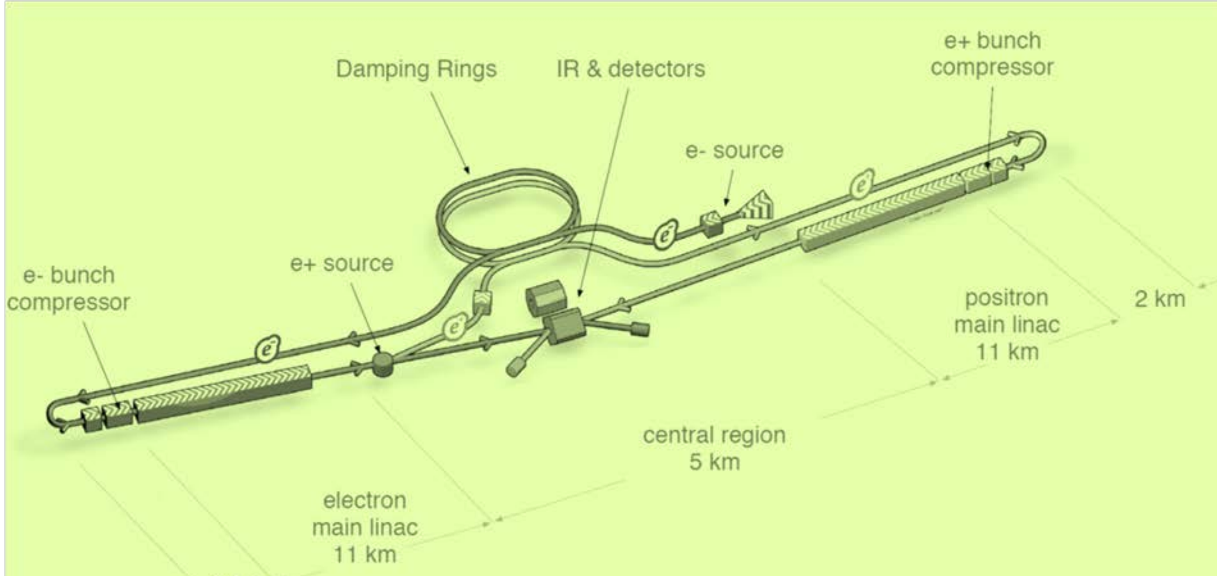
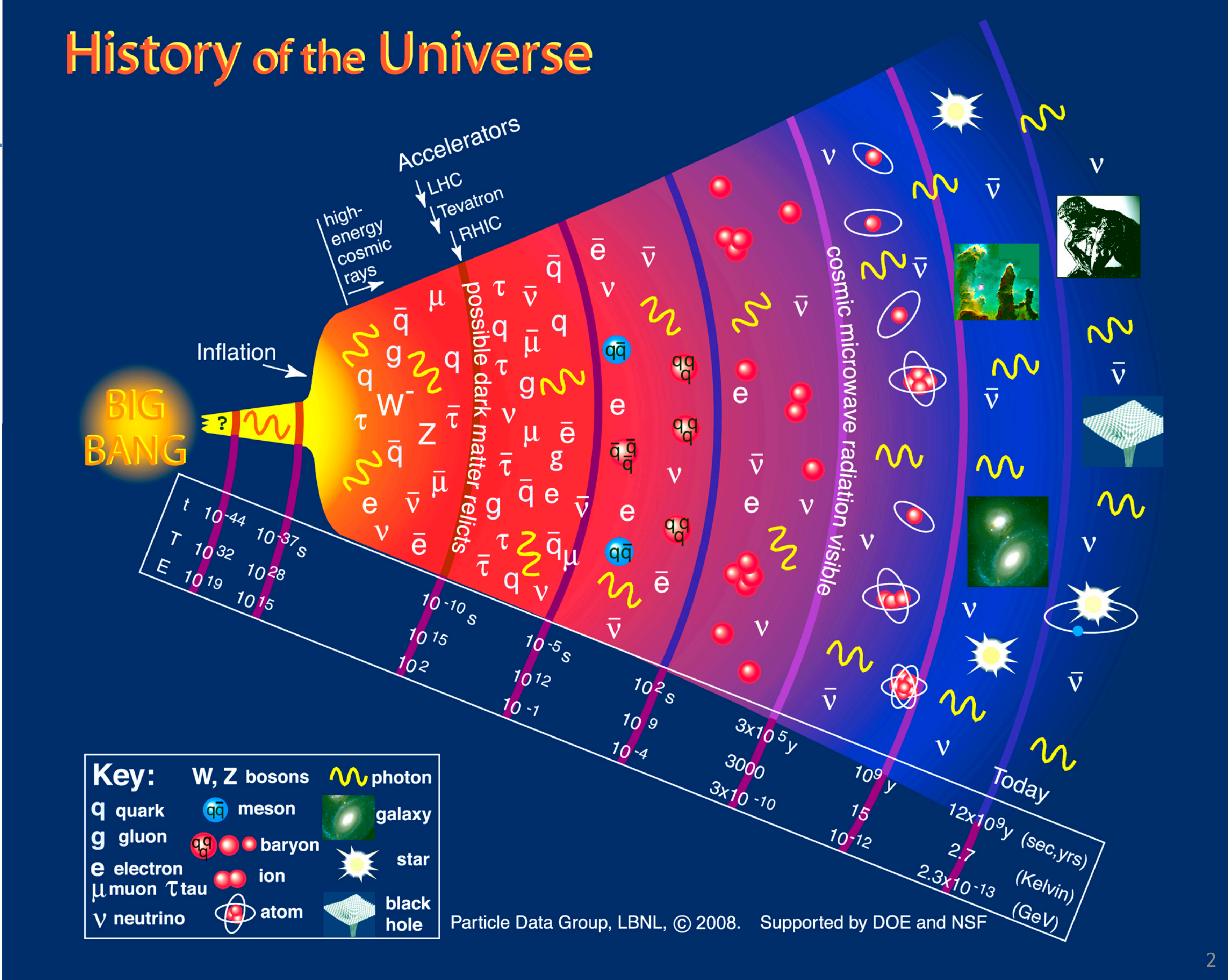


THE GREEN ILC

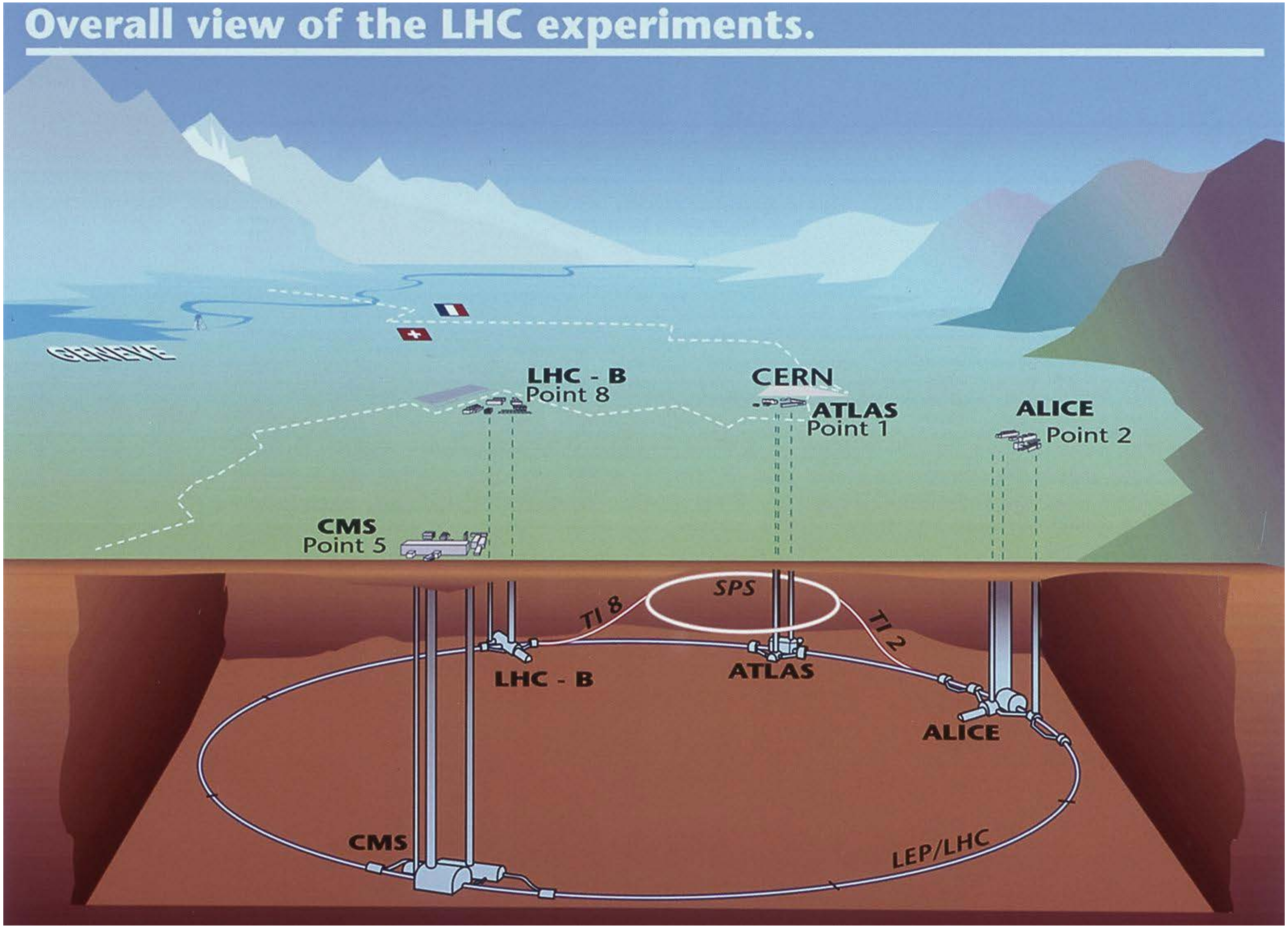
An Industry-Research Endeavor in Particle Physics

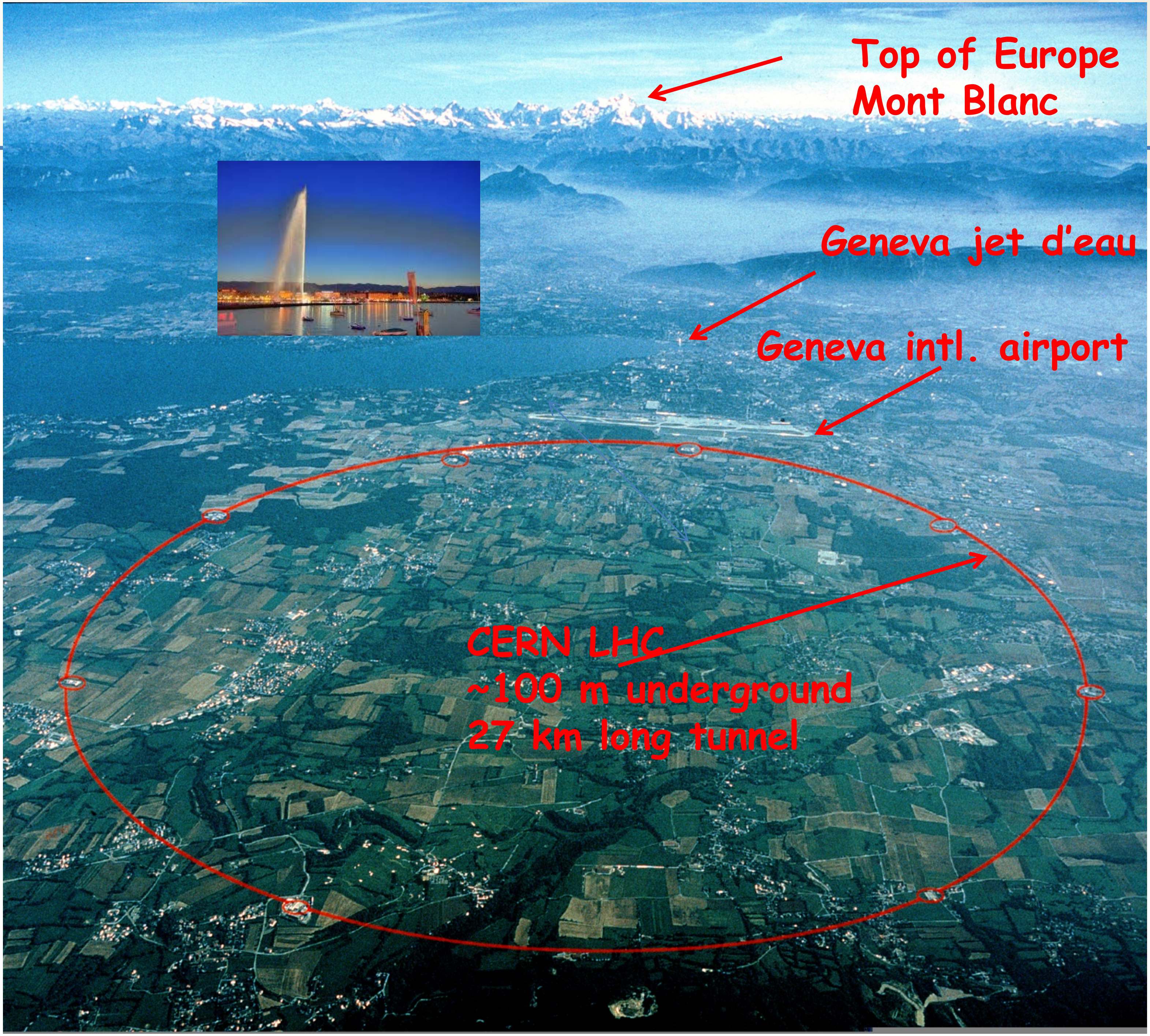
Energy for Innovation and Innovation in Energy

