specific needs ? 24/7, long shutdowns
- Distribution: Smart (Local) GRID: Full scale multi-sourced GRID management and control
  - Smooth and rapid switching between energy sources, including conventional supply
  - Energy Management and forecast: production, storage and backup

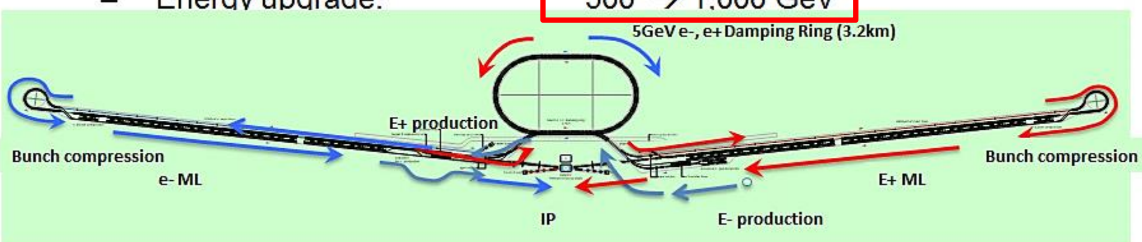
*Energy for sustainable science workshop (CERN 2013)

Power Balance of Consumption and Loss in ILC

Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

Requirements from Physics Exp.

- Basic requirements :
  - Luminosity : $\int Ldt$ = 500 fb^{-1} in 4 years
  - E_{cm} : 200 – 500 GeV and the ability to scan
  - E stability and precision: < 0.1%
  - Electron polarization: > 80%
- Extension capability :
  - Energy upgrade: 500 → 1,000 GeV



ILC 500 GeV Total Power : ～200 MW

Improve efficiency

	loss rate
Infrastructure : 50 MW	50 % : 25 MW
RF System : 70 MW	50 % : 35 MW
Cryogenics : 70 MW	90 % : 60 MW
Beam Dump : 10 MW	100 % : 10 MW
200 MW	～ 130 MW

Increase recovery

Obligation to Us

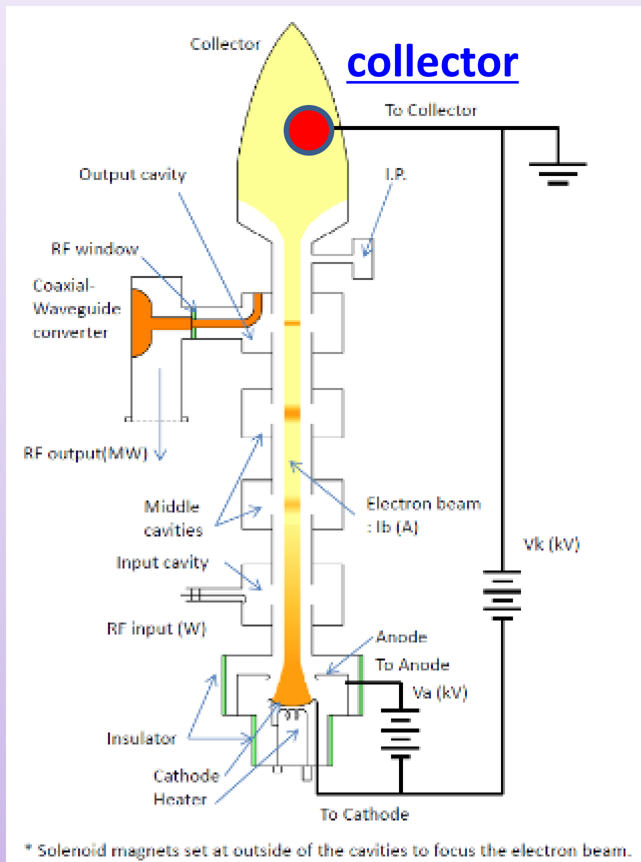
How to Improve RF Efficiency

Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

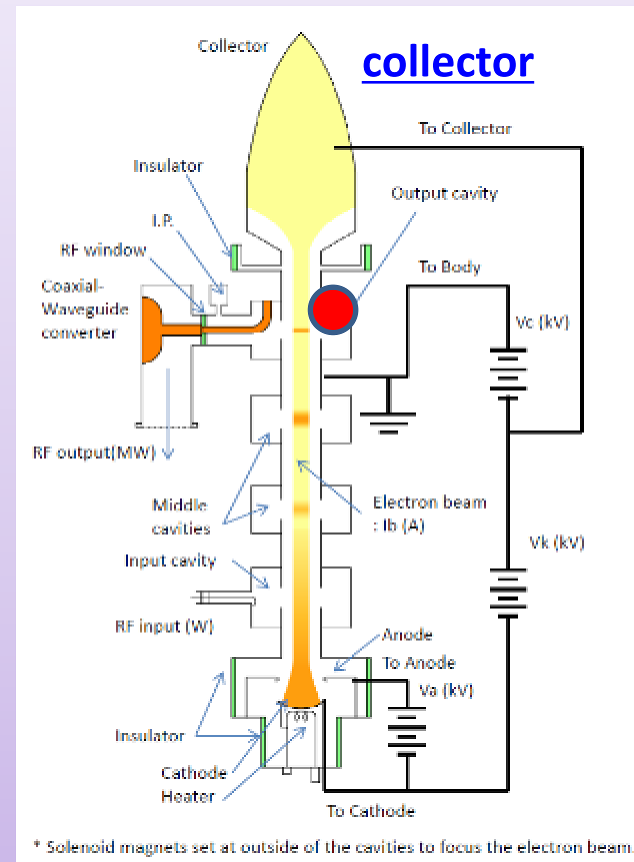
R&D of CPD (Collector Potential Depression) Klystron

CPD is an energy-saving scheme that recovers the kinetic energy of the spent electrons after generating rf power.

