Energy Recovery at ILC in Japan

T. Saeki (KEK)

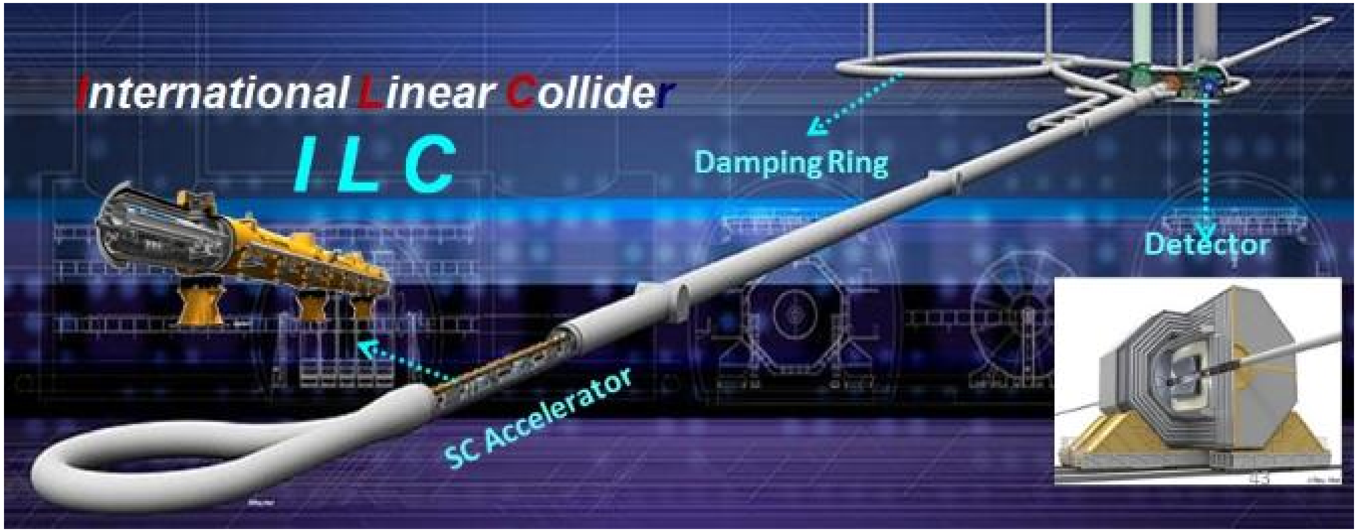
LCWS15 at Whistler / Canada

4th Nov. 2015

Improve Efficiency of Power Consumption in Accelerator Operation

Green ILC

serious issue for ILC



2nd Workshop
Energy for Sustainable Science
at Research Infrastructures

CERN, GENEVA, SWITZERLAND, 23-25 OCTOBER 2013

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

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

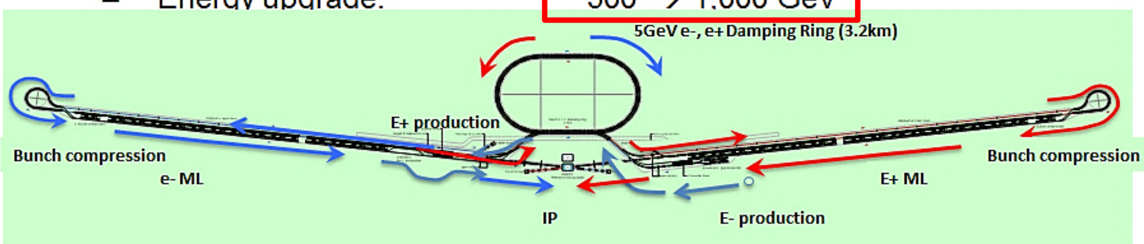
Atsuto Suzuki (KEK)

INTER-UNIVERSITY RESEARCH INSTITUTE CORPORATION
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

Power Balance of Consumption and Loss in ILC

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

Obligation to Us

Increase recovery

Activities for Green ILC in Japan

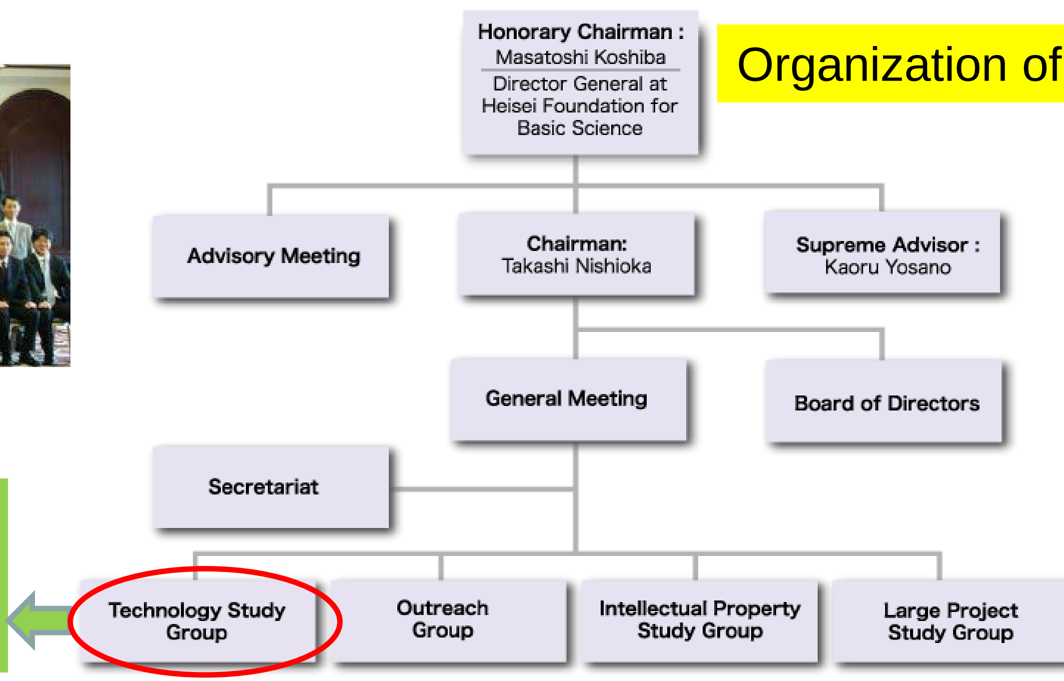
- Three presentations were given (by A. Suzuki, D. Perret-Gallix, and M. Yoshioka) in 2nd WS "Energy for Sustainable Science at Research Infrastructure" at CERN in Oct. 2013.
- A session (four presentations) was organized for Green-ILC activities in LCWS 2013 at Tokyo in Nov. 2013. A. Suzuki also presented Green-ILC activities in the plenary session in LCWS 2013.
- Green-ILC Working Group was organized in "Advanced Accelerator Association promoting science & technology (AAA) in Tokyo/Japan. The 1st meeting for the Green-ILC WG of AAA was held on 25th February 2014. (AAA home page = https://aaa-sentan.org/en/about_us.html)
- 2nd – 9th Green-ILC WG meetings were held on 5th May 2014 - 30th September 2015 in Tokyo/Japan.
- Various realistic technologies of energy-saving for ILC were proposed and discussed by industries and scientists.
- D. Perret-Gallix, T. Saeki, and H. Hayano are preparing the interactive home page for Green-ILC activities.

Advanced Accelerator Association promoting science & technology (AAA)

Association by industries and scientists

- 102 corporate organizations involved from industries（MHI, Toshiba, Hitachi, Mitsubishi Electric, etc.) as of Nov. 2015.
- 41 institutional organizations involved from universities and laboratories（KEK, Univ. of Tokyo, Univ. of Tohoku, Univ. of Kyoto, Riken, etc.) as of Nov. 2015.

Organization of AAA



Green-ILC WG started in Technology Study Group on 25th Feb. 2014.

Agenda for the 2^{nd} AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6^{th} floor, UDX Building in Akihabara, Tokyo.

1) Collector Potential Depression (CPI) Klystron (30 min.)
   by Toshiba Electron Tubes & Devices Co. Ltd.

2) Power Saving of Large-Scaled Helium Compressor (30 min.)
   by Mayekawa Manufacturing Company.

3) Examples of New Energy Power Plants (20 min.)
   by RIKEN.

4) Solar Power Plant (40 min.)
   by Japan Photovoltaic Energy Association

5) Proposal of Biomass Power Plant for ILC (20 min.)
   by Kabuki Construction Co. Ltd.

Agenda for the 3rd AAA Green-ILC WG meeting

Date: 1st July 2014 (Tue.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Energy Recovery at Beam Dump at ILC (20 min.)
by J. Fujimoto (KEK).

2) Tests of Collector Potential Depression (CPD) Klystron (30 min.)
by K. Watanabe (KEK).

3) Drag Reduction (DR) Additive for Cooling Water (30 min.)
by Shin Nippon Air Technologies Co. Ltd.

4) Examples of New Energy Power Plants (30 min.)
by RIKEN.

Agenda for the 2nd AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Collector Potential Depression (CPI) Klystron (30 min.)
by Toshiba Electron Tubes & Devices Co. Ltd.

2) Power Saving of Large-Scaled Helium Compressor (30 min.)
by Mayekawa Manufacturing Company.

3) Examples of New Energy Power Plants (20 min.)
by RIKEN.

4) Solar Power Plant (40 min.)
by Japan Photovoltaic Energy Association

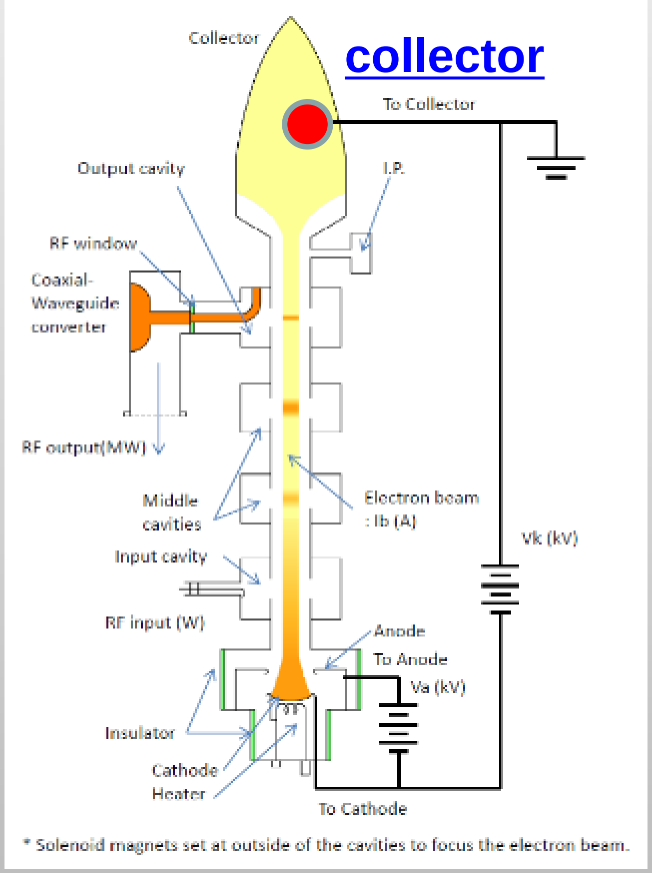
5) Proposal of Biomass Power Plant for ILC (20 min.)
by Kabuki Construction Co. Ltd.

How to Improve RF Efficiency

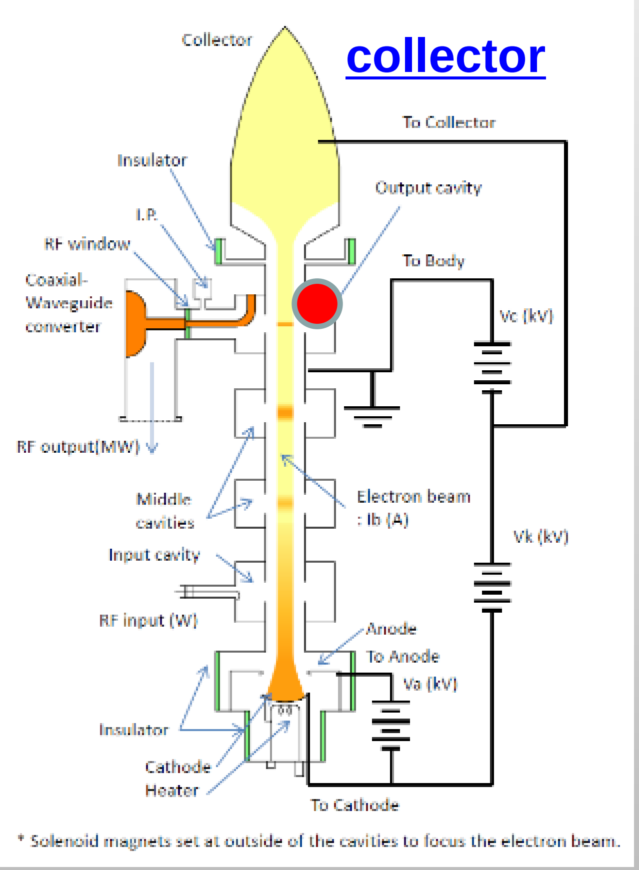
R&D of CPD (Collector Potential Depression) Klystron

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

Conventional



Schematic diagram of CPD



Agenda for the 3rd AAA Green-ILC WG meeting

Date: 1st July 2014 (Tue.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) **Energy Recovery at Beam Dump at ILC (20 min.)**
   by J. Fujimoto (KEK).

2) **Tests of Collector Potential Depression (CPD) Klystron (30 min.)**
   by K. Watanabe (KEK).

3) **Drag Reduction (DR) Additive for Cooling Water (30 min.)**
   by Shin Nippon Air Technologies Co. Ltd.

4) **Examples of New Energy Power Plants (30 min.)**
   by RIKEN.

Collective deceleration for compact beam dump

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

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)

Bethe-Bloch formula for stopping power in material

$$-(dE/dx)_I = (F/\beta^2)[\ln(2m_e\gamma^2 v^2/I) - \beta^2], \quad (1)$$

where E is the electron kinetic energy, $F = 4\pi e^4 n_{e,m}/m_e c^2 = e^2 k_{pe,m}^2$, $n_{e,m}$ is the electron density in the stopping material, $k_{pe,m} = \omega_{pe,m}/c$ is the plasma wave number, and $\beta = v/c$ is the normalized electron velocity.

There was a progress.