Denis.Perret-Gallix@in2p3.fr
CNRS/IN2P3LAPP - KEK

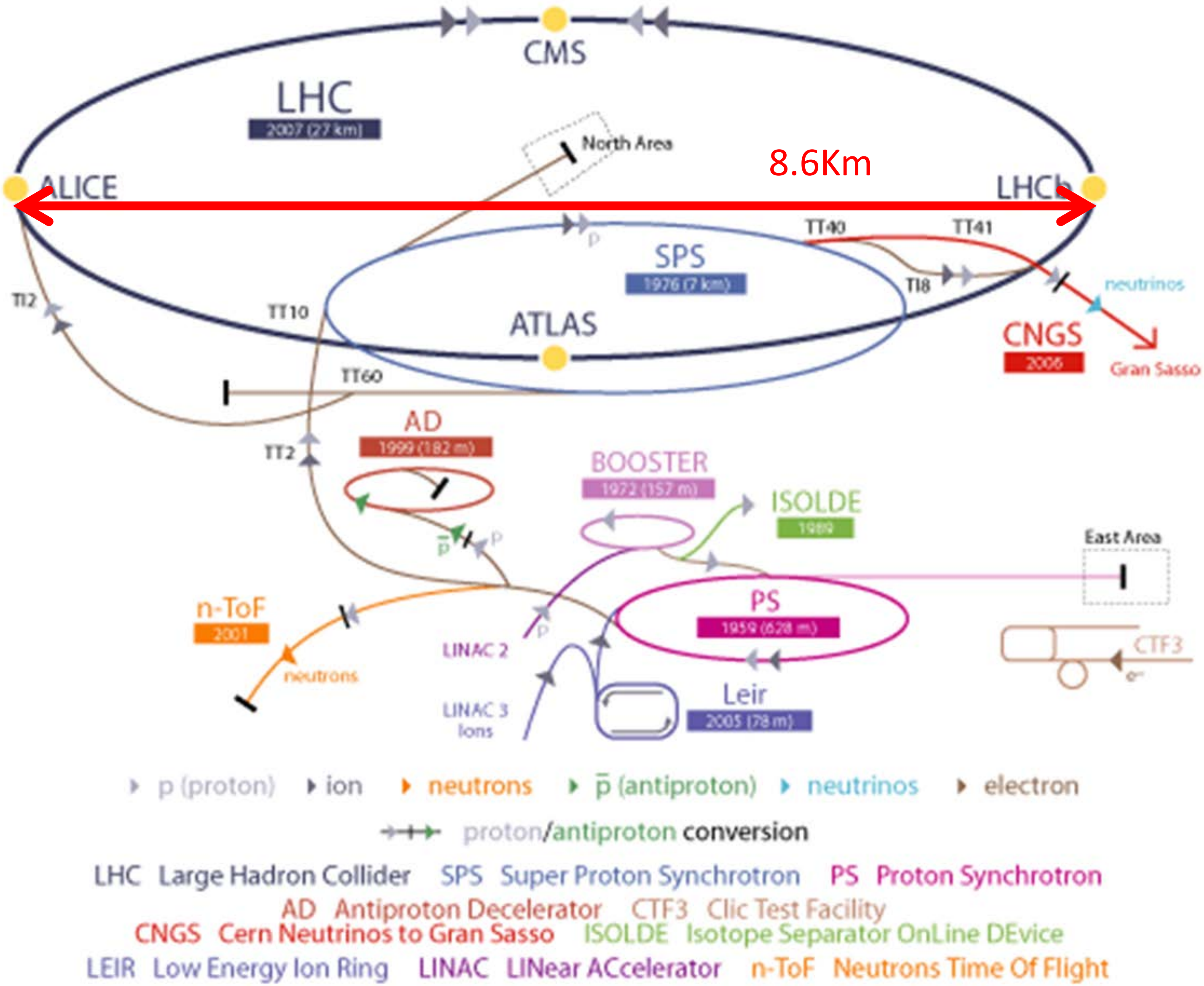

History of the Universe
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^-44 10^-37 s
T 10^32 10^28
E 10^19 10^15
10^-10 s
10^15
10^2
10^-5 s
10^12
10^-1
10^2 s
10^9
10^-4
3x10^5 y
3000
3x10^-10
10^9 y
15
10^-12
Today
12x10^9 y (sec,yrs)
2.7 (Kelvin)
2.3x10^-13 (GeV)
Key:
W, Z bosons
photon
q quark
meson
galaxy
g gluon
baryon
star
e electron
ion
μ muon τ tau
atom
black hole
ν neutrino
Particle Data Group, LBNL, © 2008. Supported by DOE and NSF

Particle Physics at CERN - LHC

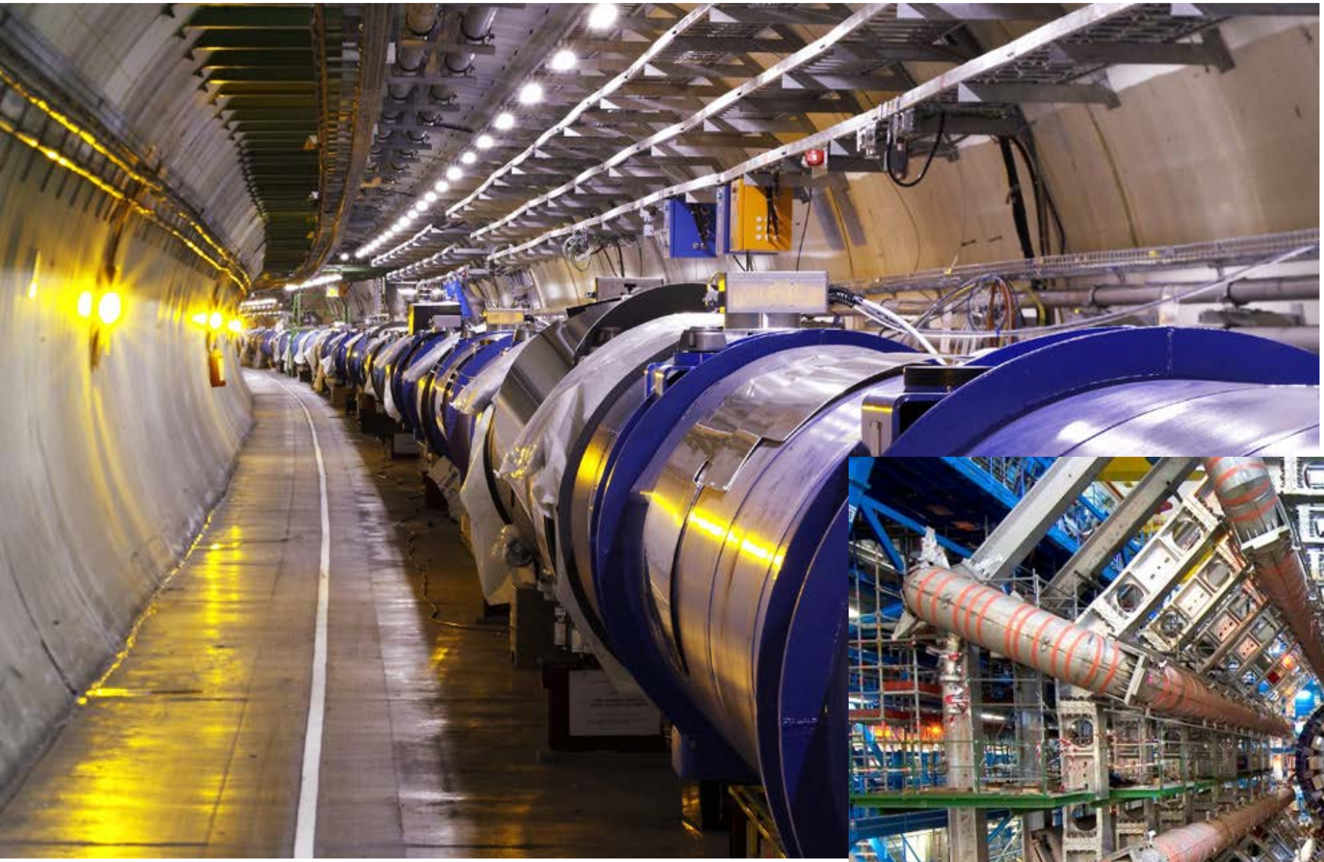


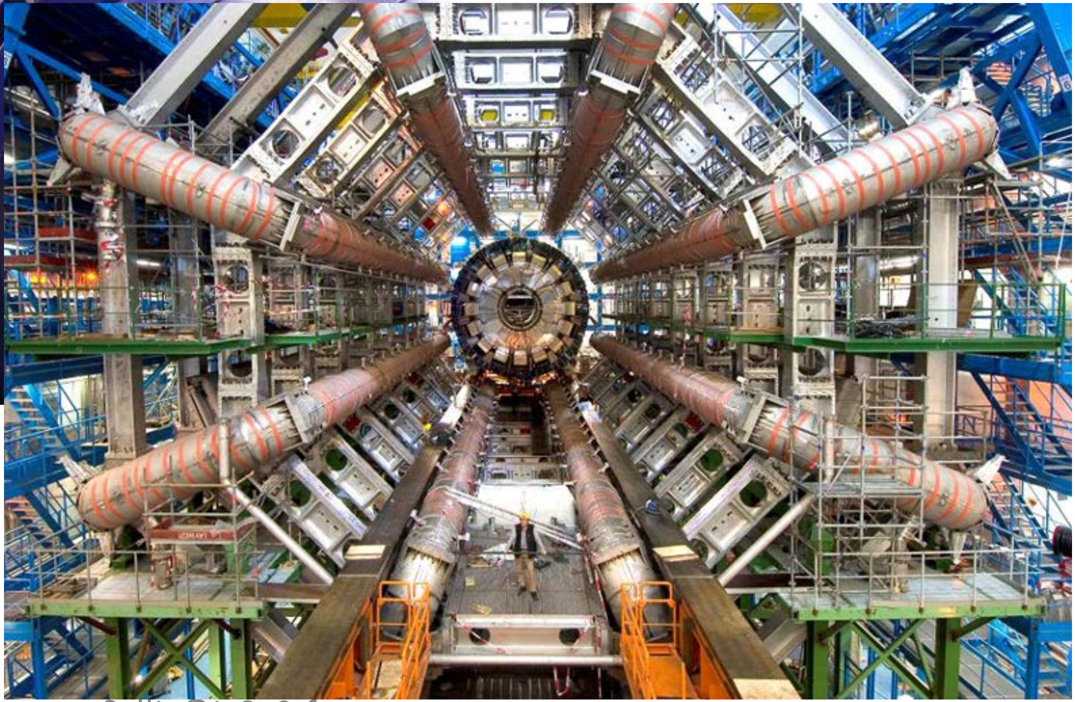

Top of Europe
Mont Blanc
Geneva jet d'eau
Geneva intl. airport
CERN LHC
~100 m underground
27 km long tunnel