Conventional



Schematic diagram of CPD



Green ILC

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*Energy for sustainable science workshop (CERN 2013)

Plasma Deceleration Dumping

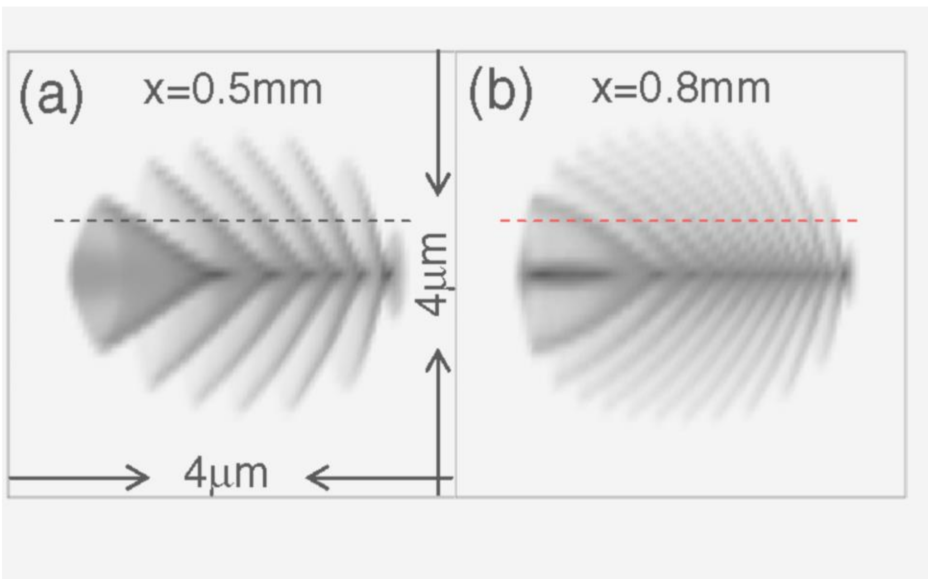
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 101303 (2010)

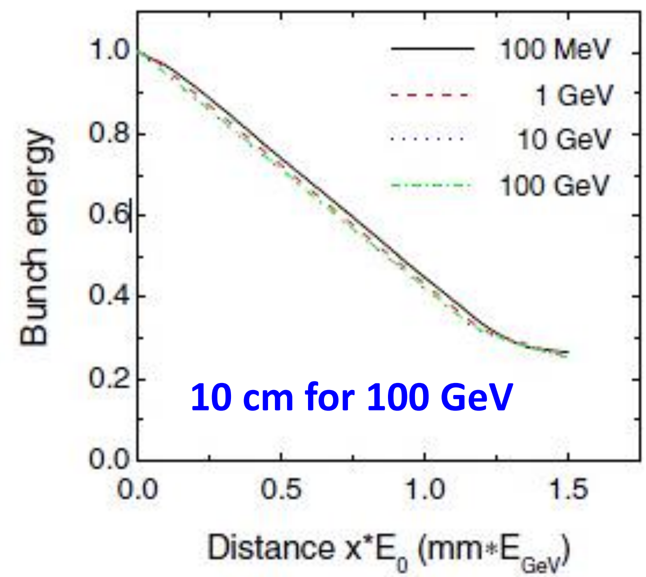
Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

Collective deceleration: Toward a compact beam dump

H.-C. Wu,[1] T. Tajima,[1,2] D. Habs,[1,2] A. W. Chao,[3] and J. Meyer-ter-Vehn[1]
[1]*Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany*
[2]*Fakultät für Physik, Ludwig-Maximilians-Universität München, D-85748 Garching, Germany*
[3]*SLAC National Accelerator Center, Stanford University, Stanford, California 94309, USA*
(Received 10 December 2009; published 5 October 2010)

Use Collective Fields of Plasmas for Deceleration





- The deceleration distance in the underdense plasma is 3 orders of magnitude smaller than the stopping in condensed matter.
- The muon fluence is highly peaked in the forward direction.

Green ILC

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  - Better component efficiency: klystron, cryocooler (see M. Yoshioka*)
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*Energy for sustainable science workshop (CERN 2013)

ILC site

The Japan energy and GRID

Jones, R. S. and M. Kim (2013), "Restructuring the Electricity Sector and Promoting Green Growth in Japan", *OECD Economics Department Working Papers*, No. 1069, OECD Publishing.
http://dx.doi.org/10.1787/5k43nxrhfjtd-en

