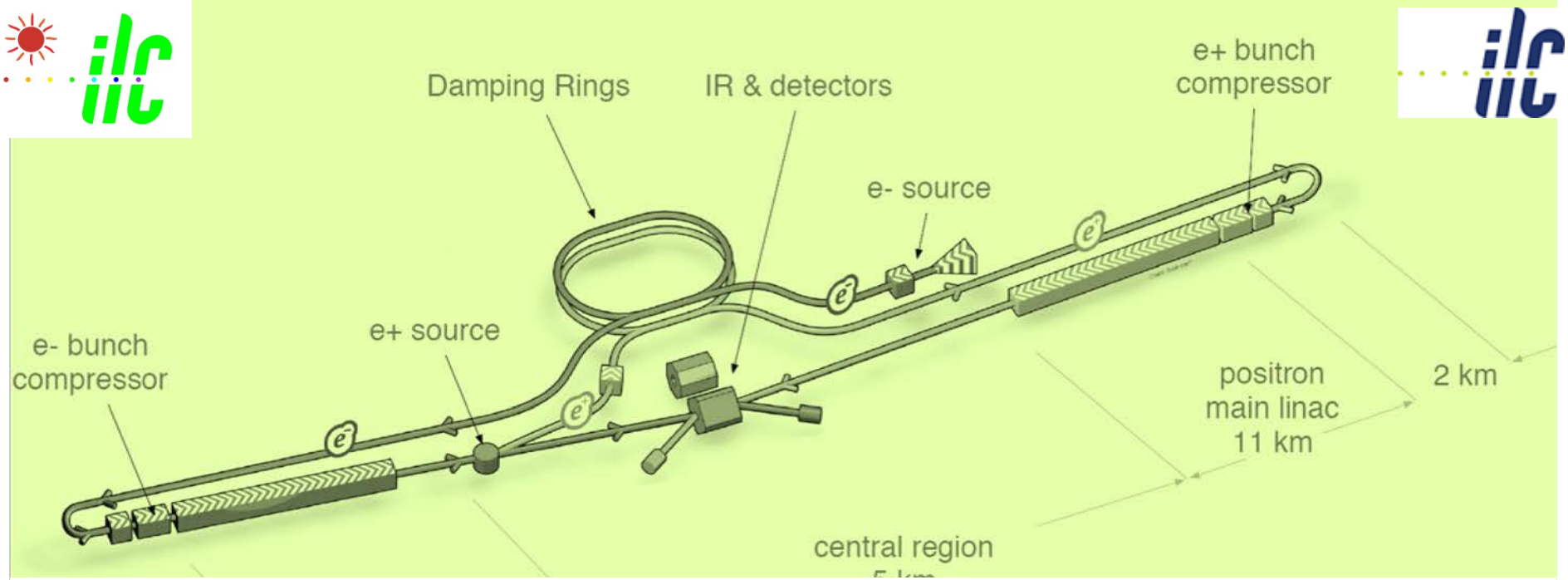

THE GREEN ILC

Energy for Innovation and Innovation in Energy

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Green-ILC

Denis Perret-Gallix by Fuze

LAPP-IN2P3/KEK

High-Energy is Energy

Other things being equal:

Beam Energy
Beam Intensity

} scales up with the wall-plug power

High Energy Frontier
High Intensity Frontier

} Depend on Energy

Particle Accelerators are Power Converters
From eV to TeV

And construction/running cost also depend on Energy …

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High-Energy is Energy

Accelerator architectures evolved from:

Fix target to colliders exp.
Normal to SC magnets
Warm to cold RF
Circular (e+e-) to linear

} Lower Energy Consumption

Next paradigm shift ?

ILC is the most energy efficient.
All future colliders (e+e-, pp, mu+mu-) linear or circular face the energy consumption issue.

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Energy for ILC (rough estimates)

- ILC: 164MW @ 500GeV → 300MW @ 1TeV (TDR)
- Experiment, Computing, Buildings => 180 MW @ 500 GeV, 320 MW @ 1 TeV.
  TDR takes an even larger margin: 300 MW 500 MW
- LHC-CERN ~ 180 MW → 1.2 TWh/year, 83% lost in cooling towers

FCC-ee : 354 MW @350 GeV
FCC-hh : 468 MW @ 100 TeV (Paul Collier, CERN)

ILC 500 GeV 18% of Iwate prefecture electricity consumption, Morioka (300,000)
ILC 1 TeV 32%

- 180$/MWh 2011 in Japan for industry (OECD 2013 report, special discount ?)

Yearly electricity running cost: 500 GeV ~ 210 M$
1 TeV ~ 380 M$

Energy consumption will become a roadblock to the future of HEP

We must address this issue.

HEP will contribute to one of the most important social issue: Energy

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Green-ILC (why ILC?)

Time has come: Energy was not a concern "before", now it is:

- 1.2 TWh (500 GeV) 20% of a nuclear reactor
- Energy/Global warming/Financial crisis in the world and in Japan
- For fundamental science …

ILC is a good place to start:

- The first world-wide fundamental science project:
  a unique showroom for physics and technology innovation
  with researchers/experts on many disciplines.
- Interdisciplinary – Technology transfer: a "Global Science City".
  Many other research labs and a strong industrial environment.

A greenfield project

- First time since ~ 50 years a new HEP site is built.
- Unleash creativity and plan with the future and expansion in mind.