CERN Accelerator Complex

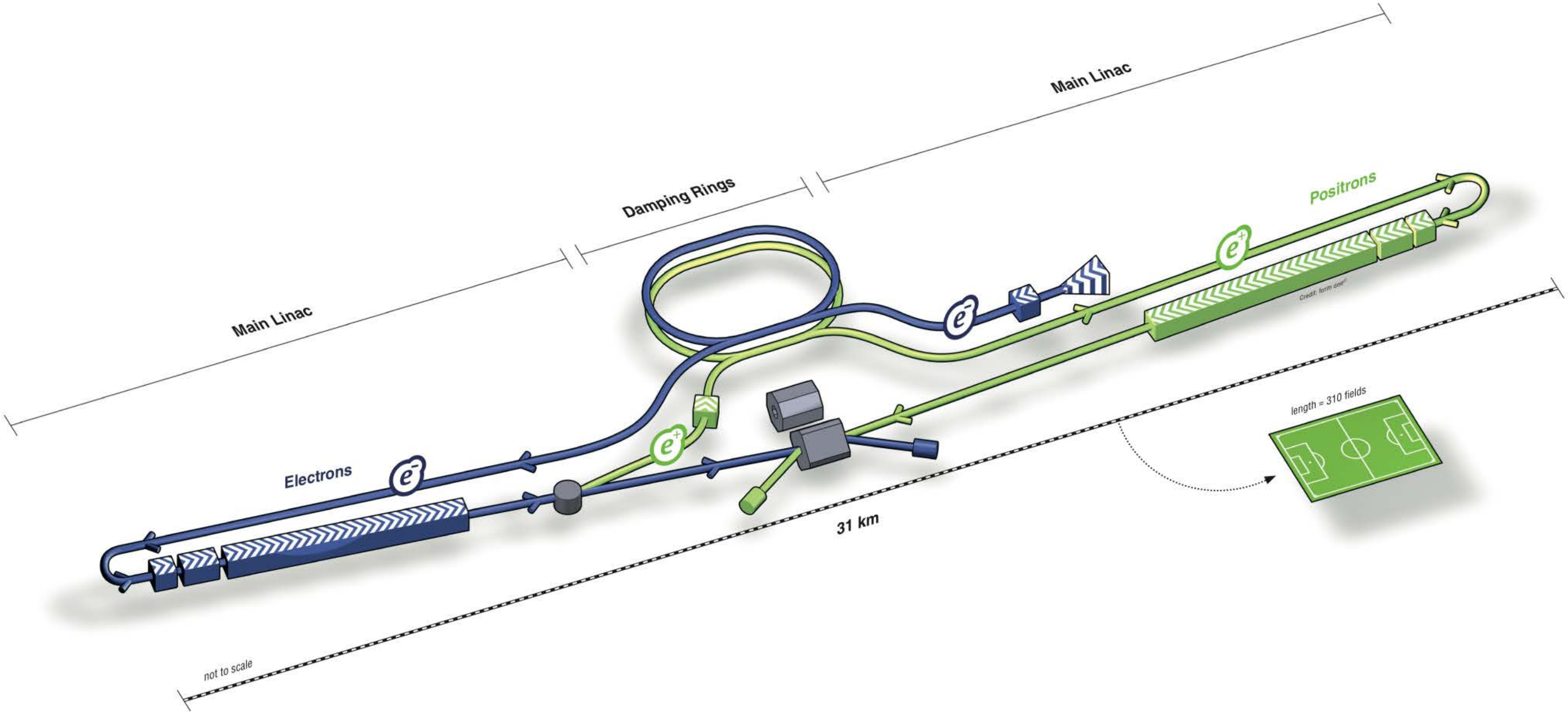


LHC- ATLAS

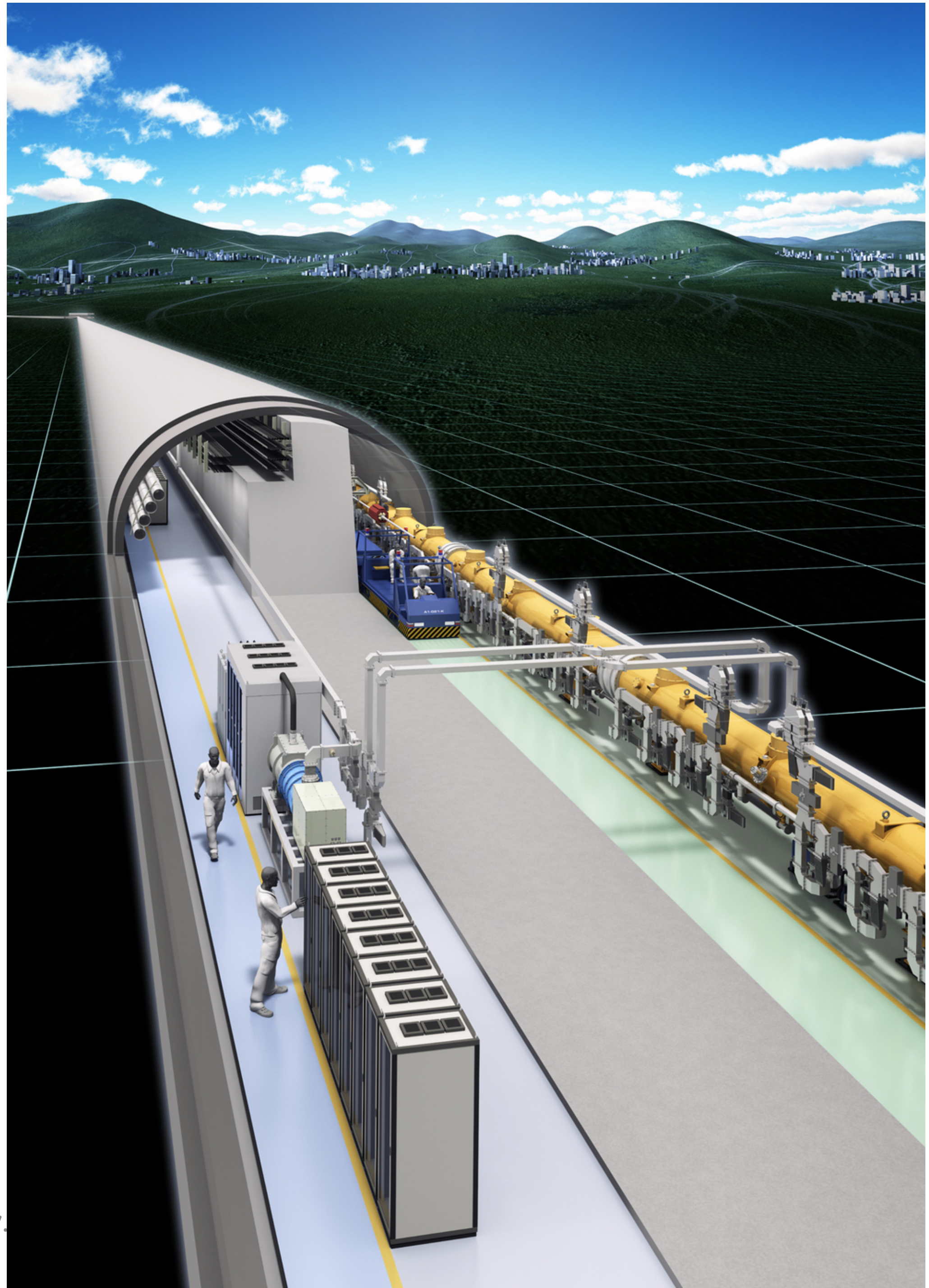




ILC: International Linear Collider



2 x 10 km linac: SC cavities @ 500 GeV → 2 x 20 km @ 1000 GeV



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	

ILC is a power converter from (m)eV to TeV
with
Wall-plug to beam power efficiency is 9.6 %

Power and Energy for Colliders

LHC-CERN ~ 180 MW - 1.35 TWh/year, 50% Geneva electr. consumption (~ 250,000)

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)
ILC lab. (Experiment, Computing, Buildings) => 180 MW @ 500 GeV, 320 MW @ 1 TeV.
TDR takes a large margin: 300 MW 500 MW
(240 MW @ 500 GeV, RDR estimation)

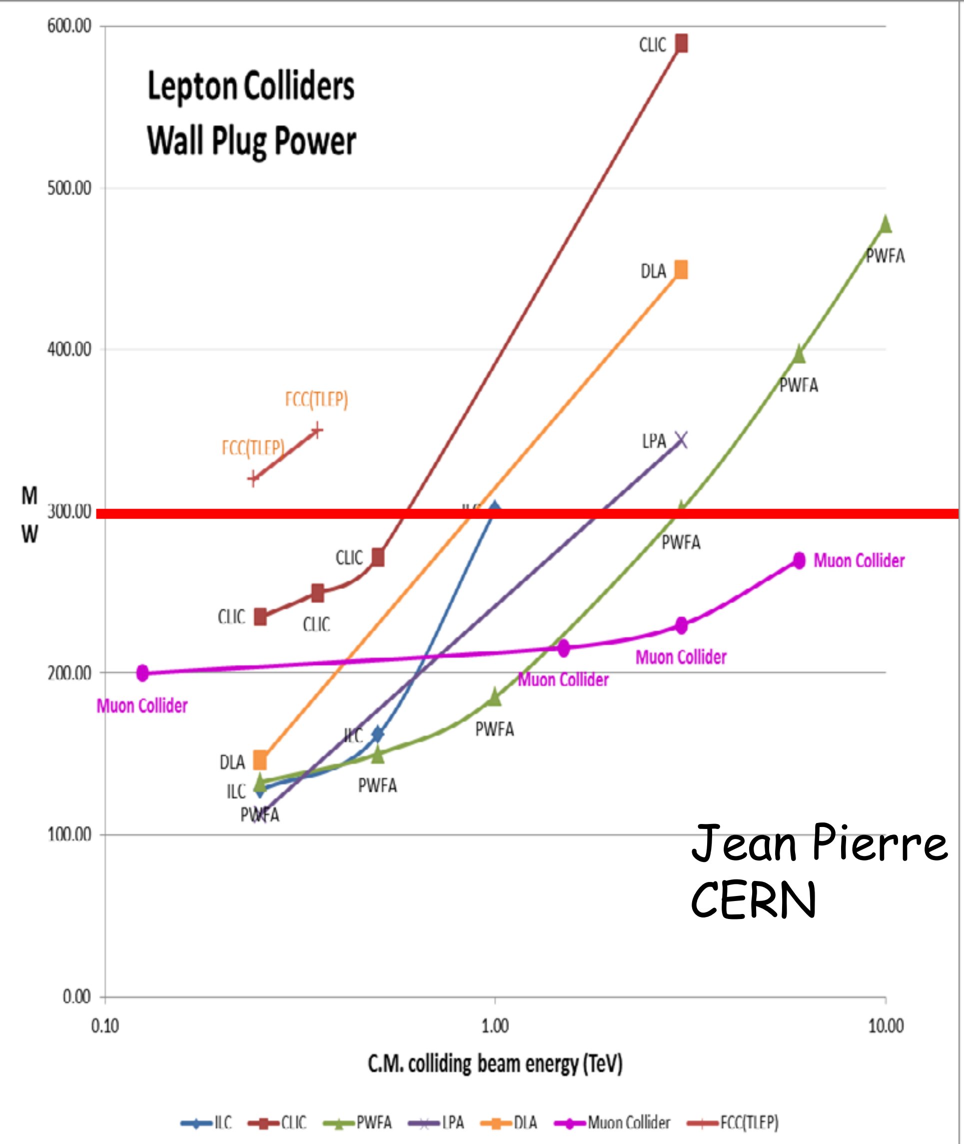
ILC 500 GeV 18% of Iwate prefecture electricity consumption, ~ Morioka (300,000)
ILC 1 TeV 32%

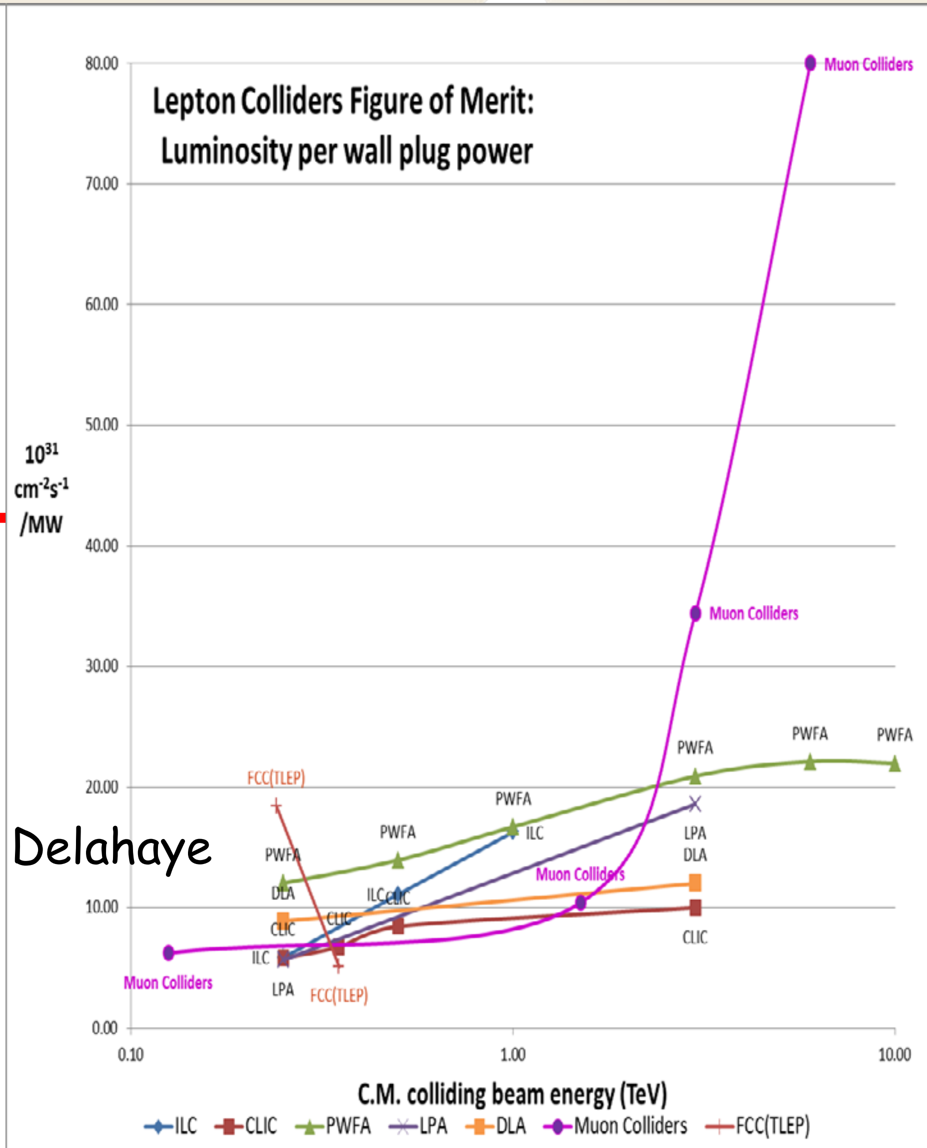
- 180$/MWh 2011 for industry (JP OECD 2013 report, special discount?, price volatility (2024))
- CERN (2011, ~ 70 $/MWh), ESS (Sweden, 110 $/MWh)

Yearly electricity running cost: 500 GeV ~ 240 M$ (10 years, ~25% of ILC capital cost)
1 TeV ~ 430 M$ (scaling on power)

HEP future: To be Green … or not to be !!

Muon Colliders extending high energy frontier with potential of considerable power savings



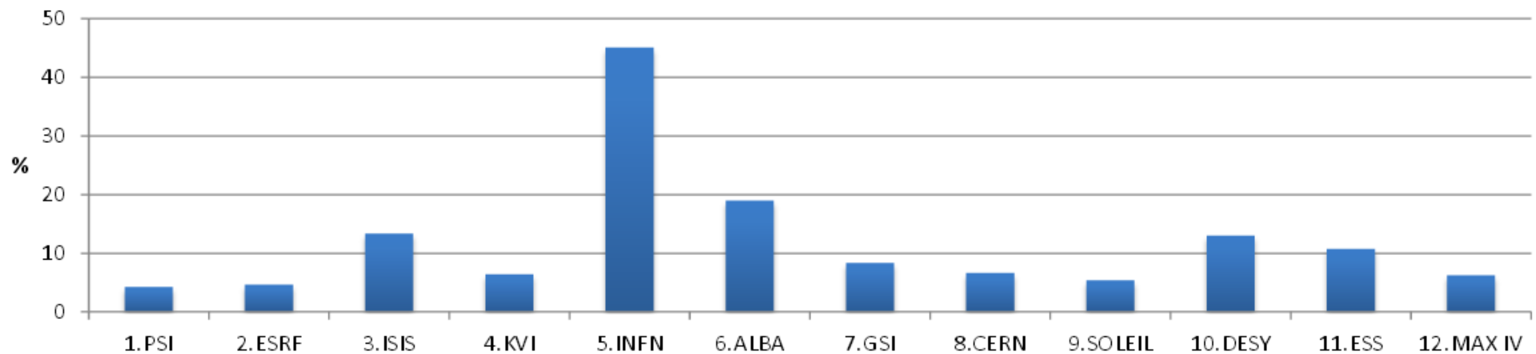


Jean Pierre Delahaye
CERN

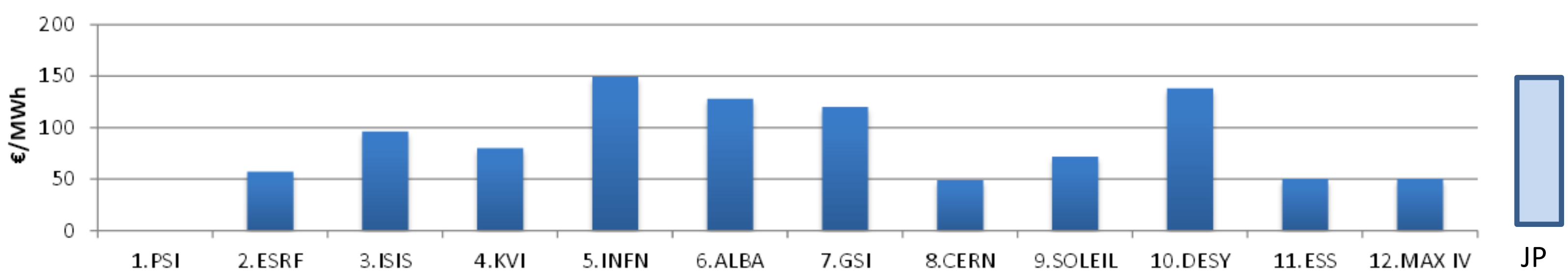
Presentation May, 2014…

J.Torberntsson, ESS

Energy-related part of costs (%)



Electricity price (€/MWh)



MAX IV LABORATORY

EuCARD²
EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

Green-ILC Objectives

ILC : lower running cost, better operational flexibility, environment friendly

Revisiting all ILC components:

