Current Status of Green-ILC Activities in Japan

T. Saeki (KEK)

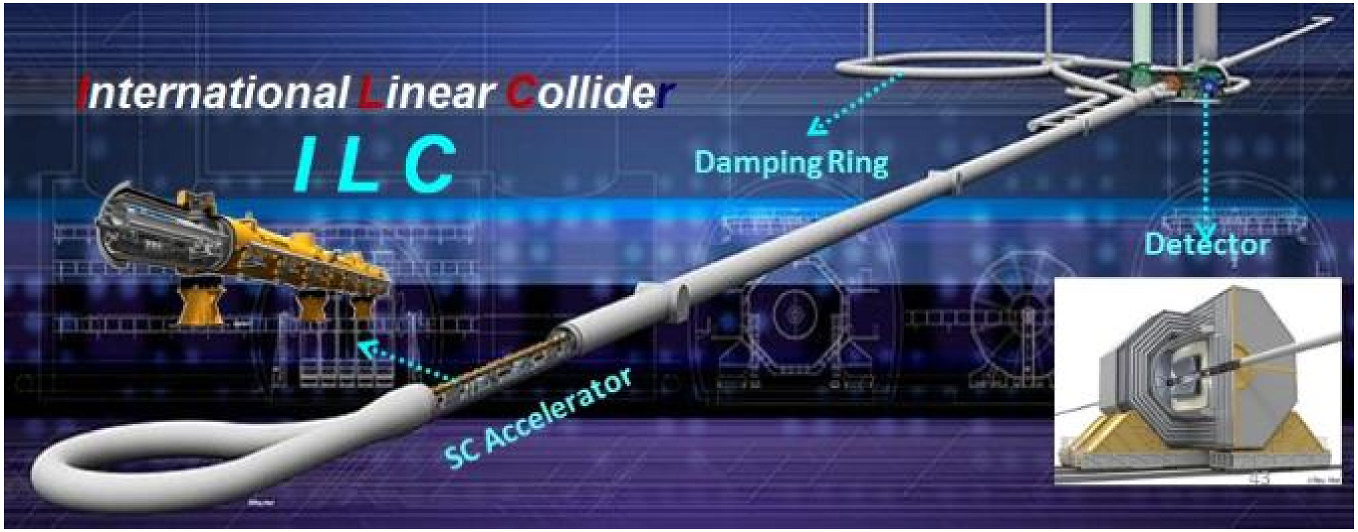
LCWS14 at Belgrade / Serbia

9th Oct. 2014

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

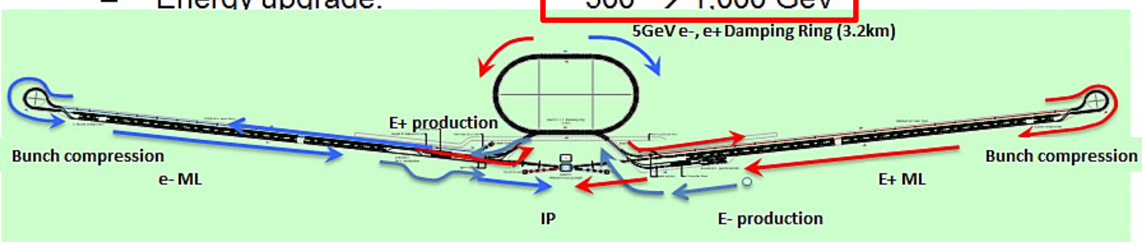
Atsuto Suzuki (KEK)

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

Increase recovery

Obligation to Us

Activities for Green ILC in Japan

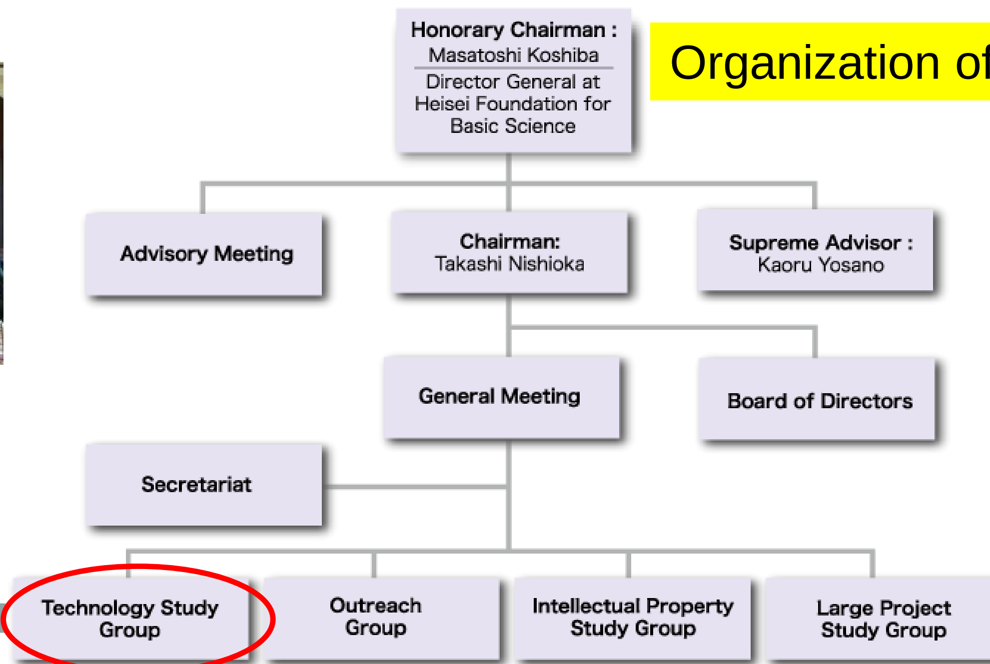
- Three presentations were given (by A. Suzuki, D. Perret-Gallix, and M. Yoshioka) in 2nd WS "Energy for Sustainable Science at Research Infrastructure" at CERN in Oct. 2013.
- A session (four presentations) was organized for Green-ILC activities in LCWS 2013 at Tokyo in Nov. 2013. A. Suzuki also presented 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, 3rd , 4th Green-ILC WG meetings were held on 5th May, 1st July, 24th September 2014, respectively, 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

- 99 corporate organizations involved from industries（MHI, Toshiba, Hitachi, Mitsubishi Electric, etc.) as of Oct. 2014.
- 40 institutional organizations involved from universities and laboratories（KEK, Univ. of Tokyo, Univ. of Tohoku, Univ. of Kyoto, Riken, etc.) as of Oct. 2014.

Organization of AAA



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

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.

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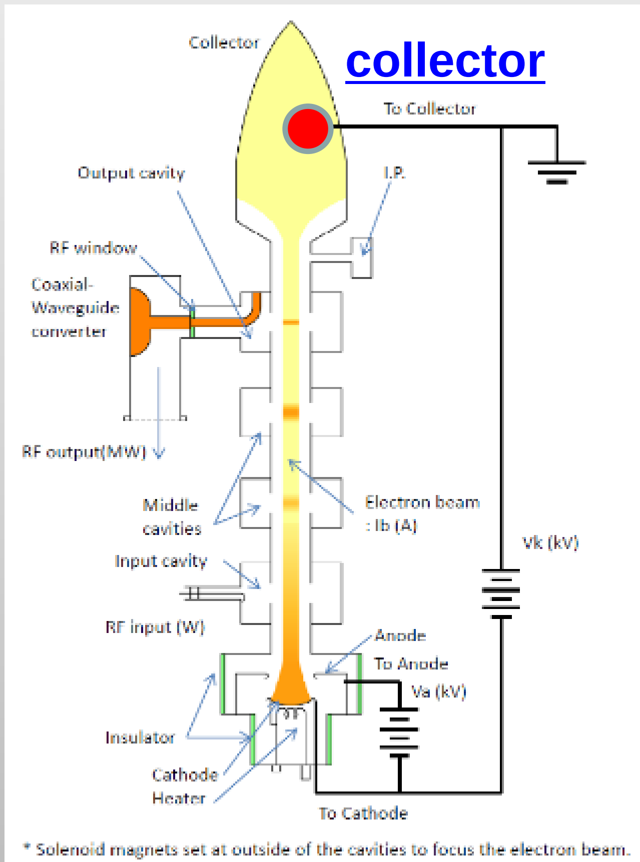
How to Improve RF Efficiency

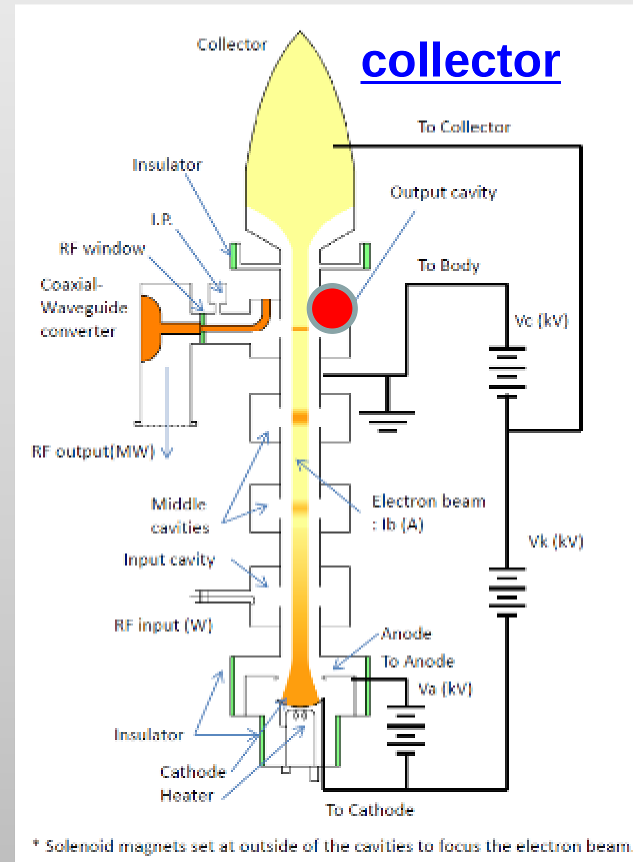
R&D of CPD (Collector Potential Depression) Klystron