~60 participants

G. Mourou (Polytech)
T. Tajima (UCI)
B. Holzer (CERN)

Study on the recovery of the beam energy of International Linear Collider (ILC) by plusma-wakefield deceleration

T. Saeki, J. Fujimoto, H. Hayano, K. Yokoya (KEK)
T. Tajima, D. Farinella, X. Zhang (University of California at Irvine)
A. W. Chao (SLAC)
D. Perret-Gallix (LAPP/IN2P3/CNRS - KEK)

15 / Oct / 2015
Outlook on Wake Field Acceleration: The Next Frontier
CERN, Geneva, Switzerland

2. Water beam dump design in Technical Design Report (TDR) of ILC

four dumps

10 bar water vessels

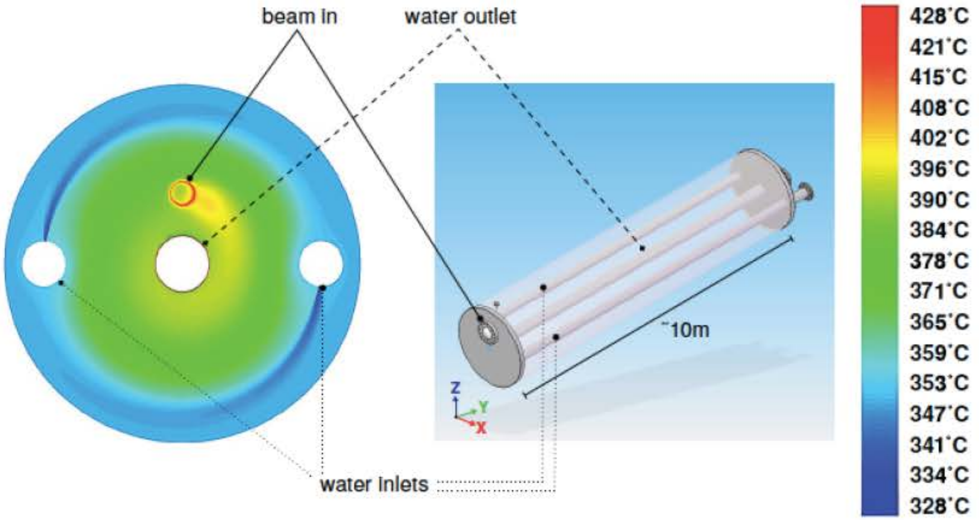
30cm diameter, 1mm thick Ti window

Chapter 8. Beam Delivery System and Machine Detector Interface

8.8	Beam dumps and Collimators
8.8.1	Main Dumps

The beam-delivery system contains two tune-up dumps and two main beam dumps. These four dumps are all designed for a peak beam power at nominal parameters of 18 MW at 500 GeV per beam, which is also adequate for the 14 MW beam power of the 1 TeV upgrade. The dumps consist of 1.8 m-diameter cylindrical stainless-steel high-pressure (10 bar) water vessels with a 30 cm diameter, 1 mm-thick Ti window and also include their shielding and associated water systems (Fig. 8.15). The design [188] is based on the SLAC 2.2 MW water dump [189, 190].

Figure 8.15 Temperature distribution at the shower maximum of the beam in the main 18 MW dump just after passage of the beam train (left). (The geometry of the dump is also shown on the right.) The colour bar shows temperature in kelvin; the maximum temperature is 155 °C [191].

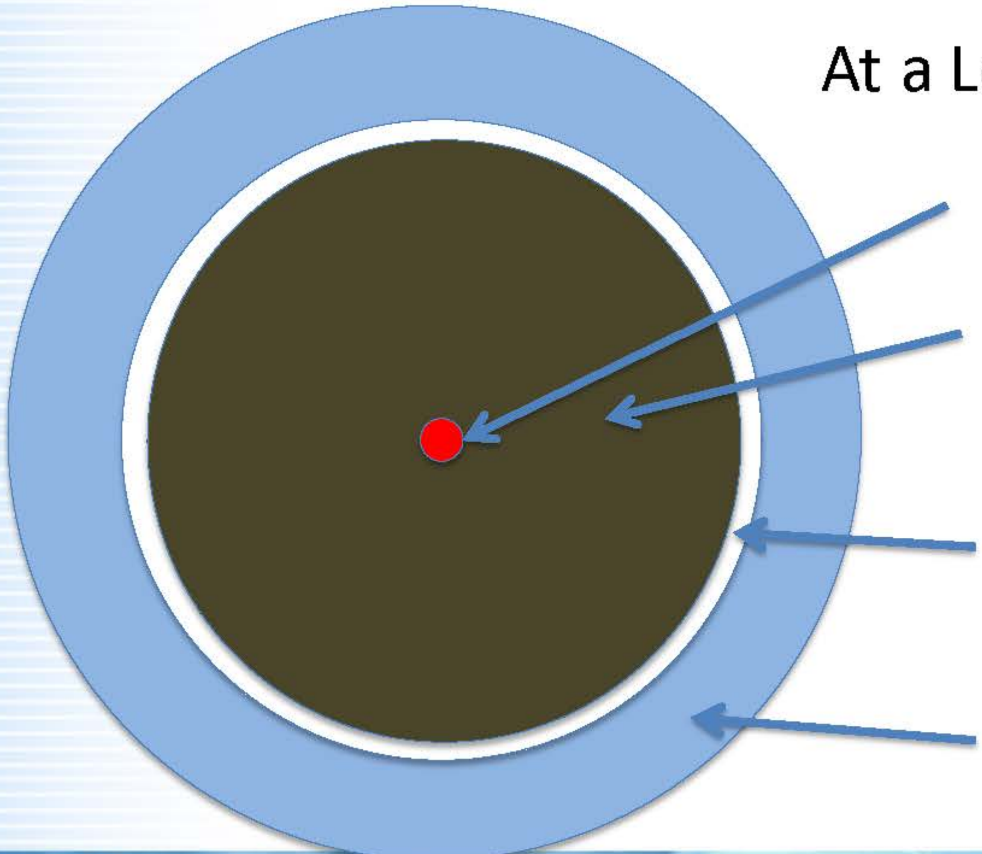


3. Alternative discussed design: noble gas dump

Based on “Another idea of a LC dump”
by Albrecht Leuschner 16/09/2003

Cross section of a tunnel

At a Length of 1000m



Pros/cons

	Water dump	Gas dump
length	10 m	1000 m
Window pressure	10 bar static	1 bar static
Window diameter	30 cm	8 cm
Hydrogen gas producing	Several liter/sec @ 20 MW	no
Tritium production	300 TBq	30 TBq (in Iron)
Component Activity	1.2 mSv/h	~ 1 … 10 mSv/h

4. Collective deceleration for compact beam dump

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

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)

Bethe-Bloch formula for stopping power in material

$$-(dE/dx)_I = (F/\beta^2)[\ln(2m_e\gamma^2 v^2/I) - \beta^2], \quad (1)$$

where E is the electron kinetic energy, $F = 4\pi e^4 n_{e,m}/m_e c^2 = e^2 k_{pe,m}^2$, $n_{e,m}$ is the electron density in the stopping material, $k_{pe,m} = \omega_{pe,m}/c$ is the plasma wave number, and $\beta = v/c$ is the normalized electron velocity.

The collective stopping power for wakefield deceleration of the electron bunch is large;

$$-(dE/dx)_{\text{coll-wave break}} = m_e c \omega_{pe}(n_b/n_e). \qquad (5)$$

Equation (5) is exact for the resonant excitation of a wake-field with bunch length $\sigma_L/\lambda_{pe} \approx 0.5$, transverse size $\sigma_T/\lambda_{pe} \geq 0.3$, and modest density ratio $n_b/n_e < 10$

where λ_{pe} is the plasma wavelength of the background plasma with density n_e, n_b is the bunch density.

For a long beam $\sigma_L/\lambda_{pe} \gg 1$, the stopping power decreases exponentially with the factor $k_{pe}\sigma_L \times \exp(-k_{pe}^2\sigma_L^2/2)$. For a narrow beam $\sigma_T/\lambda_{pe} \ll 1$, the stopping power decreases with the factor $k_{pe}^2\sigma_T^2$.

From $\sigma_L/\lambda_{pe} = ½$, then $\sigma_L = \pi\ c/\omega_{pe}$ and $n_b = N_b/(\sigma_L \sigma_T^2)$ where N_b is number of particles in a bunch.

$-(dE/dx)_{coll\text{-}wave\ break}$ [GeV/cm] = $5.74 \times N_b/\sigma_T^2$[cm]

means

L_{dump}[m] = $1.7 \times 10^{13}\ \sigma_T^2/N_b E_0$[GeV], w/ $\sigma_T > 0.6\ \sigma_L$

In the case of ILC, $N_b = 2 \times 10^{10}$, $E_0 = 500$ GeV,

L_{dump}[m] = $4.3 \times 10^5\ \sigma_T^2$[cm]
= 130 m w/ $\sigma_L = 300\ \mu$m, $\sigma_T = 0.6 \times \sigma_L = 180\ \mu$m
= 10 m w/ $\sigma_T = 50\ \mu$m, $\sigma_L = \sigma_T/0.6 = 83\ \mu$m

< 1000 m

- Collective deceleration dump
  (1) No dump window problem
  (2) No hydrogen gas production problem
  (3) Less radiative activation
  (4) Short length facility
  (5) Electricity might be extracted as electric energies
- From the view point of Green-ILC, it is worth to study the possibilities to apply collective deceleration dump system.
- It should be checked that it works for the ILC long beam condition.
- If introducing the bunch compression after the collision point, it is possible to shorten the length of the beam dump facility.
- Efficiency of recovering energy is important from the view point of Green-ILC

5. Study Group of the Green ILC Beam Dump

We successfully obtained the budget (~40,000 dollars for 3 years, 2015 - 2017) from the Japan Society for the Promotion of Science (JSPS) to study the Green Beam Dump by plasma wakefield deceleration.

The University of California at Irvine
Plasma Wakefield calculation / simulation

KEK
Organization of the group
ILC design / Providing Computer facility (KEKCC computer cluster, dedicated Linux workstation computer) for simulation

Future experiments for the plasma wakefield deceleration

SLAC
ILC design / Plasma wakefield calculation

LAPP/IN2P3/CNRS
ILC design / Plasma wakefield calculation

6. Preliminary result of beam deceleration simulation

beam :

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

$E = 250 G\,\mathrm{eV} (\gamma_0 = 5 \times 10^5)$

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

$\mathrm{N}_b = 2 \times 10^{10} (3.2 nC)$

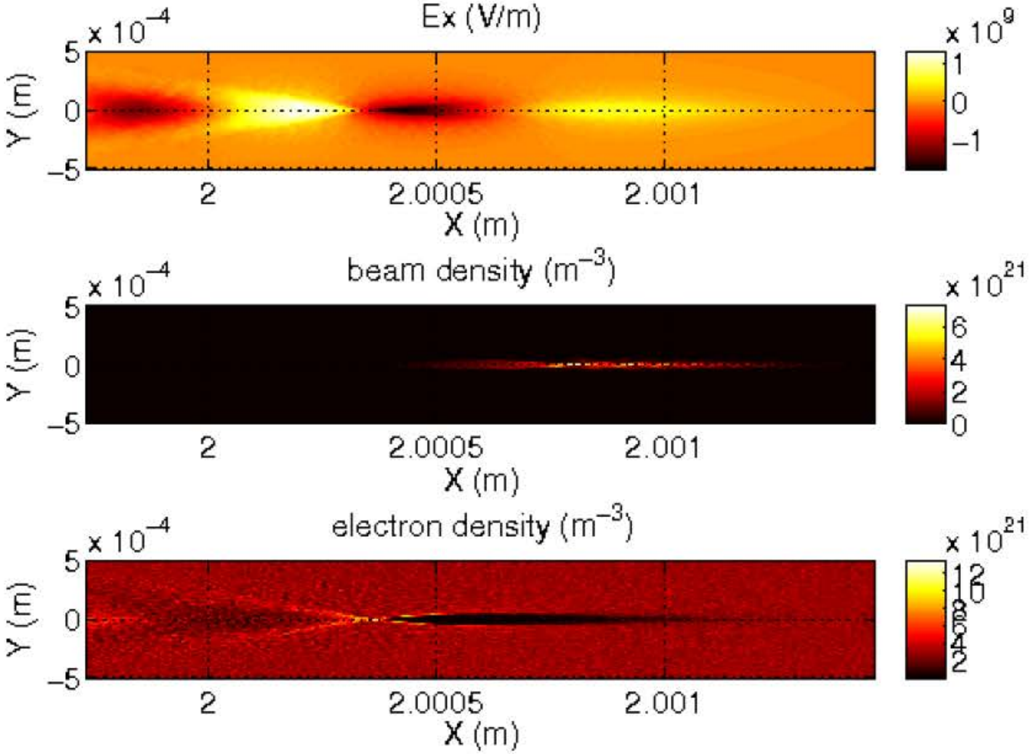
$$n_b = \frac{N_b}{(2\pi)^{3/2} (\sigma_x \sigma_r \sigma_r)} = 1.7 \times 10^{21} / m^3$$

plasma :

$n_p = 3 \times 10^{21} / m^3$

$\lambda_p \sim 600 mm$

$\sigma_x \sim \lambda_p / 2$



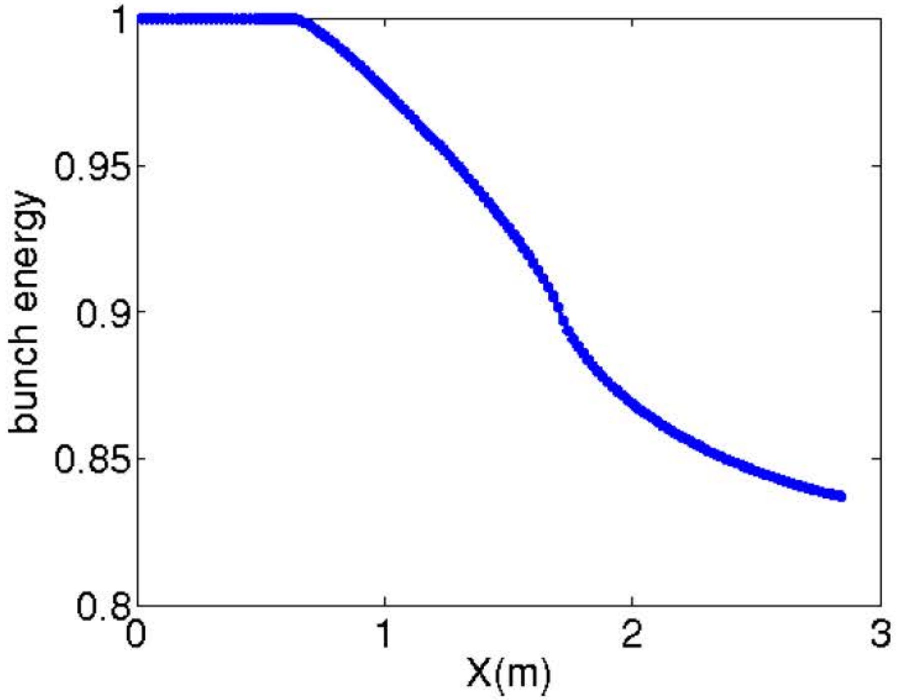
Simulation code: EPOCH

Dr. X. Zhang (UCI)

Preliminary result of beam deceleration simulation

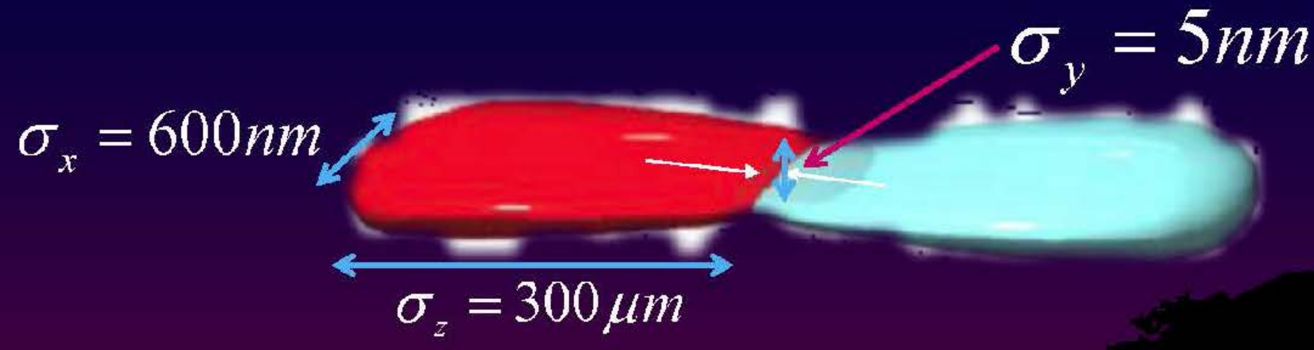
Dr. X. Zhang (UCI)

More than 15% energy loss after 3m



First result of simulation is encouraging !