1. Energy Saving: improving efficiency …. 80% lost as heat waste
2. Operational saving
3. Energy Recovery and Recycling

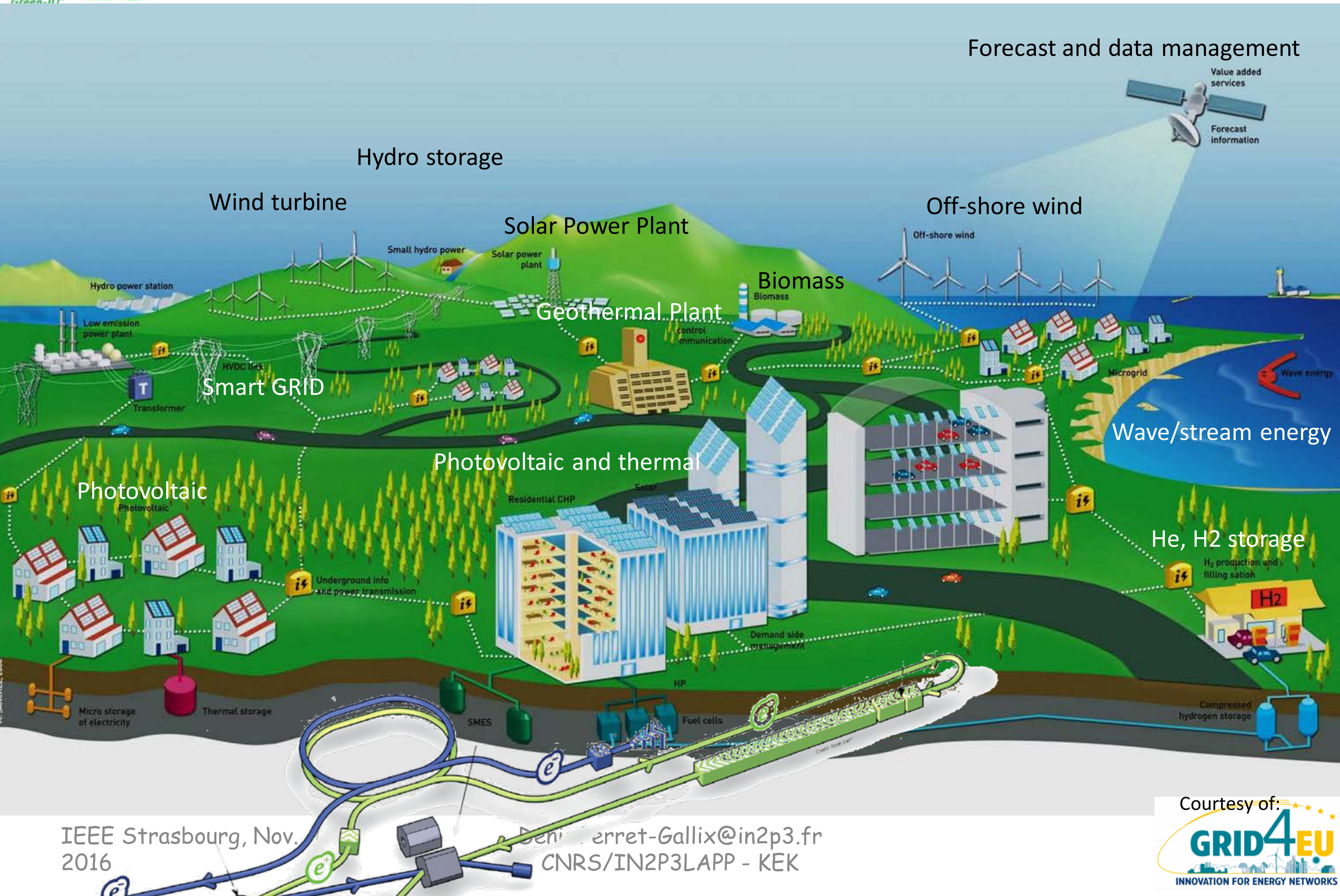
Alternative energies:

1. Renewable energy production, best for ILC and ILC site
2. Energy Storage (for energy recovery and intermittency)
3. Distribution and Management: Smart Grid

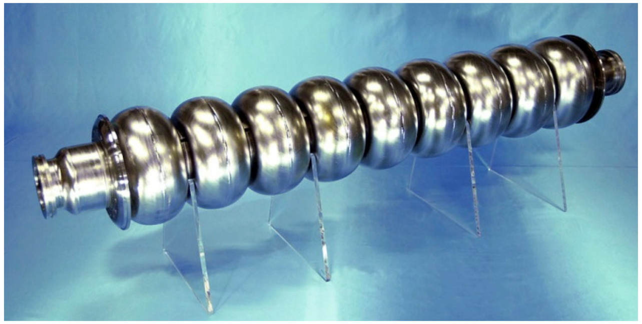
Energy for: societal needs and world economy,

1. Basic Research
2. Synergies: expertise (SC, magnets, beams, computing), photon, neutron factories
3. Technology innovation
4. ILC as a test bench: Pilot plants for ILC

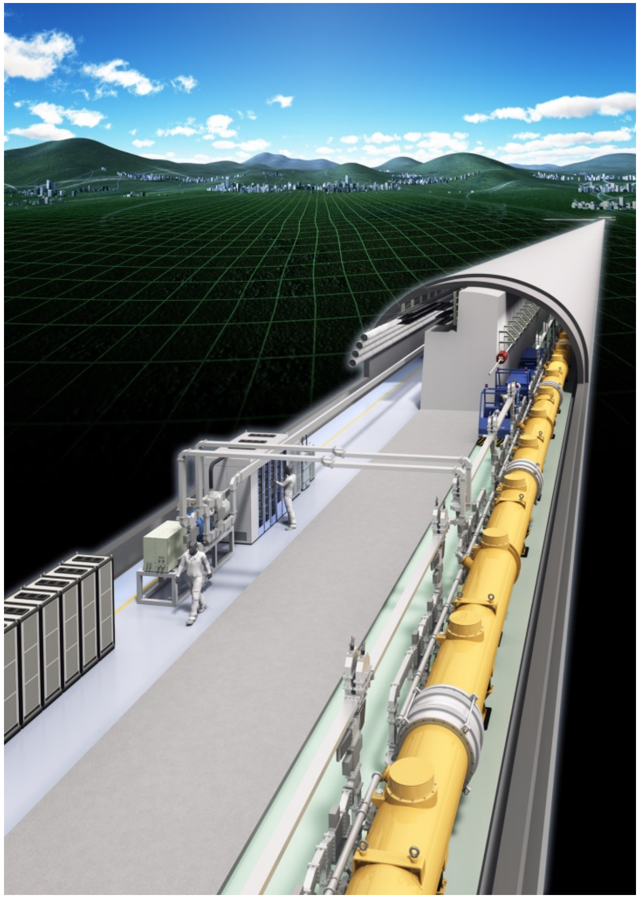
ILC Energy center (artistic) view



Energy Saving and recovery

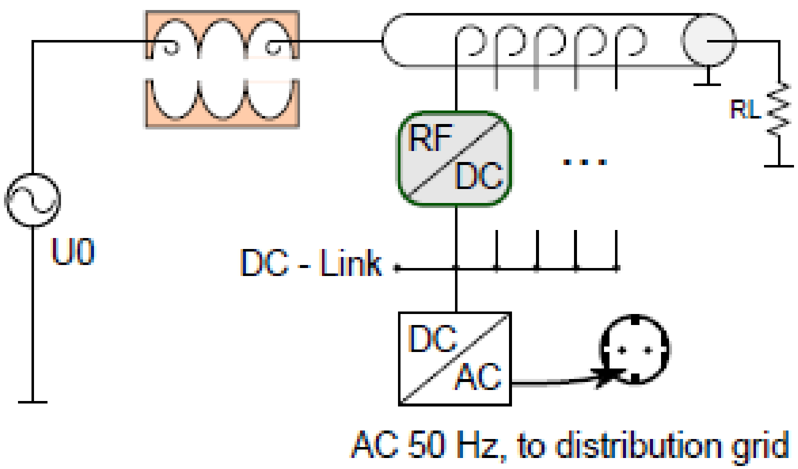


- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam

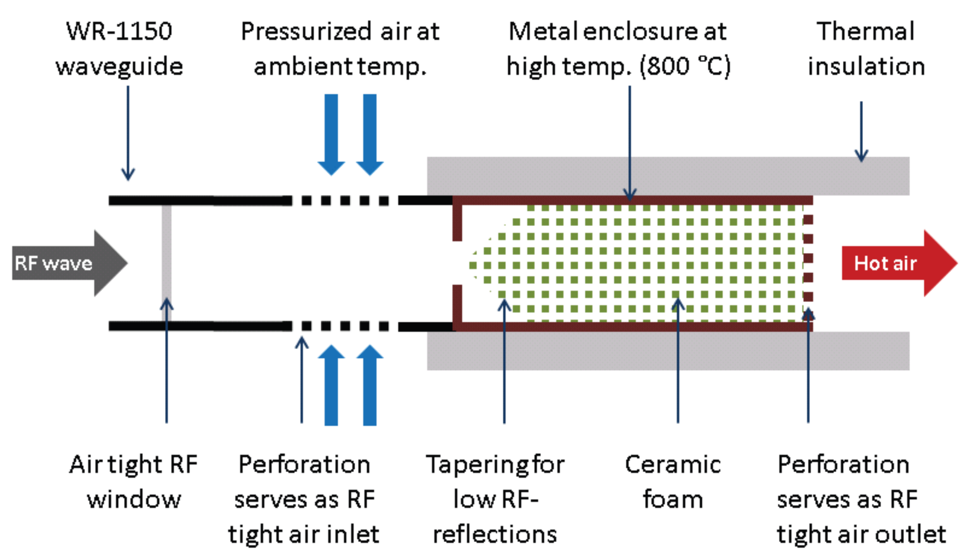


Recover non-used RF power: Smart RF loads

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

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)

Denis.Perret-Gallix@in2p3.fr
CNRS/IN2P3LAPP - KEK

Energy Saving and recovery

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- Cavities: 2 Magnetic shields -> Increase
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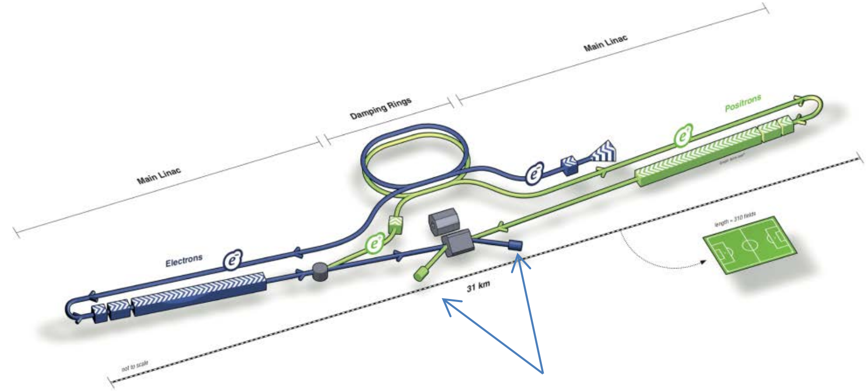
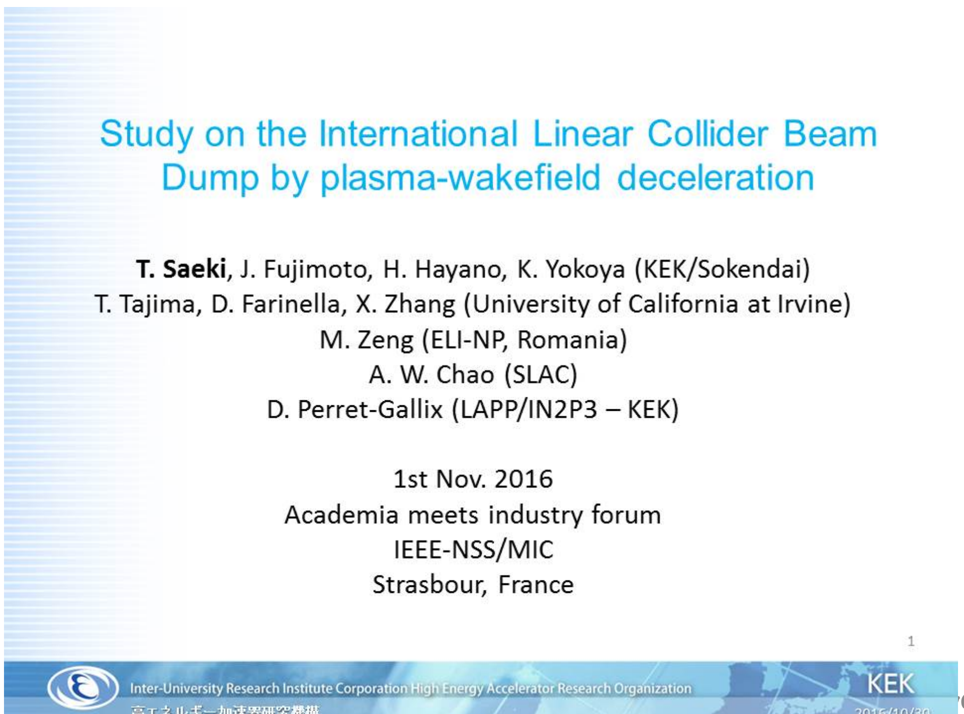
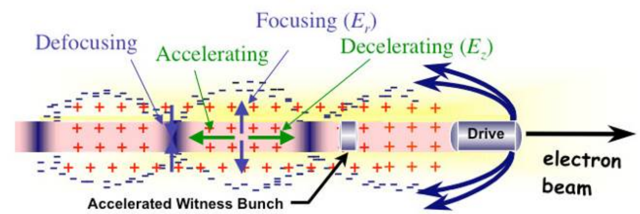
- Beam dumps
  - Wakefield deceleration for beam dump, project and test

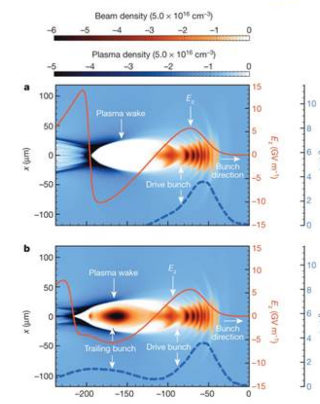


Beam dumps
10m water, 1000m gas



Plasma Acceleration, wakefield acceleration





6. Preliminary result of beam deceleration simulation

$beam:$

$\sigma_x = 300\mu m; \sigma_r = 50\mu m;$

$E = 250G\,\mathrm{eV}(\gamma_0 = 5\times10^5)$

$\mathrm{dE/E} = 0.1\%$

$\mathrm{N}_b = 2\times10^{10}\left(3.2nC\right)$

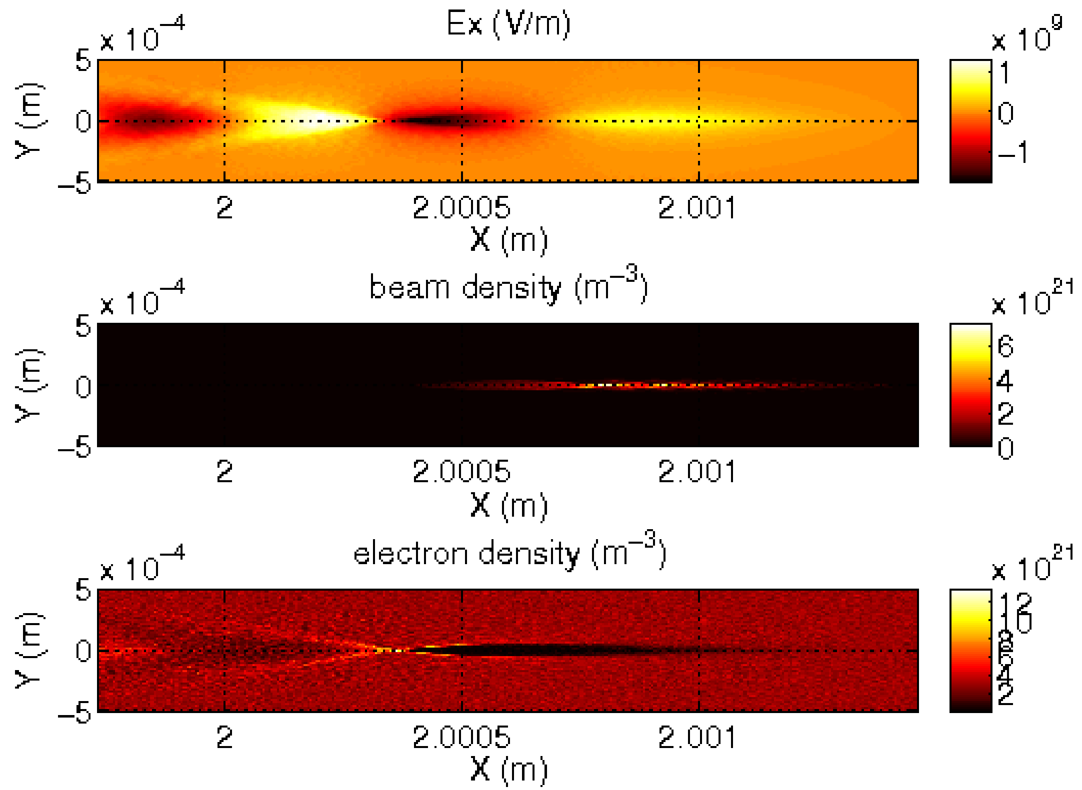
$$n_b = \frac{N_b}{(2\pi)^{3/2}\left(\sigma_x\sigma_r\sigma_r\right)} = 1.7\times10^{21}/m^3$$