Green-ILC, a first step toward Sustainable Colliders

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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

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

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)

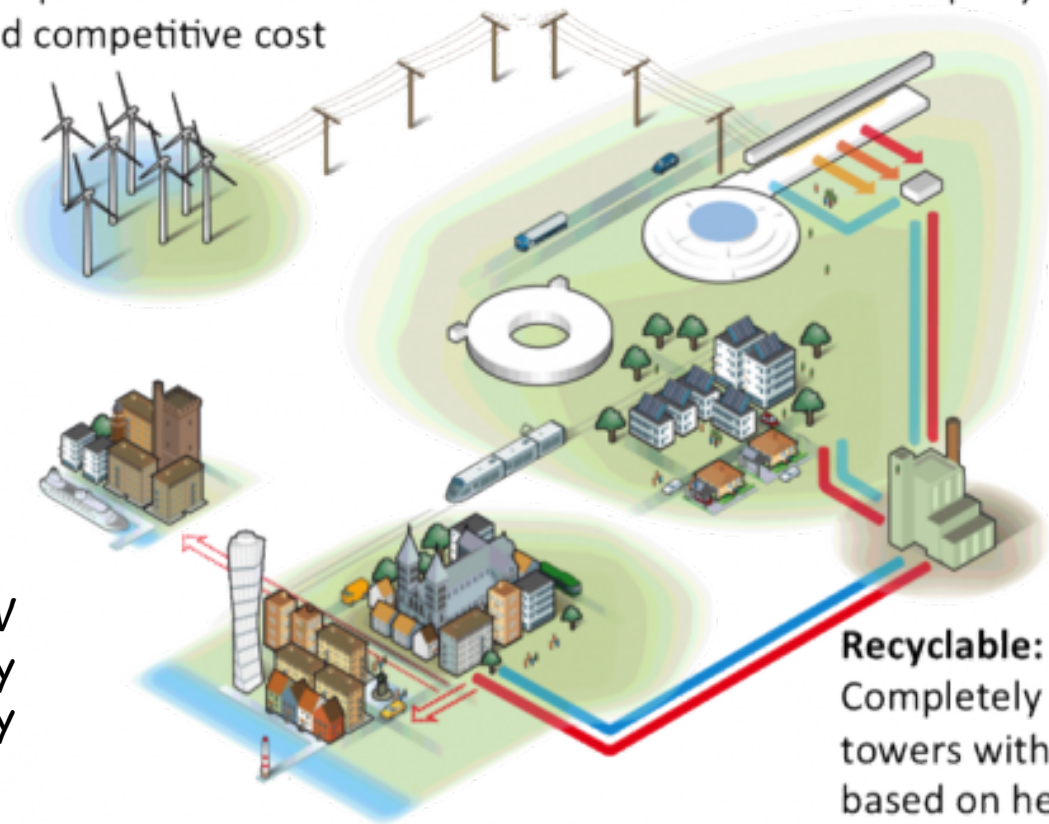
INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

European Spallation Source - 4R

neutron source

Renewable:
All energy from new, dedicated renewable production at a stable and competitive cost

Responsible:
Reduce energy use to under 270 GWh per year



Reliable
stable electricity and cooling supplies

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

Recyclable:
Completely replace cooling towers with a cooling system based on heat recycling.

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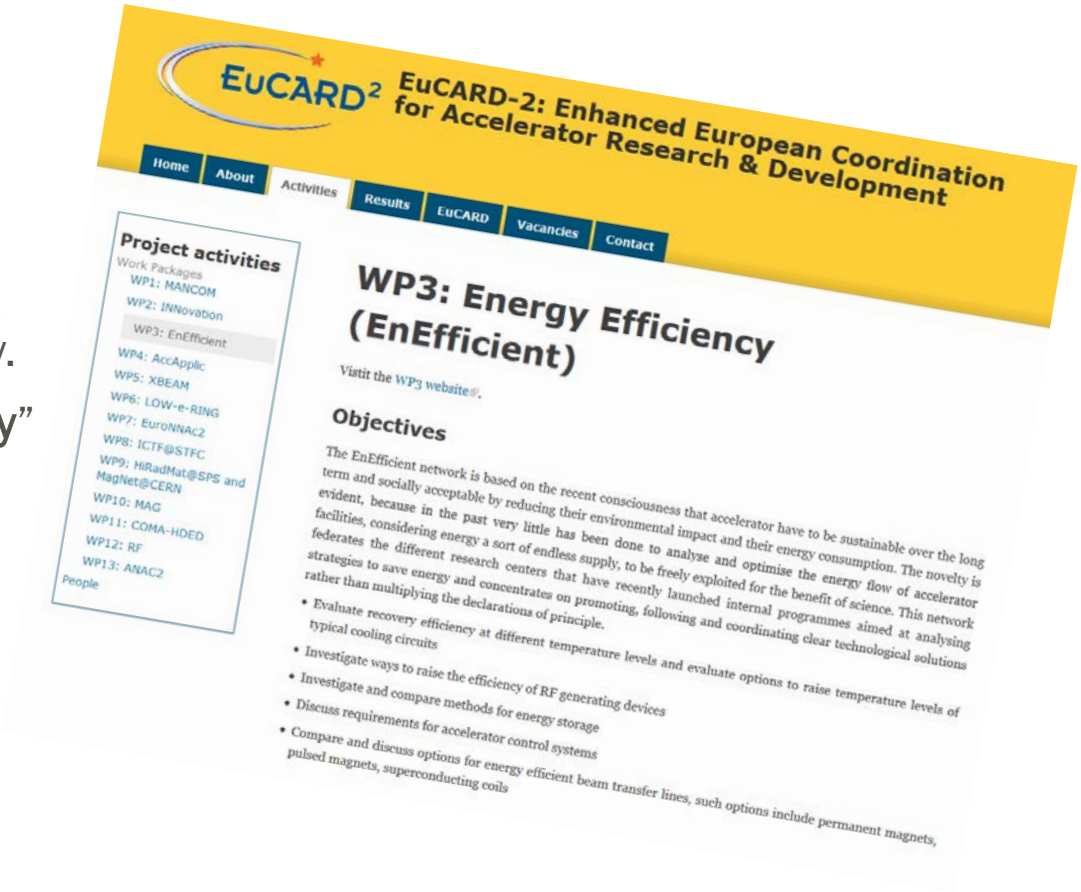
Energy Efficiency

- High efficiency, high power RF generation is needed for many future accelerator projects (proton drivers for several applications, linear colliders, material test facilities) and certainly has impact beyond the accelerator community.
- A network called "**Energy Efficiency**" has started to pick up momentum inside the European Project EuCARD2, see http://eucard2.web.cern.ch/activities/wp3-energy-efficiency-enefficient
- You are invited to become part of this network!



