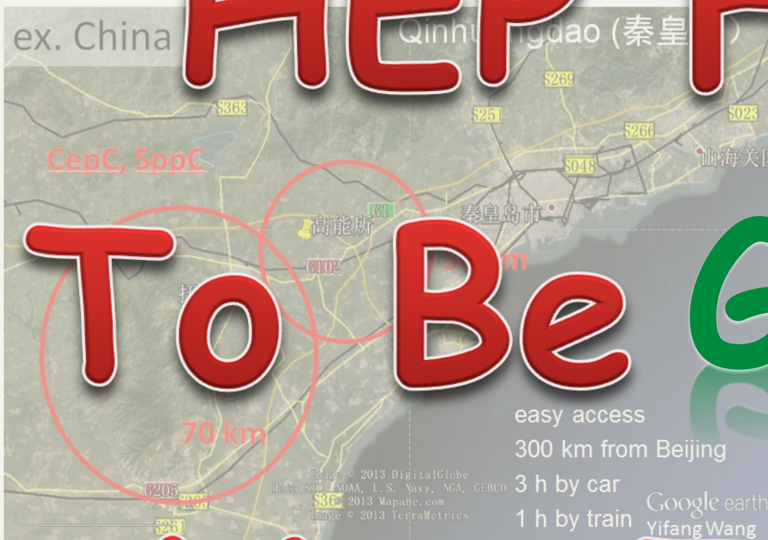
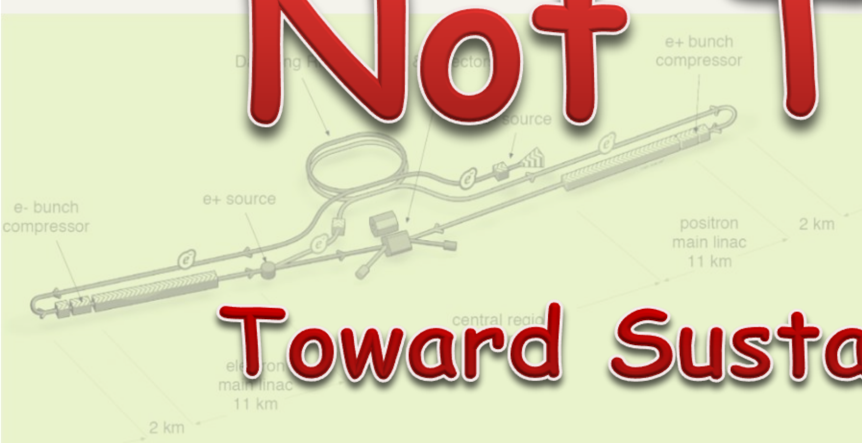
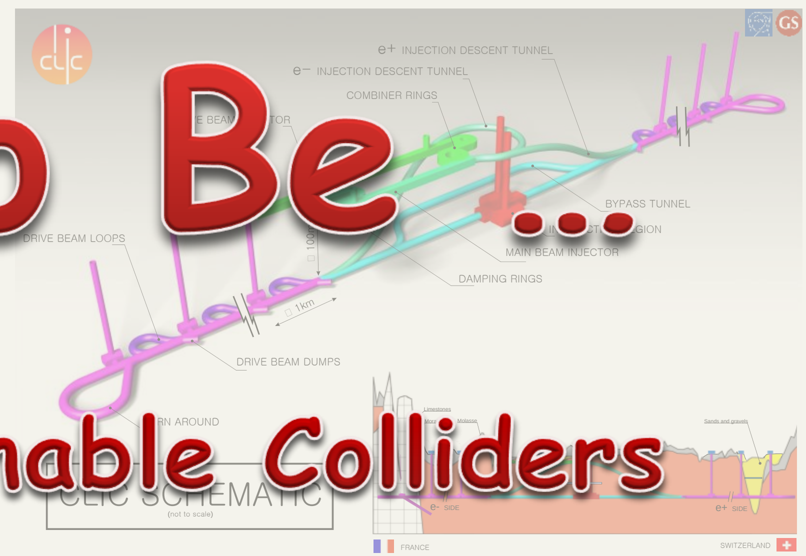
Energy for Innovation and Innovation in Energy

HEP Future:
To Be GREEN or Not To Be…

Toward Sustainable Colliders







LCWS, Belgrade, Oct. 2014

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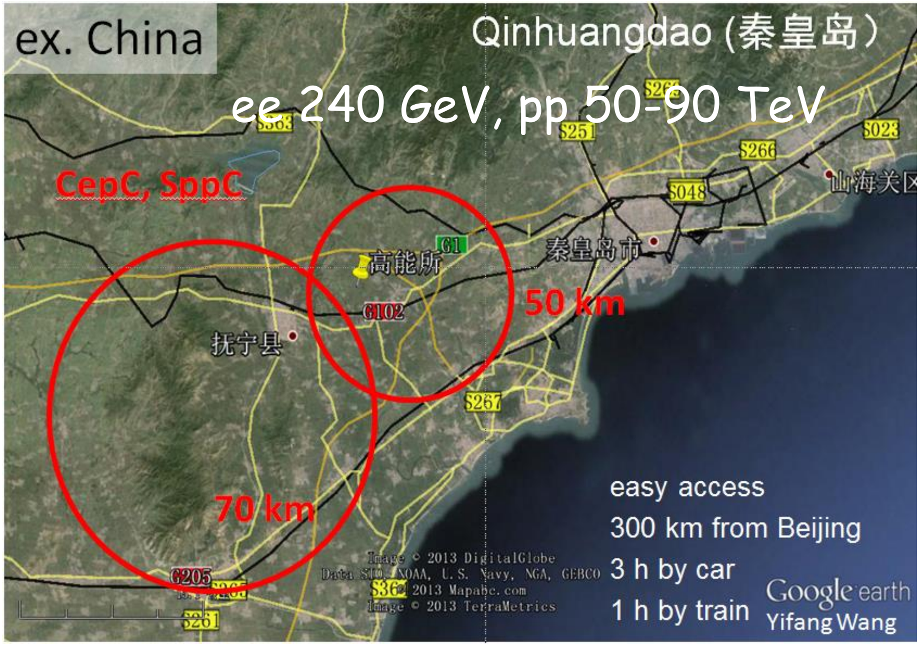
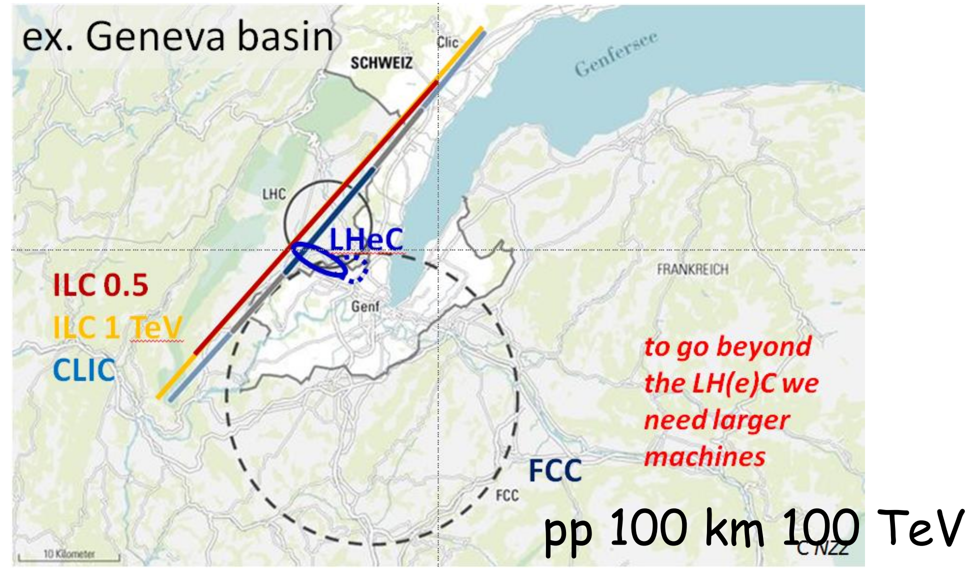
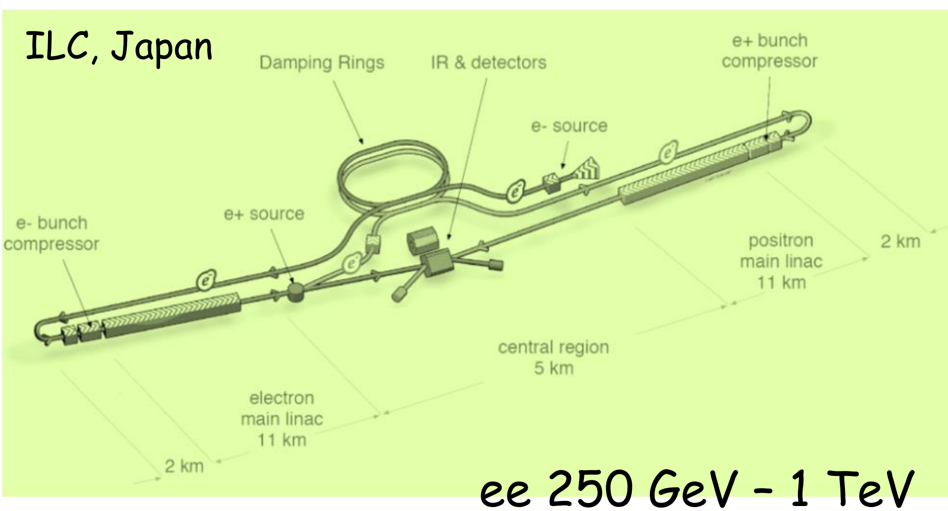
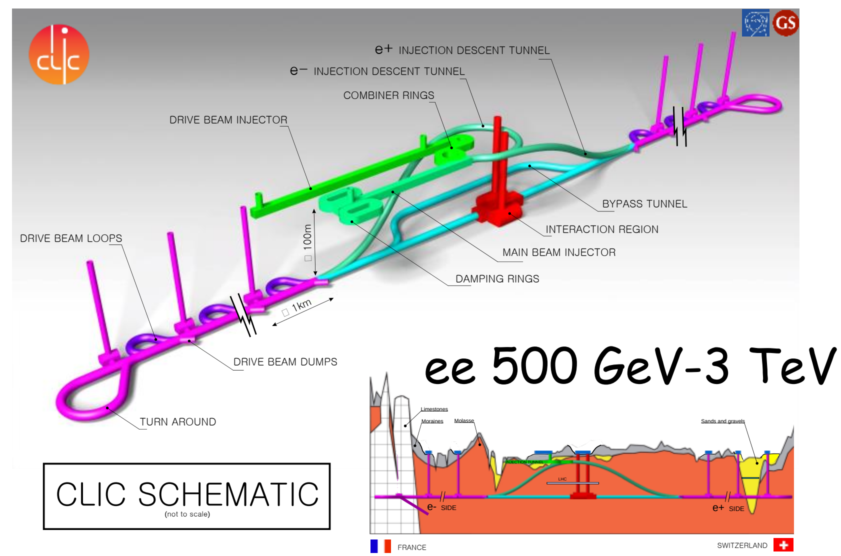
Some of the high energy frontier future infrastructures