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

Conventional



Schematic diagram of CPD



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

Newly fabricated components

- collector
- ceramic insulator
- output cavity
- output coupler

Recycled components

- electron gun
- input cavity
- intemediate cavities

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

Goal : 80 % efficiency

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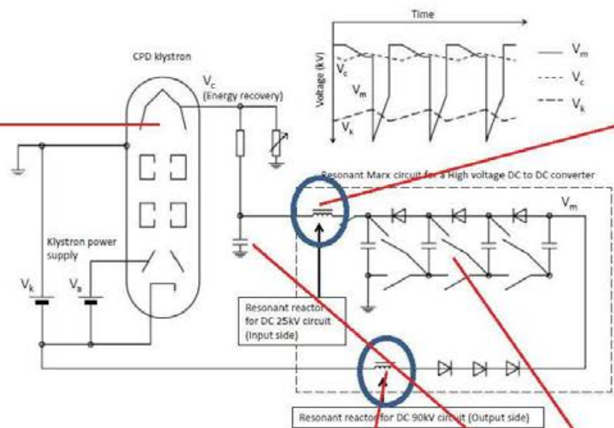
Collector Potential Depression (CPD) Klystron

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)

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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.

Energy recovery in beam dump 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."

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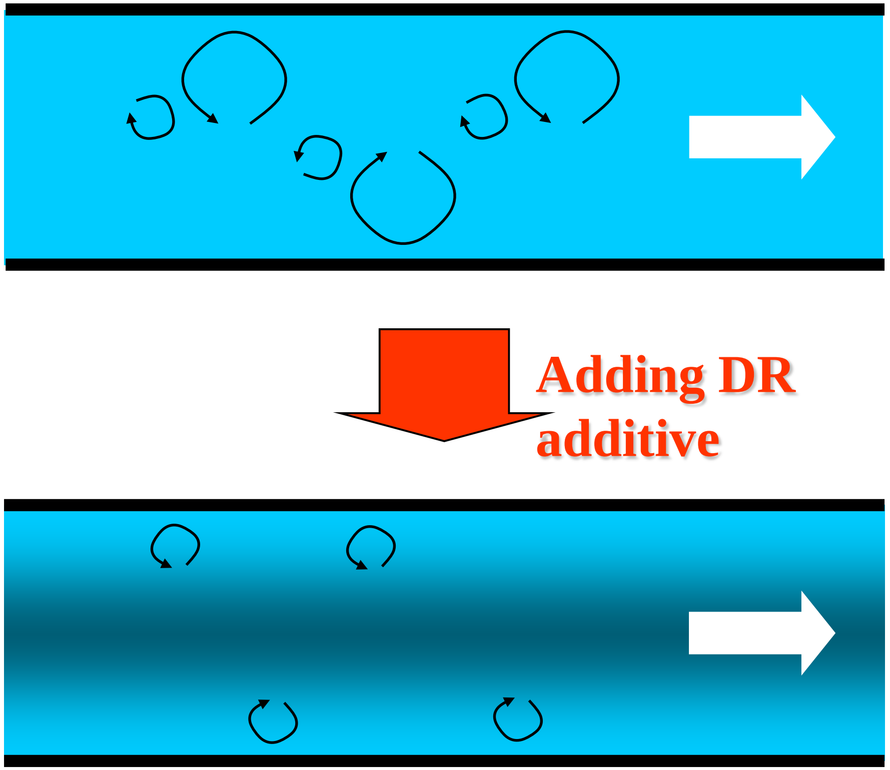
Drag Reduction (DR) Additive in Cooling Water

Effect of DR additive in cooling water

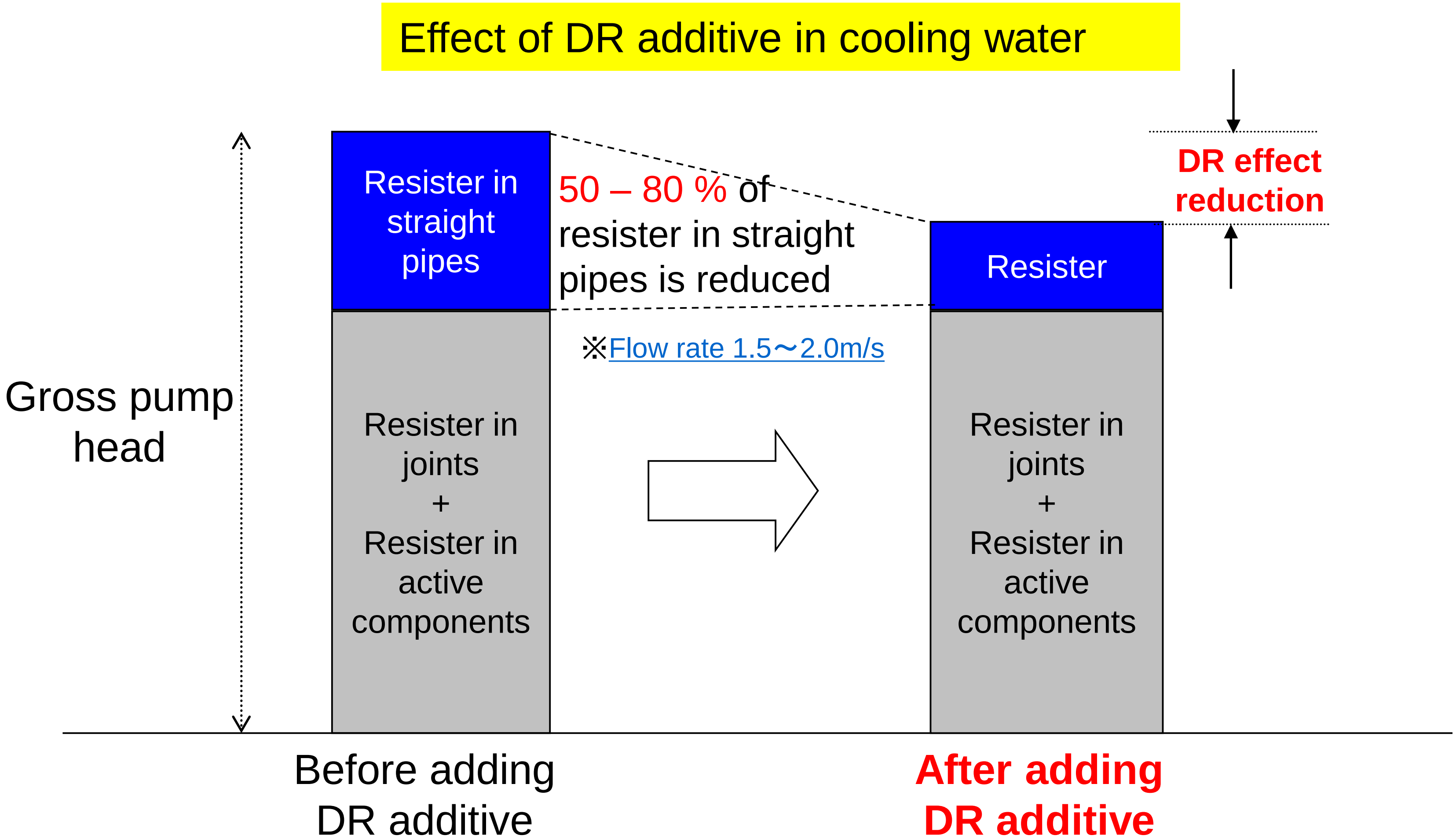
Large energy loss in the cooling water flow



Small energy loss in the cooling water flow

Slide by Shin Nippon Air Technologies Co. Lts.