EuCARD² EuCARD-2: Enhanced European Coordination for Accelerator Research & Development

Home | About | Activities | Results | EuCARD | Vacancies | Contact

Project activities

Work Packages
- WP1: MANCOM
- WP2: INNovation
- WP3: EnEfficient
- WP4: AccApplic
- WP5: XBEAM
- WP6: LOW-e-RING
- WP7: EuroNNAc2
- WP8: ICTF@STFC
- WP9: HiRadMat@SPS and MagNet@CERN
- WP10: MAG
- WP11: COMA-HDED
- WP12: RF
- WP13: ANAC2

People

WP3: Energy Efficiency (EnEfficient)

Vistit the WP3 website.

Objectives

The EnEfficient network is based on the recent consciousness that accelerator have to be sustainable over the long term and socially acceptable by reducing their environmental impact and their energy consumption. The novelty is evident, because in the past very little has been done to analyse and optimise the energy flow of accelerator facilities, considering energy a sort of endless supply, to be freely exploited for the benefit of science. This network federates the different research centers that have recently launched internal programmes aimed at analysing strategies to save energy and concentrates on promoting, following and coordinating clear technological solutions rather than multiplying the declarations of principle.

- Evaluate recovery efficiency at different temperature levels and evaluate options to raise temperature levels of typical cooling circuits
- Investigate ways to raise the efficiency of RF generating devices
- Investigate and compare methods for energy storage
- Discuss requirements for accelerator control systems
- Compare and discuss options for energy efficient beam transfer lines, such options include permanent magnets, pulsed magnets, superconducting coils

Green-ILC Strategy

Revisiting all ILC components with a focus on:

1. Energy Saving: improving efficiency
2. Energy Recovery and Recycling
3. Operational saving

Study of Alternative energies in the ILC framework:

1. Renewable energies production and use
2. Energy Storage and conversion
3. Energy Distribution and Management: Smart Grid

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ILC baseline energy budget 164 MW @ 500 GeV

Table 11.6
Estimated DKS power loads (MW) at 500 GeV centre-of-mass operation. 'Conventional' refers to power used for the utilities themselves. This includes water pumps and heating, ventilation and air conditioning, (HVAC). 'Emergency' power feeds utilities that must remain operational when main power is lost.

Accelerator section	RF Power	Racks	NC magnets	Cryo	Conventional		Total
					Normal	Emergency	
e^- sources	1.28	0.09	0.73	0.80	1.47	0.50	4.87
e^+ sources	1.39	0.09	4.94	0.59	1.83	0.48	9.32
DR	8.67		2.97	1.45	1.93	0.70	15.72
RTML	4.76	0.32	1.26		1.19	0.87	8.40
Main Linac	52.13	4.66	0.91	32.00	12.10	4.30	106.10
BDS			10.43	0.41	1.34	0.20	12.38
Dumps					0.00	1.21	1.21
IR			1.16	2.65	0.90	0.96	5.67
TOTALS	68.2	5.2	22.4	37.9	20.8	9.2	164 MW

Rank:	1	6	3	2	4	5
% :	42	3	15	23	13	5

83% lost in heat waste

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Green ILC (1)
Energy Saving

On components:

- RF high efficiency (power converter/modulator(90%), klystron (65%), waveguides, power couplers)
- Wall-plug to beam power efficiency: 9.6 %.
- Cryogenics: High efficiency cryocooler and system optimization
  - Other technologies e.g. Thermoacoustic Stirling Heat Engine Pulse Tube
- NC magnets
- ILC Lattice optimization

On operation

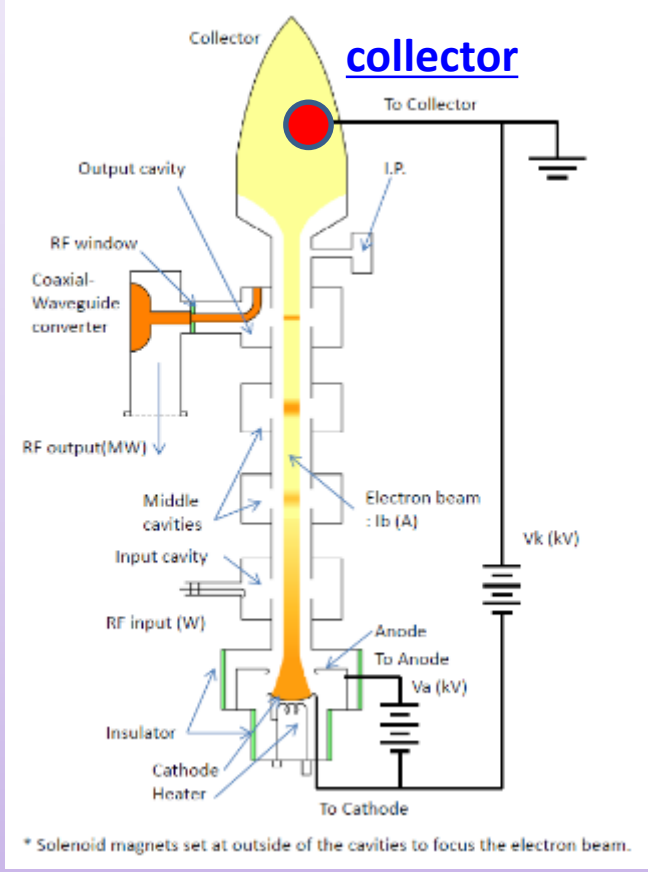
- Power reduction during idle periods:
  - system on standby and energy saving mode, More effective if made on design
  - Long running period (fewer, but longer shutdown due to cryo)
- Increase reliability (to avoid down time)