ILC beam after collision



$$L \sim \frac{n_e^2 f_{rep}}{4\pi\sigma_x\sigma_y} = \frac{n_e P_{beam} / E_{beam}}{\sigma_x\sigma_y}$$

$$P_{beam} = E_{beam} n_e f_{rep} \propto \$$$

$$\begin{cases} E_{beam} = 250GeV \\ n_e = 2\times10^{10} \\ f_{rep} = 14100 \end{cases} \Rightarrow P_{beam} = 11.3MW$$

In ILC, in order to increase the collision rate, the incoming two beams are squeezed into the small size. In the TDR, the beam shape before the collision and collision rate is estimated and simulated, but the beam shape after the collision has not been estimated and simulated.

We need the calculation, simulation, and design of optics for the collided beam to be made into the ideal shape for the collective deceleration.

Energy recovery from plasma wakefield

- The paper claimed that "in principle, the energies from the decelerated beams deposited in the form of organized plasma wakefield may be recovered into electricity."
- Any electric circuit such as a metallic loop in the plasma picks up coherent electric currents caused by the plasma collective oscillations. Then, external circuit extract electric energies rather than heat.
- "Because the energy of the plasma electrons is much less than that of the beam electrons, the collisions do not give rise to excessive radioactivation."

Agenda for the 3rd AAA Green-ILC WG meeting

Date: 1st July 2014 (Tue.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Energy Recovery at Beam Dump at ILC (20 min.)
by J. Fujimoto (KEK).

2) Tests of Collector Potential Depression (CPD) Klystron (30 min.)
by K. Watanabe (KEK).

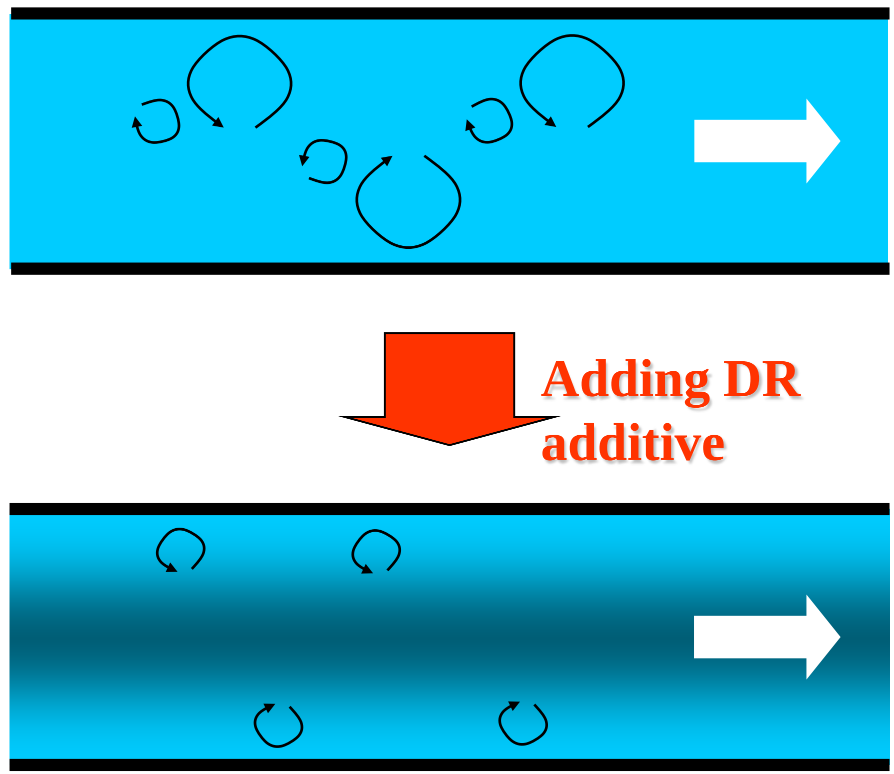
3) Drag Reduction (DR) Additive for Cooling Water (30 min.)
by Shin Nippon Air Technologies Co. Ltd.

4) Examples of New Energy Power Plants (30 min.)
by RIKEN.

Drag Reduction (DR) Additive in Cooling Water

Effect of DR additive in cooling water

Large energy loss in the cooling water flow



Small energy loss in the cooling water flow

Slide by Shin Nippon Air Technologies Co. Lts.

Agenda for the 2nd AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Collector Potential Depression (CPI) Klystron (30 min.)
by Toshiba Electron Tubes & Devices Co. Ltd.

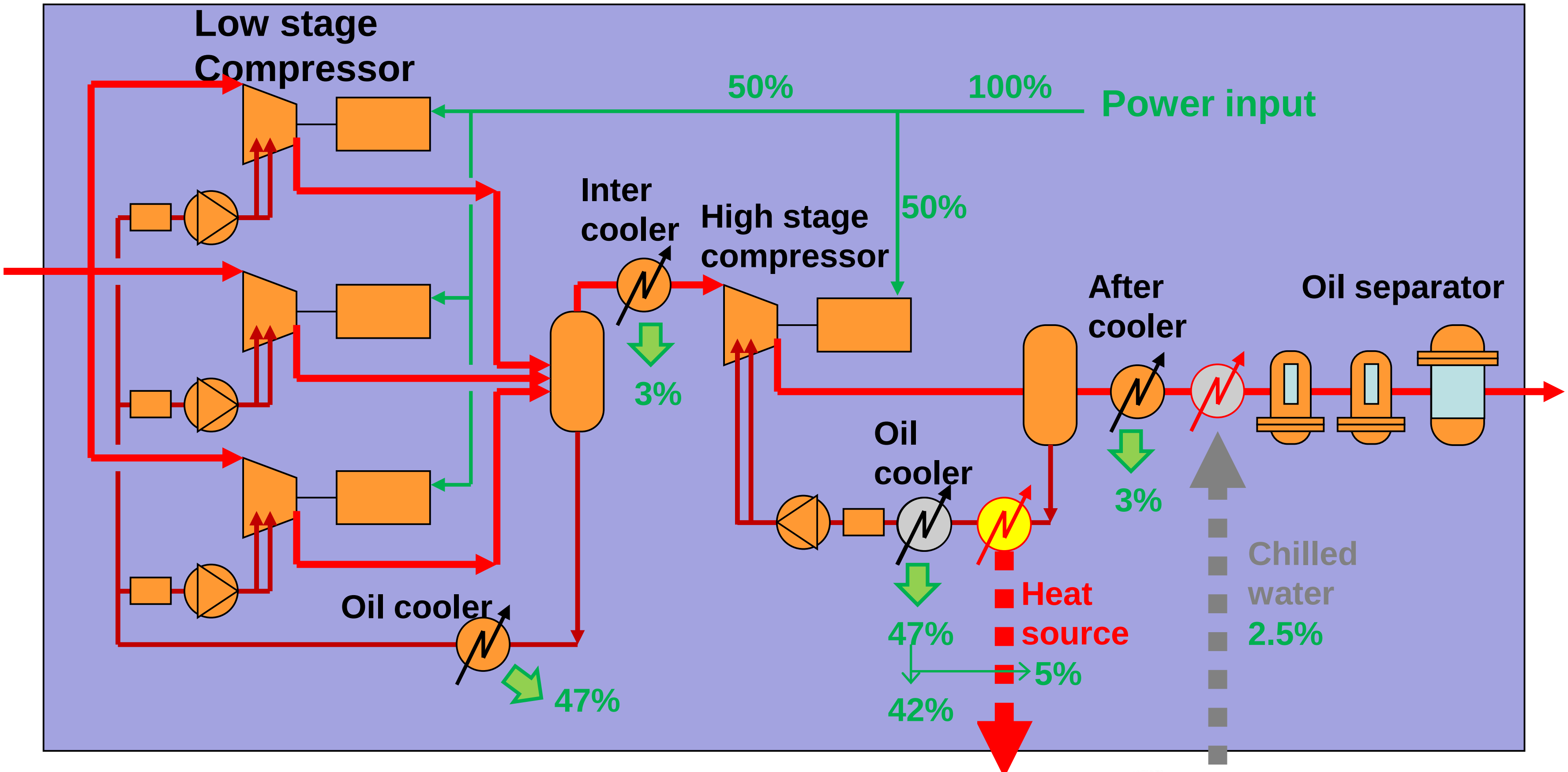
2) Power Saving of Large-Scaled Helium Compressor (30 min.)
by Mayekawa Manufacturing Company.

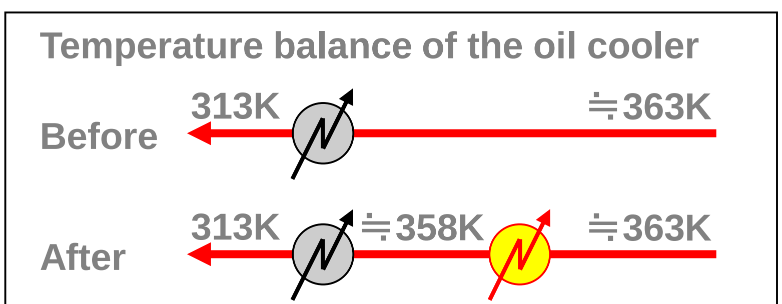
3) Examples of New Energy Power Plants (20 min.)
by RIKEN.

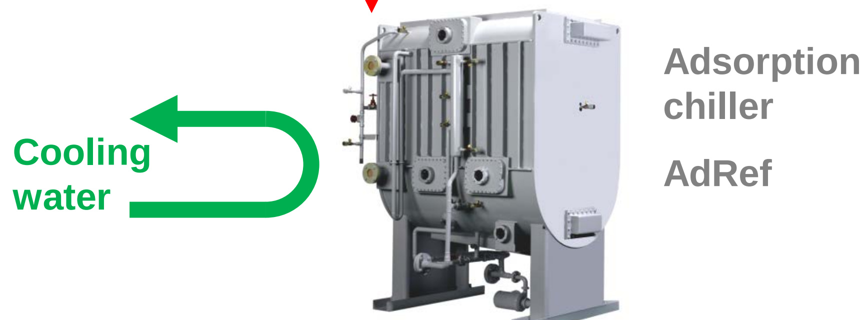
4) Solar Power Plant (40 min.)
by Japan Photovoltaic Energy Association

5) Proposal of Biomass Power Plant for ILC (20 min.)
by Kabuki Construction Co. Ltd.

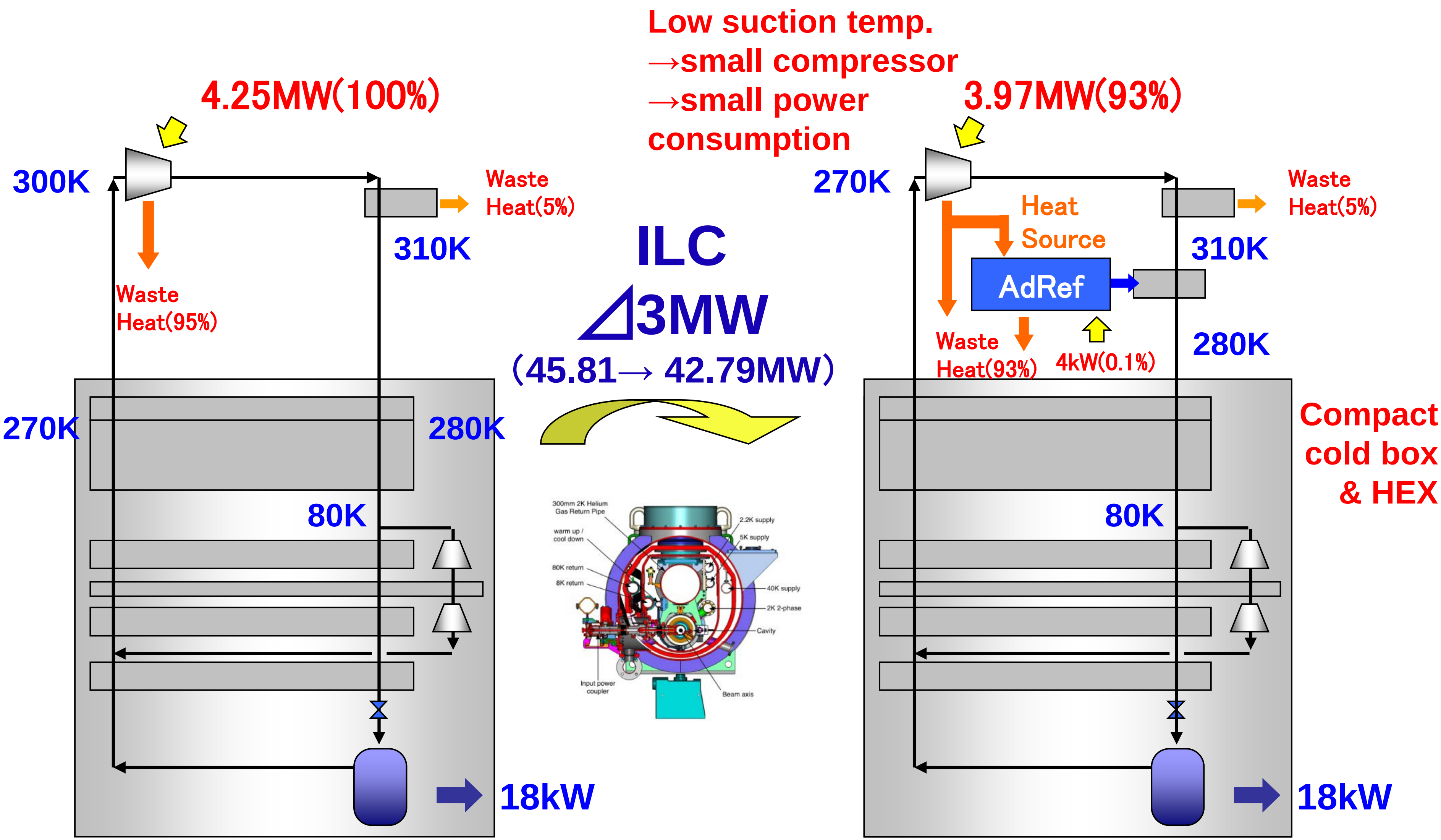
Heat source from the helium compressor







New refrigeration cycle with AdRef



Conventional cycle

New cycle with AdRef

Agenda for the 2nd AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Collector Potential Depression (CPI) Klystron (30 min.)
by Toshiba Electron Tubes & Devices Co. Ltd.