$plasma:$

$n_p = 3\times10^{21}/m^3$

$\lambda_p \sim$ 600 μm

$\sigma_x \sim \lambda_p/2$



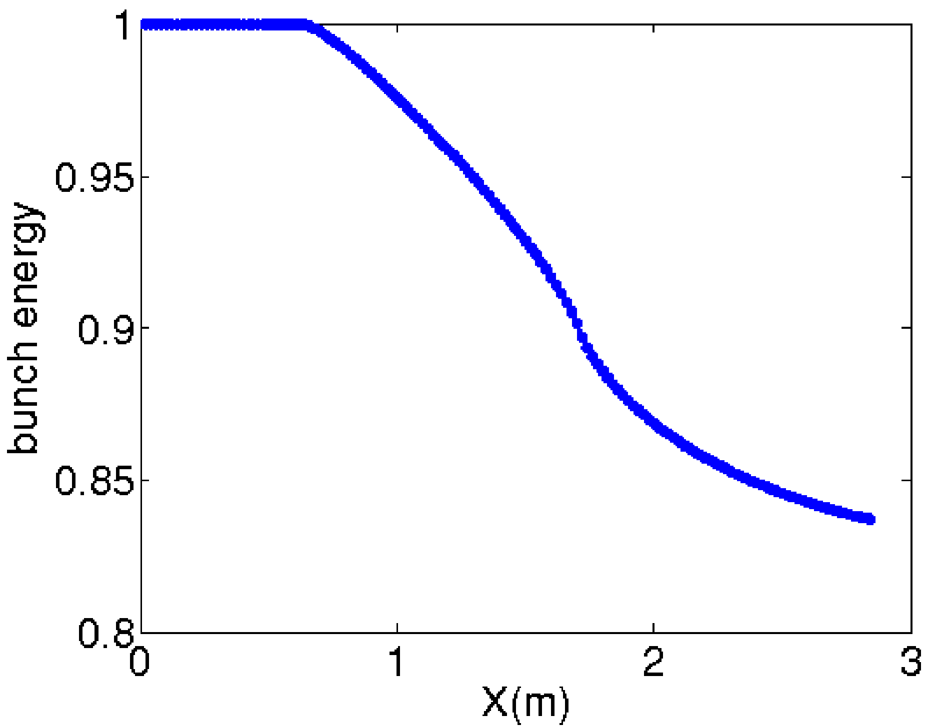
Simulation code: EPOCH

Dr. X. Zhang (UCI)

Preliminary result of beam deceleration simulation

Dr. X. Zhang (UCI)

More than 15% energy loss after 3m



First result of simulation is encouraging. Working is continuing with priority.

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test
- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling

MAYEKAWA
http://www.mayekawa.co.jp/ja/

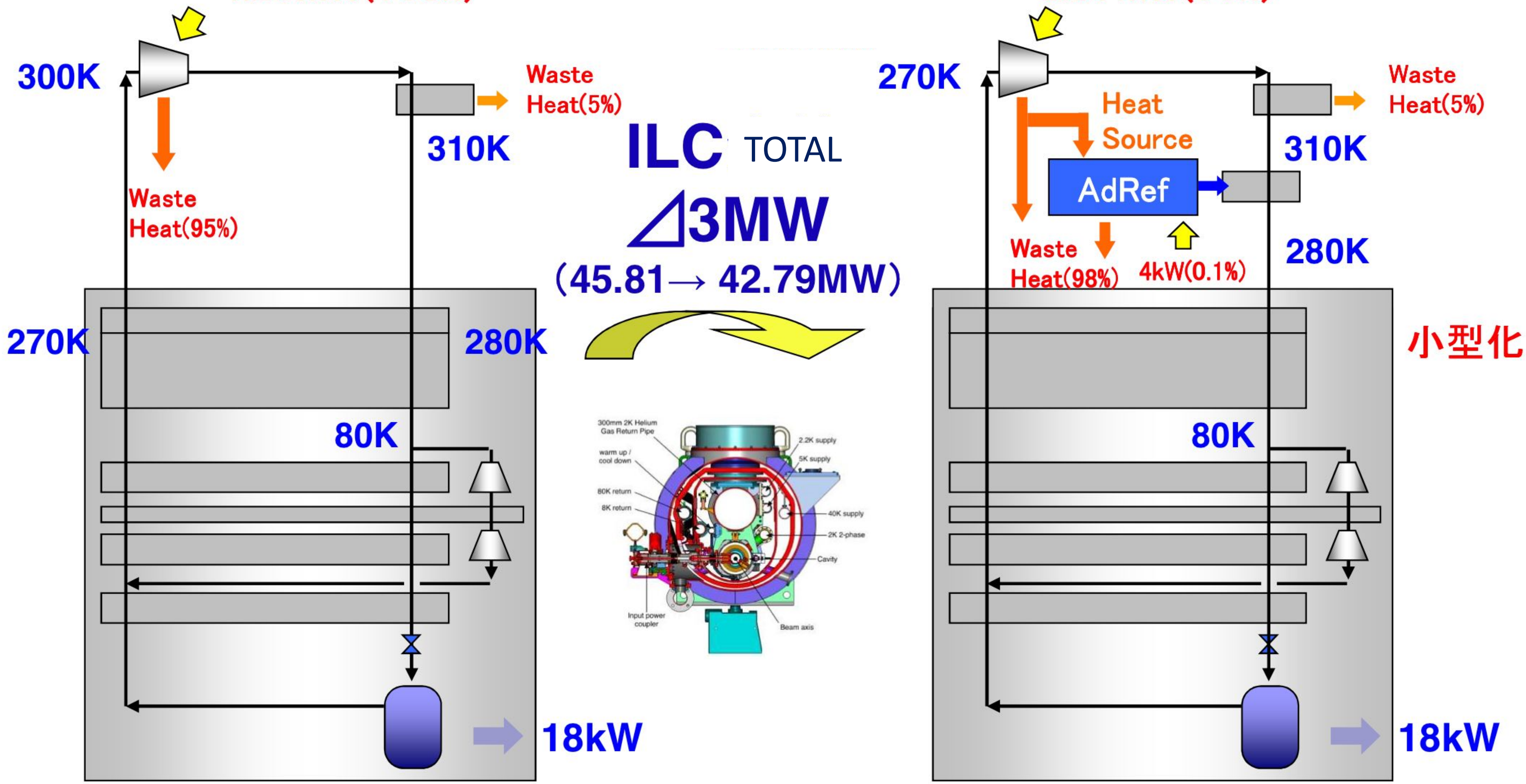
New refrigeration cycle with AdRef

7% saving

Adsorption Refrigerator

Gas Temperature down (310K -> 280K)
Then Compressor power reduce.

4.25MW(100%) 3.97MW(93%)



Conventional cycle **New cycle with ADR**

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME (10 years running)
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and test
- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling
- Transmission power lines

Green-ILC

Y-High-Tc (HTS) cable element

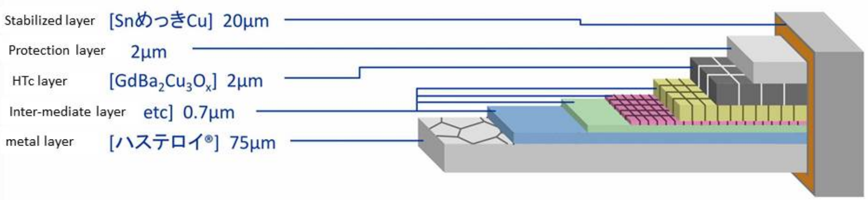
Fujikura

■ Product

Type	Width [mm]	thickness [mm]	Metal layer [μm]	Stab. layer [μm]	Critical current [A] @77K, S.F.
FYSC-SCF04	4	0.14	75	20	> 200

※ 2015年度より4mm幅標準線材を提供開始予定

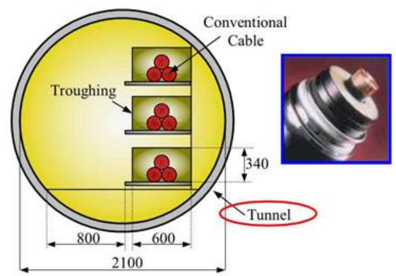
■ Cable structure (formed by copper structure)



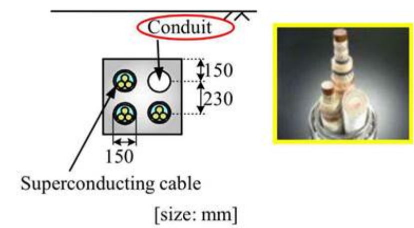
Advantages of HTS cable system

HTS cable is key technology for next generation grid.

- **Large capacity** : equivalent to conventional cable with **lower voltage**
- **Compact size** : installed within conduit
- **Low loss** : **less than 1/2** of conventional cable



Conventional cable
275 kV, 700 MVA/3cc



HTS cable
66 kV, 700 MVA/3cc

HTS cable will be applied to power plant in service, conduit of urban area etc.

SUMITOMO ELECTRIC   TOKYO ELECTRIC POWER COMPANY   MAYEKAWA

Energy Saving and recovery

- Klystron:
  - Better efficiency: from 60% to 80%
  - Energy recovery on the electron beam (Hitachi)
- Cavities: 2 Magnetic shields -> Increase cavity Q_0
  -> decrease cryo -> save 62 ME
  (O. Napoly AWLC 2014 and JLC 2013)
- Beam dumps
  - Wakefield deceleration for beam dump, project and tes
- Suiren, KEK computer ranking 2nd
  in the GREEN500 Nov. 2014/June 2015 listing
  - ~ 6.8 GFLOP/S/W for a 0.193 PFLOP/S Rmax

Green500 List for June 2015

Listed below are the June 2015 The Green500's energy-efficient supercomputers ranked from 1 to 10.

Green500 Rank	MFLOPS/W	Site	System	Total Power(kW)
1	7031.4	RIKEN	ExaScaler-1.4 80Brick, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband FDR, PEZY-SC	50.3
2	6841.3	High Energy Accelerator Research Organization /KEK	ExaScaler-1.4 16Brick, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband, PEZY-SC	28.3
3	6217.9	High Energy Accelerator Research Organization /KEK	ExaScaler 32U256SC Cluster, Intel Xeon E5-2660v2 10C 2.2GHz, Infiniband FDR, PEZY-SC	32.6
4	5272.1	GSI Helmholtz Center	ASUS ESC4000 FDR/G2S, Intel Xeon E5-2690v2 10C 3GHz, Infiniband FDR, AMD FirePro S9150	57.2

- Cryogenics
  - Helium refrigerator saving
  - LN2 pre-cooling
- Transmission power lines

Green 500 top superconputer

Fig. 2. Suiren(left) and Suiren-blue(top right) and its components(bottom right)

2nd Suiren (KEK) Nov 2015

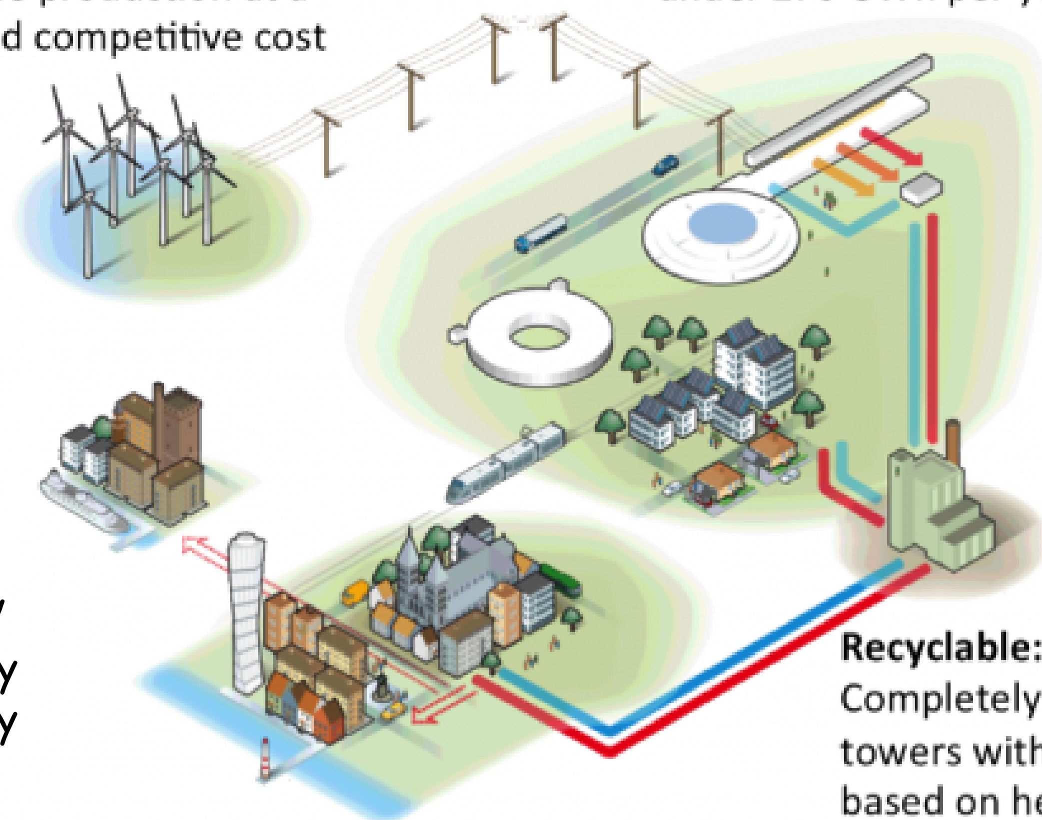
Top 500 June 2016

Green500 Rank	MFLOPS/W	Site	System	Total Power(kW)
1	6673.8	Advanced Center for Computing and Communication, RIKEN	ZettaScaler-1.6, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband FDR, PEZY-SCnp	150.0
2	6195.2	Computational Astrophysics Laboratory, RIKEN	ZettaScaler-1.6, Xeon E5-2618Lv3 8C 2.3GHz, Infiniband FDR, PEZY-SCnp	46.9
3	6051.3	National Supercomputing Center in Wuxi	Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway	15371
4	5272.1	GSI Helmholtz Center	ASUS ESC4000 FDR/G2S, Intel Xeon E5-2690v2 10C 3GHz, Infiniband FDR, AMD FirePro S9150	57.2

The Green ESS
European Spallation Source -- 4R

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.