How to Improve RF Efficiency

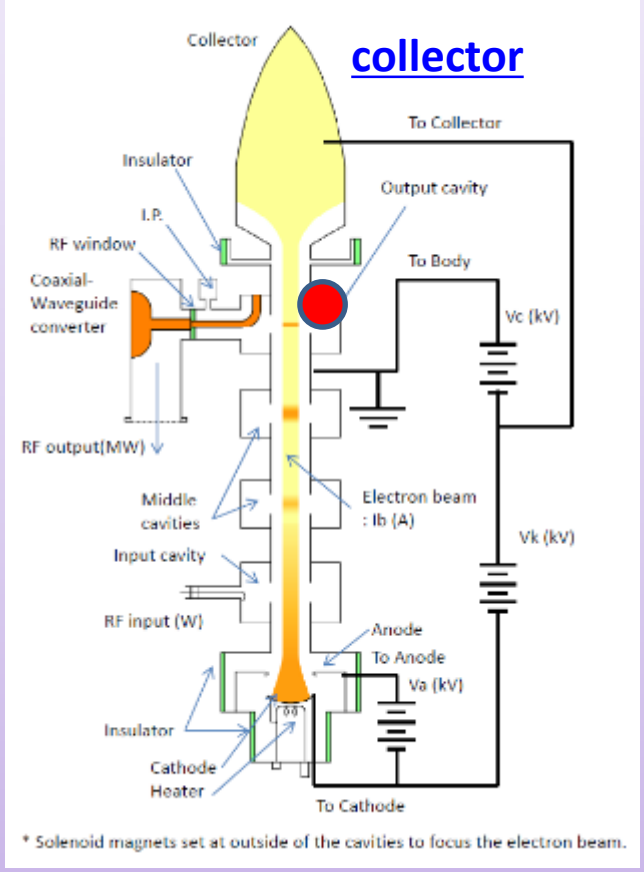
R&D of CPD (Collector Potential Depression) Klystron

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

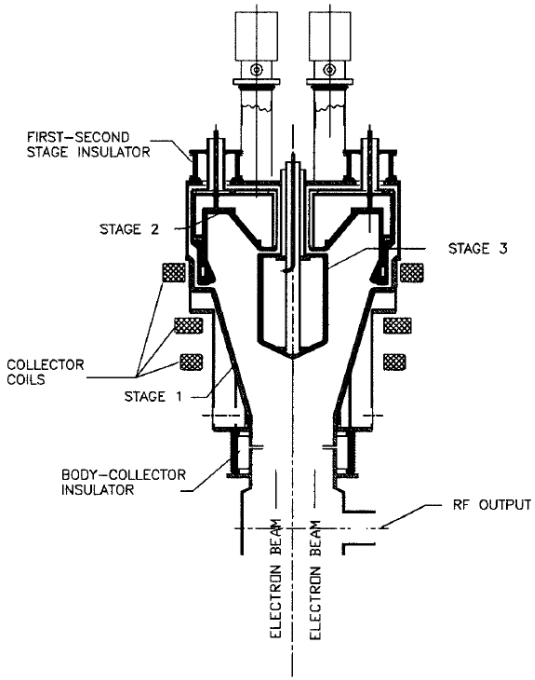
Conventional



Schematic diagram of CPD



ITER Gyrotron depressed collector



110 GHz, 1 MW
Multi-stages Depressed Collector
Efficiency increased from: 30-35% to 60%

Amarjit Singh et al.
IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 27, NO. 2, APRIL 1999

ILC Multi-Beam Klystron

From 6 beams → 30 beams …. ??

IOT Inductive Output tubes

Solid state Sys. see the 100 kW (350 MHz) of LINAC 4

Green ILC (2)
Energy Recovery and Recycling

Heat waste from the water cooling systems:

- Increase output temperature: Carnot cycle more efficient with higher temperature gradient
  - Produce electricity, Sterling engines and heat pumps, thermoelectricity, …
  - Heat/cool nearby cities, green houses, fish farms, drying industry,…
- Recycling efficiency ? Cooling efficiency ? Saving/investment ratio ?
- Many industrial applications

Beam dumps energy recovery

- 2 main full power beam dumps, 5.3 (@500 GeV) - 13.6(@1 TeV) MW, pressurized water (155 °C) + activation
- 1 BD photons 0.3 MW, water at 190 °C
- How to recover, store and recycle this energy ?, stirling engines, heat pumps, molten salts,
- Other ideas: Plasma deceleration dumping, Energy Recovering Linac