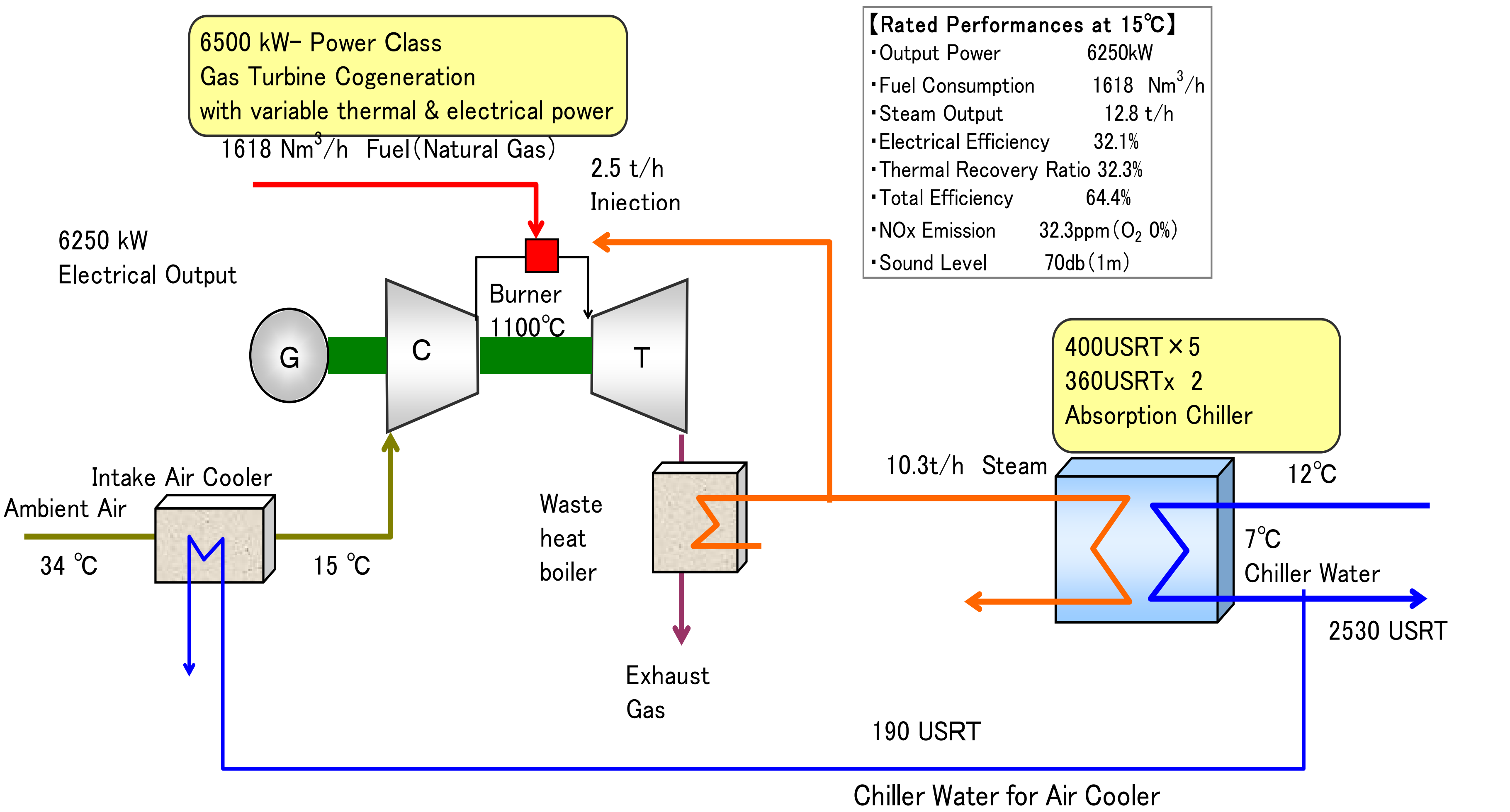
2) Power Saving of Large-Scaled Helium Compressor (30 min.)
by Mayekawa Manufacturing Company.

3) Examples of New Energy Power Plants (20 min.)
by RIKEN.

4) Solar Power Plant (40 min.)
by Japan Photovoltaic Energy Association

5) Proposal of Biomass Power Plant for ILC (20 min.)
by Kabuki Construction Co. Ltd.

CGS(Co-Generation System) at RIKEN



Agenda for the 2nd AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) **Collector Potential Depression (CPI) Klystron (30 min.)**
   by Toshiba Electron Tubes & Devices Co. Ltd.

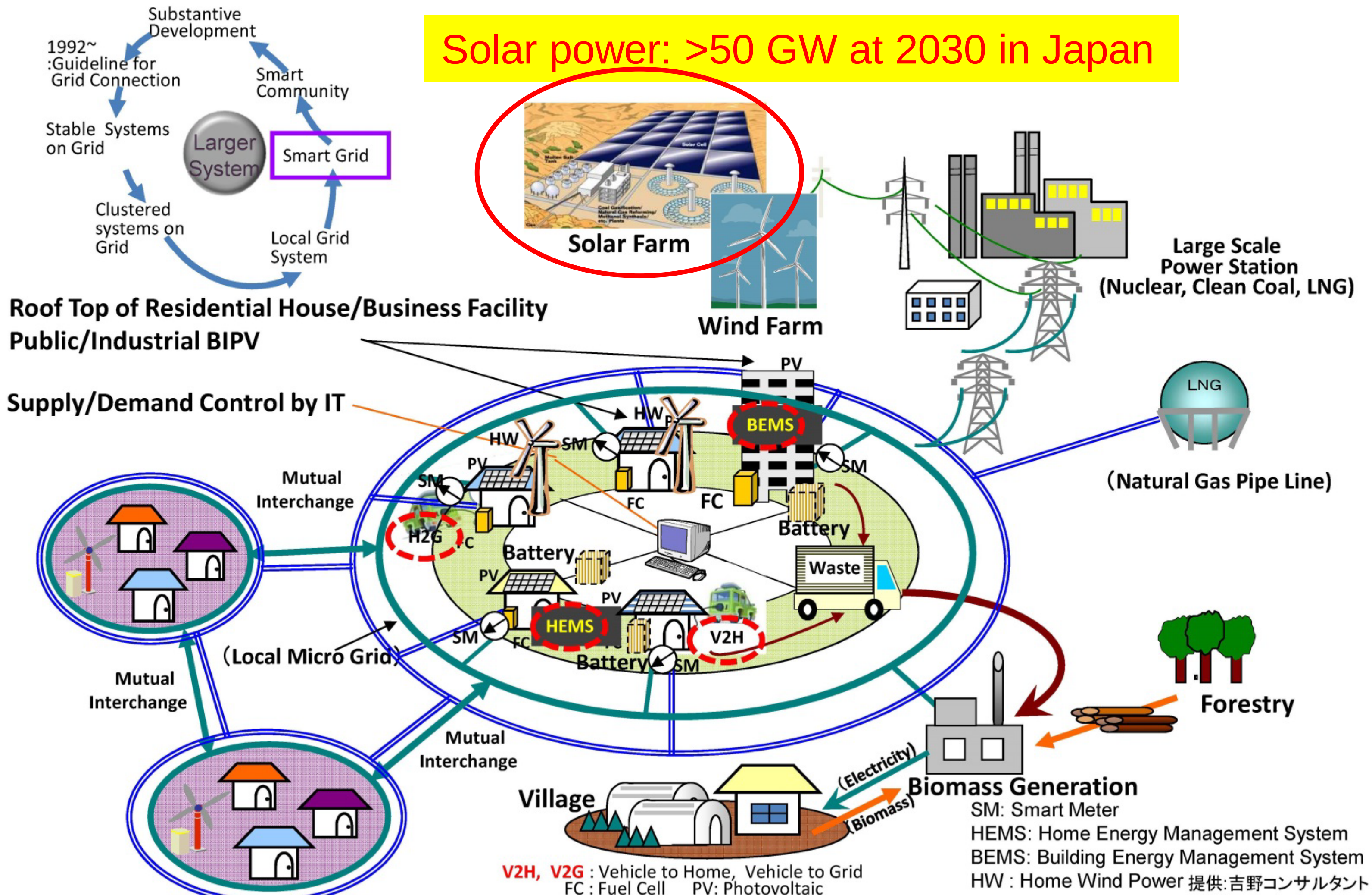
2) **Power Saving of Large-Scaled Helium Compressor (30 min.)**
   by Mayekawa Manufacturing Company.

3) **Examples of New Energy Power Plants (20 min.)**
   by RIKEN.

4) **Solar Power Plant (40 min.)**
   by Japan Photovoltaic Energy Association

5) **Proposal of Biomass Power Plant for ILC (20 min.)**
   by Kabuki Construction Co. Ltd.

Smart Country by Smart GRIG



Agenda for the 2nd AAA Green-ILC WG meeting

Date: 8th May 2014 (Thu.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) **Collector Potential Depression (CPI) Klystron (30 min.)**
   by Toshiba Electron Tubes & Devices Co. Ltd.

2) **Power Saving of Large-Scaled Helium Compressor (30 min.)**
   by Mayekawa Manufacturing Company.

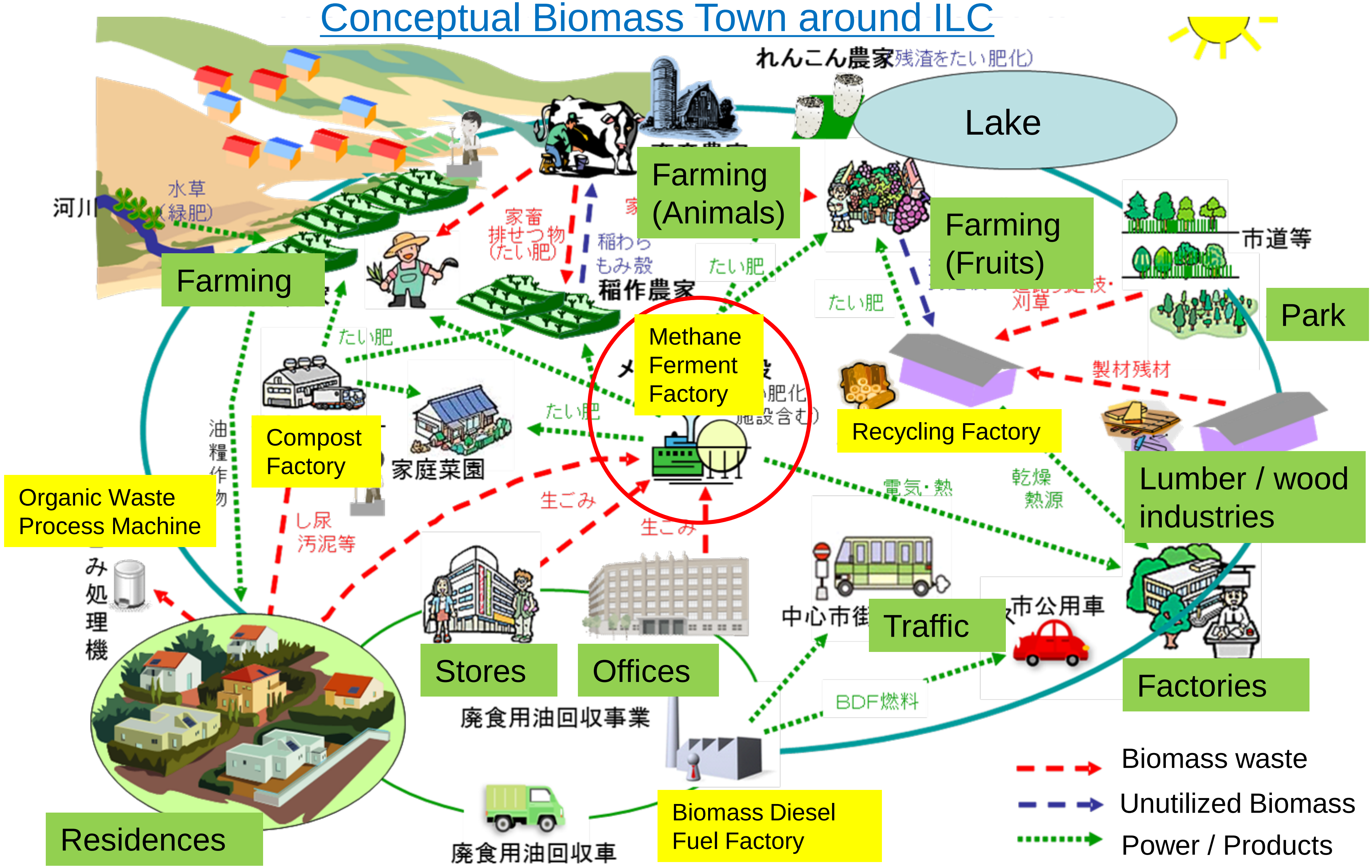
3) **Examples of New Energy Power Plants (20 min.)**
   by RIKEN.

4) **Solar Power Plant (40 min.)**
   by Japan Photovoltaic Energy Association

5) **Proposal of Biomass Power Plant for ILC (20 min.)**
   by Kabuki Construction Co. Ltd.