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Content

- Energy consumption: a burning hot parameter
- HEP future: Sustainability: efficiency and renewable energies
- Energy is HEP at core

Colliders hot parameters

- Detailed studies on:
  - Beam Energy
  - Luminosity:
    - Emittance
    - spot size
    - Bunches (nb, charge,…)
  - Chromaticity
  - Energy spread
  - Beam purity at IP
  - Stability
  - Reliability and availability
  - …

But P_{AC}: AC wall-plug power figures are often: missing, partial or poorly documented

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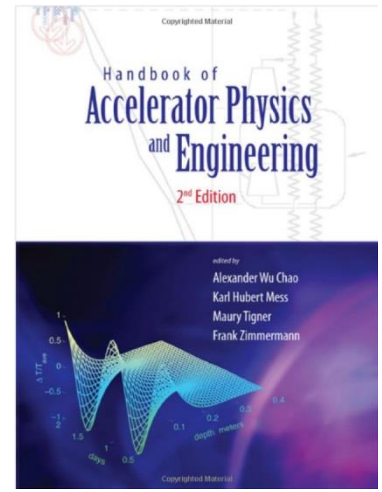
Table 1: Parameters of the Proposed FCC-hh, FCC-ee/TLEP and CepC, Compared with LEP2 and the LHC Design

parameter	LHC (pp)	FCC-hh	LEP2	FCC-ee (TLEP)					CepC
	design		achieved	Z	Z (cr. w.)	W	H	$t\bar{t}$	
species	pp	pp	e^+e^-	e^+e^-	e^+e^-	e^+e^-	e^+e^-	e^+e^-	e^+e^-
$E_{\rm beam}$ [GeV]	7,000	50,000	104	45.5	45	80	120	175	120
circumf. [km]	26.7	100	26.7	100	100	100	100	100	54
current [mA]	584	500	3.0	1450	1431	152	30	6.6	16.6
no. of bunches, n_b	2808	10600	4	16700	29791	4490	1360	98	50
N_b [10^{11}]	1.15	1.0	4.2	1.8	1.0	0.7	0.46	1.4	3.7
ϵ_x [nm]	0.5	0.04	22	29	0.14	3.3	0.94	2	6.8
ϵ_y [pm]	500	41	250	60	1	7	2	2	20
β_x^* [m]	0.55	1.1	1.2	0.5	0.5	0.5	0.5	1.0	0.8
β_y^* [mm]	550	1100	50	1	1	1	1	1	1.2
σ_x^* [μm]	16.7	6.8	162	121	8	26	22	45	74
σ_y^* [μm]	16.7	6.8	3.5	0.25	0.032	0.13	0.044	0.045	0.16
θ_c [mrad]	0.285	0.074	0	0	30	0	0	0	0
$f_{\rm rf}$ [MHz]	400	400	352	800	300	800	800	800	700
$V_{\rm rf}$ [GV]	0.016	$>$0.020	3.5	2.5	0.54	4	5.5	11	6.87
α_c [10^{-5}]	32	11	14	18	2	2	0.5	0.5	4.15
$\delta_{\rm rms}^{\rm SR}$ [%]	—	—	0.16	0.04	0.04	0.07	0.10	0.14	0.13
$\sigma_{z,\rm rms}^{\rm SR}$ [mm]	—	—	11.5	1.64	1.9	1.01	0.81	1.16	2.3
$\delta_{\rm rms}^{\rm tot}$ [%]	0.003	0.004	0.16	0.06	0.12	0.09	0.14	0.19	0.16
$\sigma_{z,\rm rms}^{\rm tot}$ [mm]	75.5	80	11.5	2.56	6.4	1.49	1.17	1.49	2.7
F_{hg}	1.0	1.0	0.99	0.64	0.94	0.79	0.80	0.73	0.61
$\tau_{\|\|}$ [turns]	10^9	10^7	31	1320	1338	243	72	23	40
ξ_x/IP	0.0033	0.005	0.04	0.031	0.032	0.060	0.093	0.092	0.103
ξ_y/IP	0.0033	0.005	0.06	0.030	0.175	0.059	0.093	0.092	0.074
no. of IPs, n_{IP}	3 (4)	2 (4)	4	4	4	4	4	4	2
L/IP [10^{34}/cm^2/s]	1	5	0.01	28	219	12	6	1.7	1.8
$\tau_{\rm beam}$ [min]	2760	1146	300	287	38	72	30	23	57
$P_{\rm SR}$/beam [MW]	0.0036	2.4	11	50	50	50	50	50	50
energy / beam [MJ]	392	8400	0.03	22	22	4	1	0.4	0.3

IPAC 2014, F. Zimmermann et al.

P_{AC}: wall-plug power

- Future projects:
  - P_{AC} often forgotten
  - A technical detail on the back burner
- In celebrated books: no mention
- Past projects:
  - Difficult to get the estimated/measured figures.
- One reason: Difficult to compute/estimate
  - Component by component (RF, Cryo, electronics, air cond., water cooling, ….)
  - General formulae and approximations



However P_{AC} is a key parameter to select a technology or a project.

Scaling laws for e+/e- linear colliders

J.P. Delahaye, G. Guignard,T. Raubenheimer, I. Wilson

In the low beamstrahlung regime:

$$M = L\frac{U_f}{\delta_B^{1/2} P_{AC}} \propto \frac{\eta_{beam}^{RF}}{\varepsilon_{ny}^{*\,1/2}} \propto \frac{\omega^{1/30} G_a^{-1/6}}{\varepsilon_{ny0}^{1/3}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}},$$

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392 J.P. Delahaye et al. / Nucl. Instr. and Meth. in Phys. Res. A 421 (1999) 369–405

$$L \propto \frac{\delta_B^{1/2}\eta_{RF}^{AC}}{U_f}\frac{\eta_{beam}^{RF}}{\varepsilon_{ny}^{*\,1/2}} P_{AC} \propto \frac{\delta_B^{1/2}\eta_{RF}^{AC}}{U_f}\frac{\omega^{1/30} G_a^{-1/6}}{\varepsilon_{ny0}^{1/3}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}} P_{AC},$$

$$P_{AC} \propto \frac{U_f^3}{\delta_B^{1/2}\eta_{RF}^{AC}}\frac{\varepsilon_{ny0}^{1/3}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}}{\omega^{1/30} G_a^{-1/6}}.$$

In the high beamstrahlung regime:

$$M = \frac{L}{\delta_B^{3/2}}\frac{U_f^{1/2}}{P_{AC}} \propto \frac{\omega^{1/4}(a/\lambda)^{1/2}}{\varepsilon_{ny}^{*\,1/2}} \propto \frac{\omega^{7/20}}{\varepsilon_{ny_0}^{1/2}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}},$$

$$L \propto \frac{\delta_B^{3/2}}{U_f^{1/2}}\frac{\eta_{RF}^{AC}}{\beta_y^{*\,1/2}}\frac{\eta_b^{RF}}{\sigma_z^{1/2}\varepsilon_{ny}^{*\,1/2}} P_{AC} \propto \frac{\delta_B^{3/2}}{U_f^{1/2}}\frac{\eta_{RF}^{AC}}{\beta_y^{*\,1/2}}\frac{\omega^{7/20}}{\varepsilon_{ny_0}^{1/2}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}} P_{AC},$$

$$P_{AC} \propto \frac{U_f^{5/2}}{\delta_B^{3/2}}\frac{\beta_y^{*\,1/2}}{\eta_{RF}^{AC}}\frac{\varepsilon_{ny_0}^{1/2}(1+\Delta\varepsilon_{ny}/\varepsilon_{ny0})^{1/2}}{\omega^{7/20}}.$$

$U_f = E_{beam}$

δ_B = % loss by beamstrahlung

$\eta^{AC}{}_{RF}$ = wall plug power to beam power

Would be nice to compare with actual data..