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Plasma Deceleration Dumping

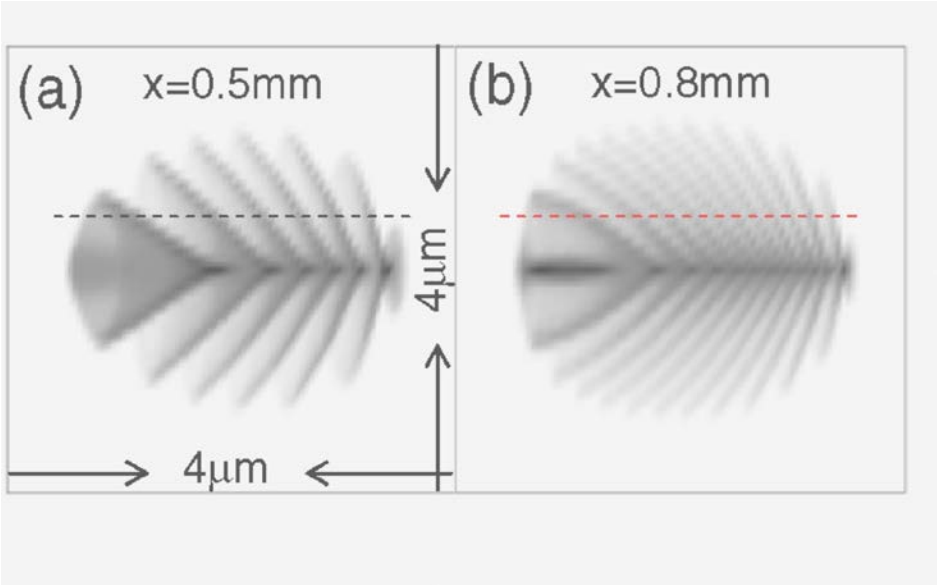
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 101303 (2010)

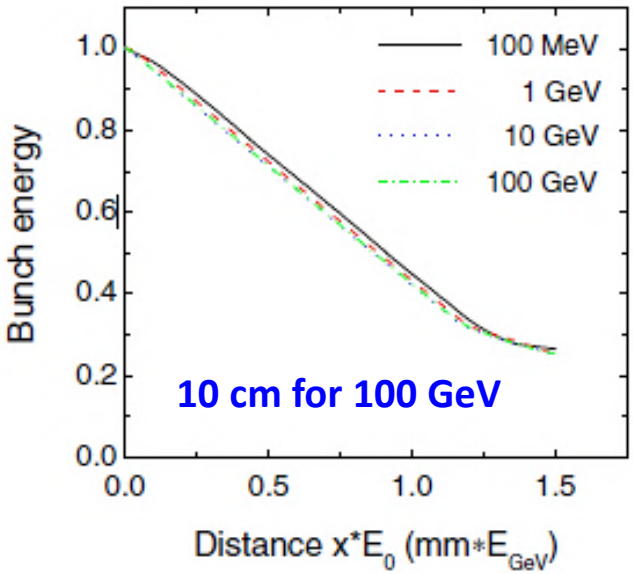
Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