Green ILC
Sustainable Energies

1) 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, …
- Power conversion: Match ILC component to the energy sources specifics:
  - RF power converter: PhotoVoltaic, fuel cells (DC)
  - Cryocooler or asynchronous liquefactors ?

2) Energy Storage: HEP, experts in some of these technologies

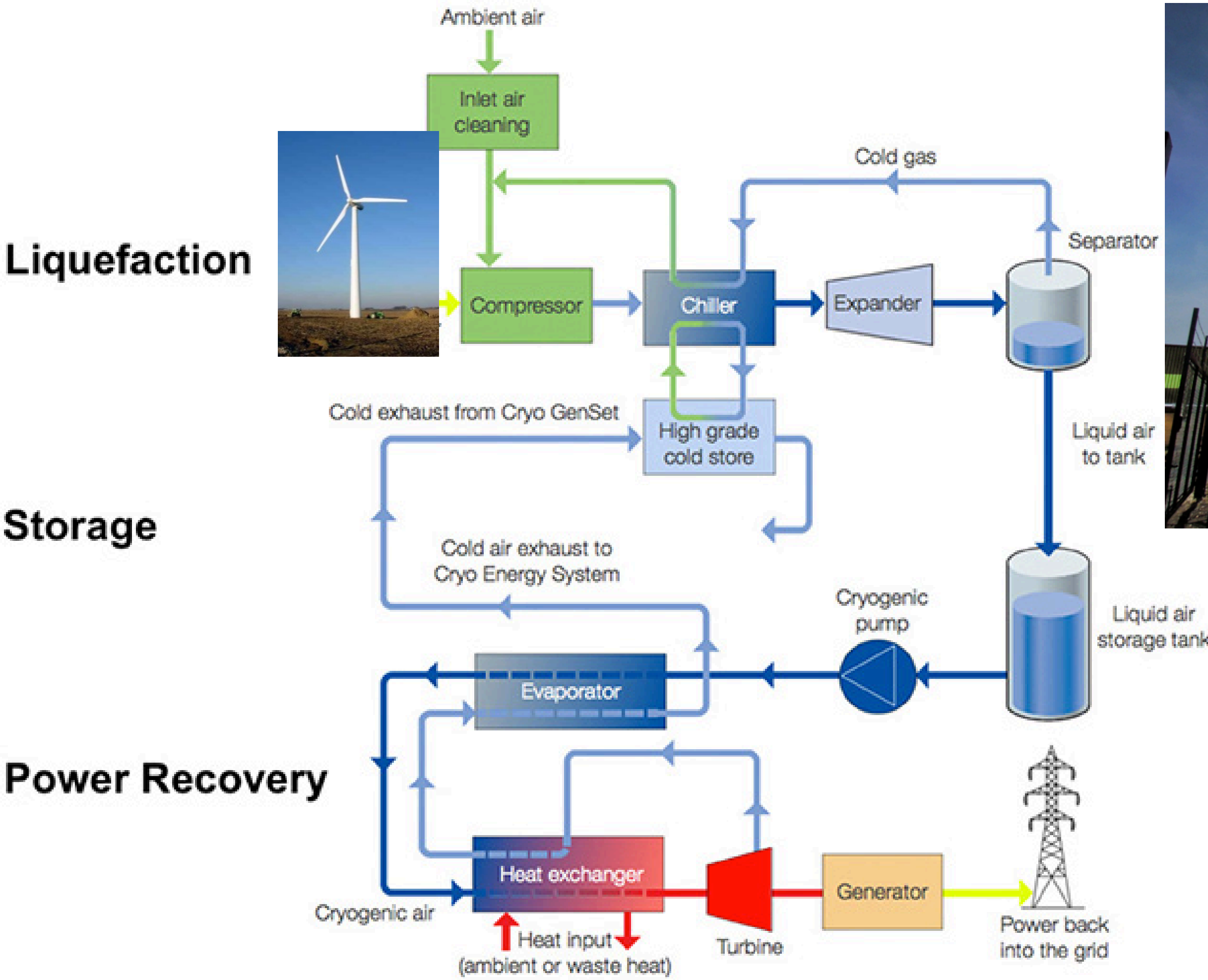
- Liquid Helium, Nitrogen, SMES(Sc Magnetic Energy Storage), Flywheel, Pumped hydro, Compressed air, Batteries, …

3) 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

LN2 as energy storage

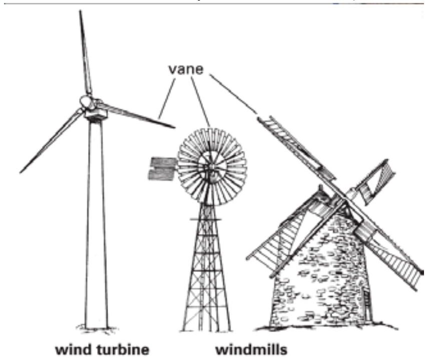


Highview Power Storage (UK)

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

LN2 process cycle

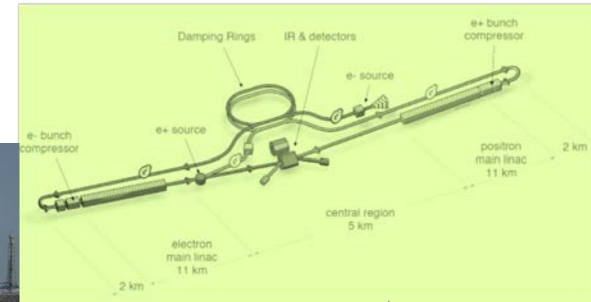
Compressor/liquefier inside



LN2

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

Energy storage



LO2, LAr, SCO2 Dry ice

To Industry

For Cooling or Sequestration

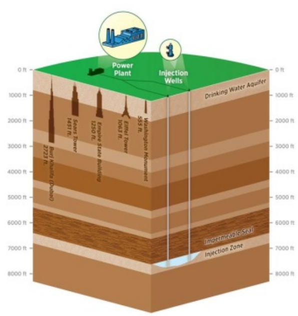
LN2 heat waste

Turbine → electrical generator

N2 gas applications

Electricity Back to ILC/GRID

i.e. Drying and preservation industry

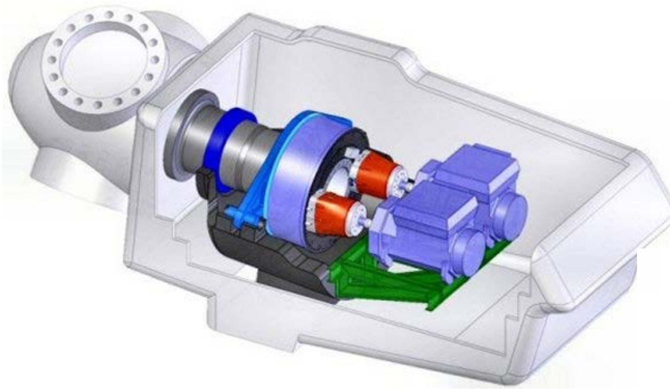


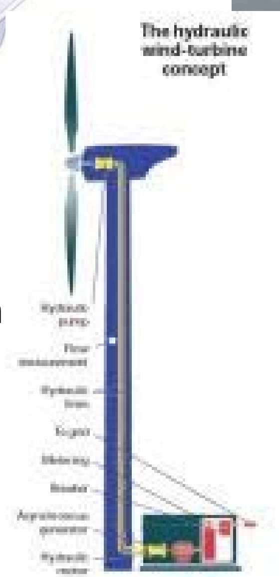
Air cleaning !!!

Hydraulic Wind engine

"Liquid nitrogen economy" update:

- The Fukushima Offshore Wind Consortium project update:
- November 2014: 7MW first large scale hydraulic wind engine (MHI, Artemis)



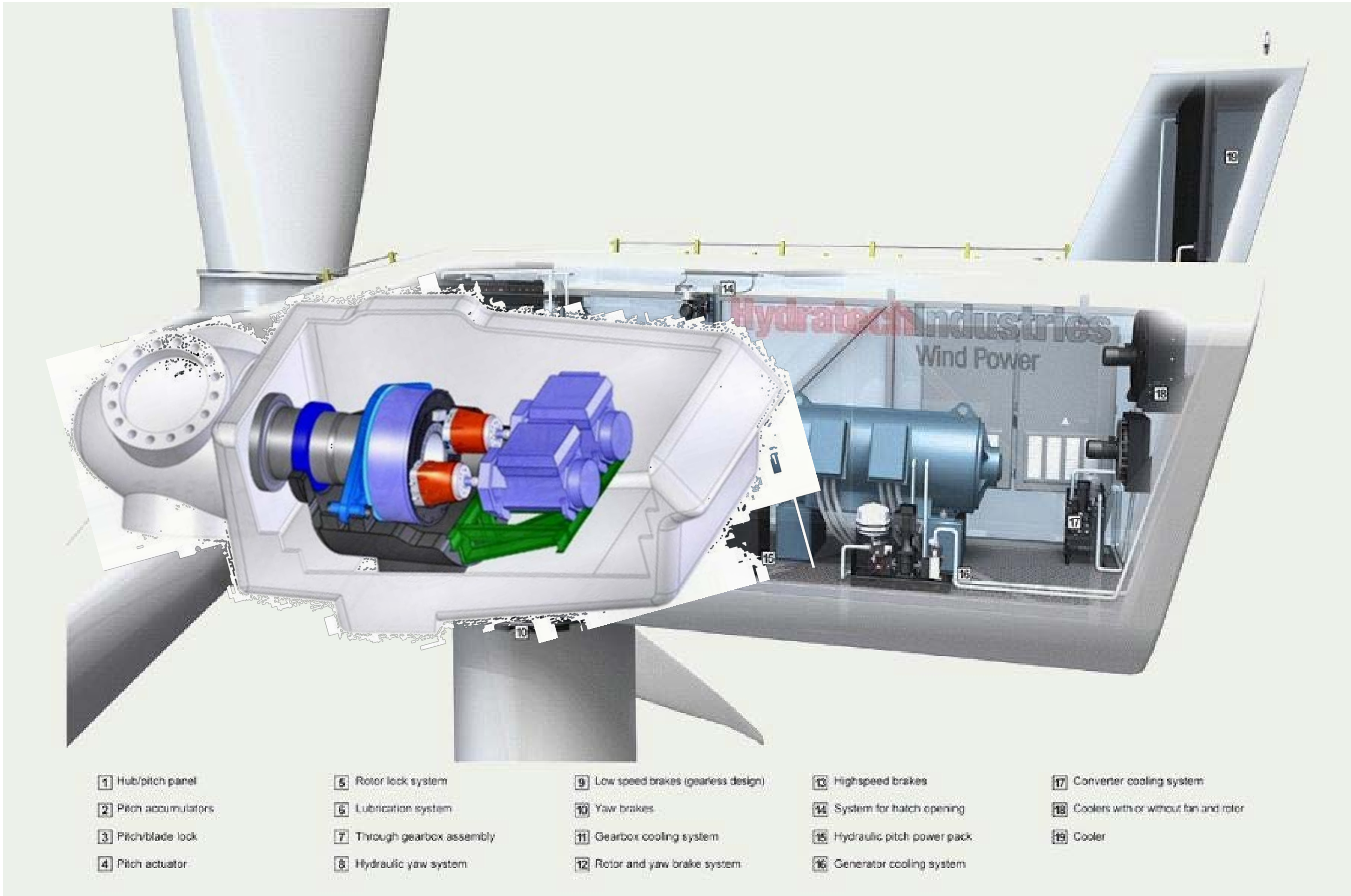


Many technical advantages:

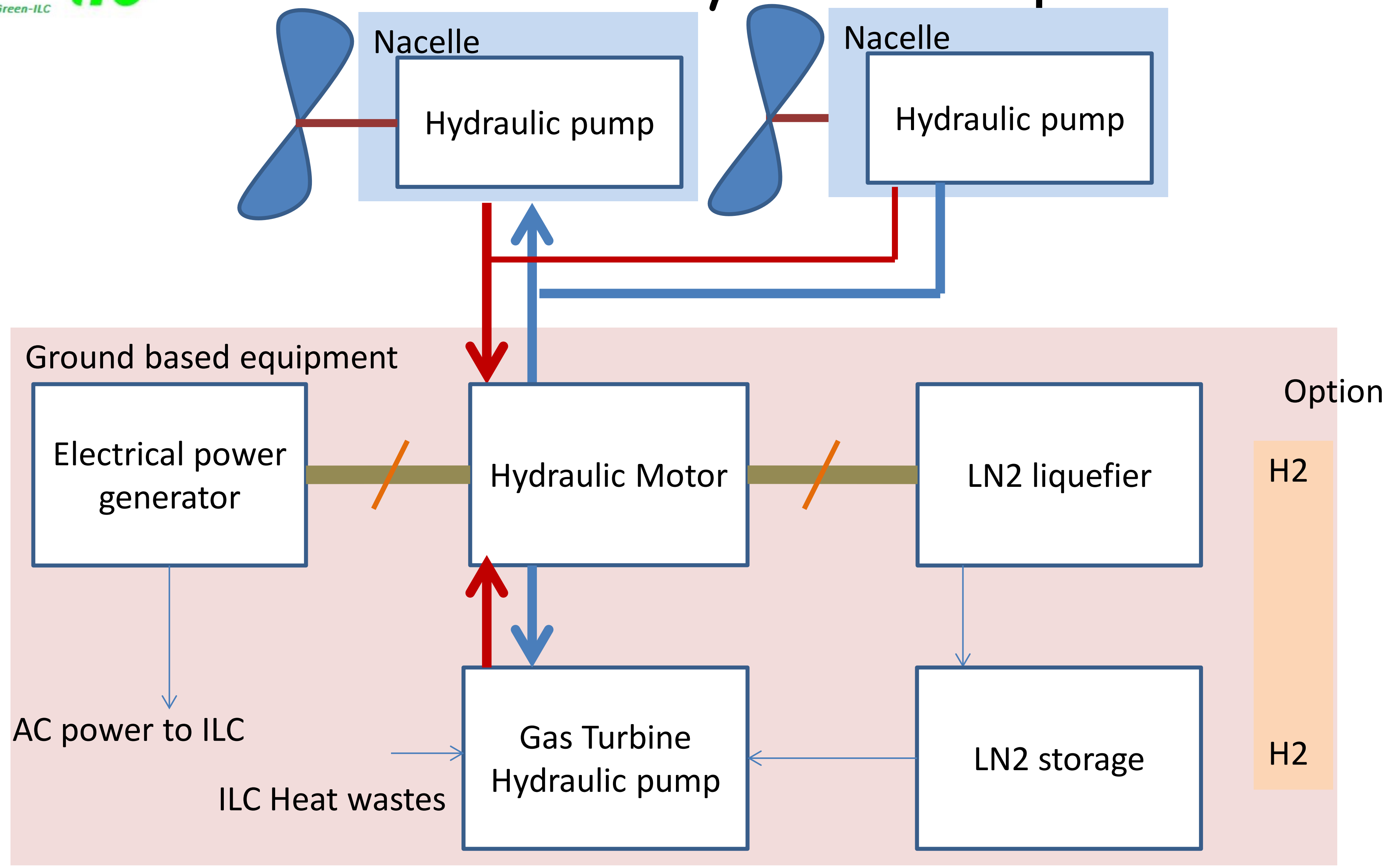
- Smaller, lighter nacelle
- Less mechanical parts and vibration
- Hydraulic accumulator
  - Larger wind speed range
  - No electrical frequency converter
- Easier maintenance at ground level