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High-Energy Physics is all about Energy
From eV to TeV

Great saving achieved: technology improvement, operation optimization, disruptive technology shift:

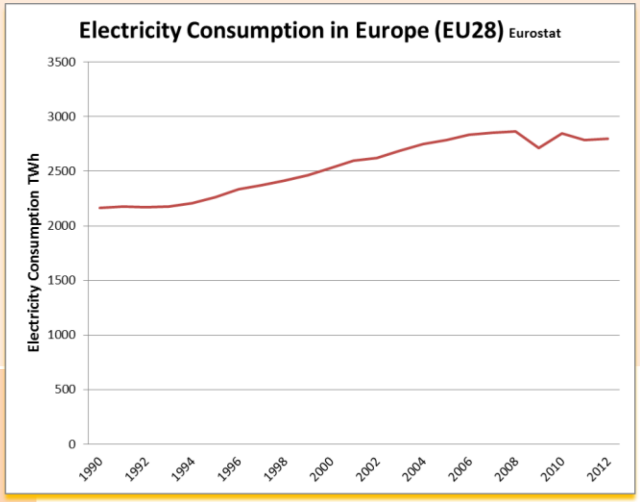
Fix target to colliders exp.
NC to SC magnets
Warm to cold RF (SC cavities)
Circular (e+e-) to linear

} Reducing Energy Consumption

Next paradigm shift for higher energies ?

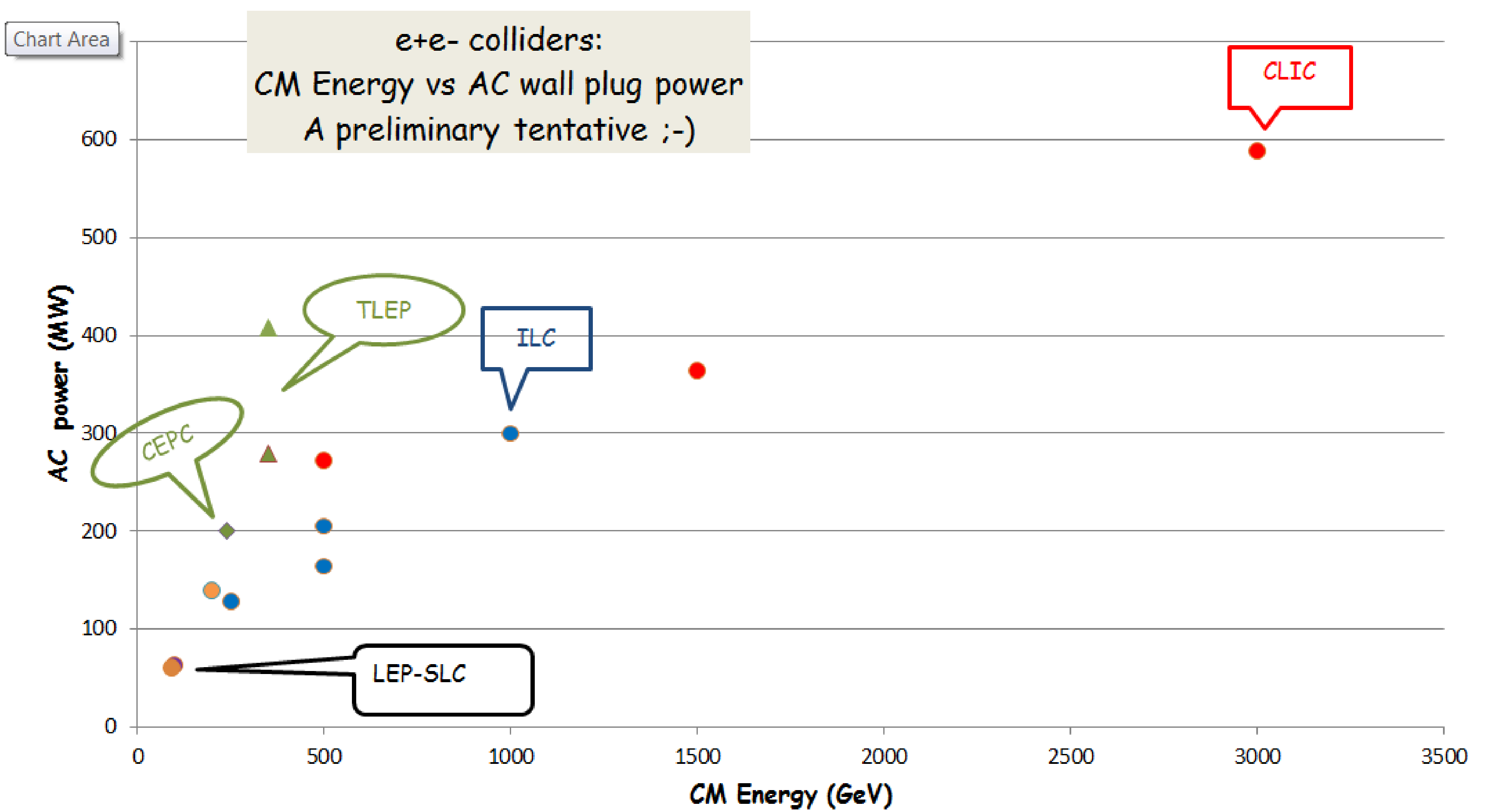
(Acceleration in plasma (laser, proton), crystal channels, muon colliders, … ??)

- Scaling with CM energy, the next colliders linear or circular:
  - Will consume more energy
  - And more, relatively to other consumers
    - People are saving, industry is saving
    - Sustainable energy are part of people life
- Energy will be more expensive
- Environmental issues



HEP got to be involved

e+/e- Colliders: P_{AC} vs E_{CM}



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Power and Energy

LHC-CERN ~ 180 MW → 1.3 TWh/year ~ 50% Geneva canton electricity consumption

FCC-ee : 354 MW @ 350 GeV (top ring and pre-injection not included)
FCC-hh : 468 MW @ 100 TeV (pre-injection NOT included (+100 MW ??) (P. Collier)

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

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

- 180$/MWh 2011 for industry (JP OECD 2013 report, special discount?, price volatility (2024))
- CERN (2011, 70 $/MWh), ESS (Sweden, 110 $/MWh)

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

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P_{AC}, E_{AC}, EC_{AC} are technology driven

- P_{AC} (200-600 MW): *AC* plug power: *good but partial indicator*
- E_{AC} (1-4 TWh/year): Yearly Energy Consumption
  - Storage colliders: Beam lifetime
  - Downtime energy consumption (cryogenics)
- EC_{AC} (~70-400 M€):Yearly Running Cost for electricity
  - Site negotiation with the utility company (
  - High tariff period technical management
  - Critical days shutdown: Standby and short time restart, beam condition reproducibility, …

Energy Consumption/year and Running cost/year are better indicators
Both depend also on technology

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K/W: Knowledge per Watt
Reducing entropy

- 100% of the energy is lost in heat waste
  - Contrary to industry which provides products or services
- Reducing entropy:
  - Industrial watts decrease entropy (temporarily) by building objects or providing services.
  - Research reduces knowledge entropy by building structured theories (e.g. Maxwell equations) … much more rewarding … ☺
- the K/W plot
  - Not only CM energy/Watt
  - Luminosity/Watt
  - Nb Higgs + top + …/Watt
  - Higgs coupling accuracy, top mass precision/Watt
  - ….

What is the best figure of merit to assess a technology ?