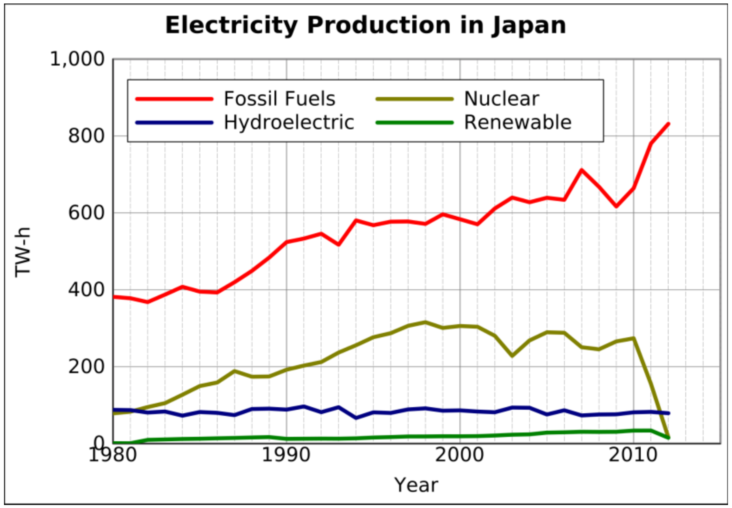
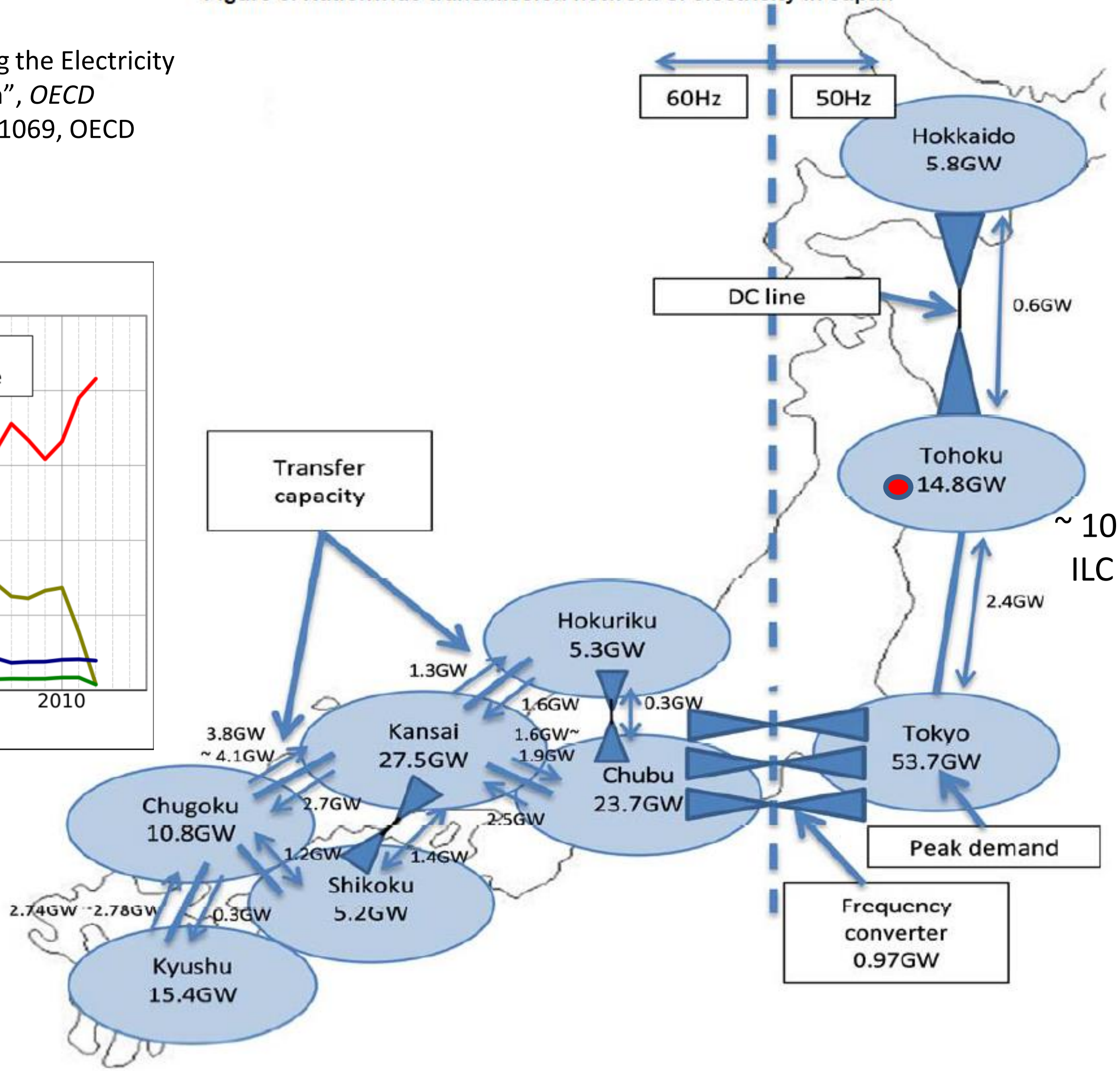