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

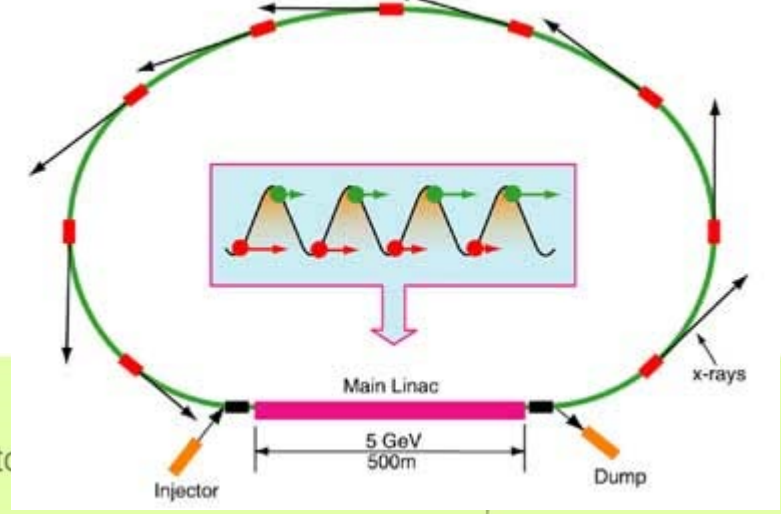


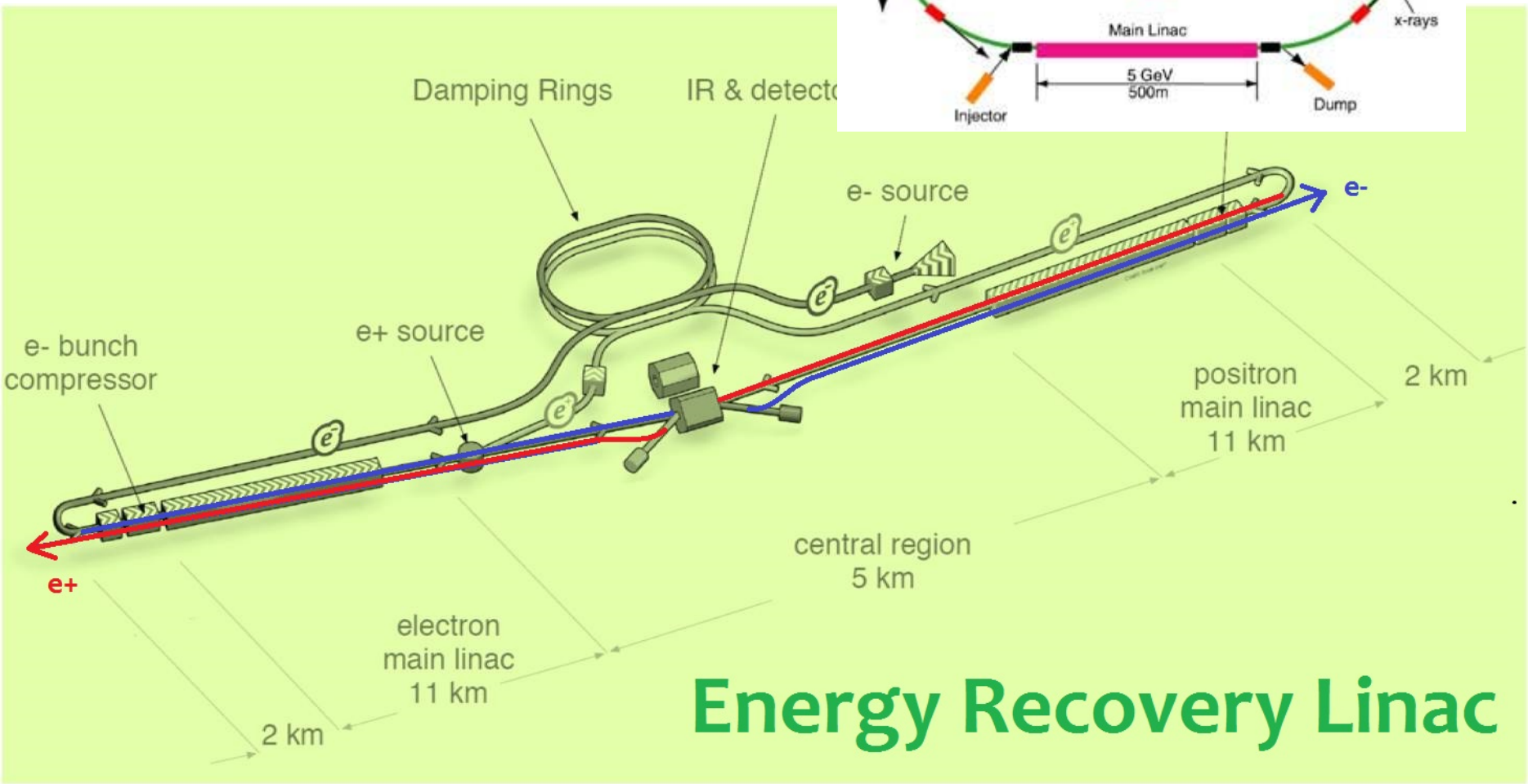


- The deceleration distance in the underdense plasma is 3 orders of magnitude smaller than the stopping in condensed matter.
- The muon fluence is highly peaked in the forward direction.

ILC-ERL

You should be joking!





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Green ILC (3)
Sustainable Energies

Energy Production:

- Study the (dis)-advantages of the various sources: solar, wind, geothermal, sea, …)
  - Availability, Price, Flexibility, Potential to improvement, Environmental impact
- Find the best mix to cover ILC specific needs ? 24/7, long shutdowns, …
- Accommodate the ILC component power requirements to the various energy sources distinctive features:
  - RF power converter: PhotoVoltaic (DC) , wind/sea (variable AC, DC), geothermal,
  - Cryocooler or asynchronous liquefactors, Solar (DC motors), wind/sea Variable AC, or mechanical compressor (no electricity)

Energy Storage: HEP: experts in some of these technologies

- Liquid Helium, Nitrogen, Hydrogen, SMES(Sc Magnetic Energy Storage), Flywheel, Hydro (Dam), Compressed air, Batteries, …

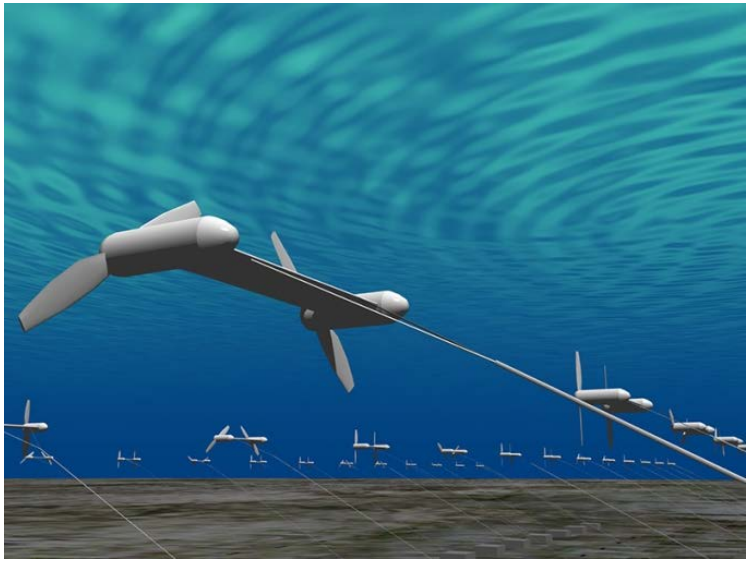
Distribution: Smart (Local) GRID:

Full scale multi-sourced, AC/DC, GRID management and control

- Smooth and rapid switching between energy sources, including conventional supply
- Energy Monitoring, Management and forecast: production, storage and backup