For HEP, Energy Consumption is a major issue

HEP future depends on how and how much we will address this concern:

- Bridging Accelerator and Energy R&D: to keep added complexity small
  - must be well structured
  - On parallel tracks and staged to minimize interferences
  - Bring in Energy R&D specific budget

- Decrease running cost and increase operation flexibility

- Contributing to the society (Energy, Environment)

- Escaping from Energy obsolescence:
  Concord supersonic travel, incandescent light bulb, vacuum tube computers, printed paper, … not simply due to energy consumption, but still …

Recent new initiatives

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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

ess EUROPEAN SPALLATION SOURCE

ERF European Association of National Research Facilities
Open to International Access

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The Green-ILC initiative

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

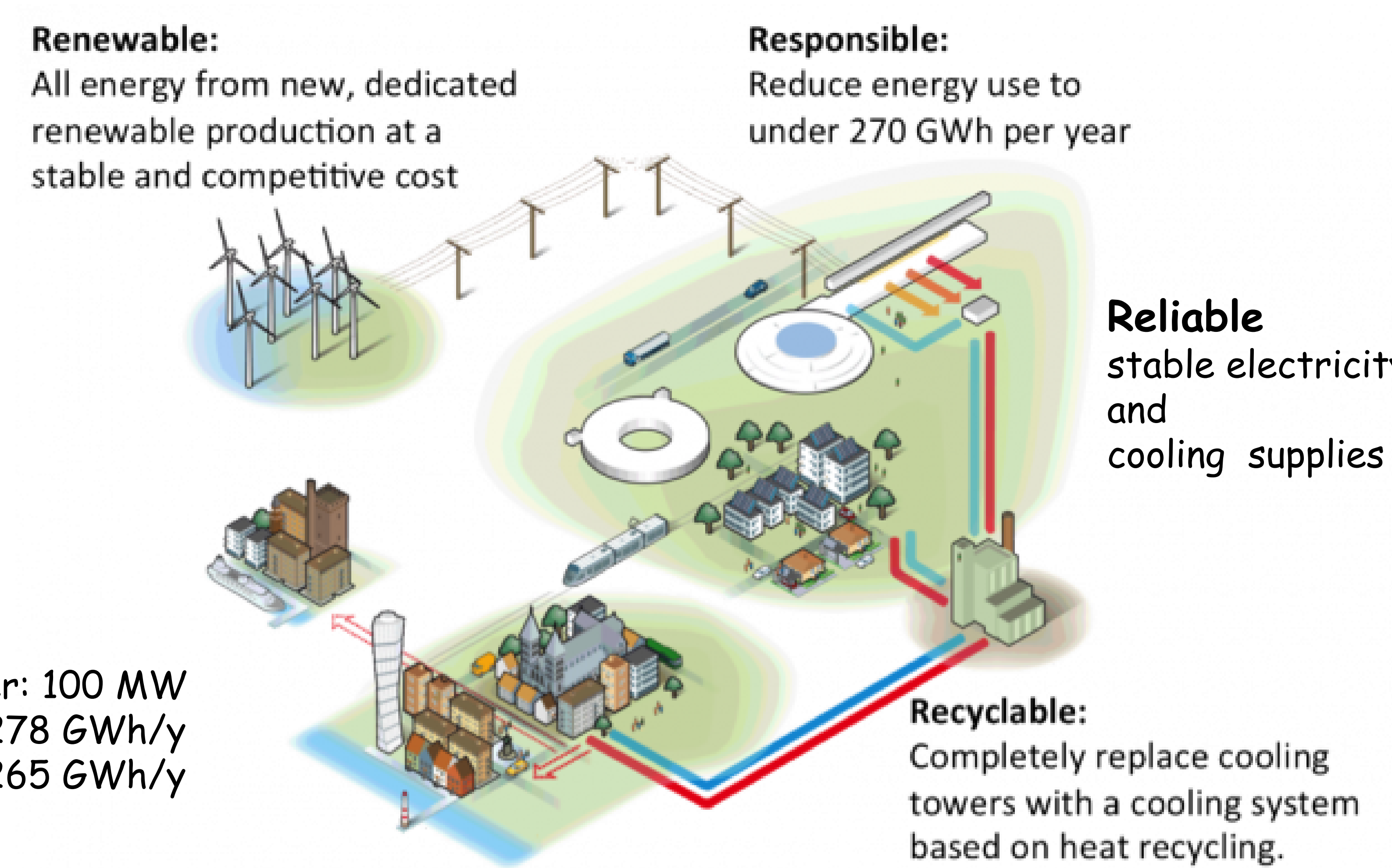
Energy Management at KEK,
Strategy on Energy Management,
Efficiency, Sustainability

Atsuto Suzuki (KEK)

INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

European Spallation Source - 4R
neutron source

ESS Energy Design report
http://europeanspallationsource.se/sites/default/files/20130131_ess_edr.pdf



Reliable
stable electricity
and
cooling supplies

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

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EnEfficient WG

ESS, T. Parker	Energy recovery from cooling circuits
CERN, E. Jensen	Higher electronic efficiency RF power generation
KIT, M. Sanders	Short term energy storage systems
GSI, J. Stadlmann	Virtual power plant
GSI, G. Spiller	Beam transfer channels with low power consumption

→ Make it global (ICFA ?)

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The Green-ILC initiative

Revisiting all ILC components with a focus on:

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

Study of renewable energies in the ILC framework:

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

Green-ILC, a first step toward Sustainable Colliders

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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

Wall-plug to beam power efficiency is 9.6 %

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Green ILC (1)
Energy Saving

On components:

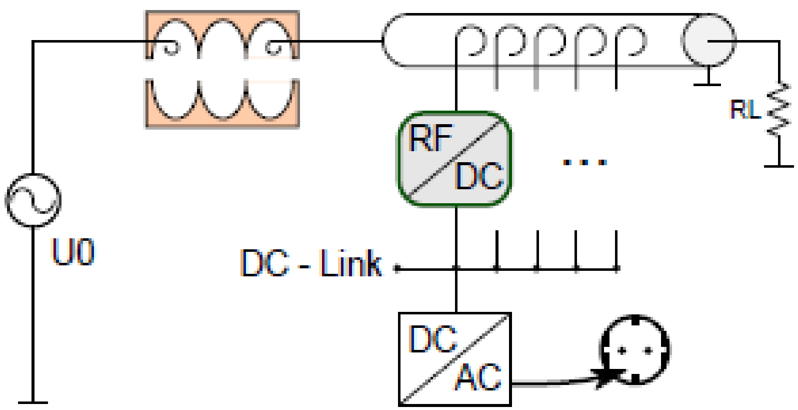
- RF high efficiency (power converter/modulator (90%), klystron (65%), waveguides, power couplers)
- Cryogenics: High efficiency cryocooler and system optimization
  - LN2 precooling and energy storage
- NC magnets
- ILC Lattice optimization

On operation

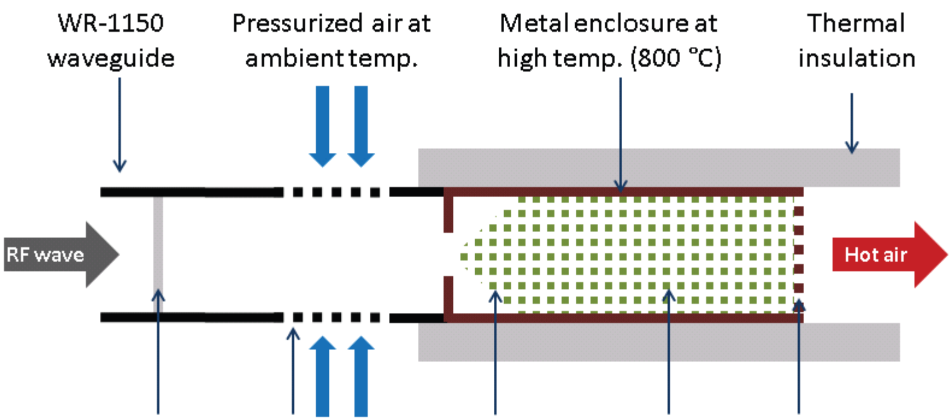
- Power reduction during idle periods:
  - system on standby and energy saving mode, More effective if made on design
  - Long running period (fewer, but longer shutdown due to cryo)
- Increase reliability (to avoid down time)

Recover non-used RF power: Smart RF loads

Idea 1) – reconvert to DC power!

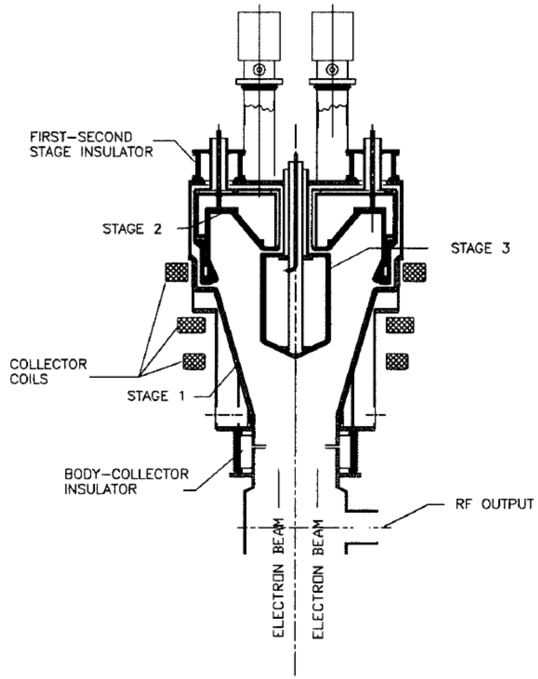


Idea 2) – use high-*T* loads!