Drag Reduction (DR) Additive in Cooling Water



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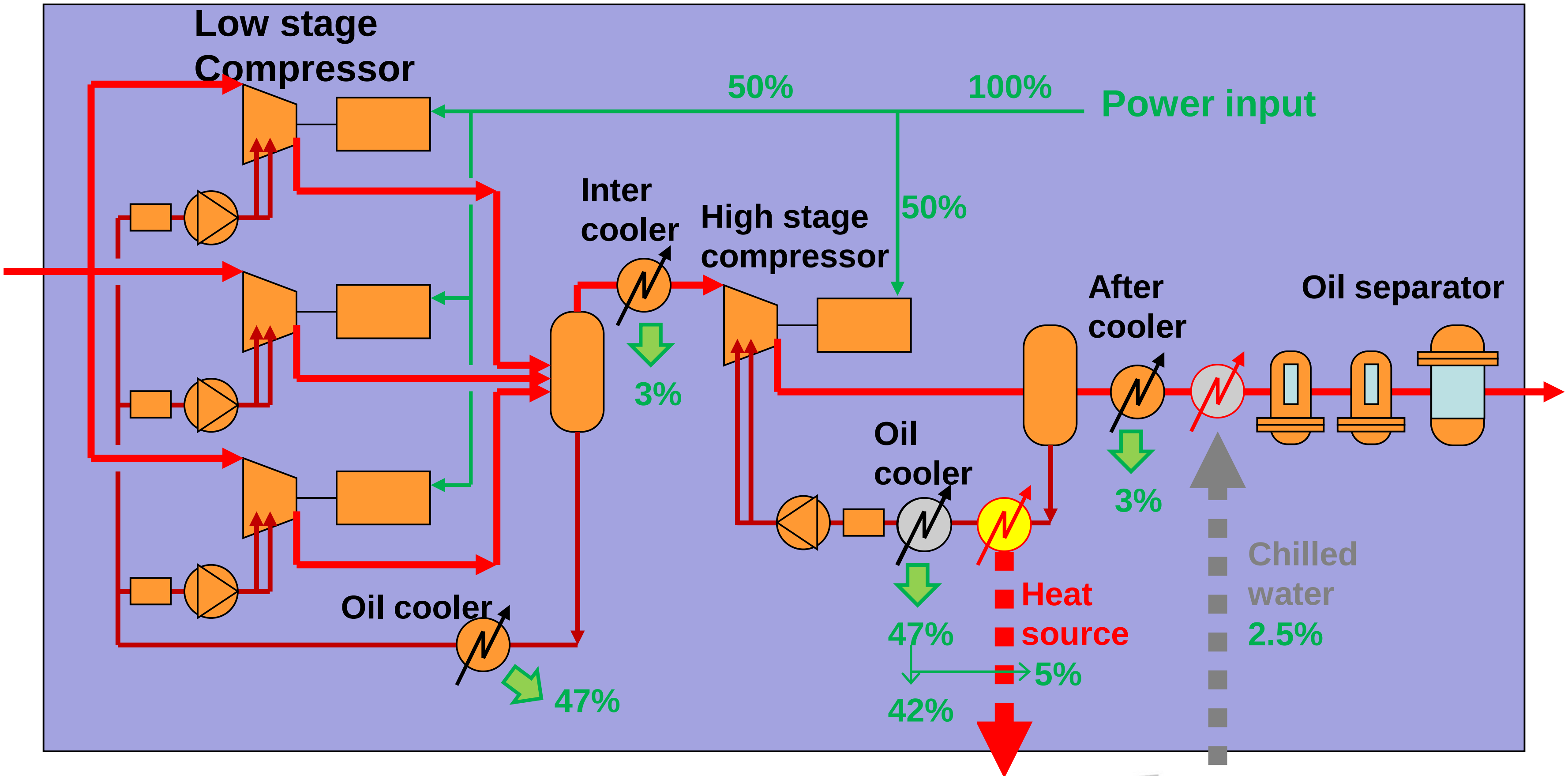
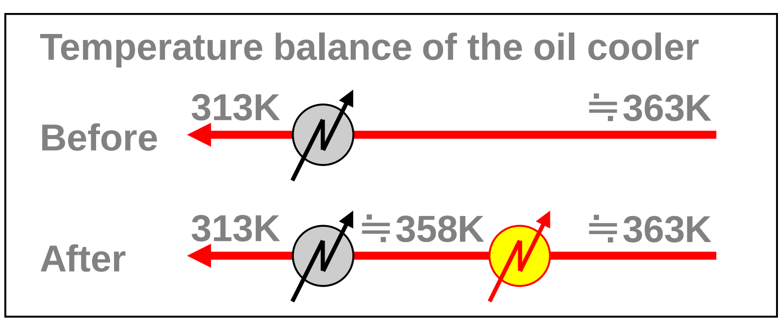
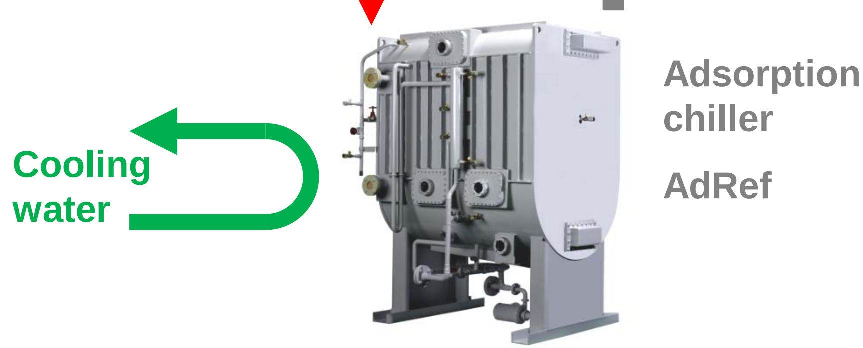
MAYEKAWA