❑ Biomass Power Plant using Organic Waste

Conceptual Biomass Town around ILC

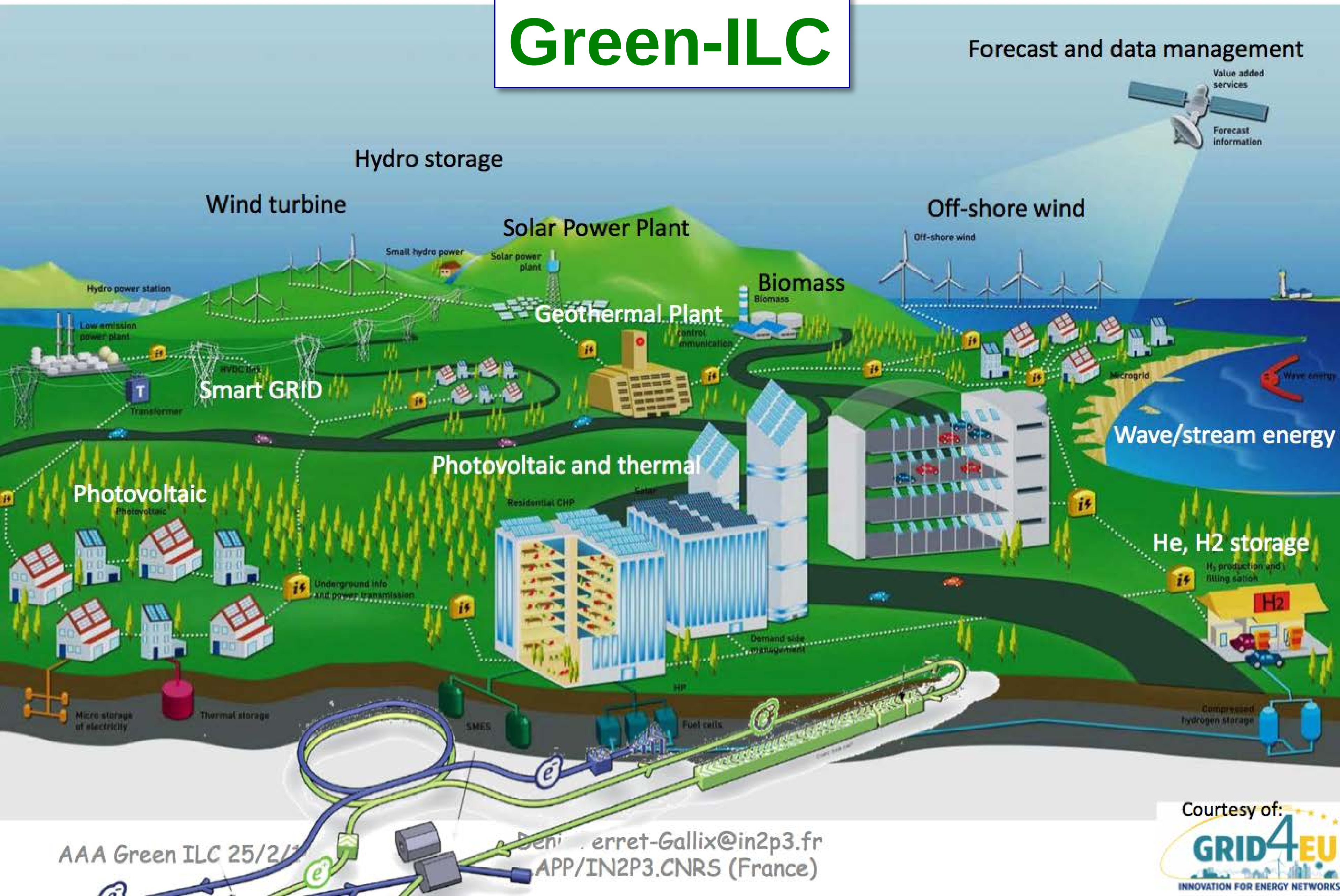


出典:土浦市バイオマスタウン構想書

Summary

- The 1st meeting for the Green-ILC WG of AAA was held on 25th February 2014 to launch the Green-ILC-AAA activity.
- The series of Green-ILC-AAA WG meetings were held since then, and various realistic technologies of energy-saving for ILC were proposed and discussed by industries and scientists in the meetings.
- **There was a progress in the study on energy recovery at beam dump.**
- The energy-saving technologies discussed in the Green-ILC-AAA meetings are ranging from the components, sub-system, ILC-system, and to ILC-city.
- Proposed items for Green-ILC energy-saving technologies will be summarized and written in the report in English under the framework of AAA in the beginning or middle of year 2016.

ILC center futuristic view



Deni erret-Gallix@in2p3.fr
APP/IN2P3.CNRS (France)

Backup slides

Present Status of R&D

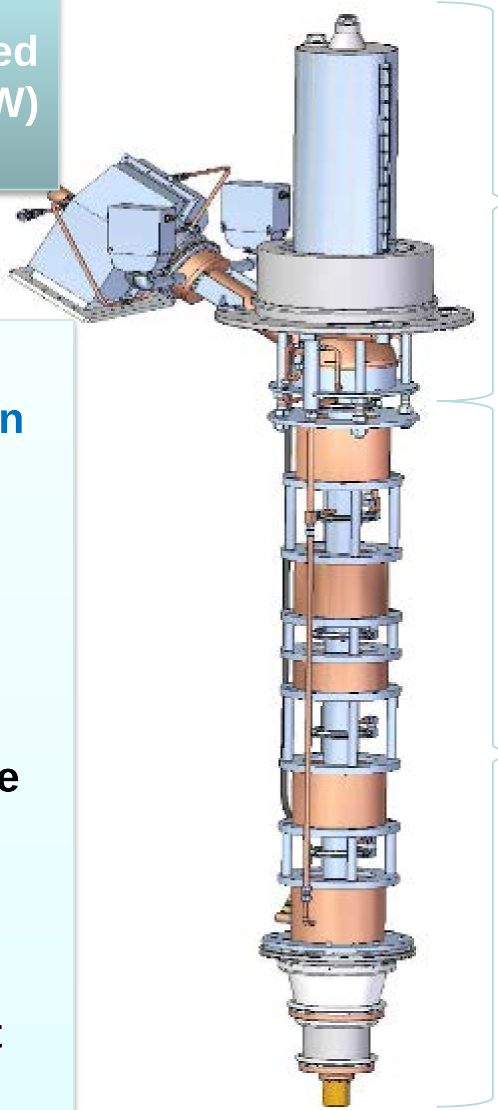
Target

proof-of-principle of CPD in the unsaturated region (a maximum rf power of 500 kW) using a KEKB 1.2MW-klystron

R&D Schedule

2013.3: Modification of an existing klystron to CPD klystron (already done)

2014.3: until then, preparation and commissioning of the test station
~2014: Verification of klystron operation without CPD
~2015: Measurement of rf leakage from the gap between the body column and the collector (with no CPD voltage applied)
Measurement of induced pulse voltage on the collector with CPD
~2017: Test of rectification by Marx circuit
Integration test of the proof-of-principle of CPD operation



Newly fabricated components

- collector
- ceramic insulator
- output cavity
- output coupler

Recycled components

- electron gun
- input cavity
- intemediate cavities

Goal : 80 % efficiency

Agenda for the 3rd AAA Green-ILC WG meeting

Date: 1st July 2014 (Tue.) 13:30 - 17:00.
Place: 6th floor, UDX Building in Akihabara, Tokyo.

1) Energy Recovery at Beam Dump at ILC (20 min.)
by J. Fujimoto (KEK).

2) Tests of Collector Potential Depression (CPD) Klystron (30 min.)
by K. Watanabe (KEK).

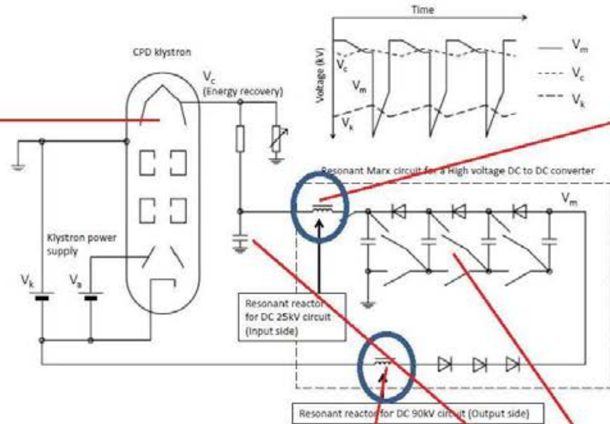
3) Drag Reduction (DR) Additive for Cooling Water (30 min.)
by Shin Nippon Air Technologies Co. Ltd.

4) Examples of New Energy Power Plants (30 min.)
by RIKEN.

Collector Potential Depression (CPD) Klystron

Preparation of CPD Klystron test at KEK

CPD Klystron



DC 90kV oscillator circuit for output

Dummy resister

DC 25kV oscillator circuit for input

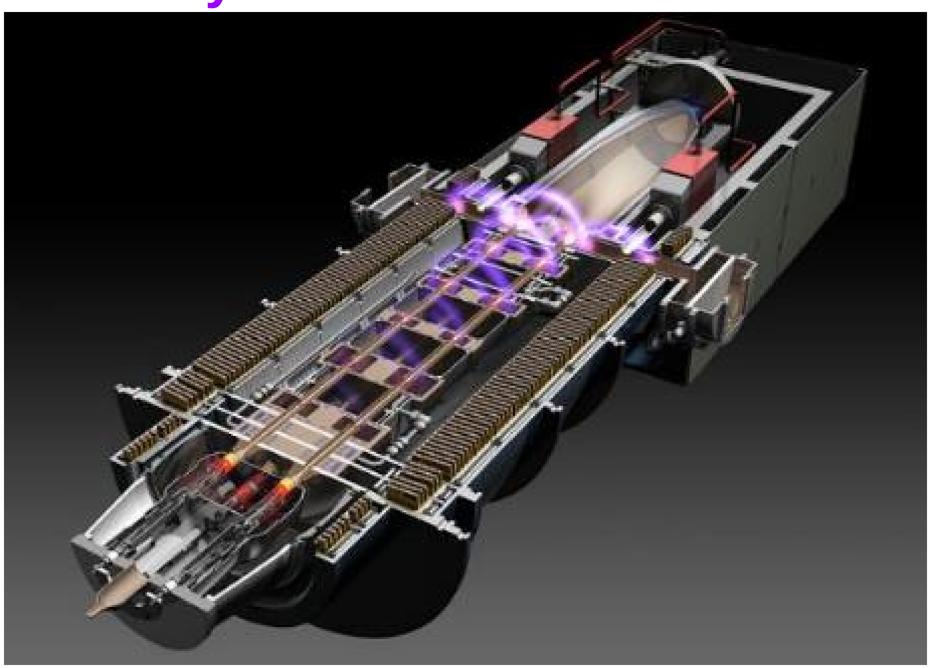
Capacitor for circuit (only one capacitor is delivered)

Multi(6) – Beam Klystron (MBK) for 26 Cavities for ILC

DEVELOPMENT OF TOSHIBA L-BAND MULTI-BEAM KLYSTRON FOR EUROPEAN XFEL PROJECT

Y. H. Chin, KEK, Tsukuba, Japan,
A.Yano, S. Miyake, TOSHIBA ELCTRON TUBES & DEVICES Co., Ltd., Ohtawa-shi, Japan,
S. Choroba, DESY, Hamburg, Germany

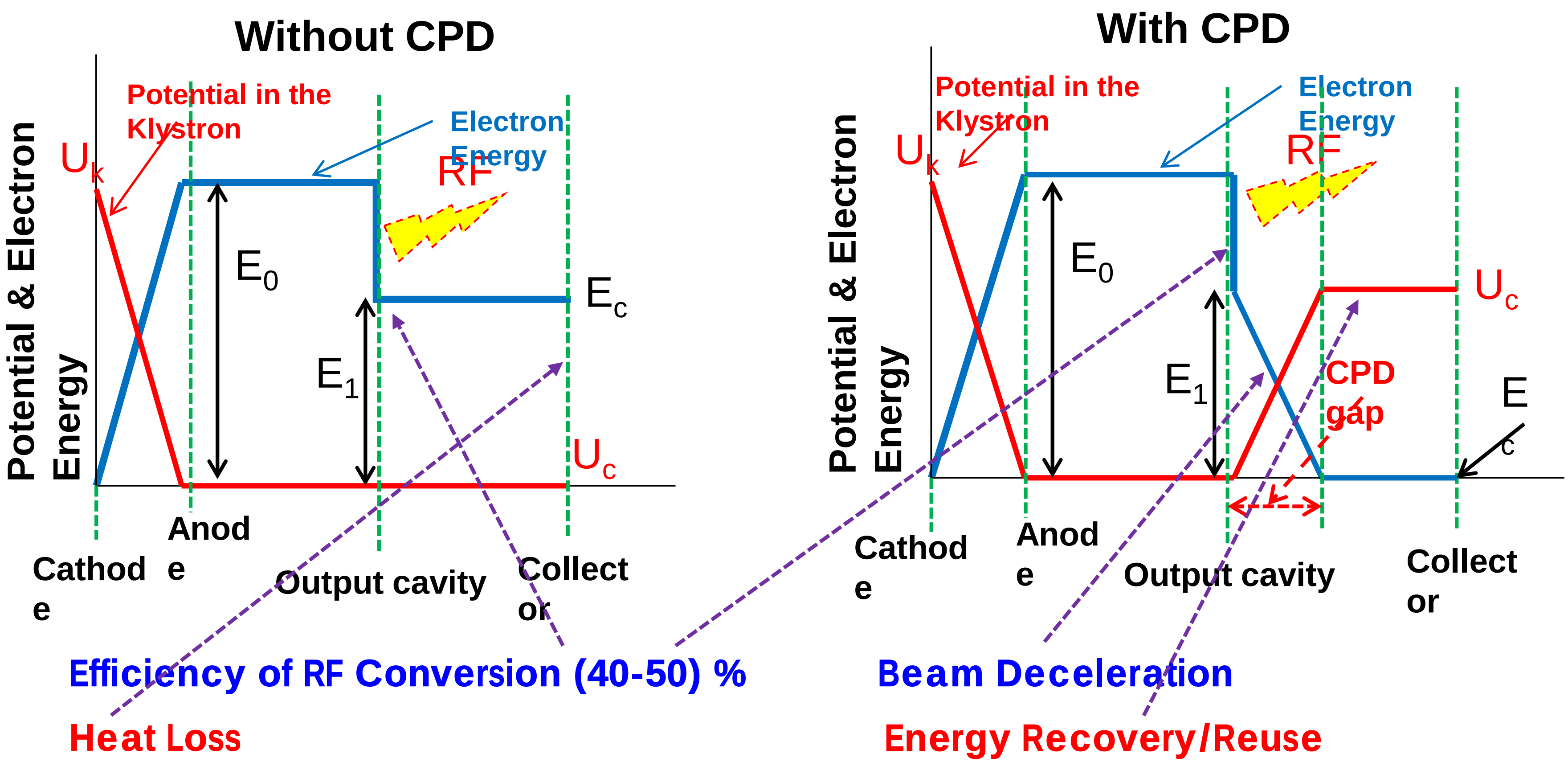
- **The design goal is to achieve 10 MW peak power with 65 % efficiency at 1.5 ms pulse length at 10 Hz repetition rates.**
- **MBK has 6 low-perveance beams operated at low voltage of 115 kV for 10 MW to enable a higher efficiency than a single-beam klystron.**



e 2: Electron Gun of the E3736.