1) http://accelconf.web.cern.ch/AccelConf/IPAC10/papers/wepd090.pdf
2) http://accelconf.web.cern.ch/AccelConf/IPAC2012/papers/thppc023.pdf

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 (multi-beam)

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 applications to industry

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, LN2
- Other ideas: Plasma deceleration dumping, Energy Recovering Linac

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Plasma Deceleration Dumping

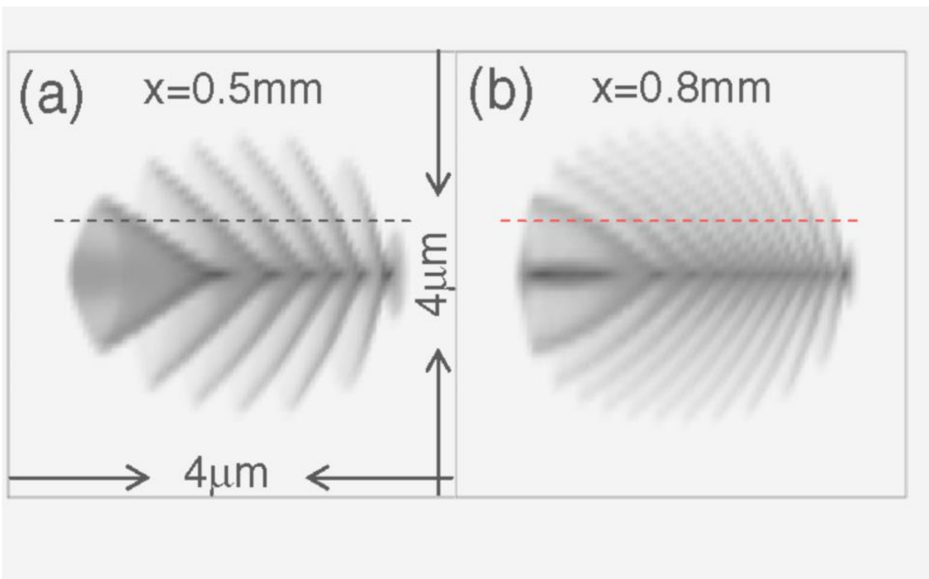
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 13, 101303 (2010)

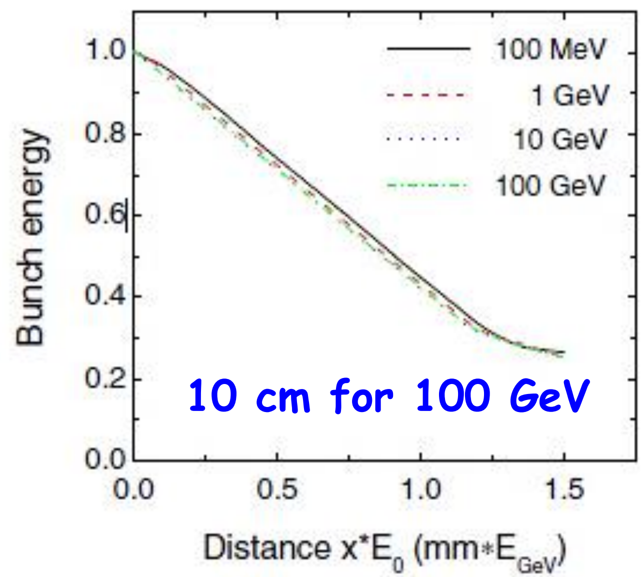
Linear Collider WS
Tokyo Nov. 15 2013
A. Suzuki (KEK DG)

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

U. Amaldi, *Phys. Lett*, 61B,v3 1976

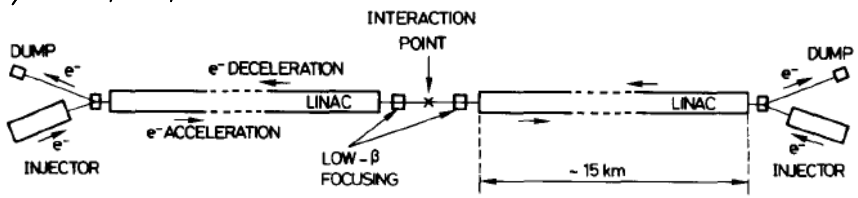
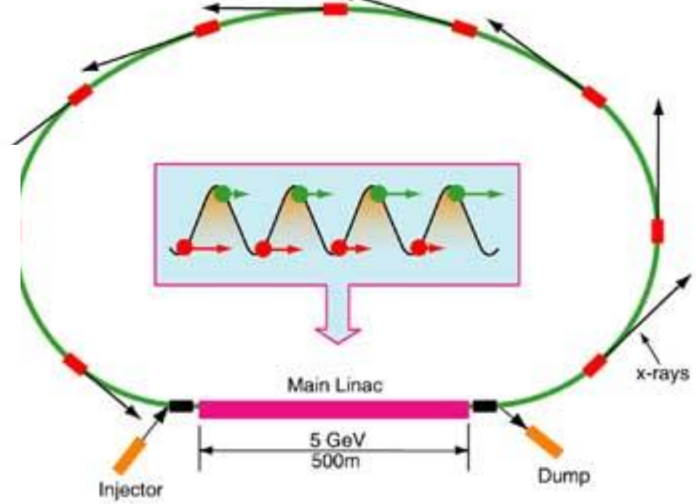
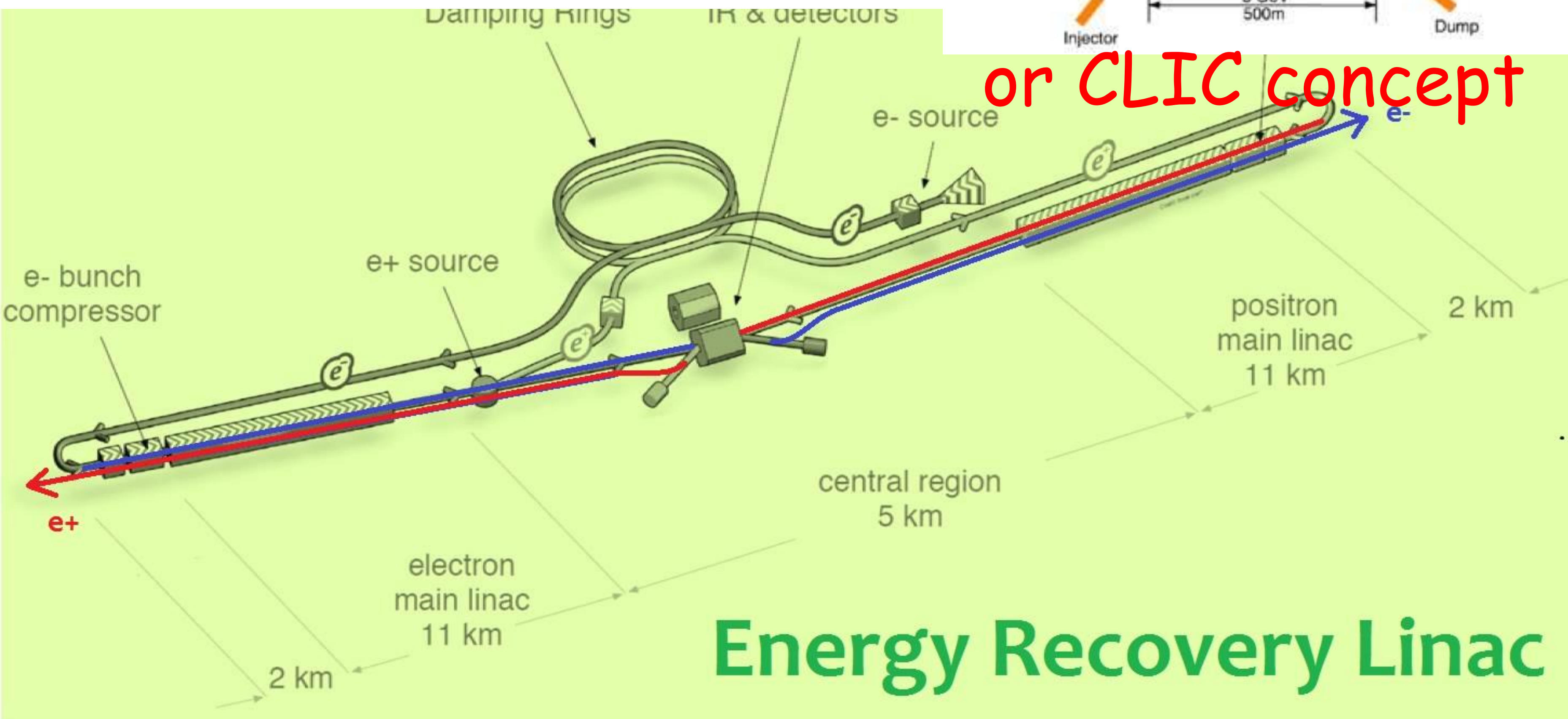


Fig. 1. Schematic drawing of the collinear electron-electron colliding beam machine. If accelerating fields of ~10 MV/m can be achieved, to obtain (150 + 150) GeV collisions the length of the superconducting linacs has to be ~15 km.



or CLIC concept



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How much will we save ?

10, 20, 30% great !!!

Will it be enough for the highest energies ???

Probably not

HEP must reach sustainability

Sustainability is efficiency and renewable energy

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Green ILC (3)
Sustainable Energies

Energy Production:

- Study the pros/cons of various sources: solar, wind, geothermal, sea, …, smr,…
  - Availability, Price, Flexibility, Potential for improvement, Environmental impact
- Find the best energy mix to cover ILC specific needs ? 24/7, long shutdowns, …
- Match ILC component to the energy sources specifics:
  - RF power converter: PhotoVoltaic, fuel cells (DC)
  - Cryocooler or asynchronous liquefactors ?