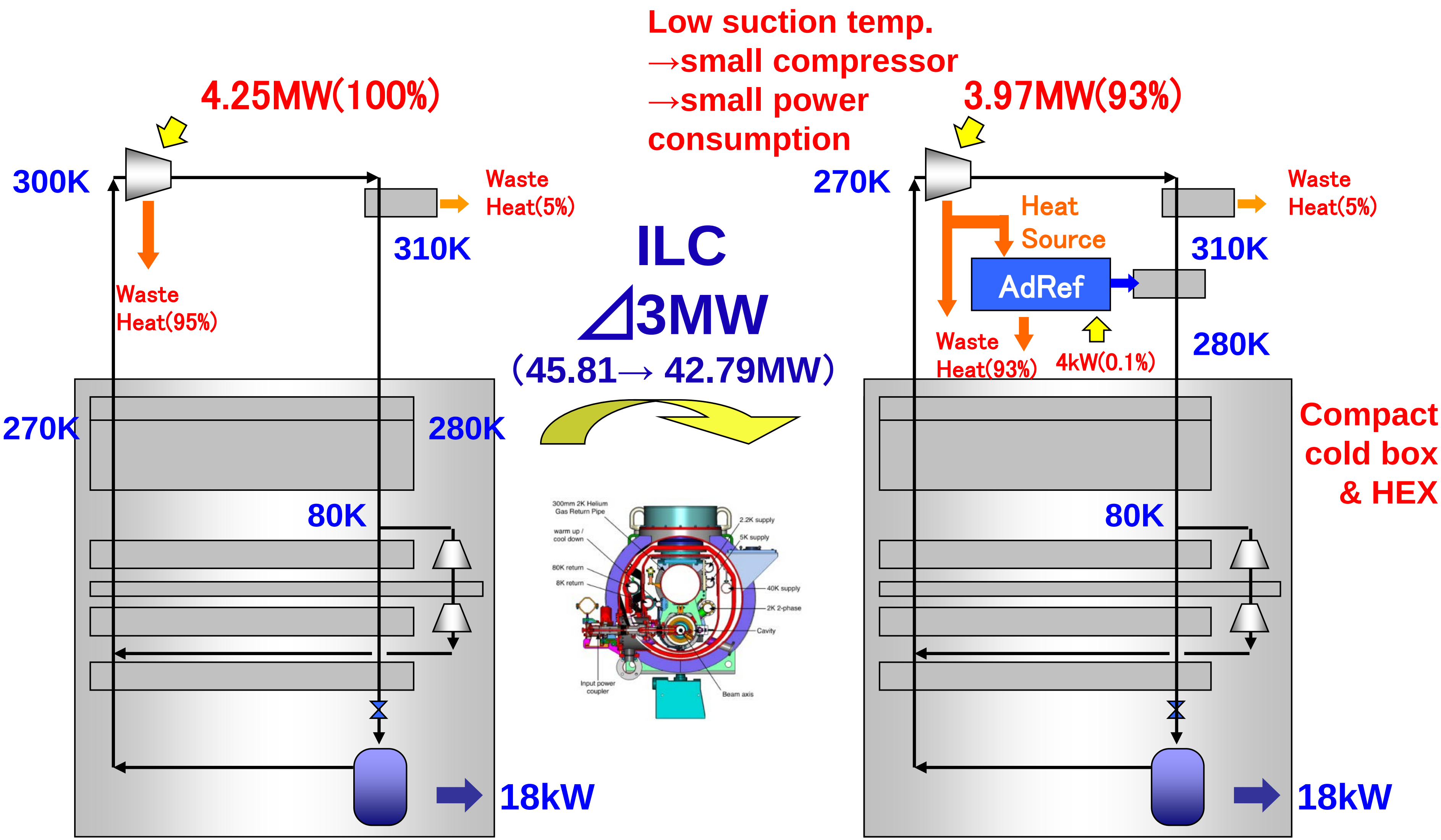
Heat source from the helium compressor







New refrigeration cycle with AdRef



Conventional cycle

New cycle with AdRef

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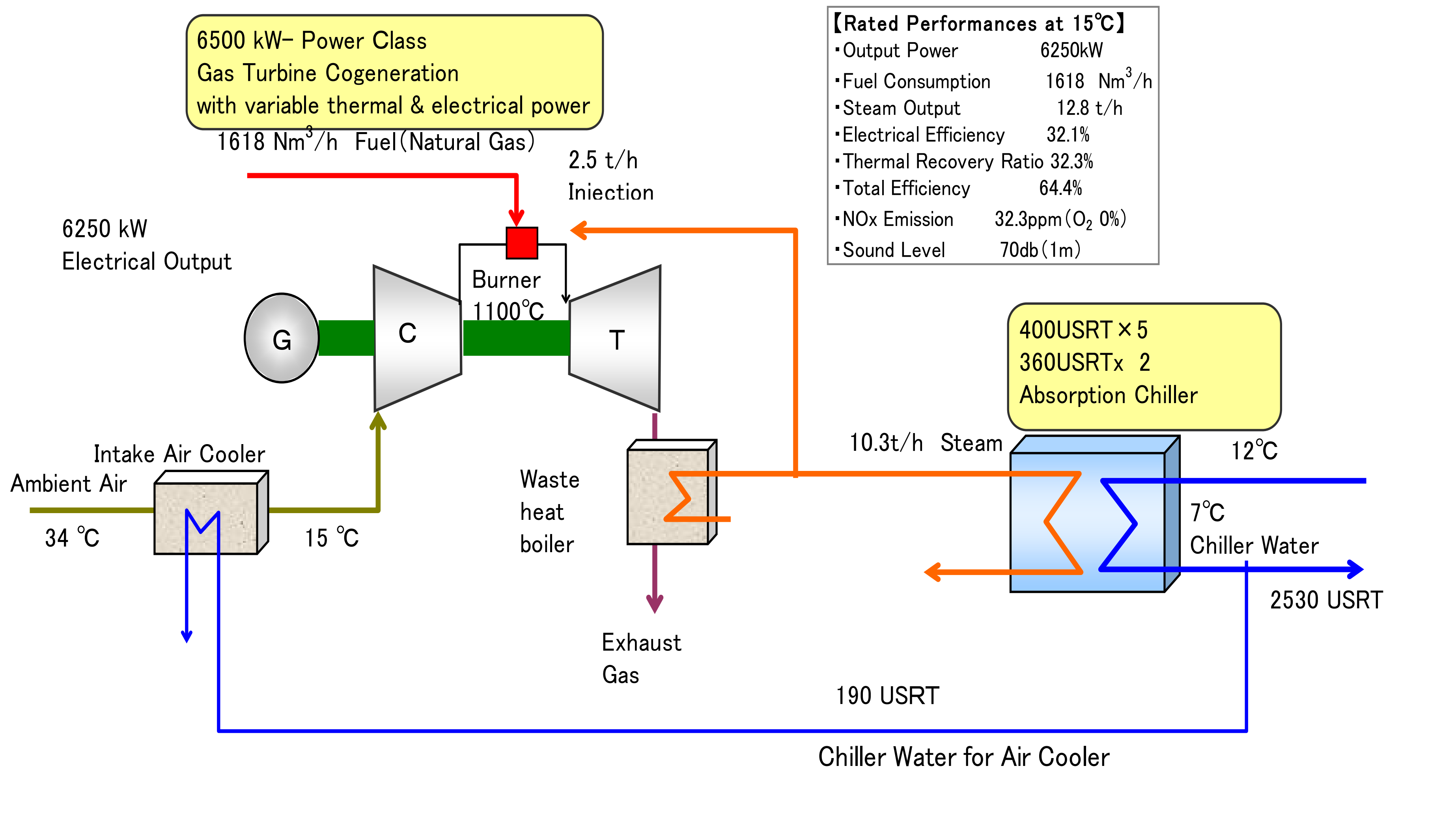
CGS(Co-Generation System) at RIKEN

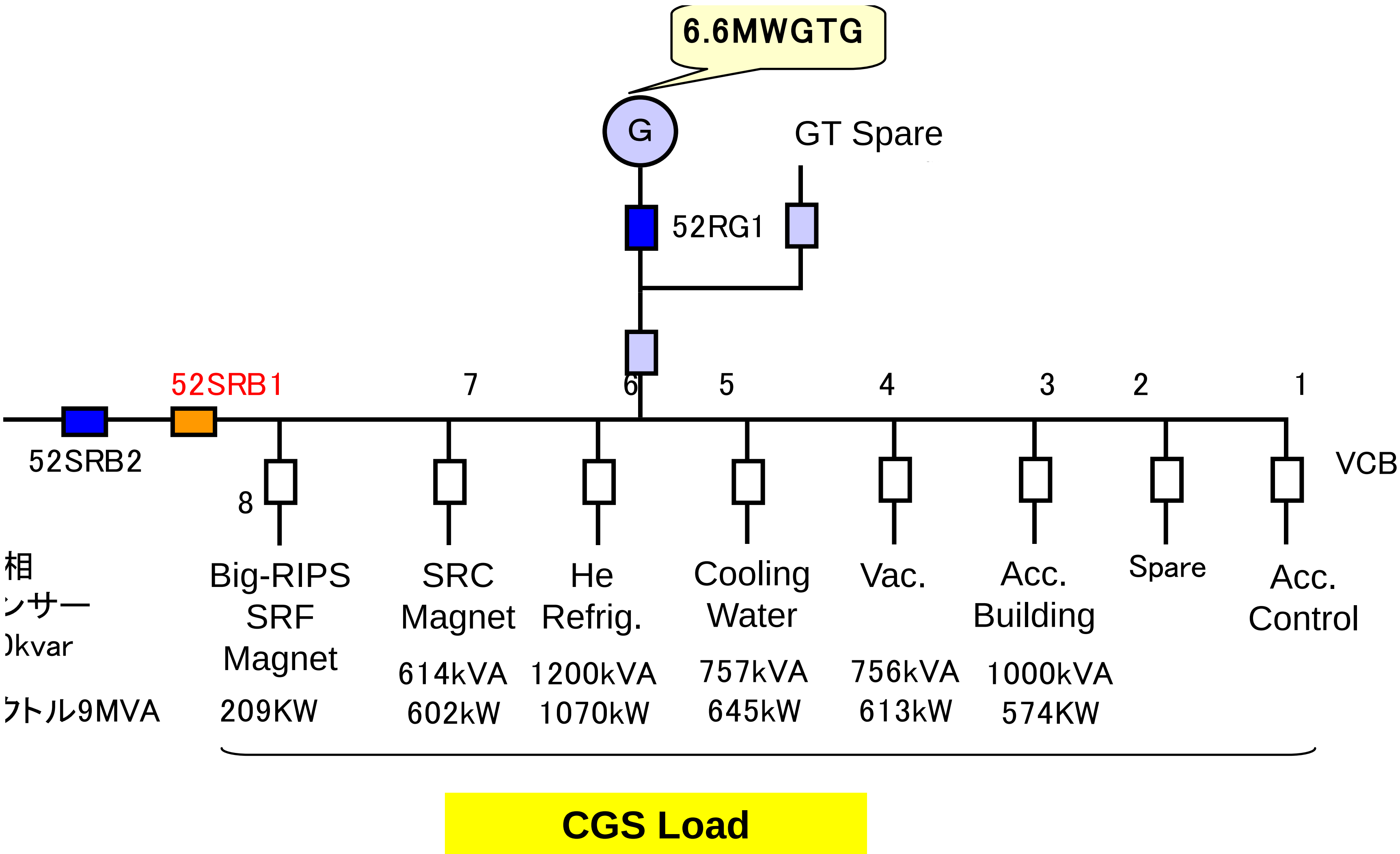


CGS (Go-Generation System) at RIKEN

- 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



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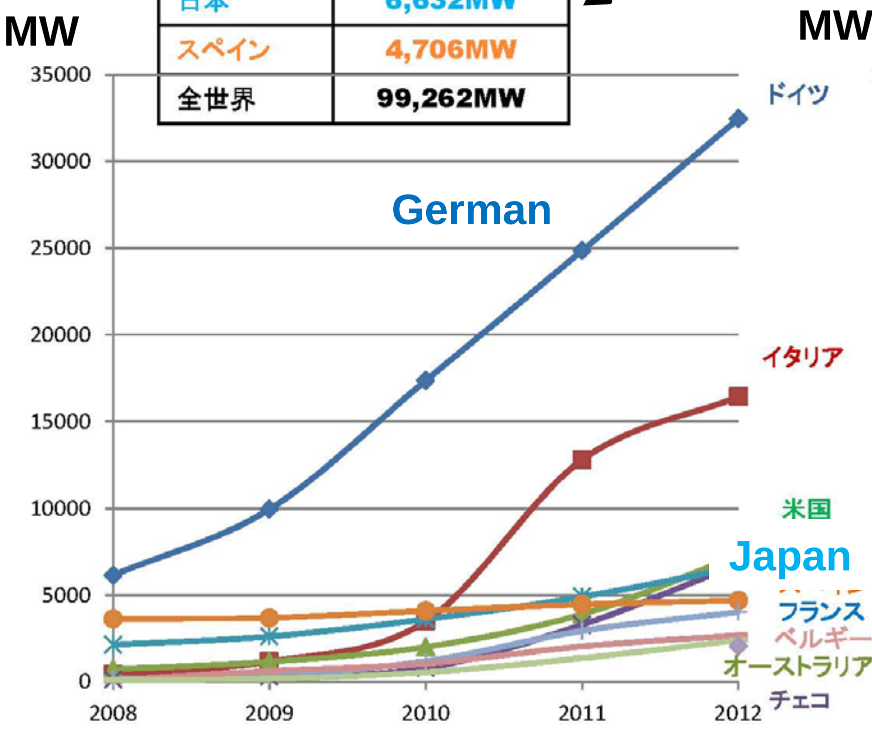
Solar Power Production / Top 6 Countries