Figure 5. Nationwide transmission network of electricity in Japan



~ 10 M people
ILC = Morioka

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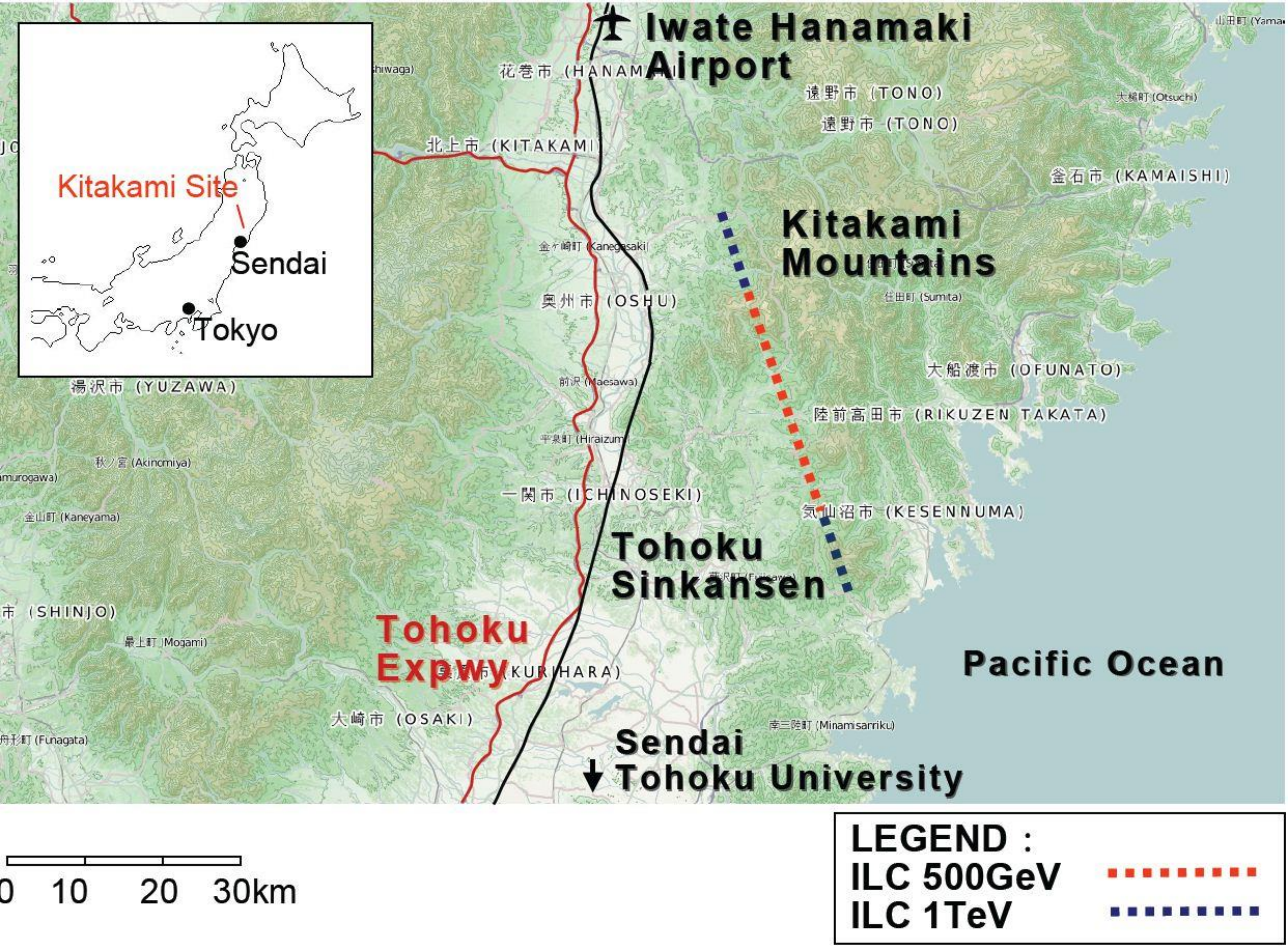
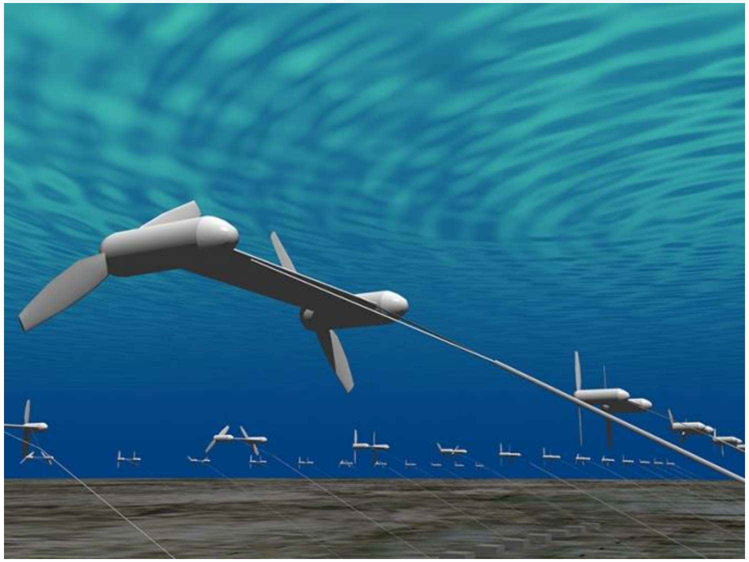

Iwate Hanamaki Airport
Kitakami Site
Sendai
Tokyo
花巻市 (HANAMAKI)
遠野市 (TONO)
北上市 (KITAKAMI)
釜石市 (KAMAISHI)
Kitakami Mountains
奥州市 (OSHU)
湯沢市 (YUZAWA)
大船渡市 (OFUNATO)
陸前高田市 (RIKUZEN TAKATA)
一関市 (ICHINOSEKI)
気仙沼市 (KESENNUMA)
Tohoku Sinkansen
(SHINJO)
Tohoku Expwy
(KURIHARA)
Pacific Ocean
大崎市 (OSAKI)
Sendai
Tohoku University
0 10 20 30km
LEGEND :
ILC 500GeV
ILC 1TeV