Good for the LN2

- "Base" based LN2 liquefier
- Many mills to one liquefier
- Hybrid: LN2 and electricity


Hydratech Industries
Wind Power
1 Hub/pitch panel
2 Pitch accumulators
3 Pitch/blade lock
4 Pitch actuator
5 Rotor lock system
6 Lubrication system
7 Through gearbox assembly
8 Hydraulic yaw system
9 Low speed brakes (gearless design)
10 Yaw brakes
11 Gearbox cooling system
12 Rotor and yaw brake system
13 Highspeed brakes
14 System for hatch opening
15 Hydraulic pitch power pack
16 Generator cooling system
17 Converter cooling system
18 Coolers with or without fan and rotor
19 Cooler

Ground based hybrid wind power

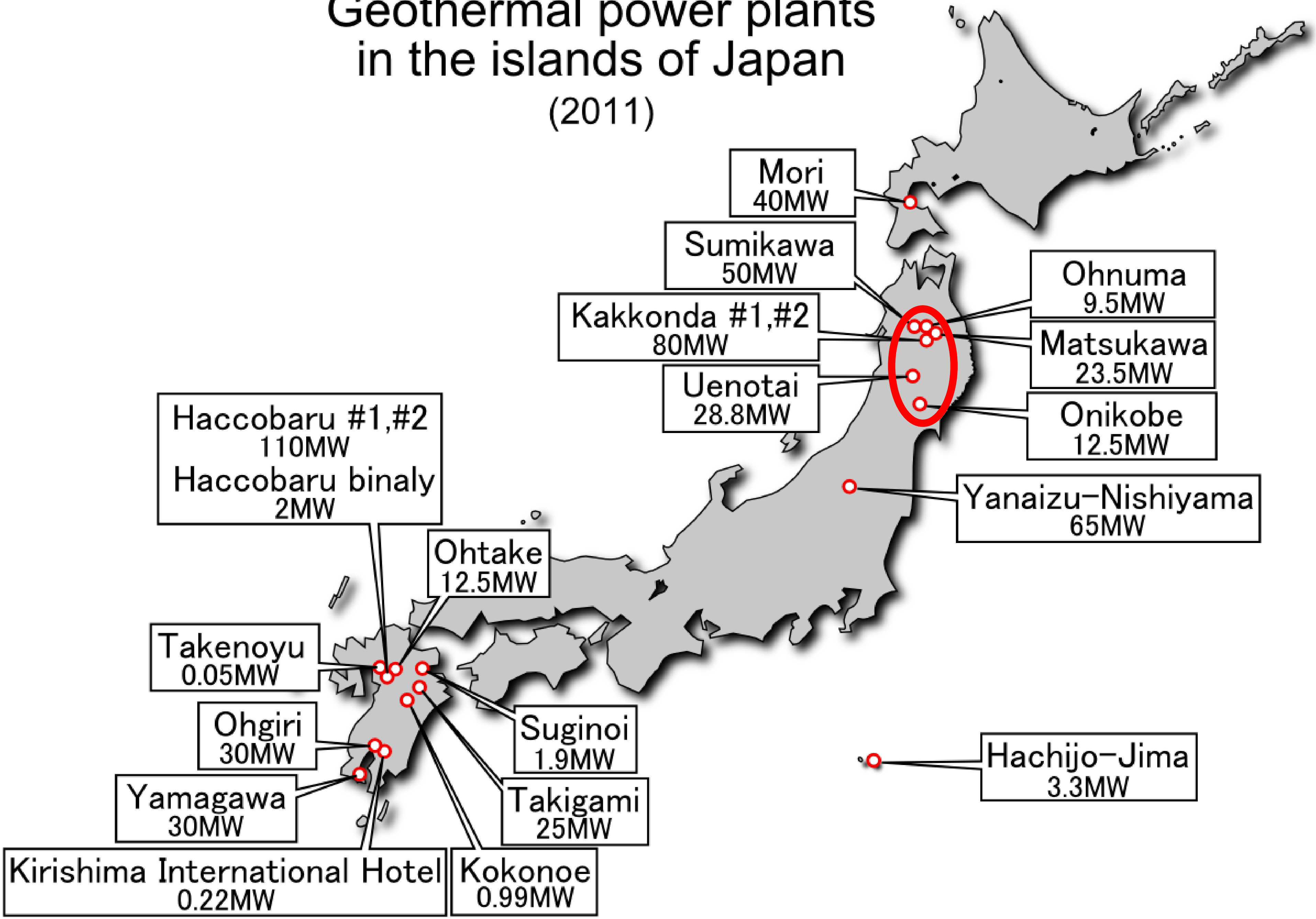


Geothermal power

- Japan has a huge potential
- No fracking, medium depth…
- Let's work with the onsen/spa industry for hybrid projects
- Output warm water: Many applications:
  - Onsen/spa for the local community
  - Heating close-by cities/villages
  - Greenhouses for vegetable and flowers growing
  - Fish farming needs to adjust water temperature

Similar for Biomass power

Geothermal power plants in the islands of Japan (2011)

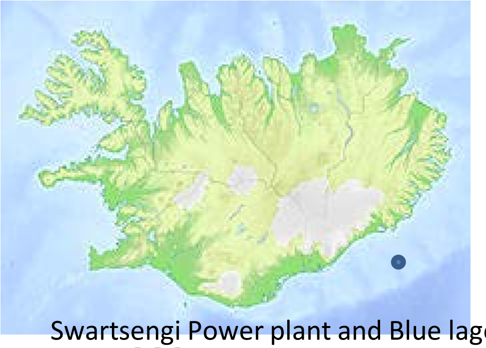


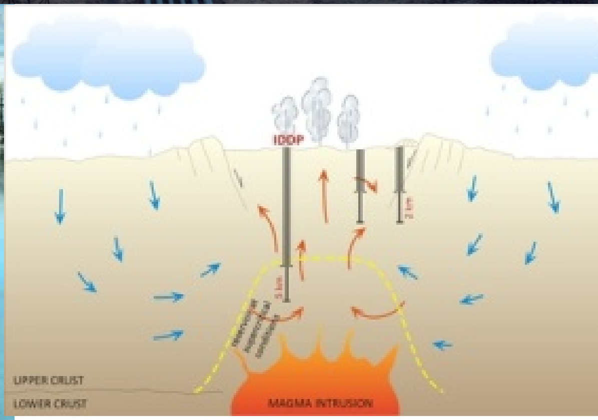
Geothermal Energy and SPA center

Iceland Svartsengi

- Geothermal plant: electricity 75 MW, thermal 150 MW
- 37 years of operation
- 600 m drill 240 C + 1000m and 2000m steam wells
- Hot drinking water to the city

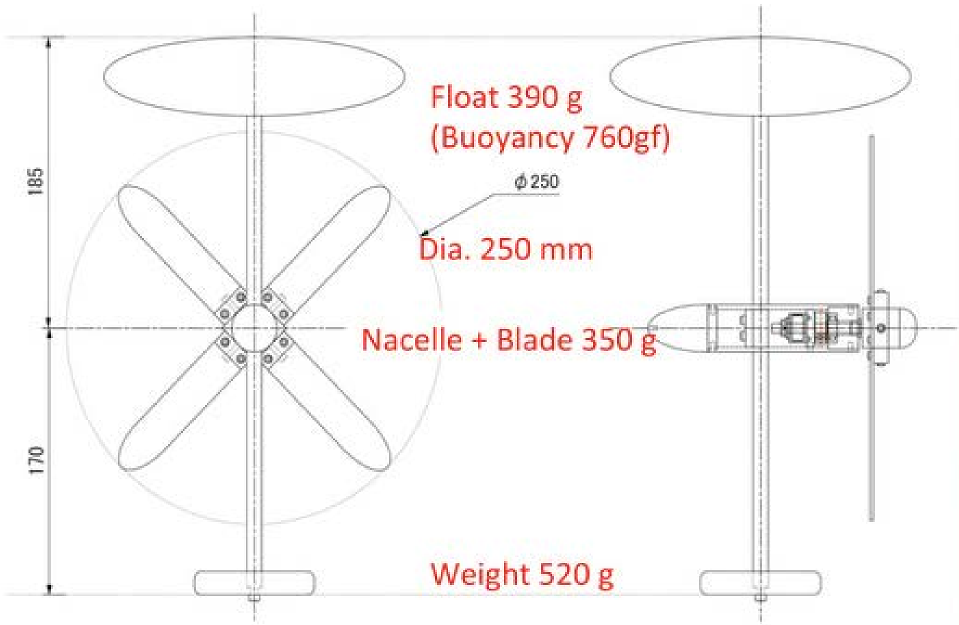
The new Hellisheiði plant: 300 MW

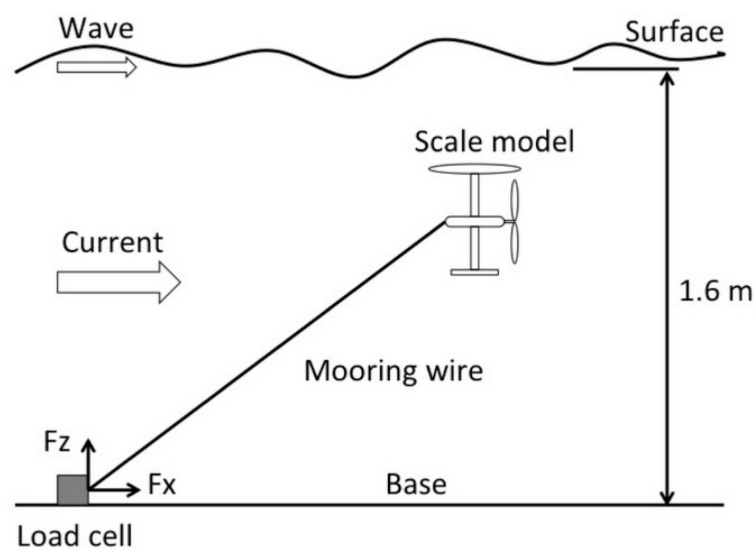




Swartsengi Power plant and Blue lagoon

Ocean Power (by Tsumoru Shintake, OIST)

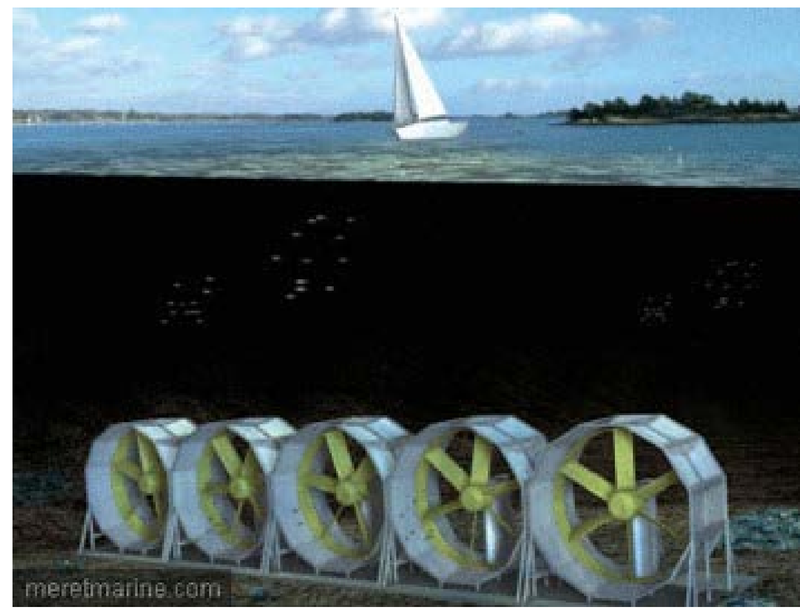




- Many big projects:
  - Little impact on landscape
  - little intermittency, but variable power
  - Could be close to the shore

0.5 MW France

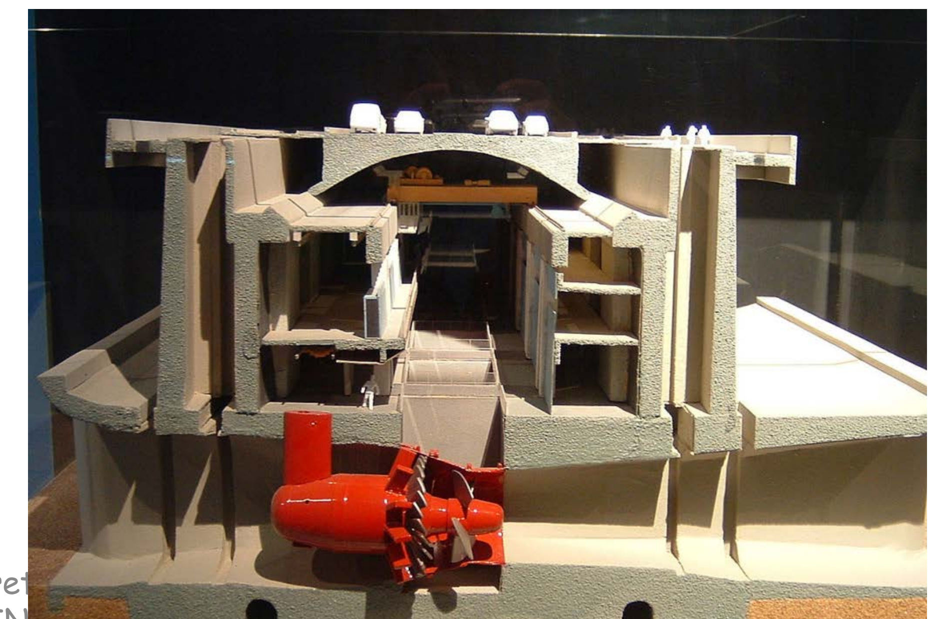
Tide power (Canada)



Tidal power

Rance Tidal Power station (1966), France

Type of dam	Barrage
Length	700 m (2,300 ft)
Reservoir	
Tidal range	8 m (26 ft)
Power station	
Type	Tidal barrage
Turbines	24
Power generation	
Nameplate capacity	240 MW
Capacity factor	40%
Annual generation	600 GWh



Solar power on Infrastructure

Infrastructures, not very eco-friendly, but necessary,
Better to use them to produce energy ?