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

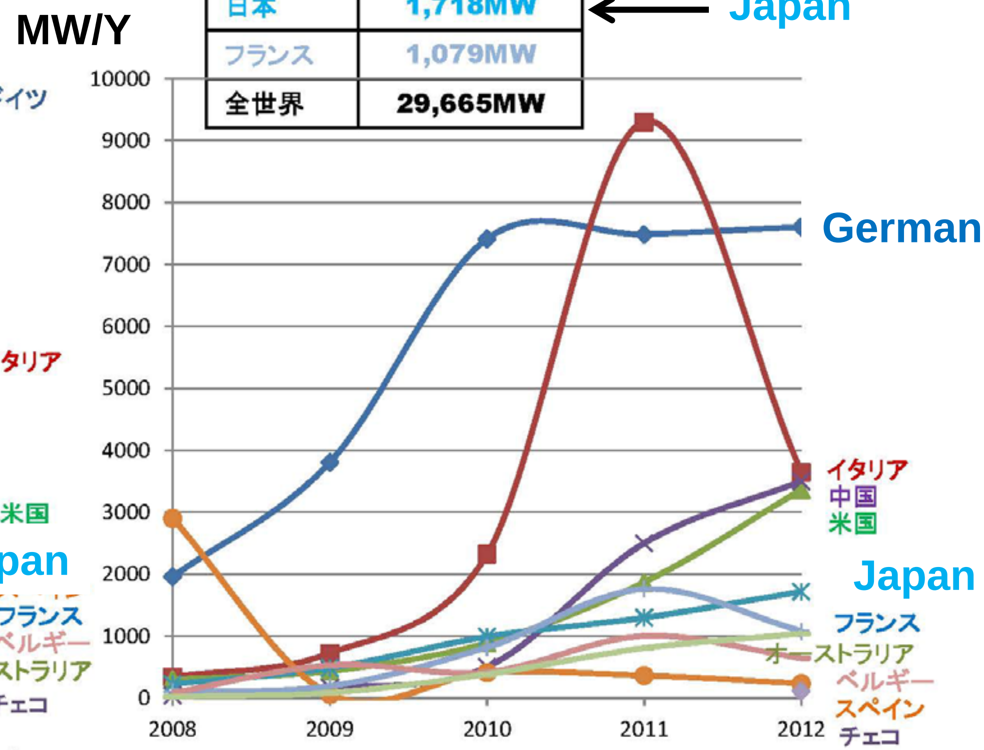


Installation per Year (2012)

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

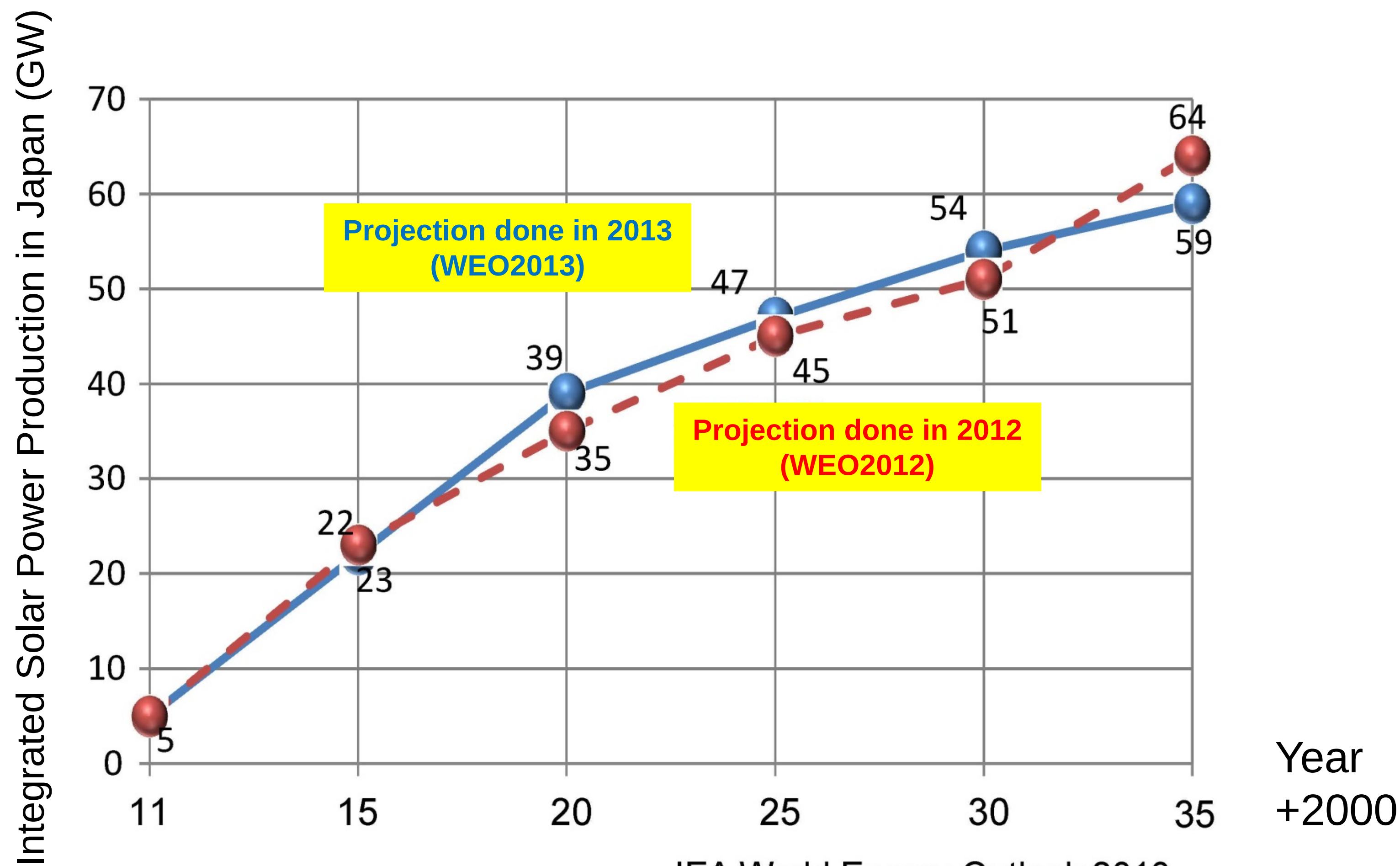
← German

← Japan



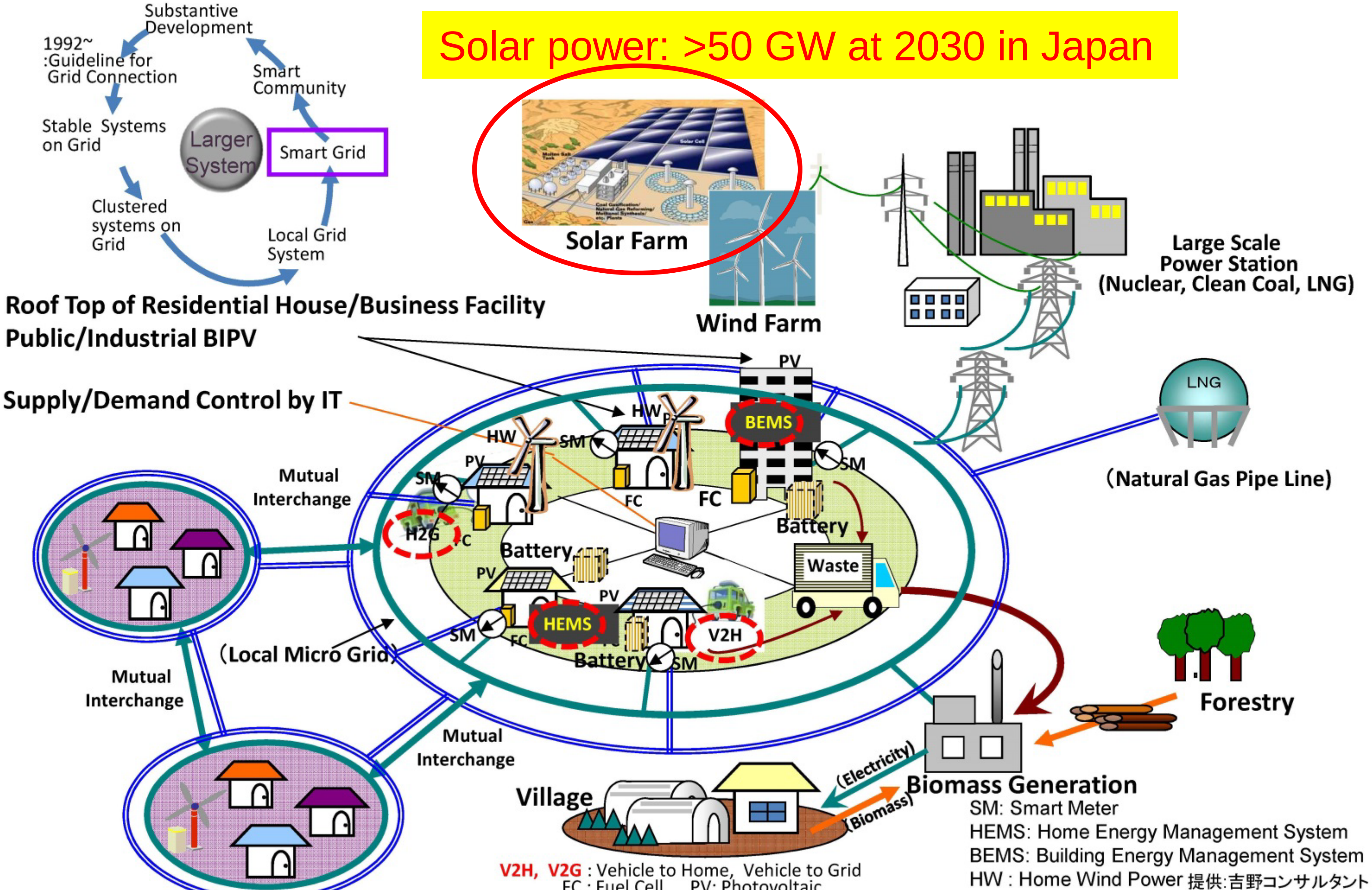
出典：TRENDS 2013 Report IEA-PVPS T1-23:2013