Frequency	1.3 GHz
Peak power	10 MW
Pulse width	1.6 ms
Rep. rate	5 Hz
Average power	78 kW
Efficiency	**65 %**
Gain	47dB
BW (- 1dB)	3 MHz
Voltage	120 kV
Current	140 A
Lifetime	40,000 h

Simplified Schematic Concept

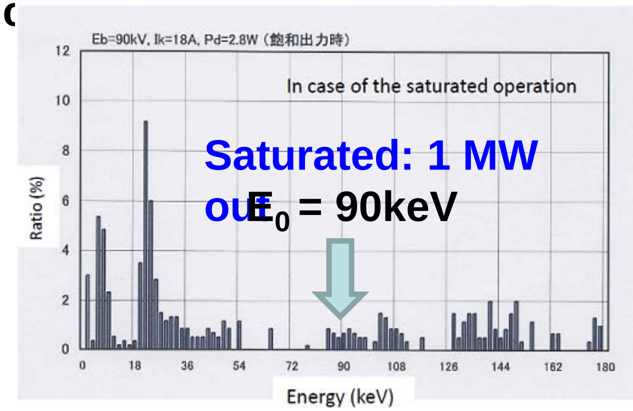


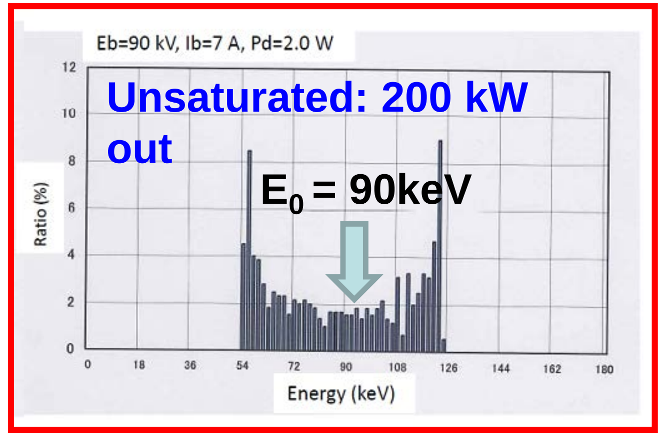
Potential denotes the electron potential energy, eV. For simplicity, input and intermediate cavities are omitted here and the anode potential is set to zero.

Issues must be addressed for CPD Klystron

(I) Energy spread

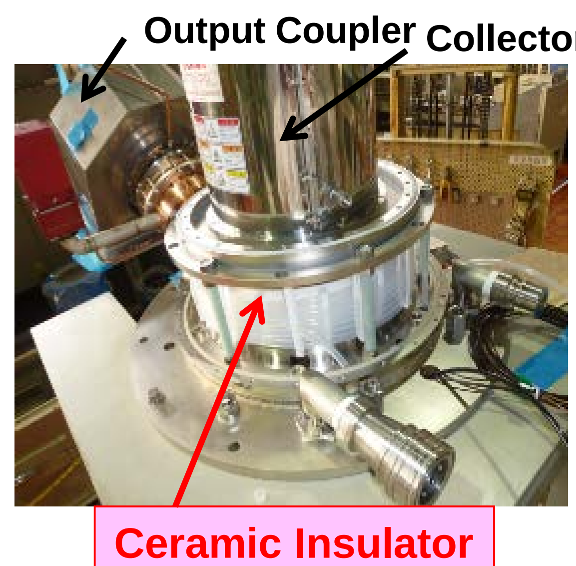
The spent electron beam has **large energy spread** through electromagnetic interaction in the cavities. Therefore, **the collector potential cannot be increased beyond the lower limit of energy distribution** of the spent electron beam, otherwise backward electrons hit the cavities or the gun, and then deteriorate the klystron performanc





(II) Pulse-to-DC conversion

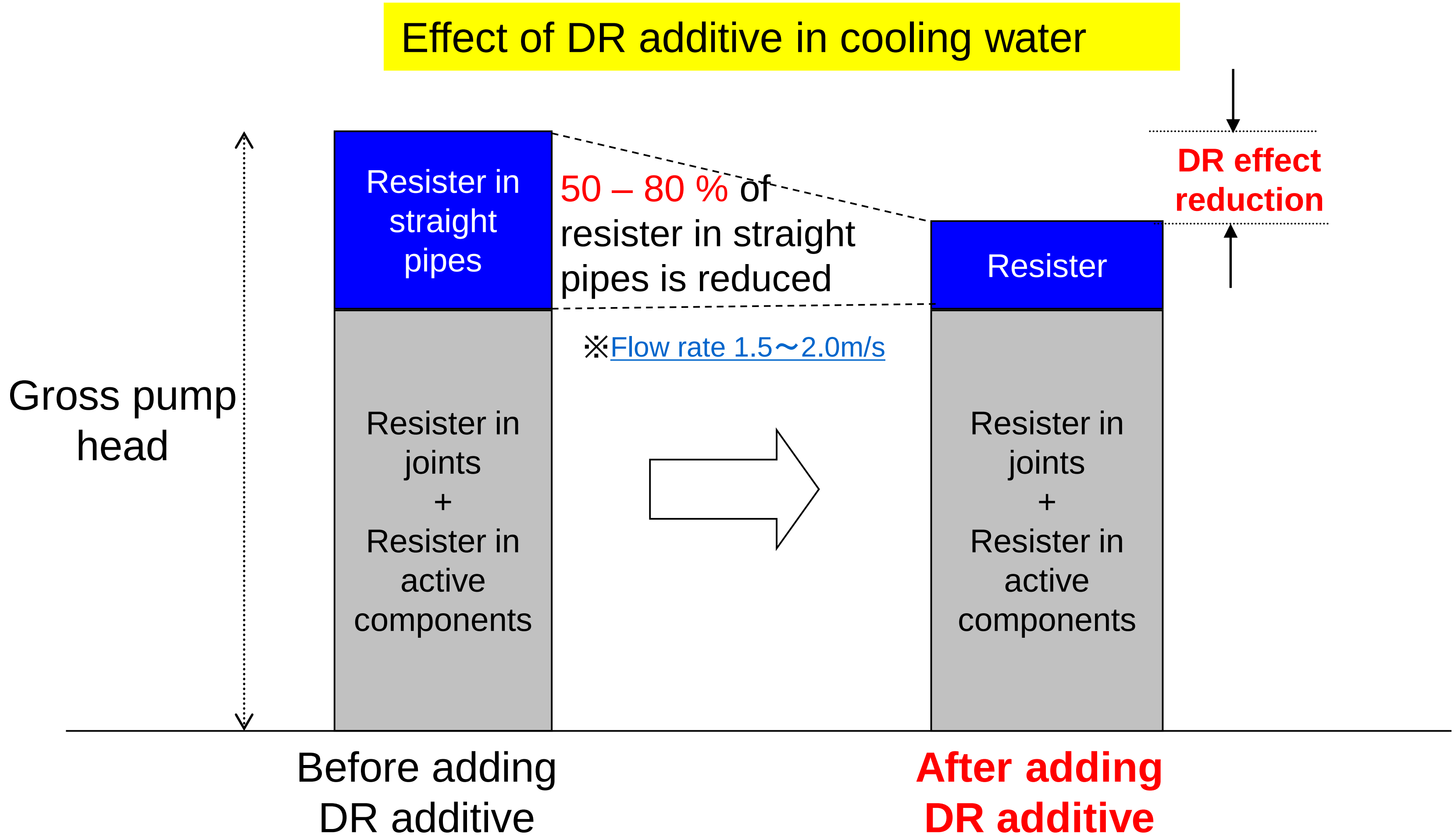
The spent electron beam is longitudinally bunched, so that **pulsed voltage is induced on the collector**. An **adequate pulse-to-DC converter** has to be implemented.



(III) RF Leakage

CPD klystron has to be equipped with an **insulator between the collector and the body column** in order to apply CPD voltage to the collector. Thus, it would be possible for the CPD klystron to **leak rf power** out more or less from the insulator.

Drag Reduction (DR) Additive in Cooling Water



Slide by Shin Nippon Air Technologies Co. Lts.

Adsorption chiller “AdRef”

<u>Environmentally Friendly Chiller.</u>

Features

1. No CFCs, HCFCs used.

   Water (H_2O) is used as refrigerant.

2. Low temperature heat source.

   As low as 65 C

3. Super Energy Saving

   Only a few HP necessary

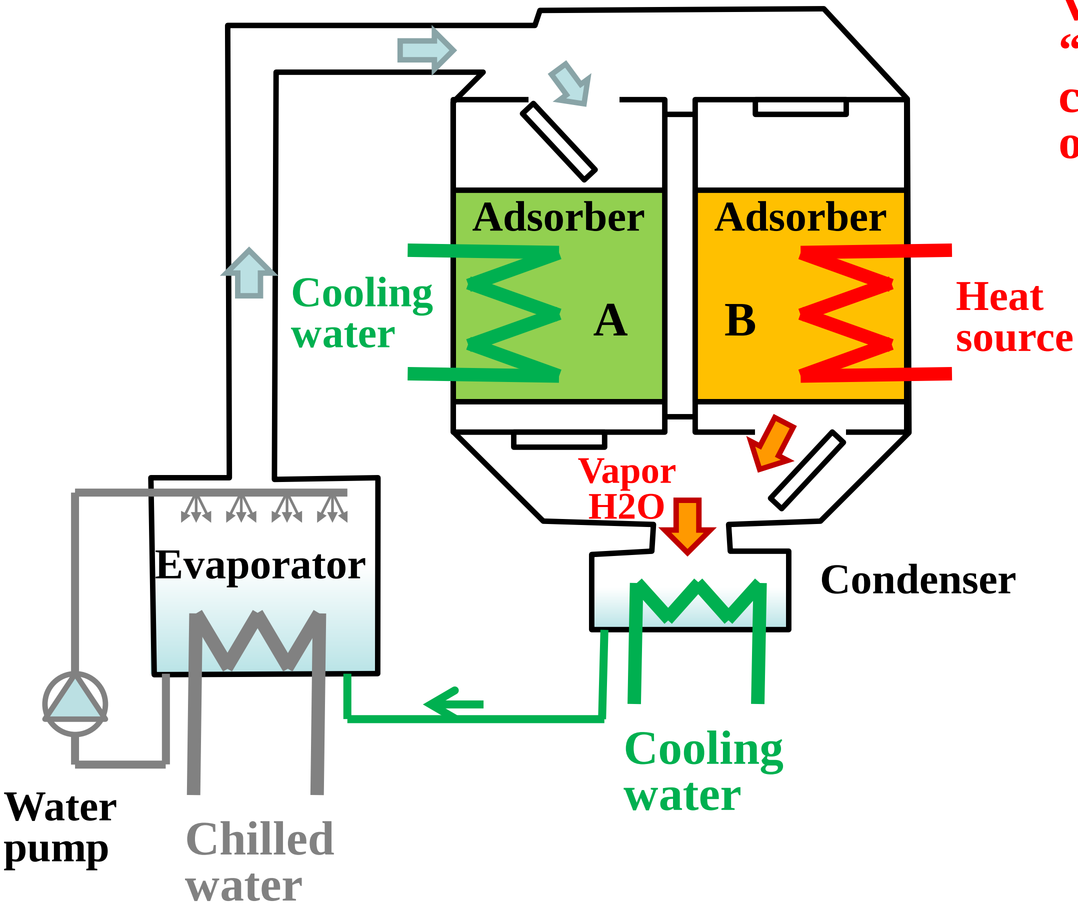
4. Easy maintenance

   Very few moving parts used.

5. Safe

   No pressure piping or refrigerant

Adsorption chiller "AdRef"



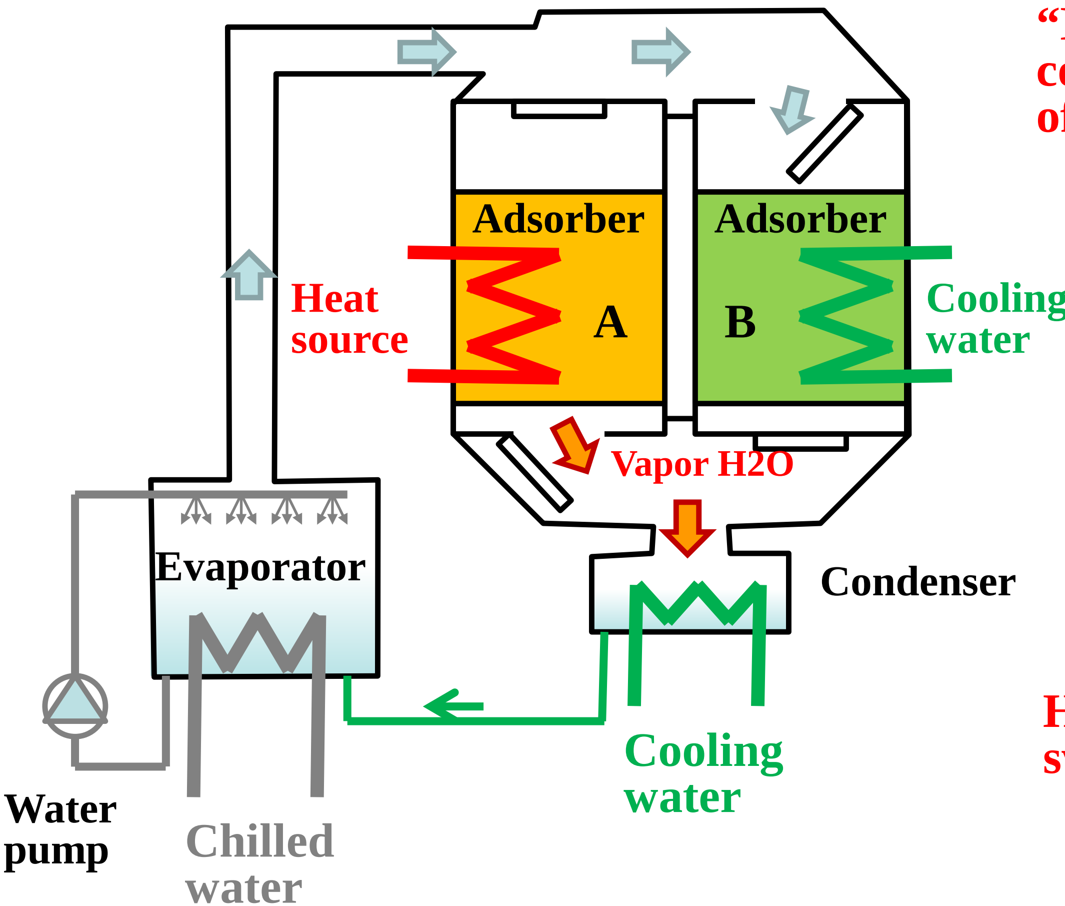
Vapor H_2O is removed from adsorber "B" by heating with warm water, and condensed in the condenser by the cool of cooling water.

Liquid water goes to the evaporator.

The adsorber "A" adsorb vapor H_2O by cool of cooling water.

Then the liquid H_2O in the evaporator evaporates, and the latent heat cool down the chilled water.

Adsorption chiller "AdRef"



Vapor H_2O is removed from adsorber "B" by heating with warm water, and condensed in the condenser by the cool of cooling water.

Liquid water goes to the evaporator.

The adsorber "A" adsorb vapor H_2O by cool of cooling water.

Then the liquid H_2O in the evaporator evaporates, and the latent heat cool down the chilled water.

Heating/Cooling of adsorber A/B is switched periodically.

Absorption refrigerator (chiller) (from Wikipedia, the free encyclopedia)

- An **absorption refrigerator** is a refrigerator that uses a heat source (e.g., solar, kerosene-fueled flame, waste heat from factories or district heating systems) to provide the energy needed to drive the cooling system.
- In the early years of the twentieth century, the vapor absorption cycle using water-ammonia systems was popular and widely used, but after the development of the vapor compression cycle it lost much of its importance because of its low coefficient of performance (about one fifth of that of the vapor compression cycle). Nowadays, the vapor absorption cycle is used only where waste heat is available or where heat is derived from solar collectors. Absorption refrigerators are a popular alternative to regular compressor refrigerators where electricity is unreliable, costly, or unavailable, where noise from the compressor is problematic, or where surplus heat is available (e.g., from turbine exhausts or industrial processes, or from solar plants).