Wind/Marine Energy

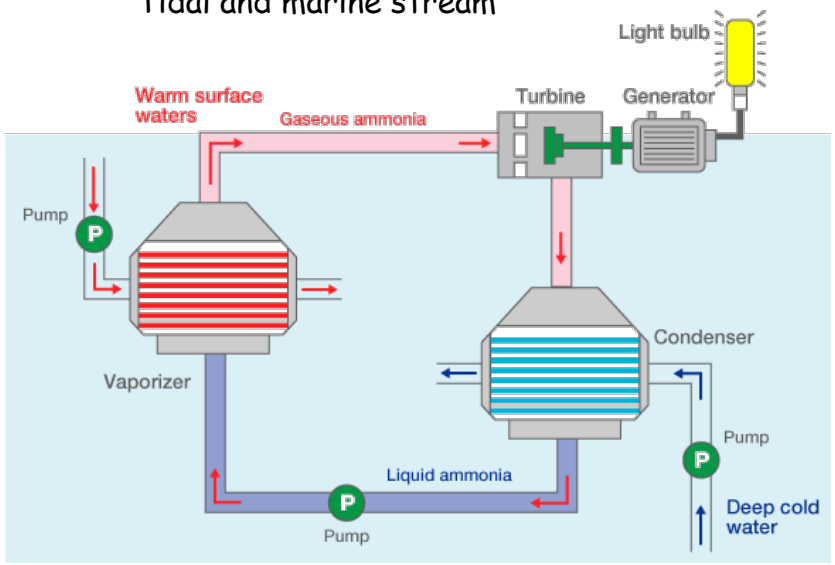
2 MW Goto island prototype



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

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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

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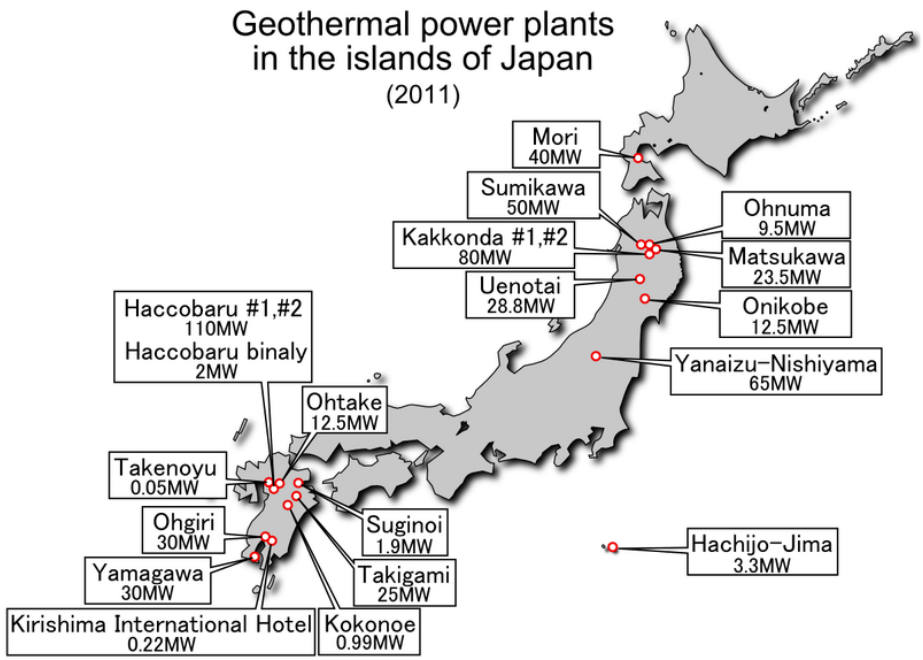
Geothermal Energy



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

CERN press office

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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

LN2 Economy

- The cryogenics is consuming ~ $\frac{1}{4}$ ~ 40 MW of ILC Wall-plug power
  - All cooling is based on LHe. Using LN2 as a pre-coolant would boost the cooling efficiency by a factor 2.

- LN2 produced by sustainable energies
  - Close to or in the Kitakami site by solar, wind, geothermal, marine energy.
  - Wind energy: the electricity generator could be replaced by a compressor/liquefier system, bypassing electricity production and improving efficiency. Byproducts liquid oxygen, argon, capture CO_2, …

- LN2 as Energy storage
  - With the heat waste, produce electricity when needed. 70% efficiency
  - LN2 could be used to recycle low temperature waste:
  - No need for cooling tower -> produce electricity with LN2-> N2 turbine

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Green-ILC governance

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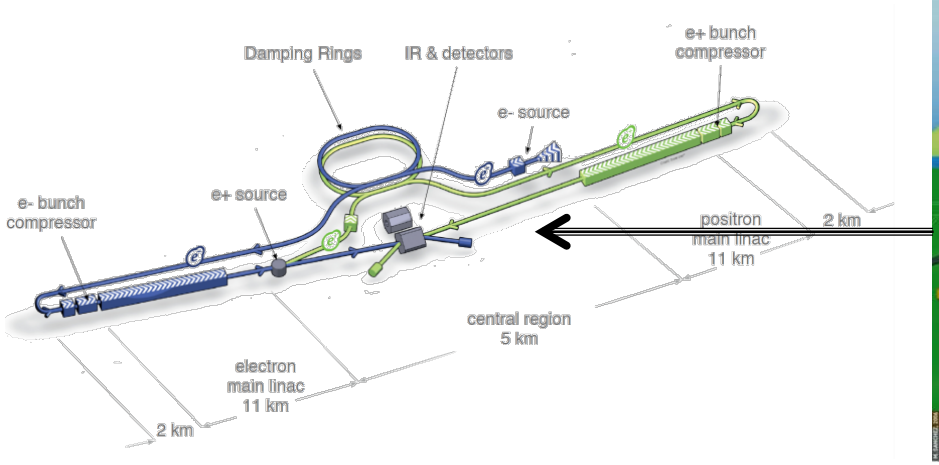
Global organization for Green ILC

ILC Energy Center

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

ILC Sustainable Energy Research Center
- Basic Research
- Technology R&D
- Pilot Power plants for ILC