Projection of Solar Power Production in Japan by IEA



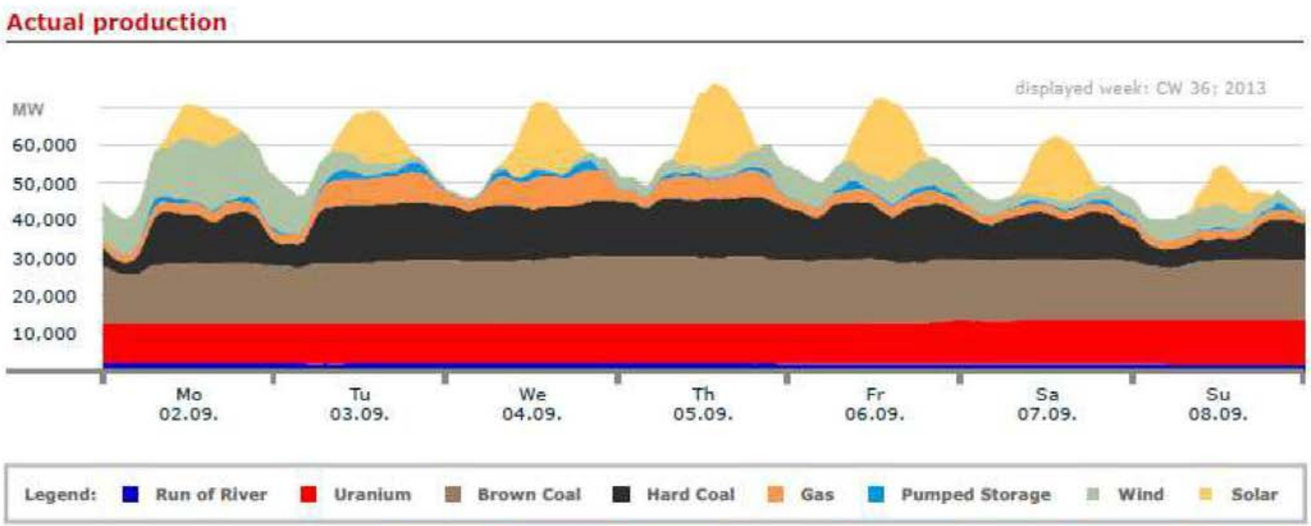
IEA World Energy Outlook 2013

Smart Country by Smart GRIG



Weekly Production in Germany (2012)

Electricity Production in Germany: Calendar Week 36



	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

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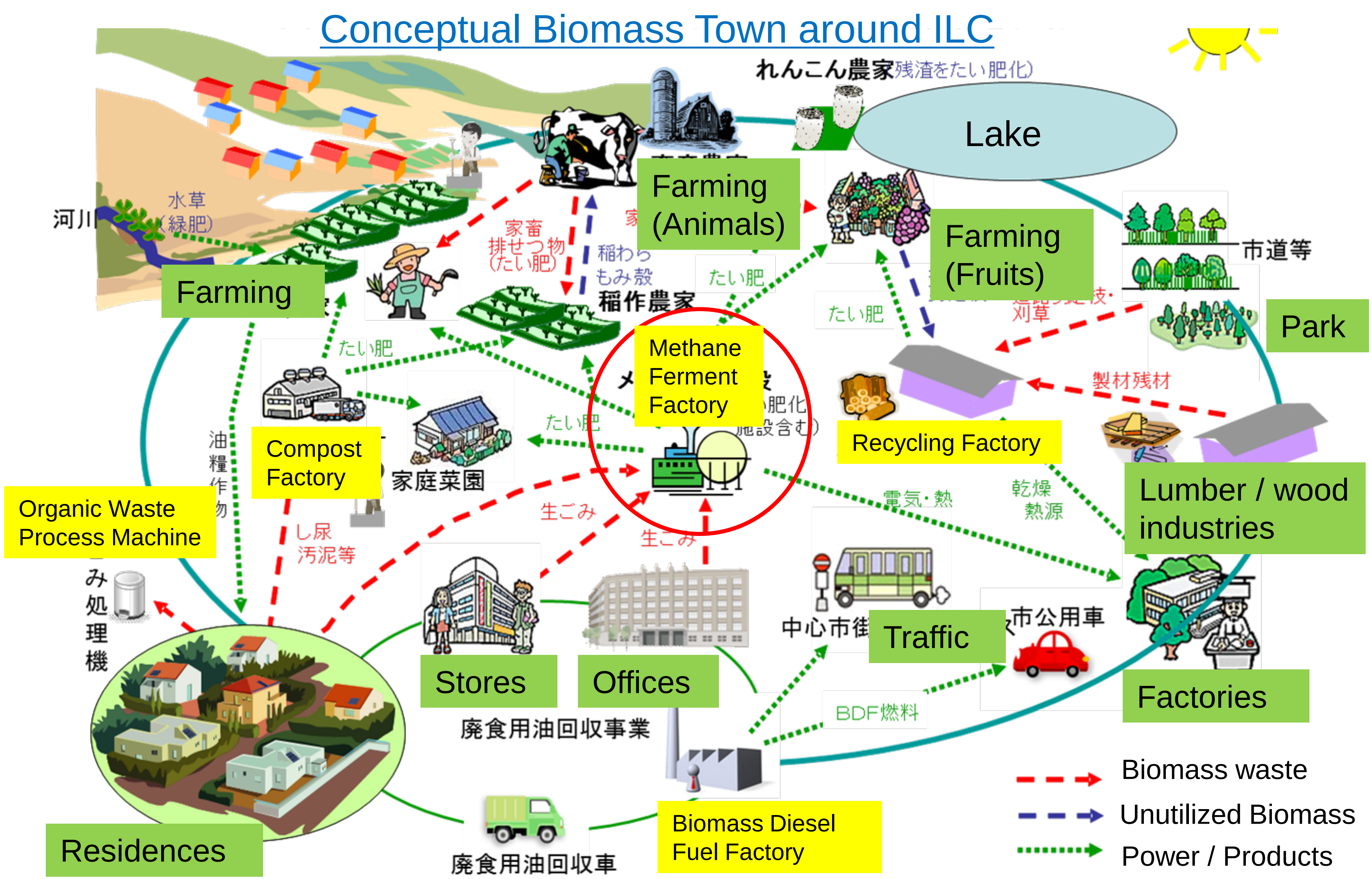
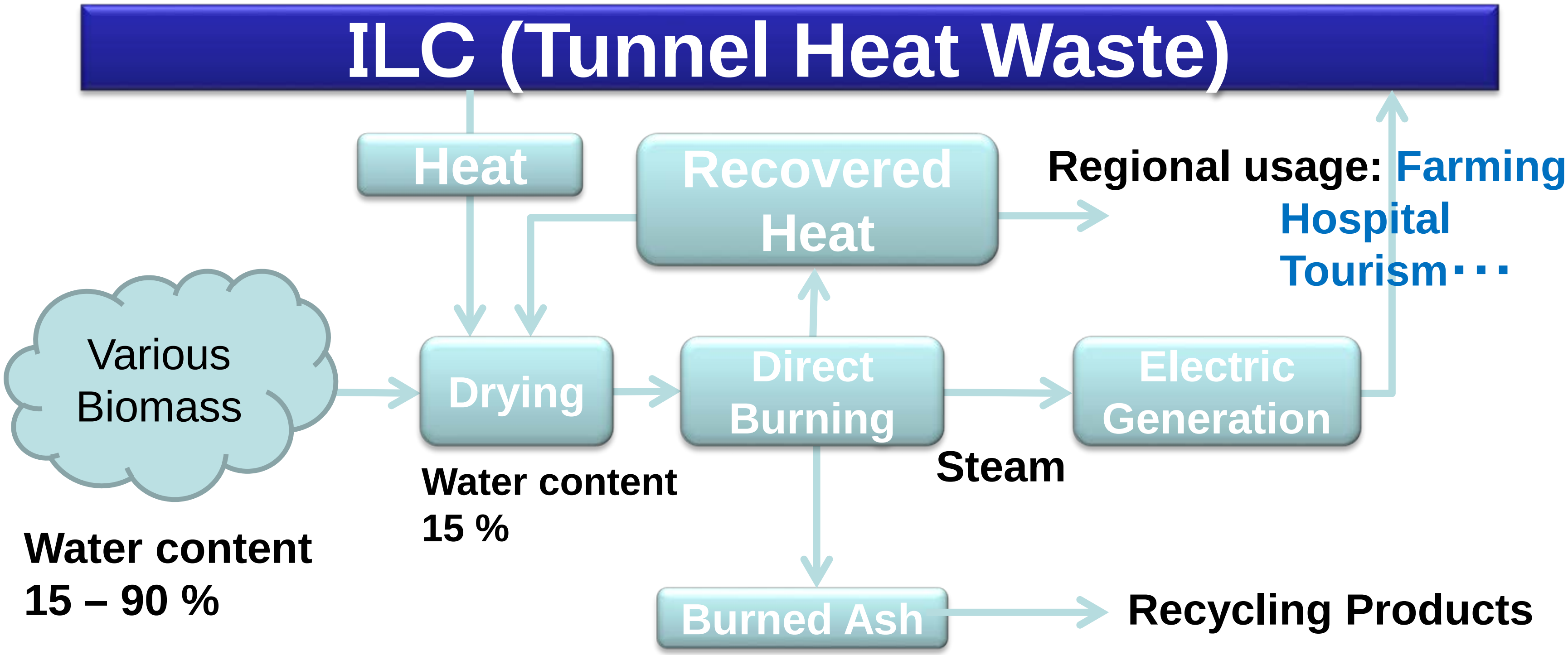
Biomass Power Plant using Organic Waste



出典:土浦市バイオマスタウン構想書

❑ 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

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.
- The energy-saving technologies discussed in the Green-ILC-AAA meetings are ranging from the components, sub-system, ILC-system, and ILC-city.
- Proposed items for Green-ILC energy-saving technologies will be summarized and written in the report under the framework of AAA in the year of 2015.