Scheme of the water system for the water beam dump

TESLA

DESY, February 2001, TESLA Report 2001-04

Concept of the High Power e± Beam Dumps for TESLA

W. Bialowons, M. Maslov, M. Schmitz, V. Sytchev

- 70°C hot water can be obtained.

  - Energy recovery

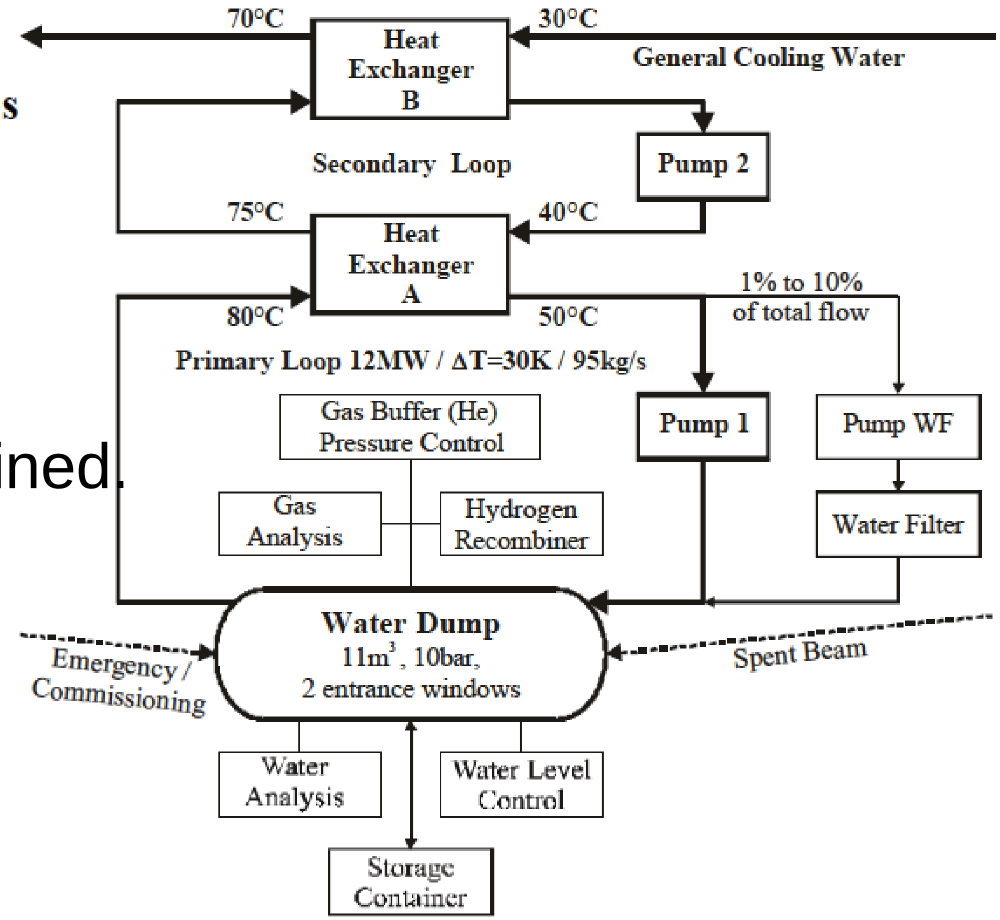


Figure 6: Scheme of the water system for the water based beam dump

ILC parameters

	IP and General Parameters			TF = Traveling Focus					L Upgrade	E_{cm} Upgrade A1	E_{cm} Upgrade B1b
	Centre-of-mass energy	E_{cm}	**GeV**	**200**	**230**	**250**	**350**	**500**	**500**	**1000**	**1000**
	Beam energy	E_{beam}	GeV	100	115	125	175	250	500	500	500
	Collision rate	f_{rep}	Hz	5	5	5	5	5	5	4	4
	Electron linac rate	f_{linac}	Hz	10	10	10	5	5	5	4	4
	Number of bunches	n_b		1312	1312	1312	1312	1312	2625	2450	2450
	Electron bunch population	N_-	$\times10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74
	Positron bunch population	N_+	$\times10^{10}$	2.0	2.0	2.0	2.0	2.0	2.0	1.74	1.74
	Bunch separation	Δt_b	ns	554	554	554	554	554	366	366	366
	Bunch separation $\times f_{RF}$	$\Delta t_b\, f_{RF}$		720	720	720	720	720	476	476	476
	Pulse current	I_{beam}	mA	5.8	5.8	5.8	5.8	5.79	8.75	7.6	7.6
	RMS bunch length	σ_z	mm	0.3	0.3	0.3	0.3	0.3	0.3	0.250	0.225
	Electron RMS energy spread	$\Delta p/p$	%	0.206	0.194	0.190	0.158	0.125	0.125	0.083	0.085
	Positron RMS energy spread	$\Delta p/p$	%	0.187	0.163	0.150	0.100	0.070	0.070	0.043	0.047
	Electron polarisation	P_-	%	80	80	80	80	80	80	80	80
	Positron polarisation	P_+	%	31	31	30	30	30	30	20	20
	Horizontal emittance	$\gamma\varepsilon_x$	μm	10	10	10	10	10	10	10	10
	Vertical emittance	$\gamma\varepsilon_y$	nm	35	35	35	35	35	35	30	30
	IP horizontal beta function	$\beta_x{}^*$	mm	16.0	14.0	13.0	16.0	11.0	11.0	22.6	11.0
	IP vertical beta function (no TF)	$\beta_y{}^*$	mm	0.34	0.38	0.41	0.34	0.48	0.48	0.25	0.23
	IP RMS horizontal beam size	$\sigma_x{}^*$	nm	904	789	729	684	474	474	481	335
	IP RMS veritcal beam size (no TF)	$\sigma_y{}^*$	nm	7.8	7.7	7.7	5.9	5.9	5.9	2.8	2.7
analytical estimates	Horizontal distruption parameter	D_x		0.2	0.2	0.3	0.2	0.3	0.3	0.1	0.2
	Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6	24.6	18.7	25.1
	Horizontal enhancement factor	H_{Dx}		1.0	1.1	1.1	1.0	1.1	1.1	1.0	1.0
	Vertical enhancement factor	H_{Dy}		4.5	5.0	5.4	4.5	6.1	6.1	3.5	4.1
	Total enhancement factor	H_D		1.7	1.8	1.8	1.7	2.0	2.0	1.5	1.6
	Geometric luminosity	L_{geom}	$\times10^{34}$ cm^{-2}s^{-}	0.30	0.34	0.37	0.52	0.75	1.50	1.77	2.64
	Luminosity	L	$\times10^{34}$ cm^{-2}s^{-}	**0.50**	**0.61**	**0.68**	**0.88**	**1.47**	**2.94**	**2.71**	**4.32**
	Average beamstrahlung parameter	Υ_{av}		0.013	0.017	0.020	0.030	0.062	0.062	0.127	0.203
	Maximum beamstrahlung parameter	Υ_{max}		0.031	0.041	0.048	0.072	0.146	0.146	0.305	0.483
	Average number of photons / particle	n_γ		0.95	1.08	1.16	1.23	1.72	1.72	1.43	1.97
	Average energy loss	δE_{BS}	%	0.51	0.75	0.93	1.42	3.65	3.65	5.33	10.20
simulation	Luminosity	L	$\times10^{34}$ cm^{-2}s^{-}	0.498	0.607	0.681	0.878	1.50	3.00	3.23	4.31
	Coherent waist shift	ΔW_y	μm	250	250	250	250	250	250	190	190
	Luminosity (inc. waist shift)	L	$\times10^{34}$ cm^{-2}s^{-}	**0.56**	**0.67**	**0.75**	**1.0**	**1.8**	**3.6**	**3.6**	**4.9**
	Fraction of luminosity in top 1%	$L_{0.01}/L$		91.3%	88.6%	87.1%	77.4%	58.3%	58.3%	59.2%	44.5%
	Average energy loss	δE_{BS}		0.65%	0.83%	0.97%	1.9%	4.5%	4.5%	5.6%	10.5%
	Number of pairs per bunch crossing	N_{pairs}	$\times10^3$	44.7	55.6	62.4	93.6	139.0	139.0	200.5	382.6
	Total pair energy per bunch crossing	E_{pairs}	TeV	25.5	37.5	46.5	115.0	344.1	344.1	1338.0	3441.0

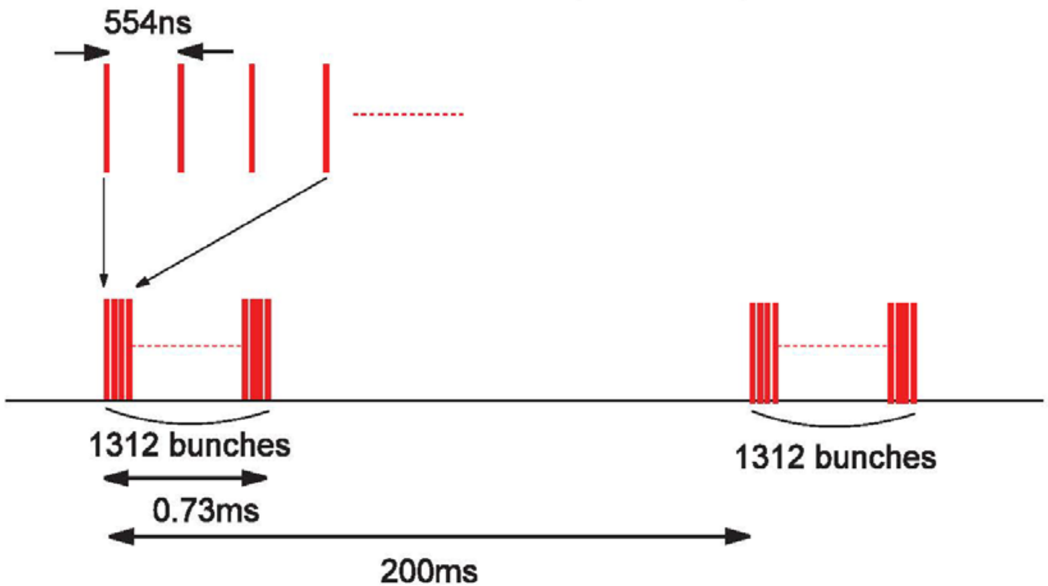
ILC parameters

基本的ビームパラメータ（baseline, 5Hz）

繰り返周波数	5Hz
パルスあたりバンチ数	1312
バンチあたり粒子数	2x10^10
バンチ間隔	554 ns
バンチ長	0.3 mm

水平エミッタンス	10 μm
垂直エミッタンス	35 nm
衝突点水平ビームサイズ	474nm
衝突点垂直ビームサイズ	5.9nm

Beam Pulse Structure (Low Power)

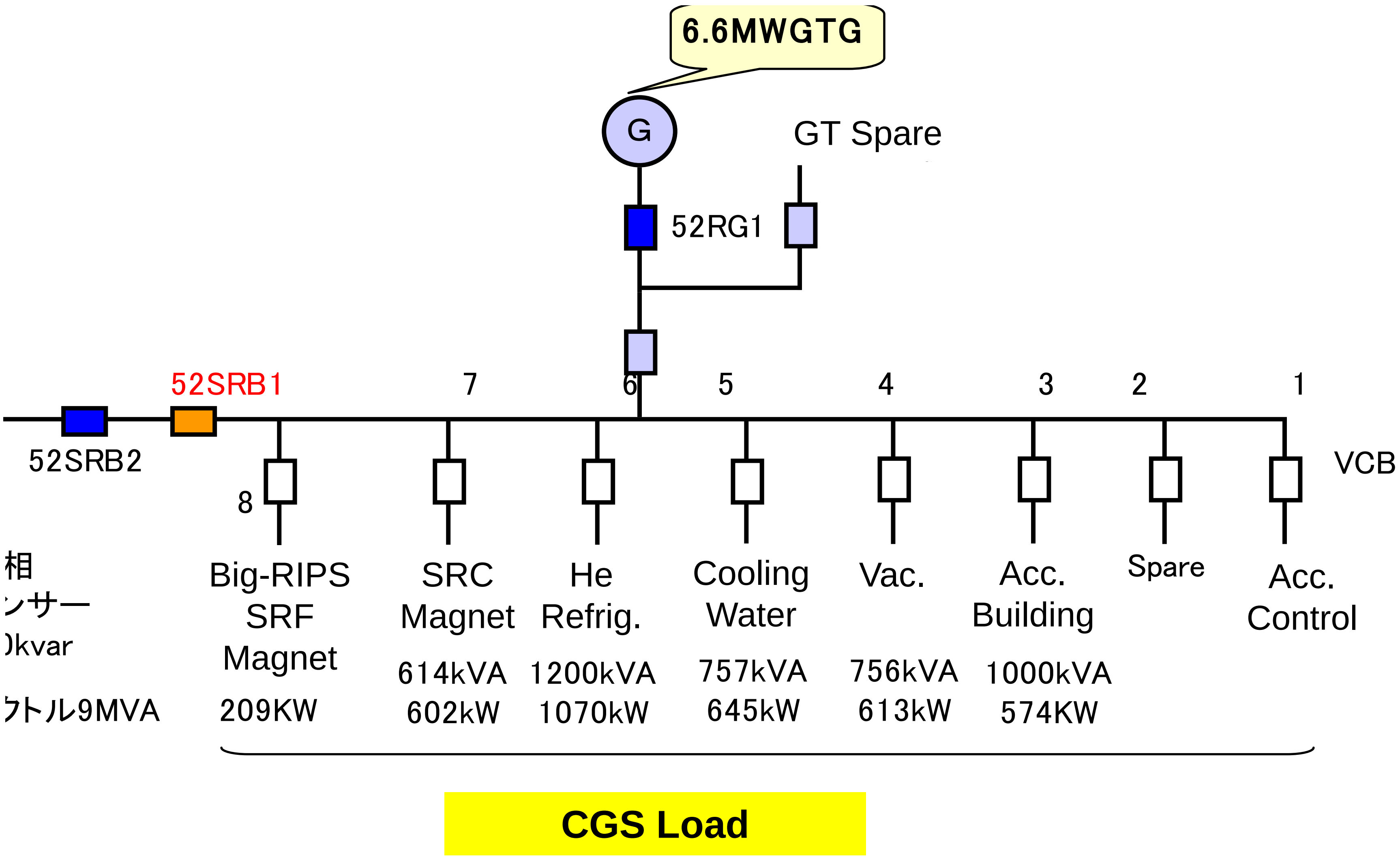


CGS (Go-Generation System) at RIKEN

- 6.5 MW + 2720 USRT
- 1Hz (20msec) power switch for blackout.
- Efficiency：68%, as of June 2010.

- G：7MVA. 6.6kV. 50Hz.
- T :1100℃/480℃. 14000rpm. 6.6MW /12℃.
- B :480℃/160℃. 1.6MPa(210℃)12.5t/h
- C :400 USRT x 5 + 360 USRT x 2, 7℃ at outlet (1 USRT=3.52kW.)