Wind/Marine Energy

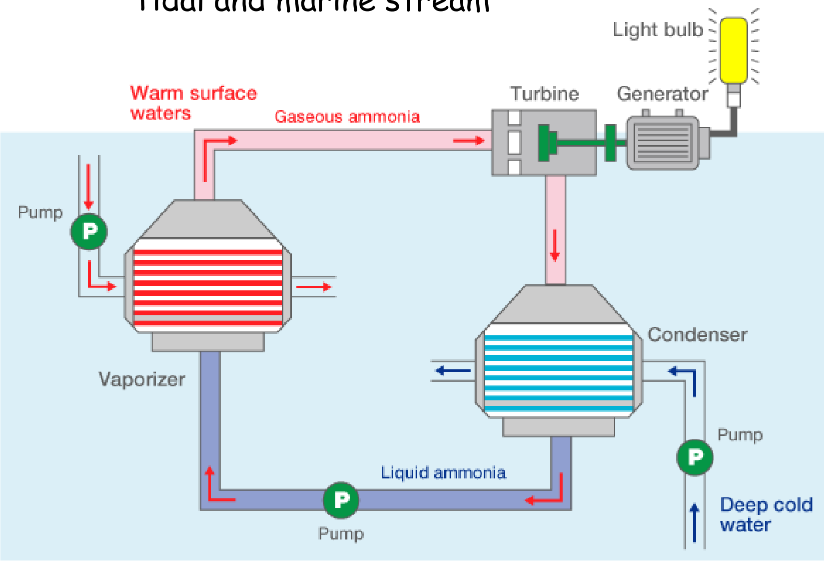
2 MW Goto island prototype



Tidal and marine stream

2.3 GW installed, none failed after 3/11

Wind Projects
6 floating 2MW wind turbines off Fukushima
up to 80 in 2020



Sea temperature gradient

Biomass/biofuels Energy

Idemitsu Kosan Co. 5 MW

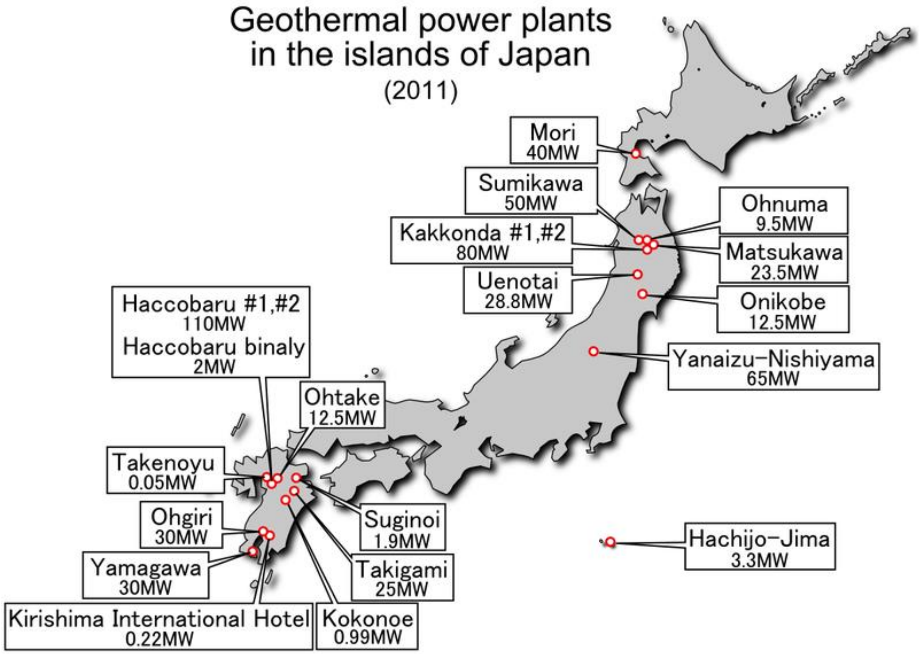
Miyasaki, Nishinippon Env. Energy co. 11.7 MW

Installed 2.3 GW (2011)
very little progress since 2011

Many sources including:
Rice, fishery and agricultural wastes
Algae
Other cattle and human wastes

Co-generations heat and electricity

Geothermal Energy



Installed 2011 : 0.5 GW.
Geothermal potential sources : ~ 20 GW

No substantial progress since 2011

But:

- Avoid National Parks
- Get agreement with the onsen industry
- No Fracking

Photovoltaic and Thermal Solar energy

10 MW Komekurayama 30 km Fuji-san (TEPCO)

Installed: 8.5 GW
Projects:
341 MW in Hokaido
100 MW Minami Soma

2009 Target Japanese gov.
28 GW of solar PV capacity by 2020
53 GW of solar PV capacity by 2030
10% of total domestic primary energy demand met with solar PV by 2050

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Major contract signed for supply of solar panels derived from CERN technology

09 Mar 2012

SRB Solar field in Valencia (Image: CERN)

Solar thermal Energy

C. Benvenuti
CERN Physicist

Note in passing
ILC: an amazing energy transformer

Assuming an ILC powered by photovoltaic energy:

Energy at the particle level:
from 1 eV to 1 TeV:
12 orders of magnitude, a Tera scaling