Energy Storage: HEP, experts in some of these technologies

- Liquid Helium, Nitrogen, SMES(Sc Magnetic Energy Storage), Flywheel, Pumped hydro, Compressed air, Batteries, …

Distribution: Local Smart 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

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Example: An LN_2 Economy for ILC

The ILC cryogenics is consuming ~ 40 MW (25% of ILC AC power)

- In current design all cooling is done with LHe. LN_2 as a primary coolant -> 20 MW
- LN_2 cooling: HTc (MgB_2) power transmission lines, NC magnets, electronics/computers,
- LN_2 could be used to recycle low grade heat waste or/and high temp. beam dumps
- And produce electricity with high-pressure gas turbine (70% efficiency)

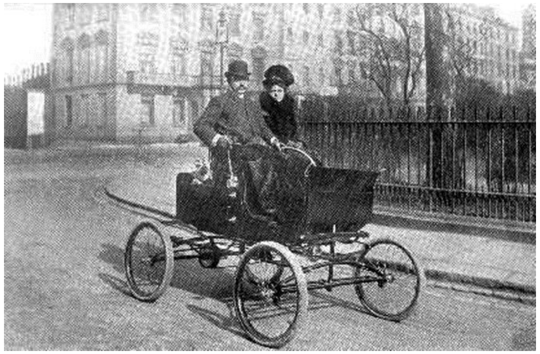
LN_2 could be produced by sustainable energies

- Close to or at the ILC site (wind, solar, geothermal energy)
- Wind energy: from electricity or direct compression
- Byproducts: liquid oxygen, argon, capture CO_2, …

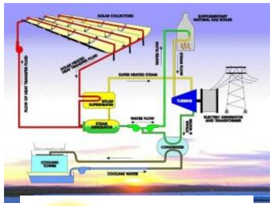
LN_2 Energy storage

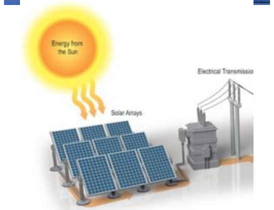
Sumimoto

First LN2 car


Liquid air energy network

LN2 as energy storage

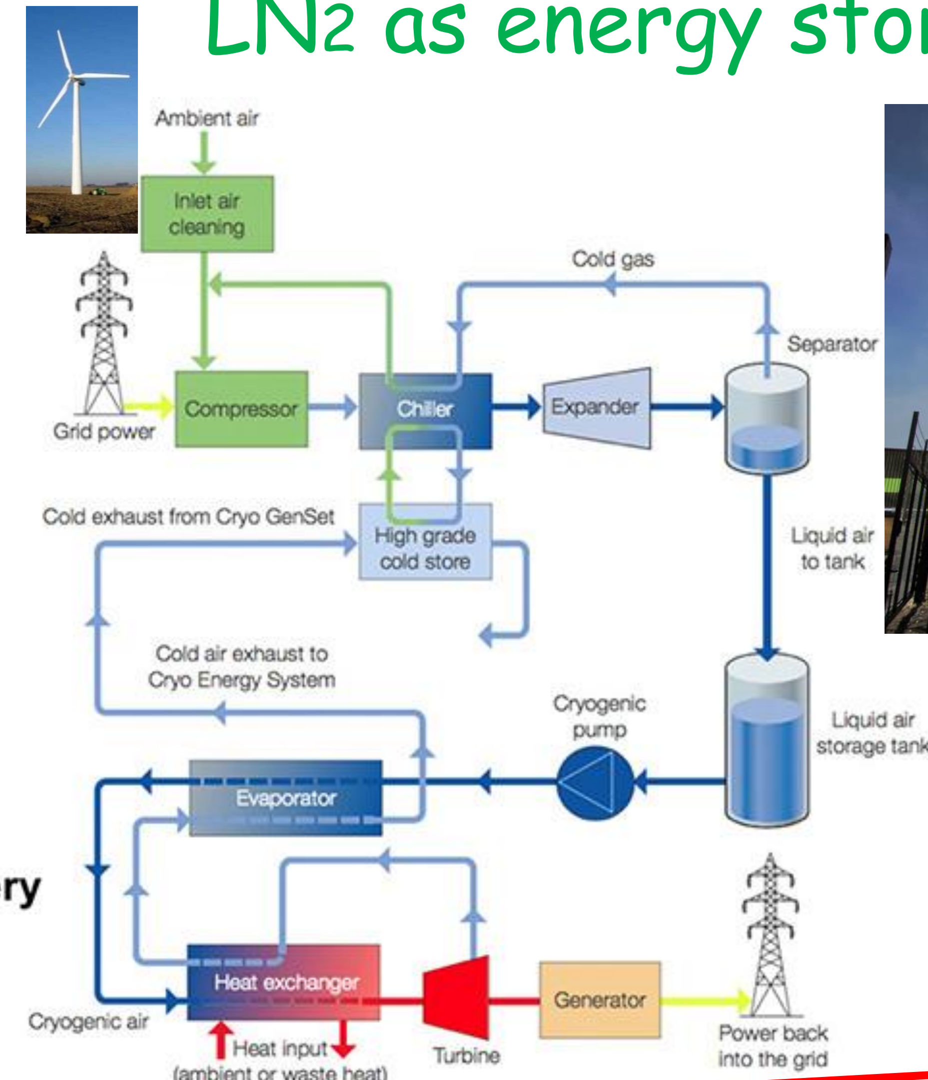




Liquefaction

Storage

Power Recovery



Highview Power Storage (UK)

ILC heat waste

Expected Efficiency up to 70% using heat waste (~ 115 ⁰C)

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Global Energy Center

Global organization for Green ILC

ILC Energy Center

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

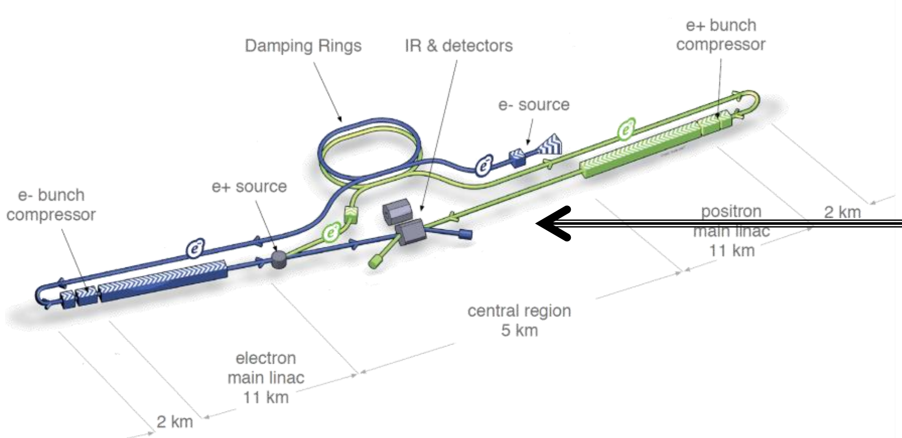
Industry

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

High-Energy community

Electrons, photons, neutrons factories
HPC/GRID Computing
Energy storage tech.

Energy community



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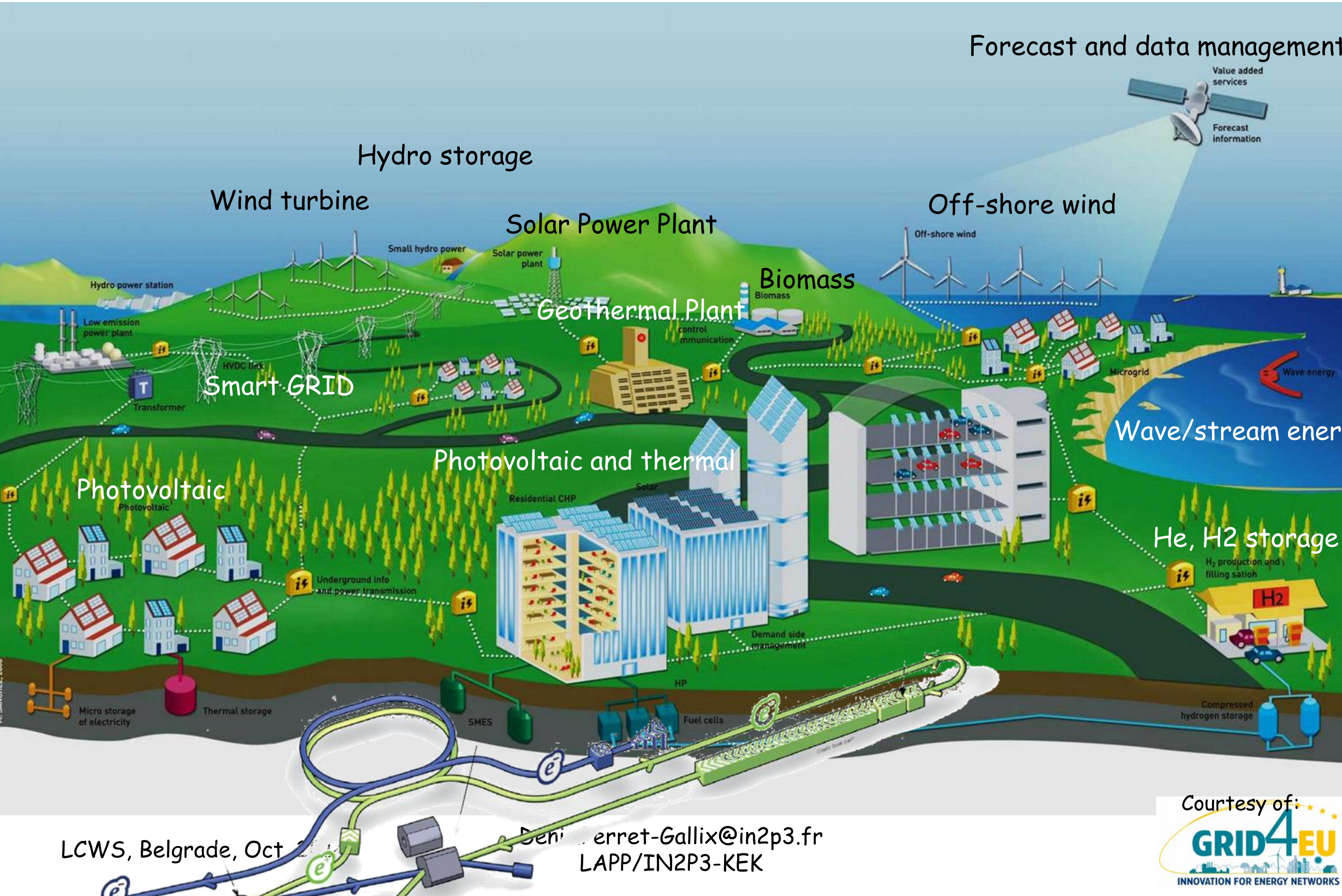
The "ILC Energy Center"