ILC center futuristic view

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

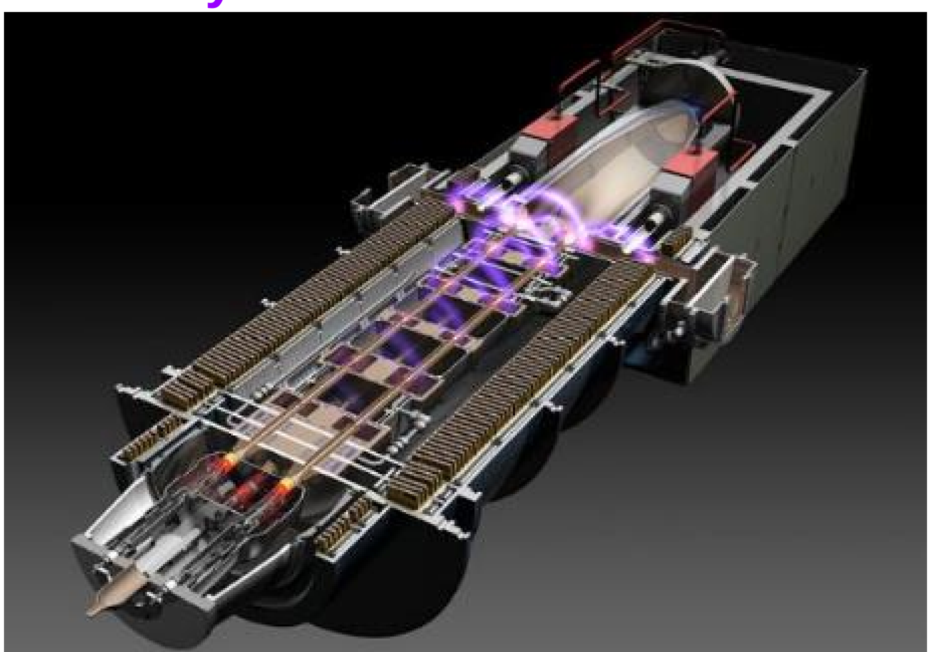
Backup slides

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

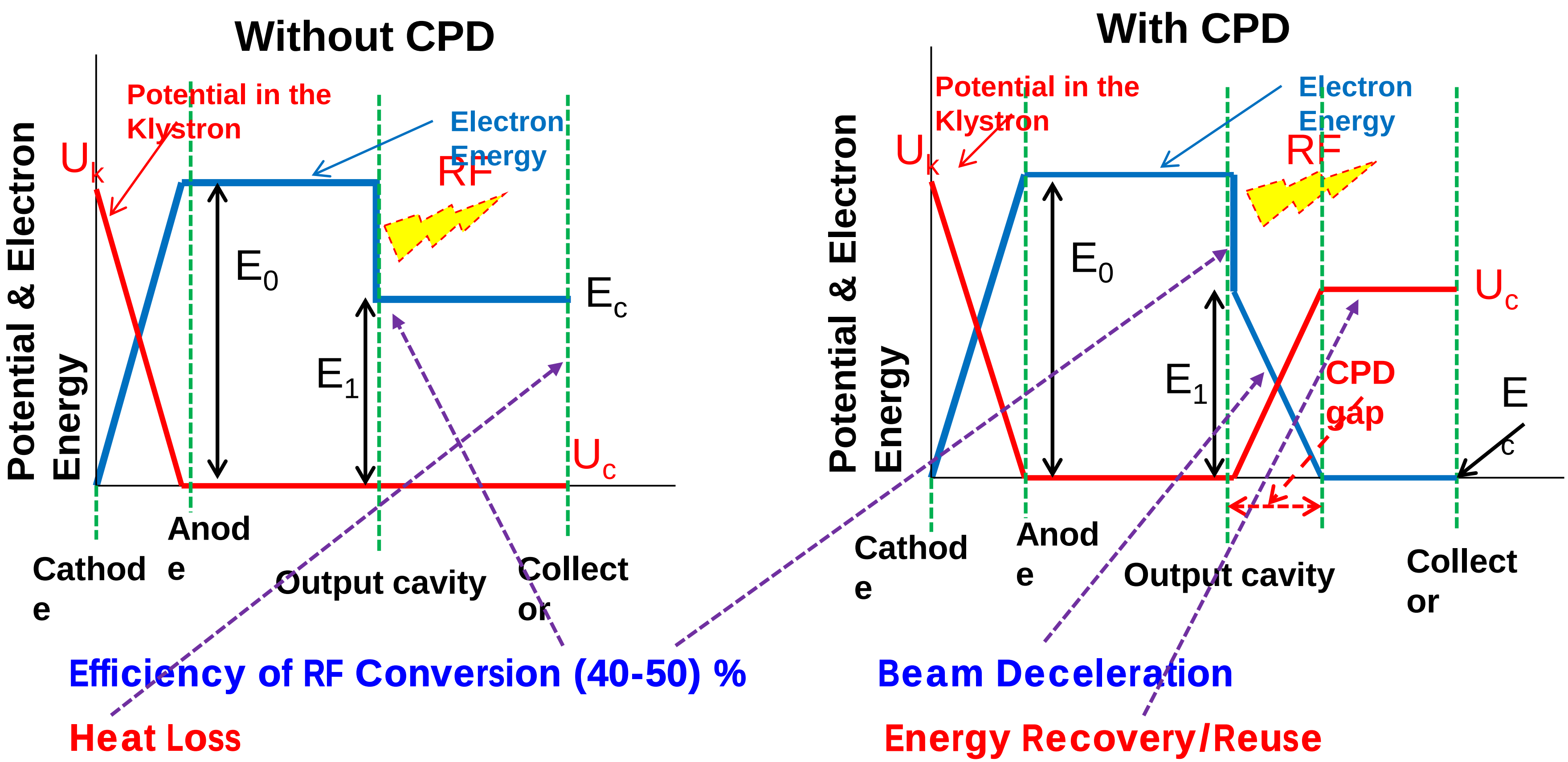
- **The design goal is to achieve 10 MW peak power with 65 % efficiency at 1.5 ms pulse length at 10 Hz repetition rates.**
- **MBK has 6 low-perveance beams operated at low voltage of 115 kV for 10 MW to enable a higher efficiency than a single-beam klystron.**



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

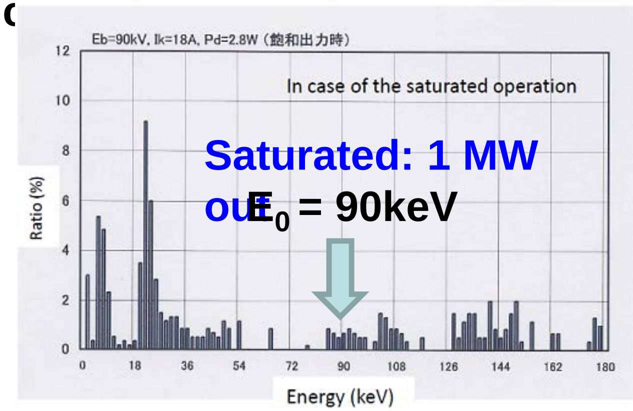


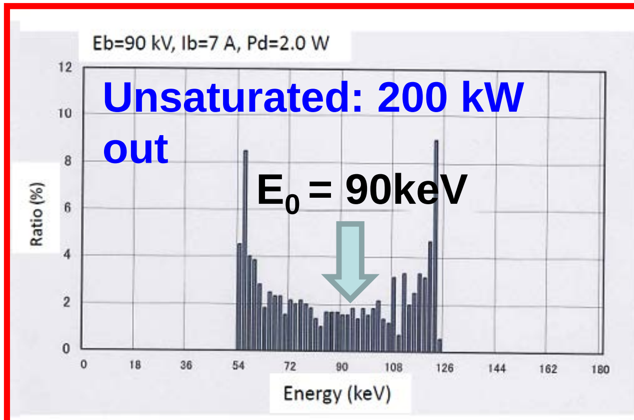
Potential denotes the electron potential energy, eV. For simplicity, input and intermediate cavities are omitted here and the anode potential is set to zero.