Energy concentration:
Ratio of the PV surface to collect 82 MW(one beam) to the beam size:
20 orders of magnitude, almost Zetta scaling

But energy transformation efficiency:
Beam power/AC power: 6-7%

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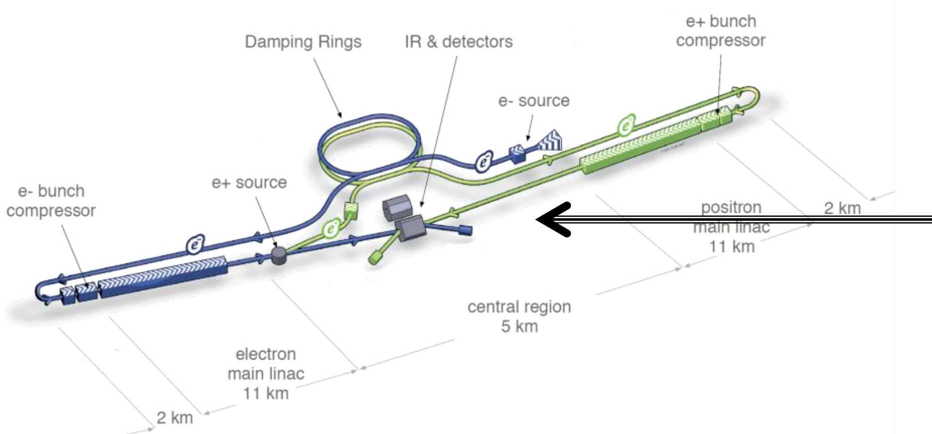
Global organization for Green ILC

ILC Energy Center

ILC High-Energy Research Center
- Fundamental Research
- HEP Applications

ILC Sustainable Energy Research Center
- Basic Research
- Application R&D
- Pilot Power plant for ILC

Electrons, photons, neutrons factories
HPC/GRID Computing



ILC Sustainable Energy Research Center

- Two main objectives:
  - R&D on Sustainable Energies, attracting the best experts.
  - Powering ILC
- Industry participation
  - Energy issues relate to most of the industry (much more than HEP)
  - Twofold interest: be part of a global research endeavor and reach ILC market
  - ILC achievements: a showcase for the companies
- Institutes and organizations related to energy can be involved:
  - In Japan JCRE Japan council on renewable energies, JREF, ..
  - In the world: IEA, NREL (US), CREST, Narec(UK), CENER(SP), ..

However:

- Must run parallel to ILC, minimum impact on ILC timeline
- Must have its own specific budget from:
  - public programs, governmental and regional (EU) plans (US-EU energy council, …)
  - Industry participation and contribution

Main missions

- Contribute to the most advanced and promising researches:
  - Basic research … is the most needed and less funded in energy research
    - Nanotech for energy production and storage, for lighting, …: graphene, nanotubes, quantum dots, …
    - Biomimetic research (artificial photosynthesis) and quantum effects in solid states
    - New materials for: catalysts, fuel cell membranes, high-Tc SC, solar cells high efficiency
    - Low energy harvesting devices, STEG (thermo-electricity), …
    - Characterization tools and computer modeling
  - Technology and engineering (devices and systems)
    - Hybrid systems, best mix, energy transformation, matching energy source and accelerator components
    - Specific equipment like: Solar Powered Cryocooler (DC compressor, Thermoacoustic Stirling Heat Engine Pulse Tube), solar energy to RF, fuel cells for computing systems
    - R&D on biomass, geothermal, wind/stream turbines
    - Smart GRID
- Power the ILC:
  - Identify power plant locations with low environmental impacts.
  - Design and build pilot power plants (a few 10 MW each) from various complementary energy sources for real scale studies and substantial ILC power supply.
  - Build the ILC Smart Grid with connection to: conventional grid, pilot plans, storage

Can the ILC project reach energy self-sufficiency? How and when ?

Benefits for Energy Research

Research in a cross-disciplinary and global center.

"*Scientific work is still too fragmented and specialized, with a focus on incremental change rather than on transformation.*" OECD Sustainable Energy Forum 2013

Focus on basic research, rarely done in other frameworks: Innovation and Industry target short term returns