Courtesy of:
GRID4EU
INNOVATION FOR ENERGY NETWORKS

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http://green-ilc.in2p3.fr

Green-ILC Project

Green ILC

Energy for Innovation, Innovation in Energy

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The Green ILC Project

ILC, the International Linear Collider, is the next fundamental science project in high energy physics and the first ever true global basic science center.

What CERN did for the European HEP community, ILC will do for the world. But the e+e- ILC project may go even beyond mere fundamental science and contribute to one of the world most pregnant issue: Energy, not merely high-energy but, more generally: energy for the society.

Artistic view of the ILC center in Kitakami (Japan) ILC-Iwate

The ILC scientific goal is simple: high precision study of the Higgs particle recently discovered at LHC (CERN) and other signals LHC could possibly single out. New effects will also be searched for, effects which could have been missed by the LHC due to the heavy background. Higher precision here concerns, more particularly, the various Higgs couplings, limited at LHC, in part, by the complex structure of the interacting particles, the protons compared to the elementary electrons. Higher precision through higher order corrections would also shed light on an energy regions

Recent Posts

- EUCARD2 EnEfficient
- Liquid Air in the Energy and Transport Systems
- CEA Liten
- Mega Solar Plant in Japan
- Ivanpah: World Largest Solar Plant

Links

- email: green.accelerators@gmail.com
- Green-ILC wiki
- Green-ILC group discussion

Messages

- Energy consumption is a burning hot parameter
  - Linked to many scientific, technological, financial, societal, political issues
  - Could be a no-go for some projects
  - Not a taboo or worst a technical detail: must be bluntly addressed

- Future of HEP: Saving, recovery, recycling: a must, but not enough for sustainability,
  → renewable energy
  - Follow and contribute to energy/environment civilization shift
  - Storage, a master word, needed for recycling and renewable energies.
  - E.g. LN_2 economy

- Energy R&D is core to HEP Research
  - HEP is all about energy, HEP needs energy.
  - Must structure a Global effort:
    - Build on existing initiatives: Green-ILC, EUCARD2 EnEfficient, Sustainable Science Workshop,…
    - Collaboration with Energy R&D and Industry (Japan AAA Green-ILC)
    - ICFA could take initiative: sustainable accelerator panel
  - Next global infrastructure should be seen as an "Energy Center"
  - Make HEP a bright future and bring benefit to the society

Let's do it the smart way

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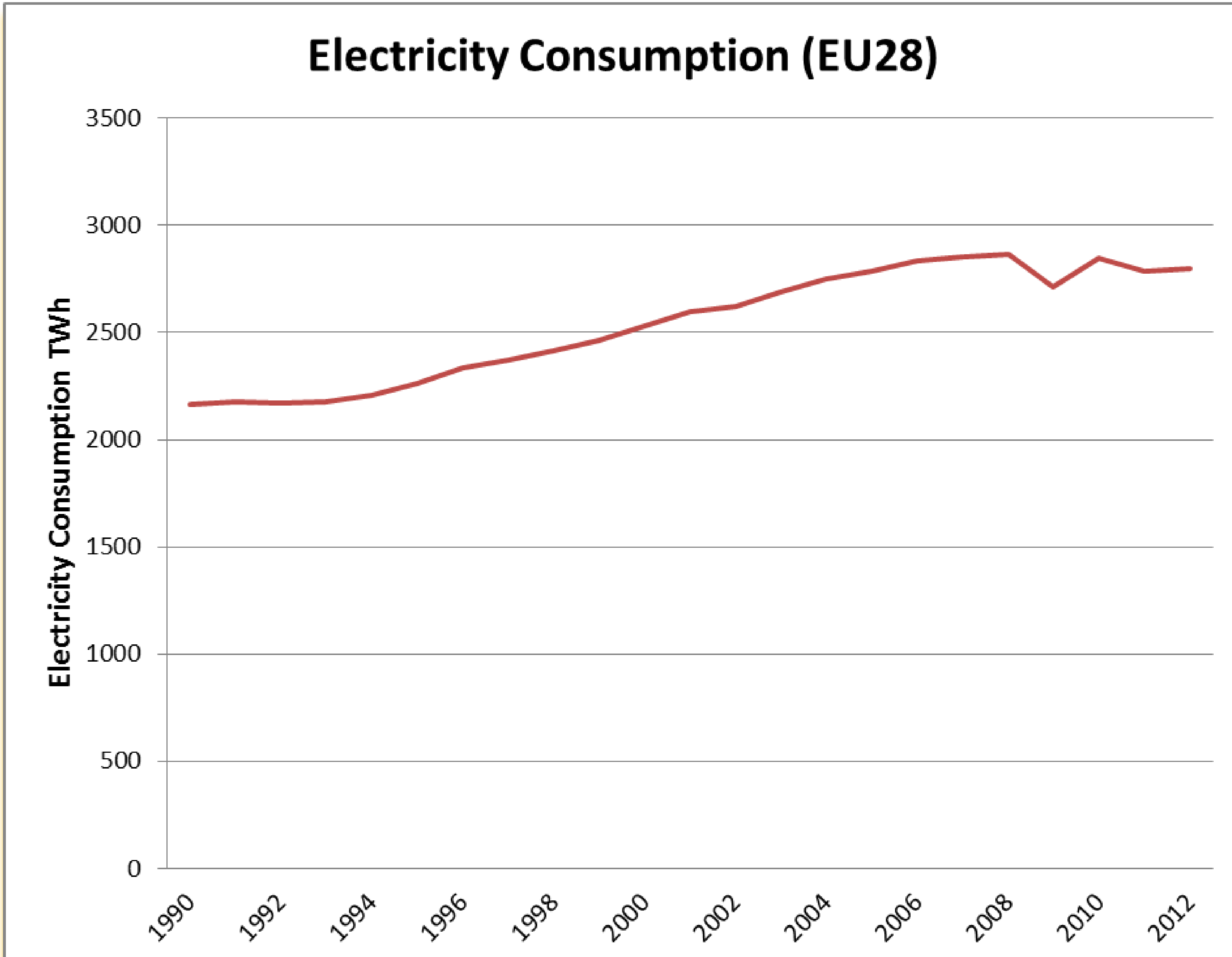
Thank you for your attention



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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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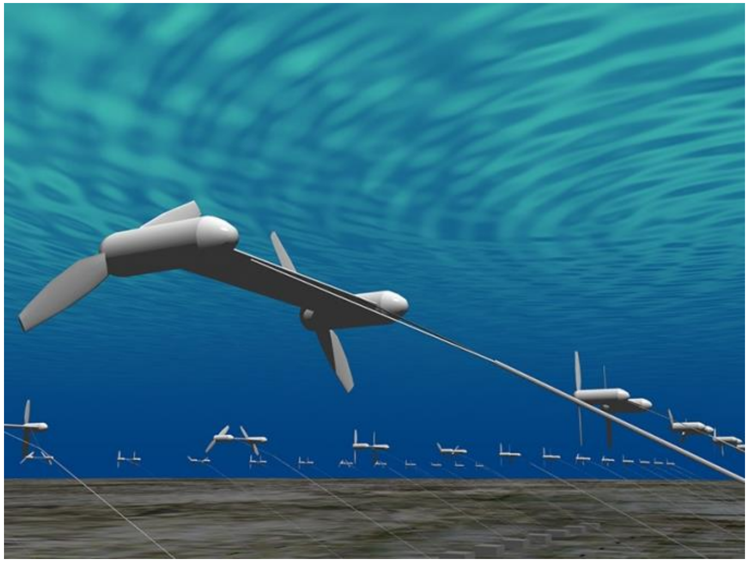
Wind/Marine Energy