Power Line Circuit



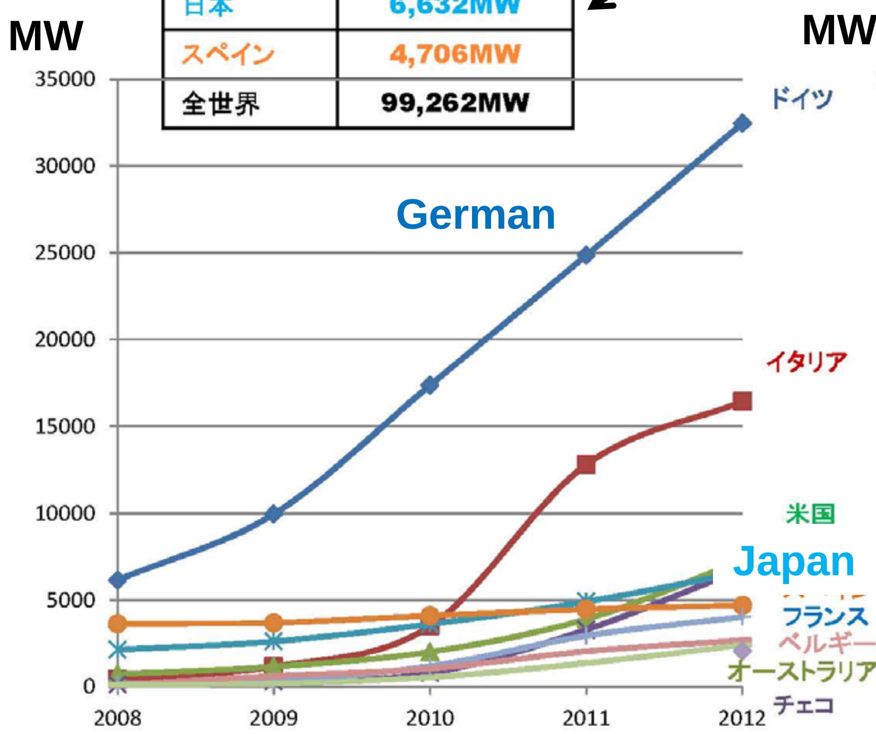
Solar Power Production / Top 6 Countries

Integrated Installation (2012)

2012年暦年末までの累積導入量	
ドイツ	32,462MW
イタリア	16,450 MW
米国	7,272MW
中国	6,800MW
日本	6,632MW
スペイン	4,706MW
全世界	99,262MW

German

Japan

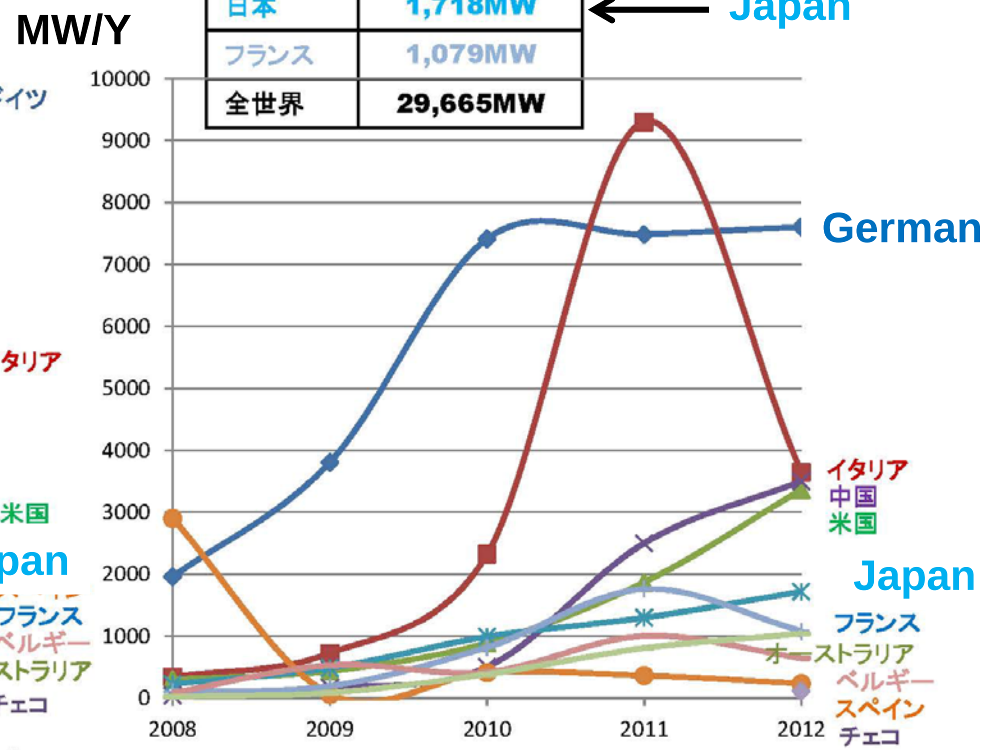


Installation per Year (2012)

2012年暦年の年間導入量	
ドイツ	7,604 MW
イタリア	3,647 MW
中国	3,500MW
米国	3,362MW
日本	1,718MW
フランス	1,079MW
全世界	29,665MW

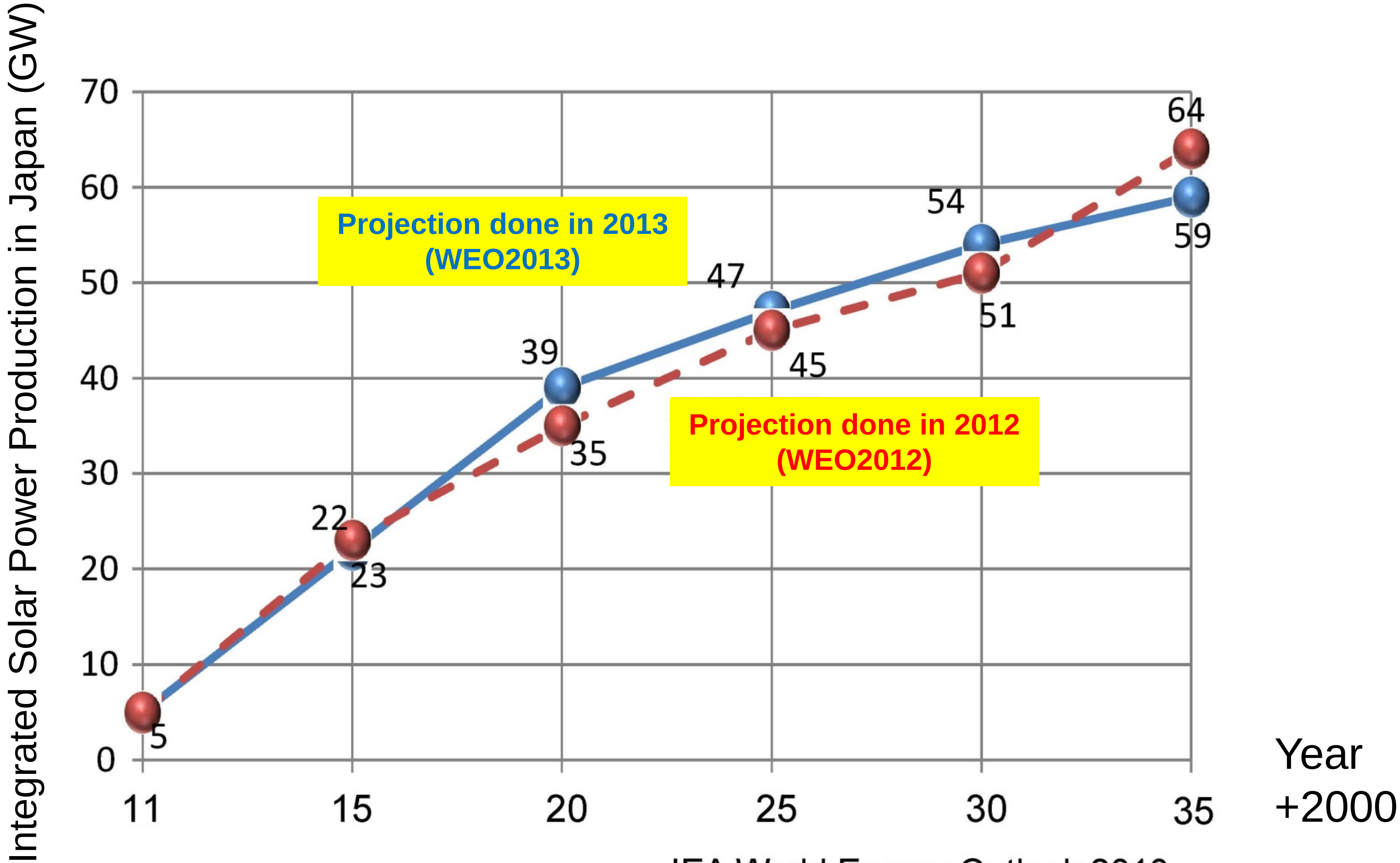
German

Japan



出典：TRENDS 2013 Report IEA-PVPS T1-23:2013

Projection of Solar Power Production in Japan by IEA

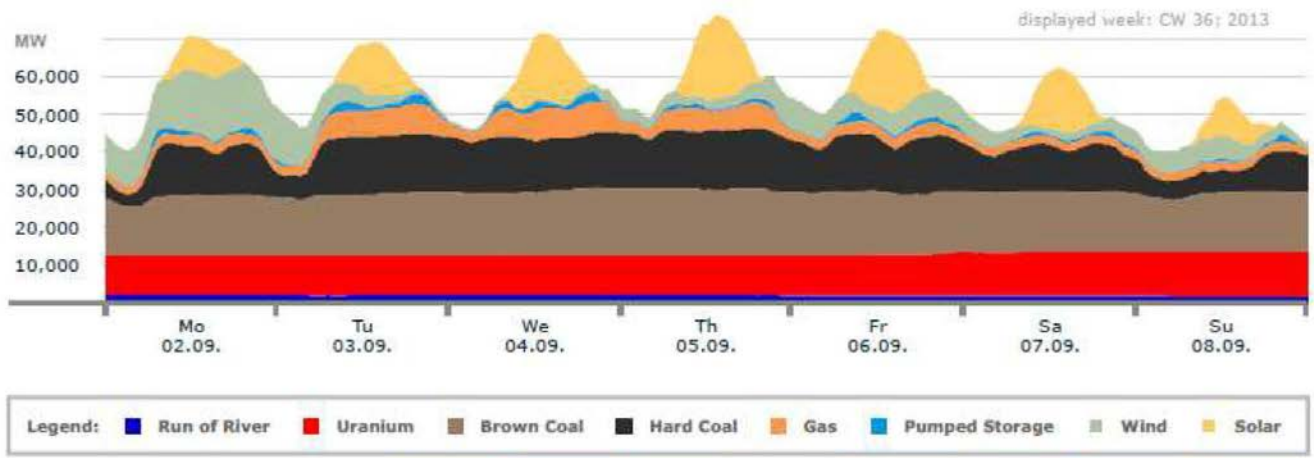


IEA World Energy Outlook 2013

Weekly Production in Germany (2012)

Electricity Production in Germany: Calendar Week 36

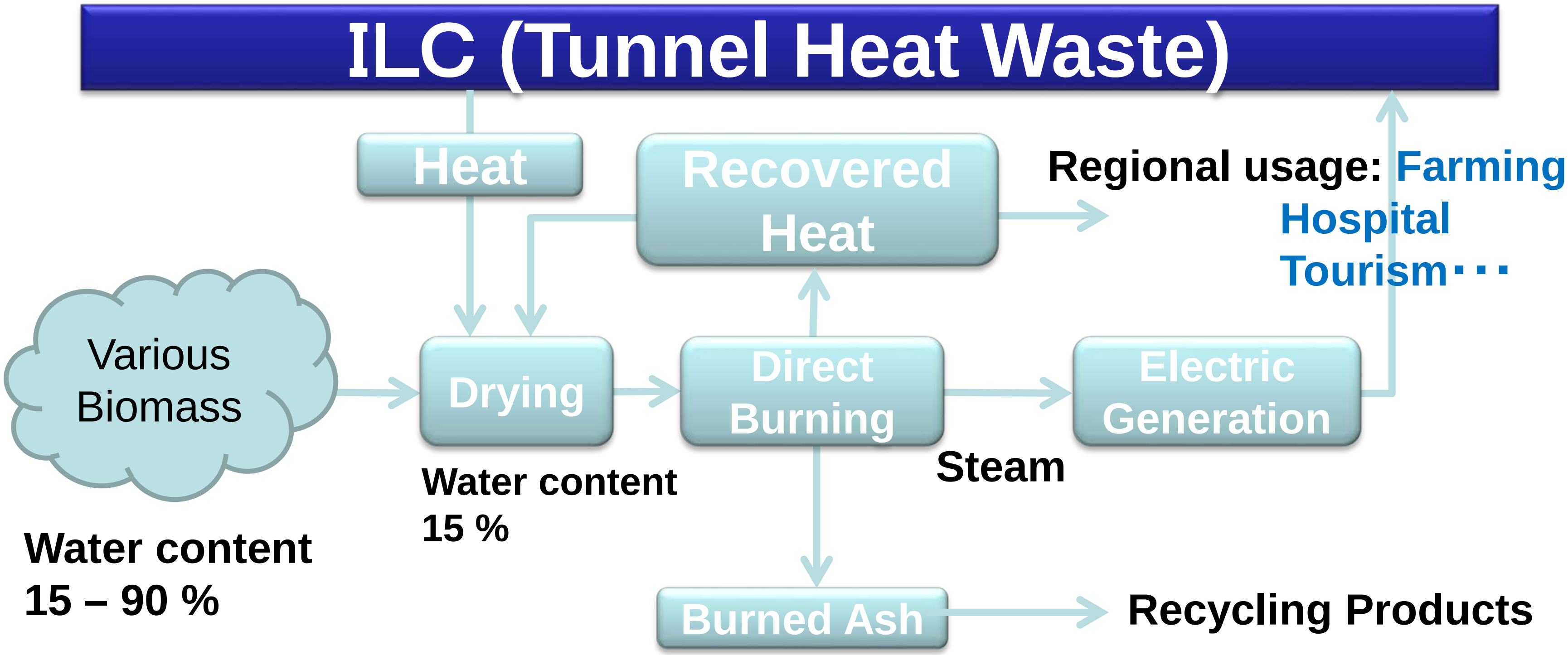
Actual production



	RoR	Uran	BC	HC	Gas	PSt	Wind	Solar
min. power (GW)	1.5	10.3	12.7	3.2	2	0	0.1	0
max. power (GW)	2	11.9	17.8	16	8.7	2.8	17	22
weekly energy (TWh)	0.3	1.8	2.7	2	0.7	0.1	0.9	0.8

Graph: Bruno Burger, Fraunhofer ISE; Data: EEX Transparency Platform

❑ Estimate of Biomass Electric Power



Estimate of Electric Power

Assuming the efficiency of 10～20%

Kitakami Site	58,104 kW × 10 ～20% = 6,000～10,000kW
Sefuri Site	43,280 kW × 10 ～20% = 5,000～10,000kW