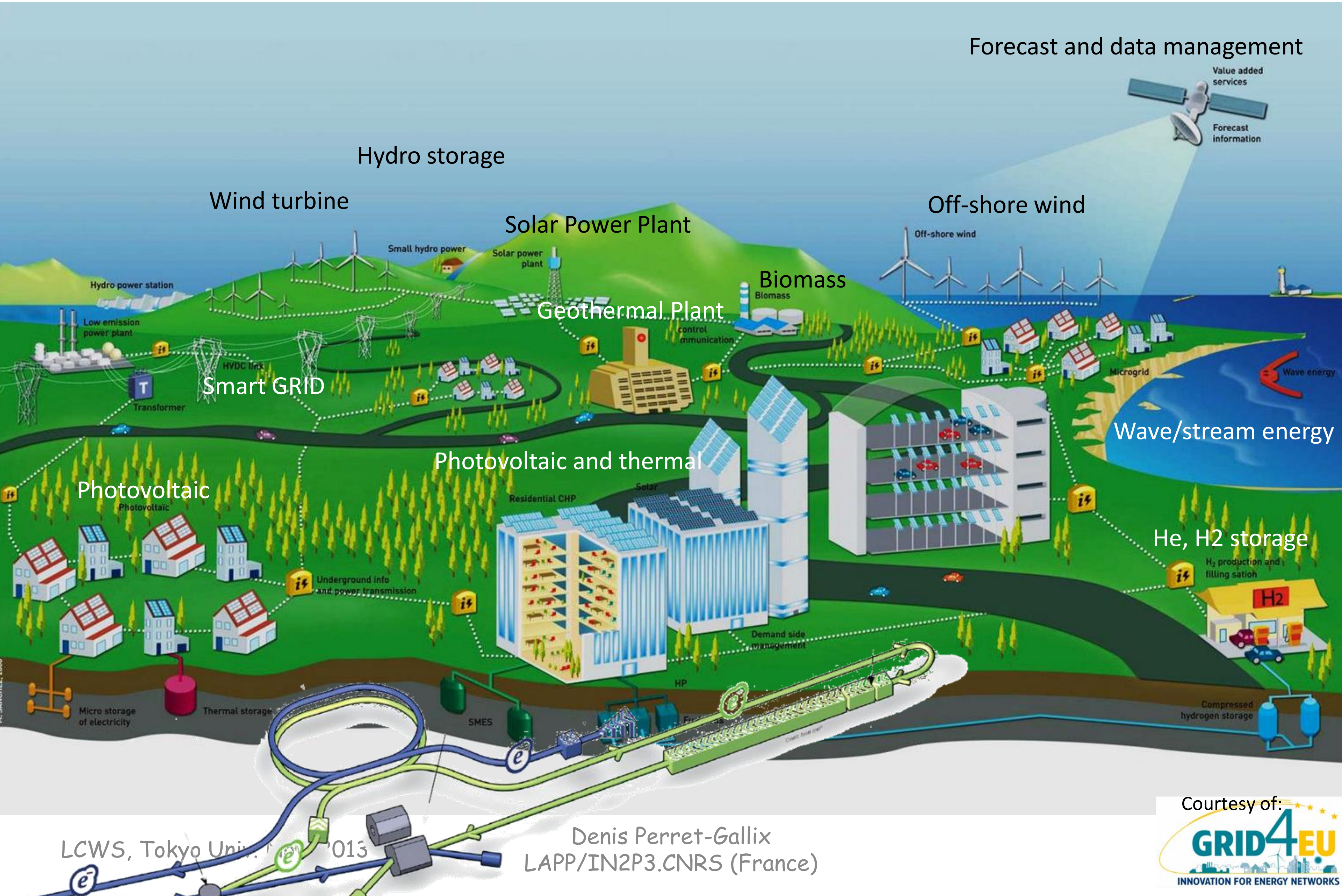
"*Science can be perceived as working too much for vested corporate interests and not enough for the public interest*" OECD Sustainable Energy Forum 2013

Comprehensive framework: From basic research to pilot plants

Synergies with HEP/accelerator:

- Material analysis (photon factories (XFEL), neutron sources, …)
- Large computing centers (GRID), Geant4 simulations, turbulences,
- Expertise in advanced electronics, large electronics and computing system management,
- Expertise in very high vacuum, surface treatment and cleaning, …
- Expertise in large scale manufacturing industrialization (cavities and magnets): from design to commissioning (quality control, …)

ILC center futuristic view



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Gradual Multi-Staged Implementation

1. As a backup of the conventional power supply (~ 7 MW current diesel engines)
2. To cover buildings energy (electricity and heating) (~ 10 MW) (zero energy)
3. To power some parts of the ILC components: some of the cryo plants, computers, …. (10-20 MW)
4. To power more of the previous components (30-40 MW)
5. To power some of the klystrons (100 MW)
6. All 500 GeV ILC electrical supply (170 MW)
   - Conventional power supply is now in backup mode
7. Get ready for the 1 TeV (additional 150 MW)