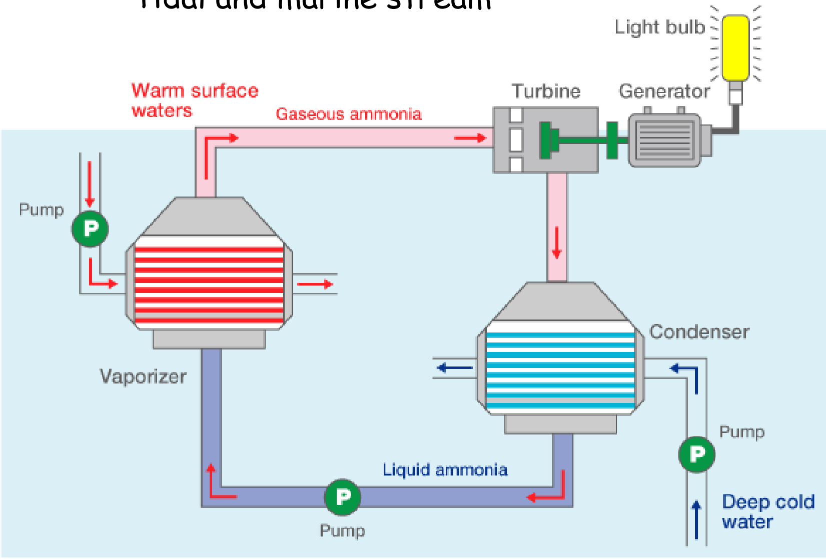
2 MW Goto island prototype



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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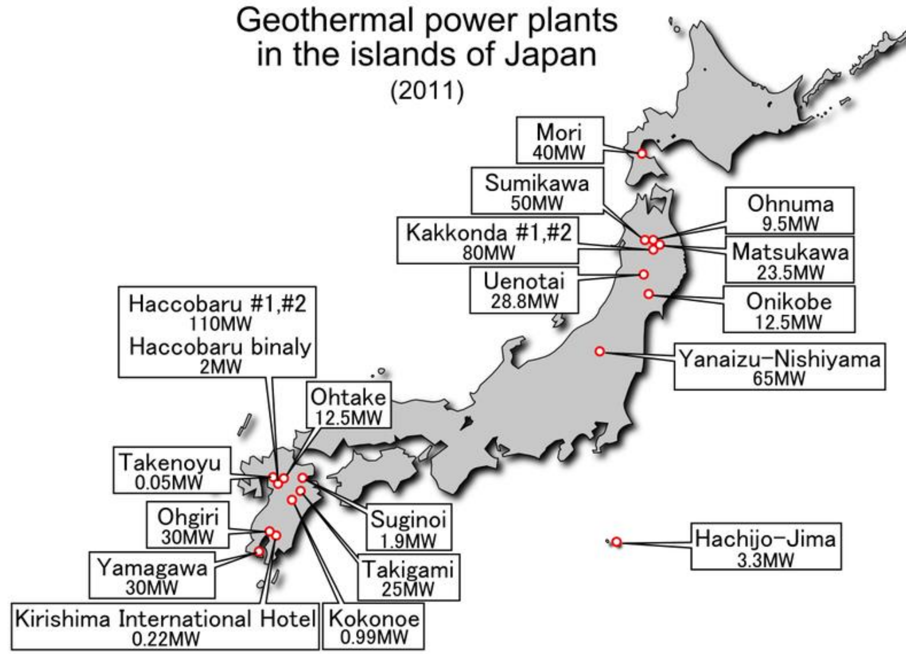
Geothermal Energy



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

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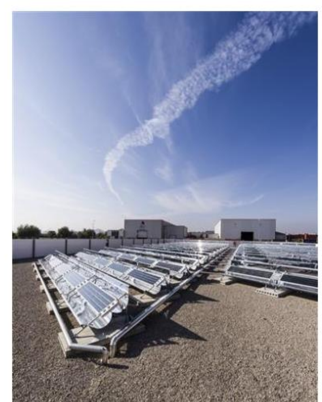
Major contract signed for supply of solar panels derived from CERN technology

09 Mar 2012

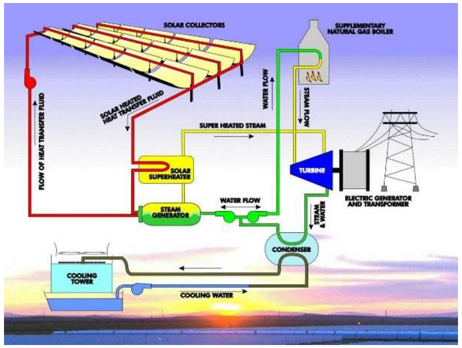


SRB Solar field in Valencia (Image: CERN)

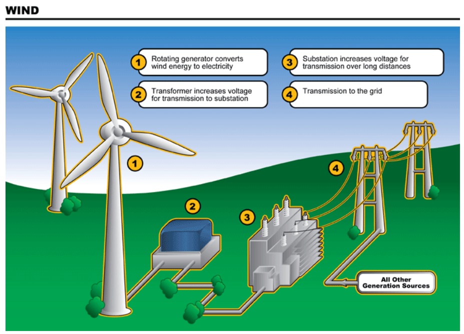
Solar thermal Energy

C. Benvenuti
CERN Physicist

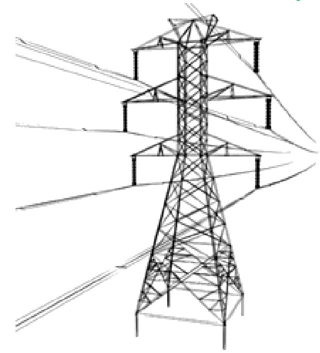
LN_2 Electrical Production and Transport

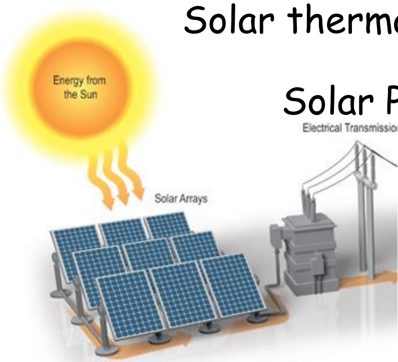


Solar thermal



Grid/ILC



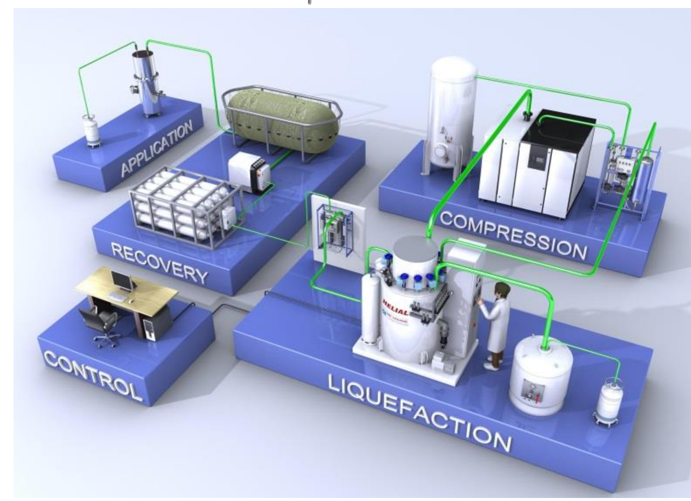


Solar PV

Wind,
Geothermal, biomass

Electricity
OR .....

Make LN_2



By Cryo Pipeline
Longest LNG ~ 5 km

HTc SC power line (project)
by 20 Km long section

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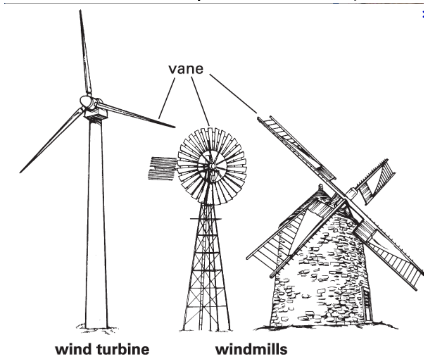
LN_2 process cycle

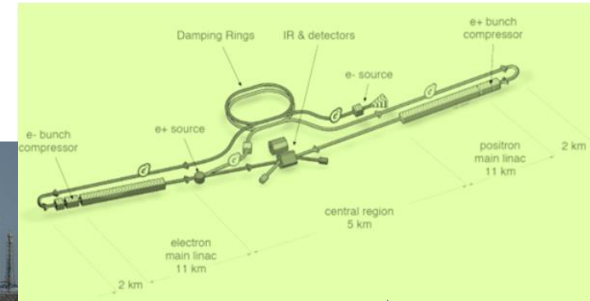
Compressor/liquefier inside



LN_2

- Cryocooler may save 50% electrical power
- Cooling NC magnets
- HTc power Transmission lines
- Cooling electronics and computers

Energy storage



LN2 heat waste

Turbine → electrical generator

N2 gas applications

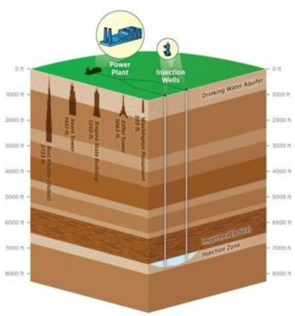
Electricity Back to ILC/GRID

i.e. Drying and preservation industry

LO_2, LAr, SCO_2 Dry ice

To Industry

For Cooling or Sequestration



Air cleaning !!!

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