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 performance.





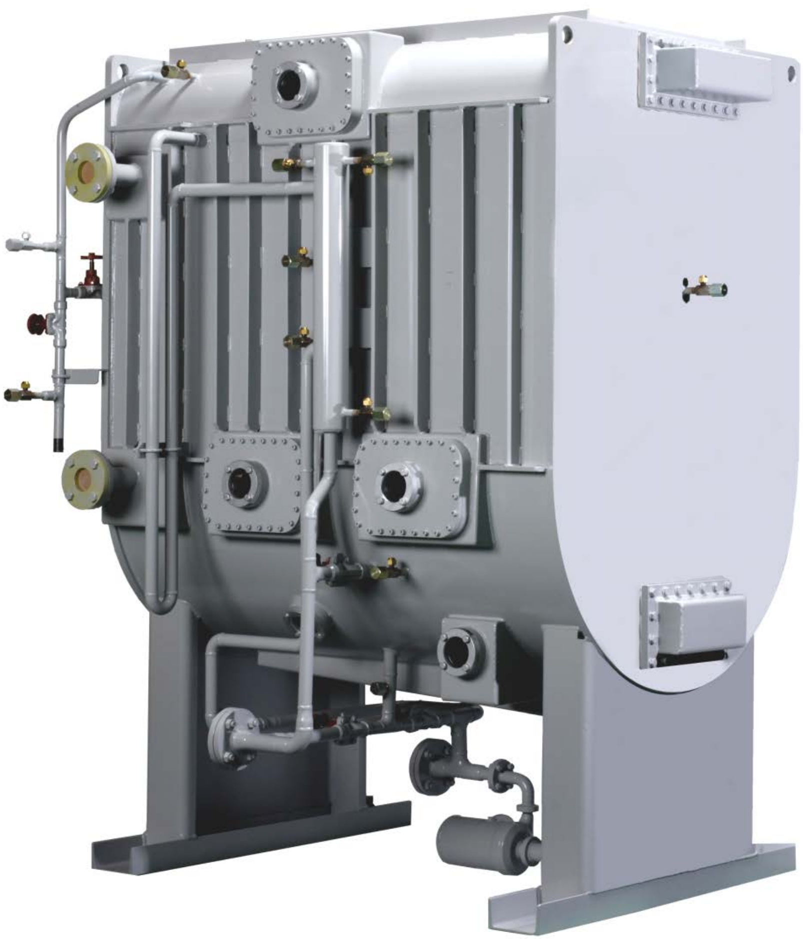
(II) Pulse-to-DC conversion

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.

Adsorption chiller "AdRef"



Environmentally Friendly Chiller.

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

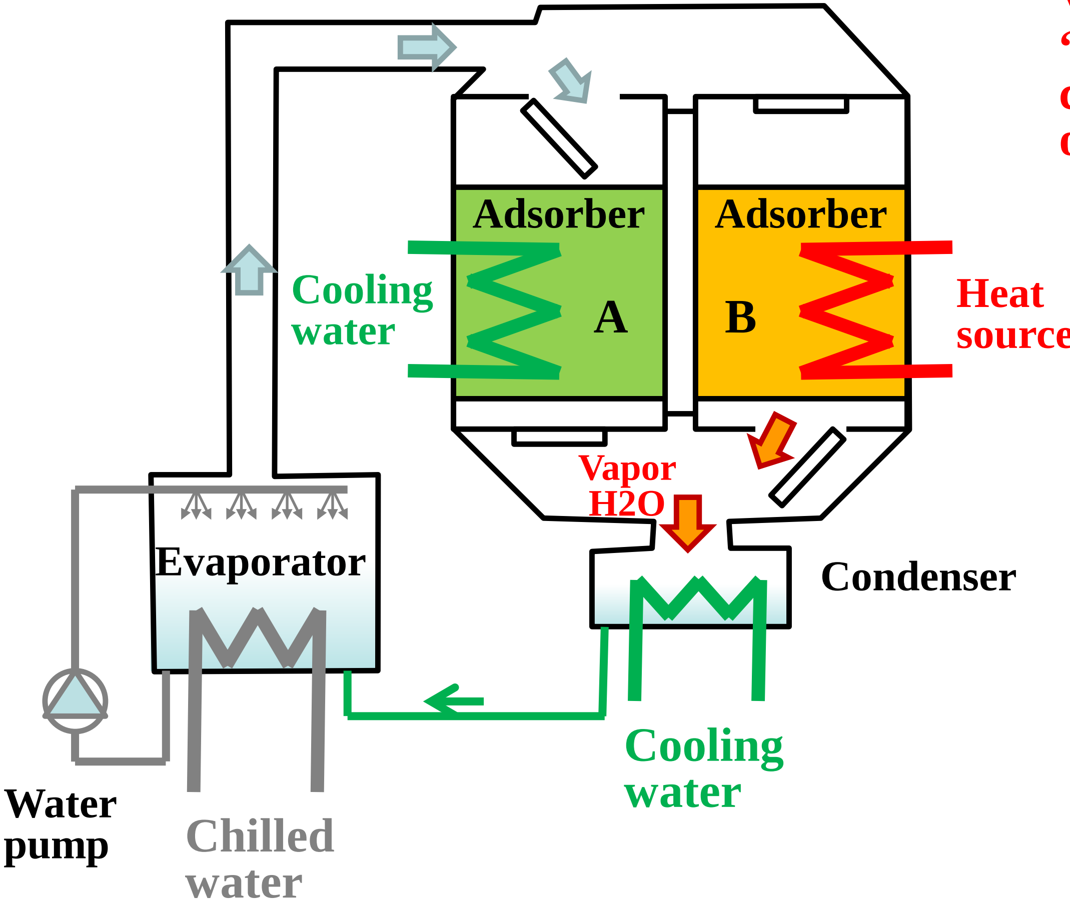
4. Easy maintenance

   Very few moving parts used.

5. Safe

   No pressure piping or refrigerant

Adsorption chiller “AdRef”



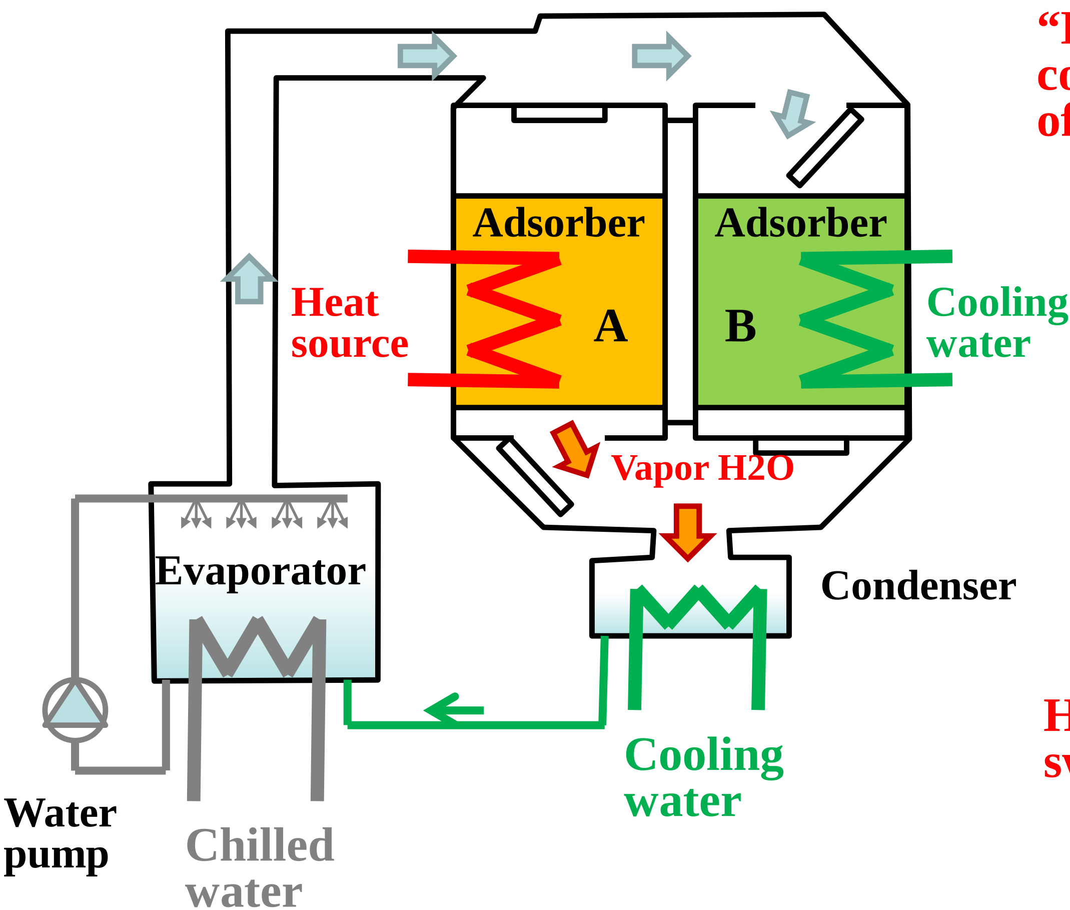
Vapor H2O is removed from adsorber “B” by heating with warm water, and condensed in the condenser by the cool of cooling water.

Liquid water goes to the evaporator.

The adsorber “A” adsorb vapor H2O by cool of cooling water.

Then the liquid H2O 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).