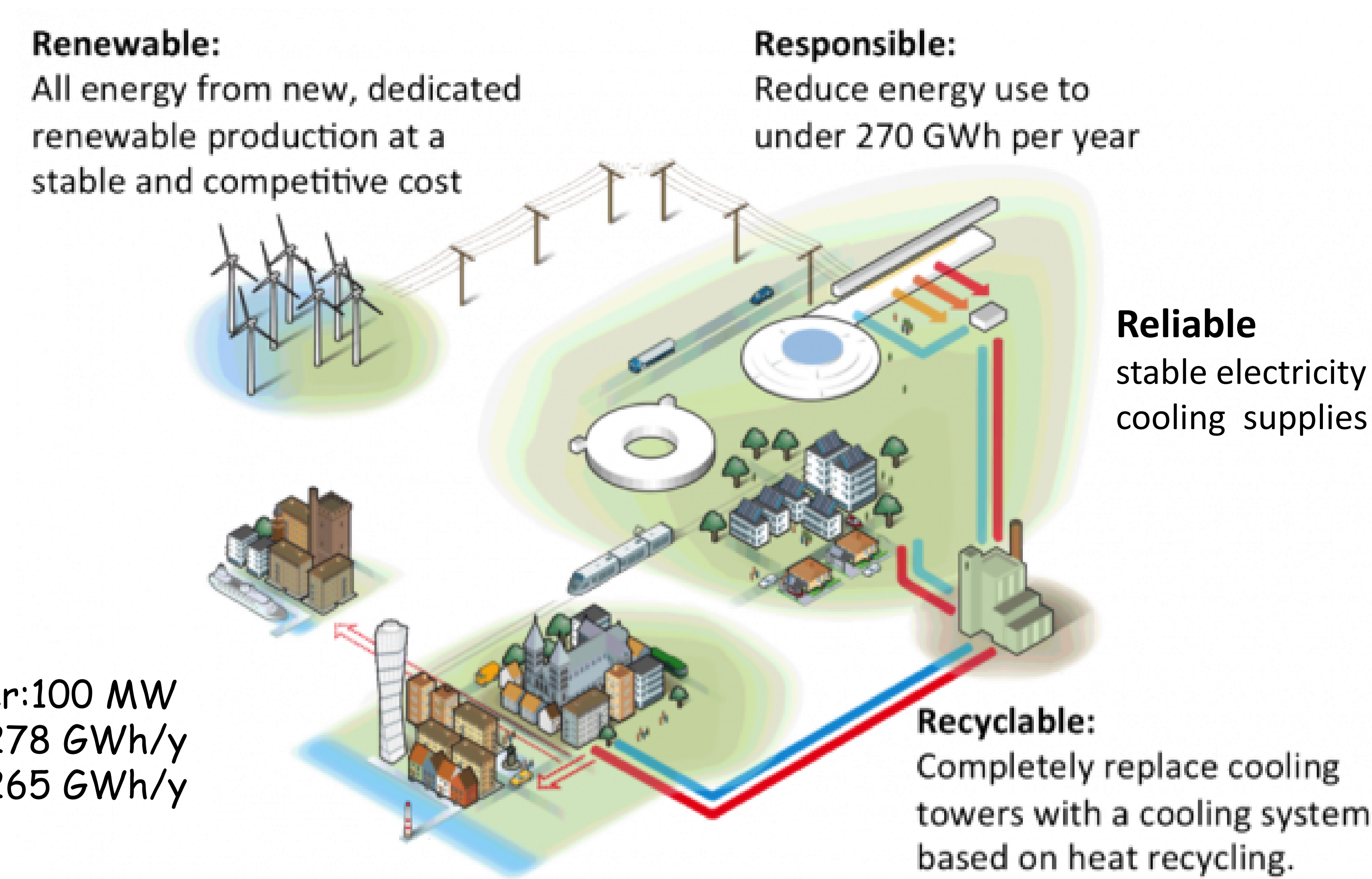
ILC Sustainable Energy Research Center Location

- Most genuinely close to ILC, in Kitakami vicinity
- But not necessarily, through special agreements between electrical power utility companies
  - could be anywhere in Japan or even with plants disseminated at the most favorable locations
  - Anywhere in the world, could be part of the country running costs contributions, but should be sustainable energy… reinventing the Data GRID model

Next step
ILC Energy Working Group

- Members: Energy, ILC and Industry experts
- Missions:
  - Identify all possible energy saving and recovery technologies related to the ILC project
  - Setup a baseline project as well as an advanced research line on more innovative technologies
  - Evaluate the impacts on the ILC project it-self in term of:
    - ILC Design modification and implementation
    - Budget spending and saving
  - Design a global sustainable energy project for the ILC
    - Identify short term renewable energy pilot plants with build-in upgradability
    - Identify basic energy researches in line with the ILC project
    - Propose an "ILC Energy Center" global organization
- Report: Green ILC Feasibility report by 2014-2015

The Green ESS
European Spallation Source -- 4R



Reliable
stable electricity and cooling supplies

Wind Power:100 MW
Machine: 278 GWh/y
Cooling: 265 GWh/y

Conclusions

- ILC being the size of a city, in terms of electricity consomption ,is a real scale workbench to develop, maintain and manage a mix of sustainable energy sources.
- HEP: a driver for innovation: a unique opportunity to link HEP and Energy R&D in an ambitious but rewarding endeavor:
  - Societal impacts:
    - Tackle one of the most important world-wide issue: Energy, boost basic energy research which is most needed today
    - Raise ILC and fundamental research public visibility and appreciation
    - Better local appraisal: ILC provides rather than consumes energy resources
  - Great saving in running cost particularly if R&D/infrastructures are supported by a separate additional budget. ILC is a (very) long term effort, investing in green energies makes sense.
  - Better flexibility in ILC operations (less GRID dependence)
- Additional motivations for the decision makers: ILC goes beyond basic science
  - In Japan:
    - Revitalization of the economics (Abenomics), Re-industrialization after Tsunami in Tohoku, Global cities (Japan Policy Council), industry (AAA) and internationalization
  - Elsewhere: fewer incentives. But energy is a big and motivating issue for everyone

Additional slides

Renewable energy Japan (METI)

Energy Source	Total capacity before FY2011	Total capacity starting operation in FY2012	Total capacity starting operation in FY2013 (as of May 31, 2013)
Photovoltaic power (for households)	4.4 GW	1.269 GW	0.279 GW
Photovoltaic power (non-household)	0.9 GW	0.706 GW	0.961 GW
Wind power	2.6 GW	0.063 GW	0.002 GW
Small and medium hydropower (1,000 kW or more)	9.4 GW	0.001 GW	0 GW
Small and medium hydropower (less than 1,000 kW)	0.2 GW	0.003 GW	0 GW
Biomass power	2.3 GW	0.036 GW*	0.038 GW
Geothermal power	0.5 GW	0.001 GW	0 GW
Total	**20.3 GW**	**2.079 GW**	**1.280 GW**