Electrons, photons, neutrons factories
HPC/GRID Computing



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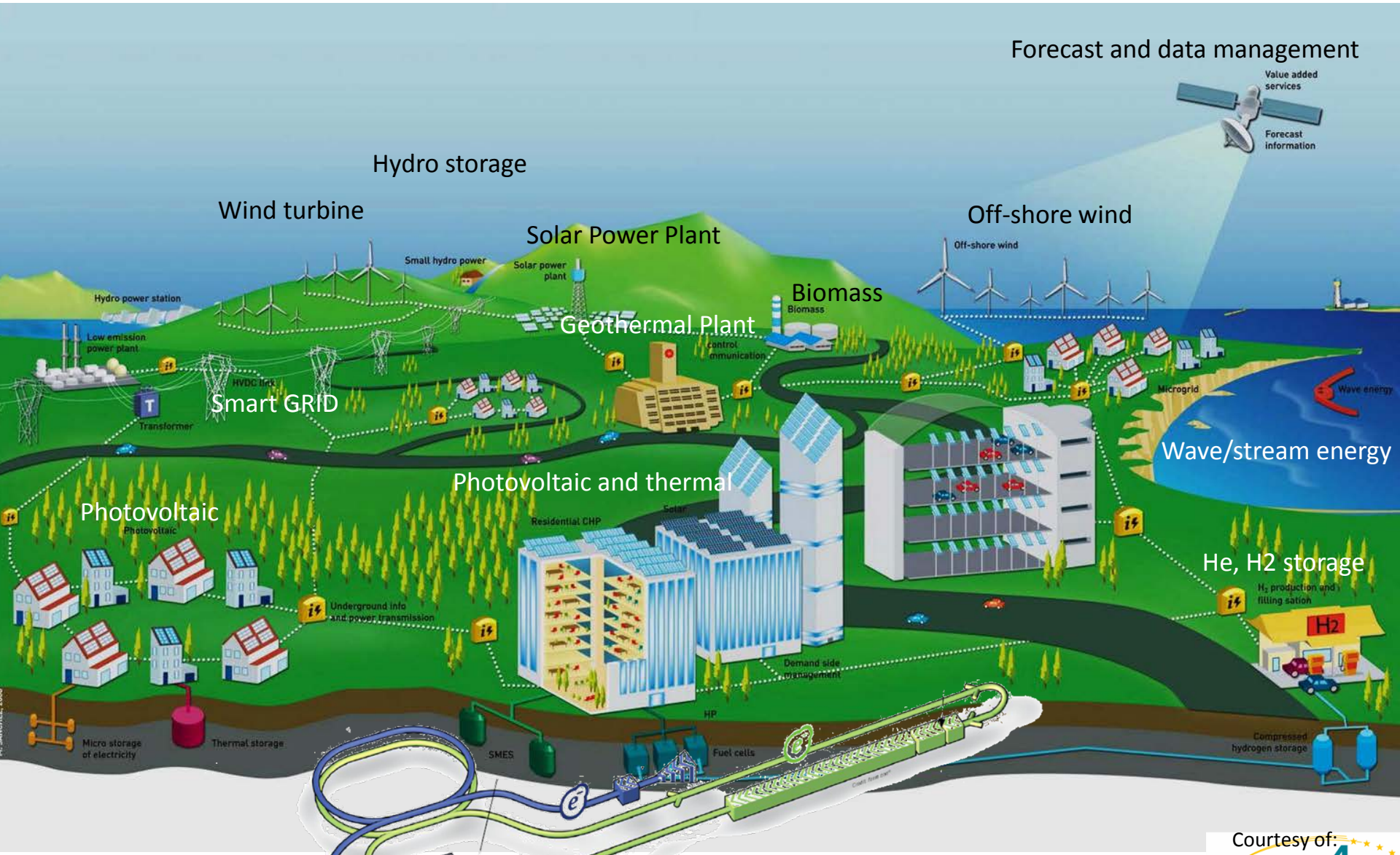
The "ILC Energy Center"



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Courtesy of:

Green-ILC Roadmap

- Identify the energy saving, recycling and recovery potentials for all major ILC components.
  Base-line and Advanced-line on more innovative technologies.
  - ILC Design modifications:
    - What can be implemented in the design before request for tenders ?
    - What advanced R&D should be carried out before future extensions ?
  - Implementation timeline (minimum impact of the ILC planning)
  - Budget assessment: additional spending and saving

- Design a global sustainable energy program for ILC
  - Get the "Energy research" community and organization and the "Industry leaders" involved in a network.
  - Propose a global governance scheme for the "ILC Energy Center"
  - Form an additional budget for the "Sustainable Energy Center" (no ILC money)
  - Identify short term renewable energy pilot plants with build-in upgradability
  - Identify basic energy researches in line with the ILC project

Green-ILC project report by 2015

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Timeline for a sustainable ILC

Gradual and Multi-Staged

e.g.

1.	As a backup to the conventional power supply (diesel engines)	7 MW
2.	To cover buildings energy through recycling and storage (electricity and heating) (zero energy)	10 MW
3.	To cover some parts of the ILC: computers (fuel cells), water cooling, part of the cryo plants	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 – Conventional power supply is now in backup mode	170 MW
7.	Get ready for the 1 TeV	+150 MW

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Conclusions

Energy consumption: a major limiting factor to higher beam energies and intensity

The Green-ILC project precisely addresses this issue.

ILC consumption being similar to a city, it is a full scale workbench:

- To study and implement: energy saving, recycling and storing
- To develop, maintain and manage a mix of sustainable energy sources.

Green-ILC links High-Energy physics and Energy R&D :

- Substantial running cost saving and better flexibility in ILC operations.
- A disruptive approach but an exciting challenge toward "Sustainable Colliders"
- Energy R&D, a Societal Issue: the green-ILC project would:
  - boost "basic energy research" which is most needed today and promotes a strong Industry-Research collaboration.
  - improve basic research public visibility and appreciation
  - Provide additional incentives on decision making

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Thank you for your attention

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