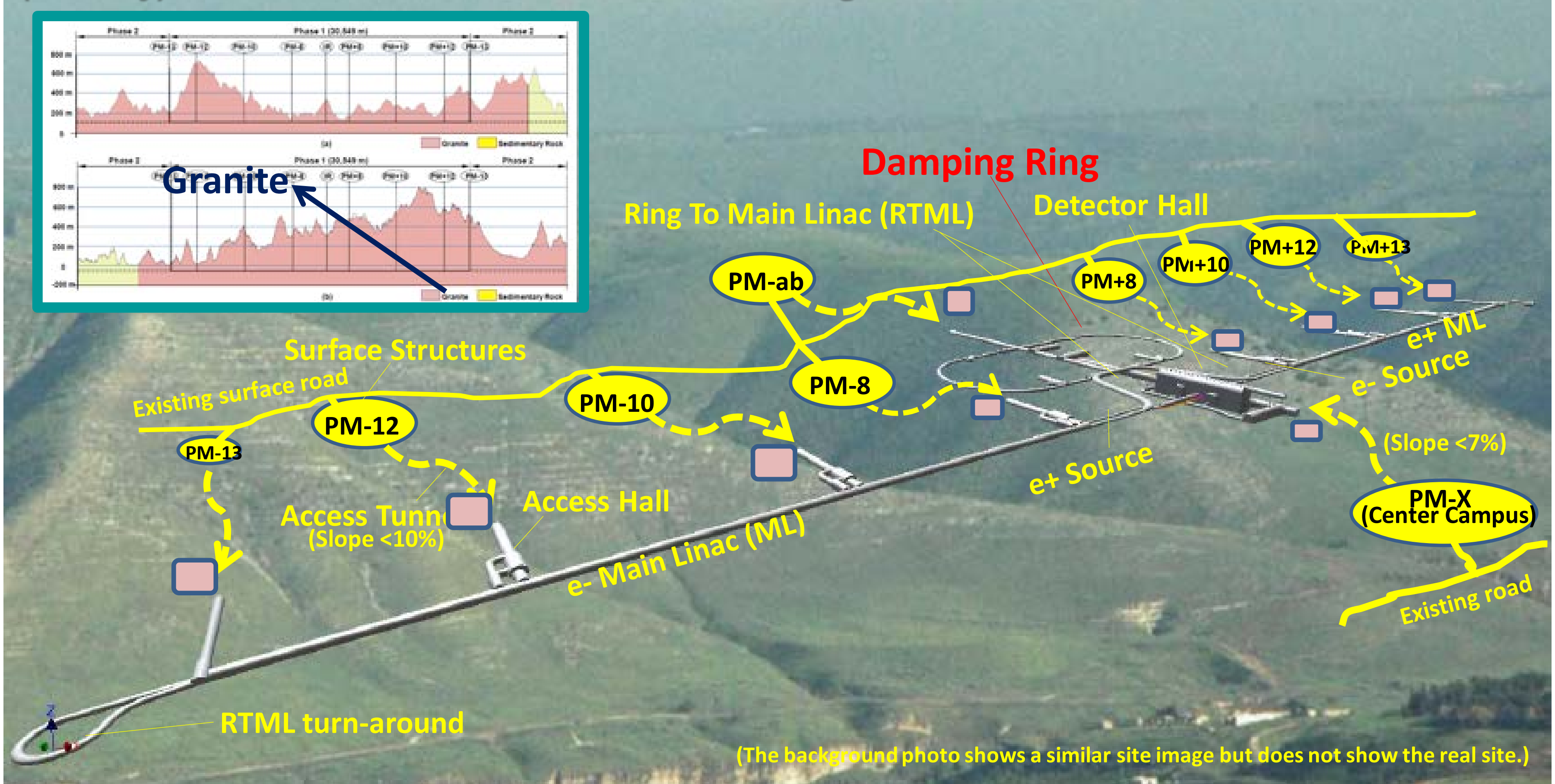
Assuming: solar panels (thermal or PV) ~200 W/m2

- ILC Buildings: ~ 103 buildings ~ 91,000 m2 (80%) -> ~15 MW
- Roads: 10 tunnel access → 10 semi-private roads (1-2 Km each)
  - ~ 10-20 km
    - Side road: * 3m = 30-60.000 m2
    - Top road: * 10 m = 100-200,000 m2
- Parking lots: covered by solar panels

- PB.: cleaning, snow, support structures, storage, … price …

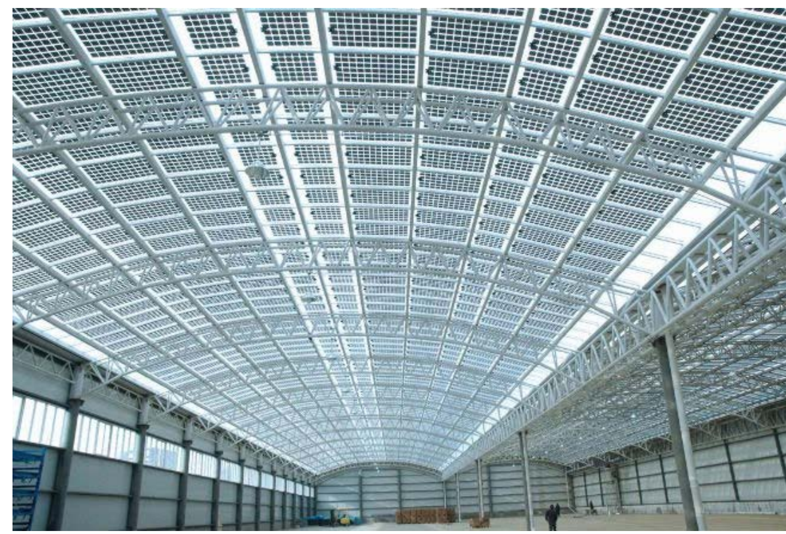
Asian Site Conventional Facility – Introduction

(Site) Mountainous green field not far from big towns, accessible with existing roads.
(Facility) Smaller surface structures and underground structures.

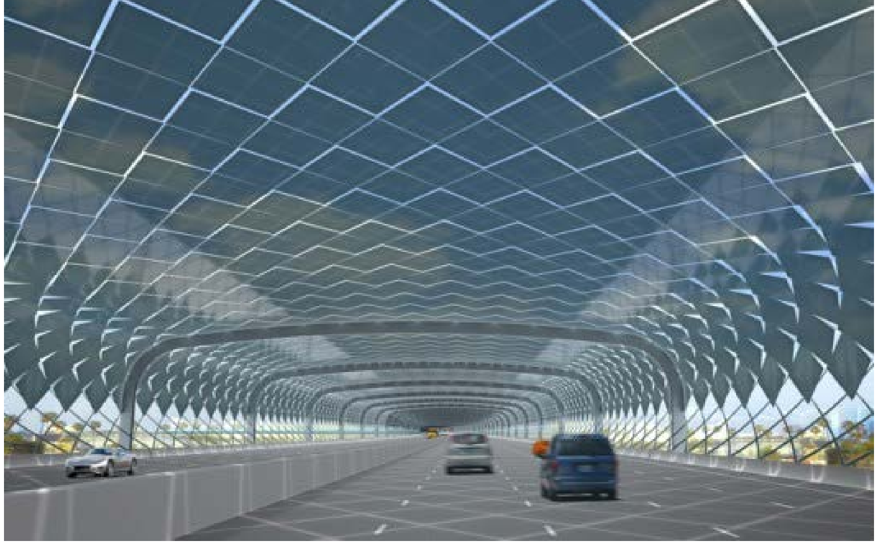


"Renault" car company to install 450,000m2 of solar panels: 60 MW 140W/m2

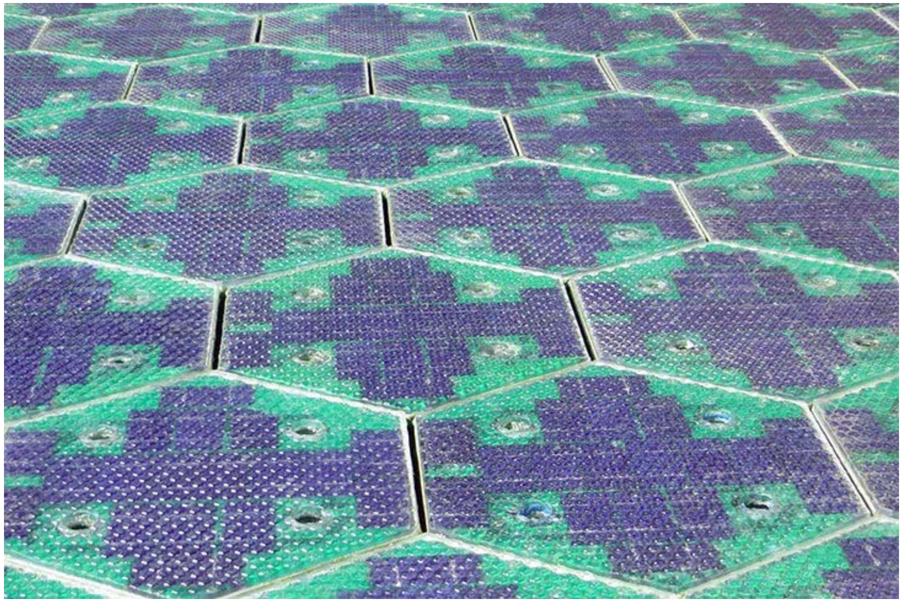
Shandong Huayi Sunlight Solar Energy
115W/m2



SRB and CERN: Thermal panels, Geneva airport roof



http://www.greenpepperenergy.com/index.php/roof-over-roads-to-tap-solar-power/



Solar roadways

Visually disruptive equipements

Industrial complex, reuse of polluted zone,

Fos sur mer (France)

Off-shore

Amusement parks (Ferris Wheel ~165 m high)

Denis.Perret-Gallix@in2p3.fr
CNRS/IN2P3LAPP - KEK

Excavated earth for pumped hydro dam

~ 3.2 Mm^3 will be removed from tunnels digging

Can be used to build earth dams see for comparison:

Kutataragi Pumped Storage Power Station (奥多々良木発電所) 1.9 GW

Kansai Electric Power Company (Hyōgo Prefecture

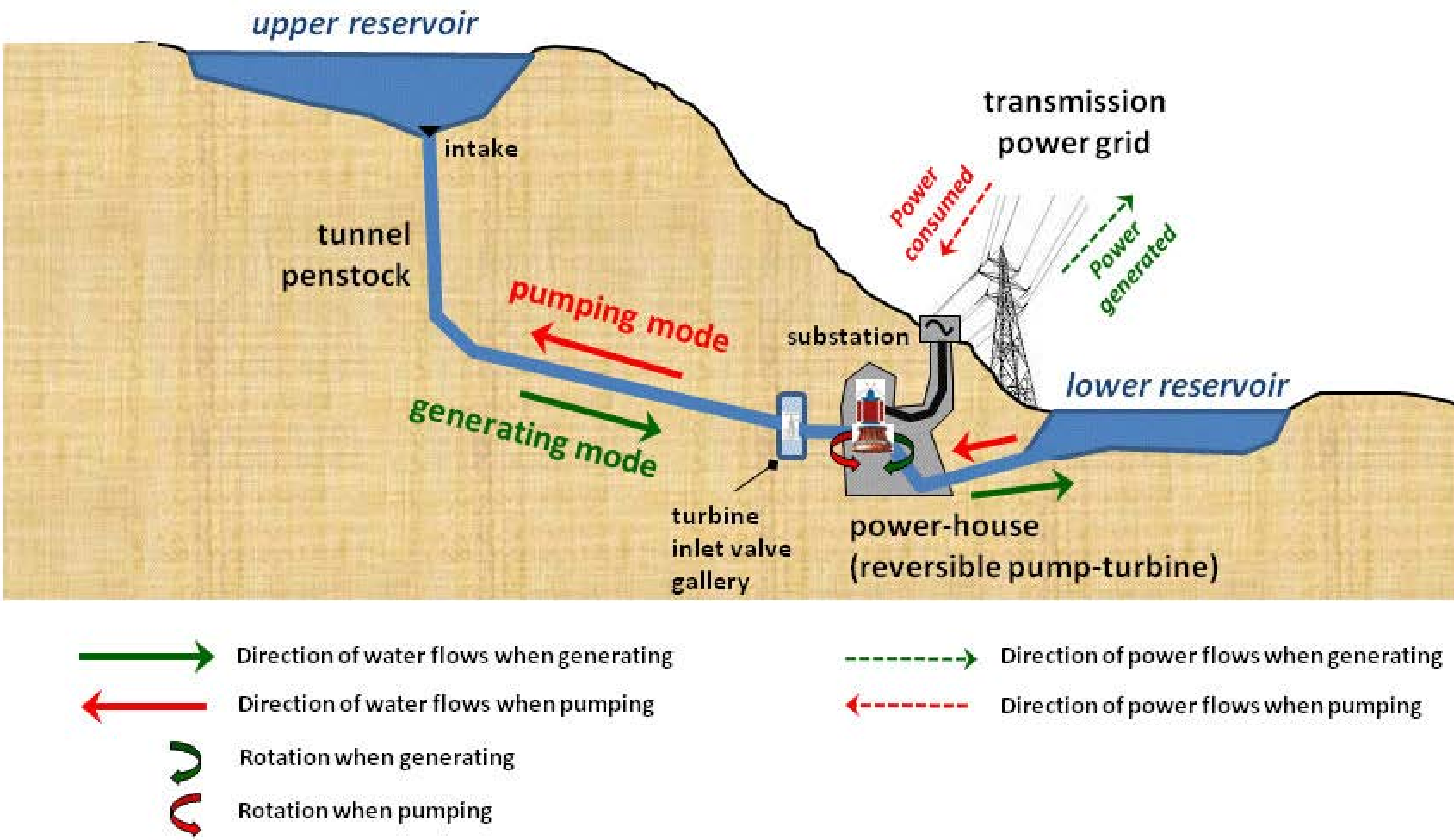
Kurokawa Reservoir (3.6 Mm^3 earth)

98 m tall, 325 m long

Tataragi Reservoir (1.4 Mm^3 earth)

64.5 m tall, 278 m long

Principle of a pumped-storage power plant



International Linear Collider

I L C

Innovation = Leadership x Creativity

International Panel on “Sustainable colliders and accelerators”

ICFA: International Committee on Future Accelerators
has setup a panel: ~ 20 people headed by Mike Seidel (PSI, Switzerland)

- strategy & coordination
- energy efficient accelerator concept
- energy efficient and sustainable accelerator technology
- energy management for large research facilities

Green-ILC

Green-ILC Project

Green ILC

Energy for Innovation, Innovation in Energy

http://green-ILC.in2p3.fr

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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.

Recent Posts

- Green-ILC in LC Newsline
- New Hydraulic Wind Turbine
- Green Session at LCWS 2014
- EUCARD2 EnEfficient
- Liquid Air in the Energy and Transport Systems

Links

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

Thank you