# 6 Installation of Renewable Energy into Accelerator

## Examples of New Energy Power Plants for the Green ILC

(Tadashi Fujinawa, Riken)

1.Abstract

Construction of the International Linear Collider (ILC) in Japan will soon begin. This facility will be very large, so it will also consume considerable energy. It will operate continuously for 7,000hours per year. Thus, it is necessary not only to consider how to save energy, but also to introduce new kinds of energy, including renewable energy, for use in the ILC.

The government declared that renewable energy should account for between 23% and 25% of all electrical energy sources in 2030. However, renewable energy sources currently provide only 10% of all energy. A large portion of those sources are hydro-powered, but no suitable locations for additional hydro-power generation remain.

In this paper, forms of renewable energy that could be developed for ILC use will be described, namely, solar energy, wind energy, geothermal energy, hydraulic energy, biomass, and thermal energy obtained from a temperature difference or thermal recovery.

2.Solar cells (photo-voltaic systems: PV systems)

Solar power stations are among the easiest renewable energy systems to build, in contrast to wind power generators and geothermal power stations. However, PV systems are not reliable or stable power sources.

In this paper, we will discuss the solar park for the Green ILC (design date supplied by UNISUN JAPAN). The AC output capacity will be 200MW, and the DC capacity at installation will be 220MW. A similar plant is shown in Fig. 1.

The inverter will be a TMEIC 1500kW (750kW x 2)/unit. TMEIC has the largest market share in Japan at more than 70%, as well as more than half of the global share.

The output voltage will be 22kV, and the solar panels will each generate 265W.

A one (1) MW solar power station requires 15,000m$^2$ of land. The basic design is as follows.

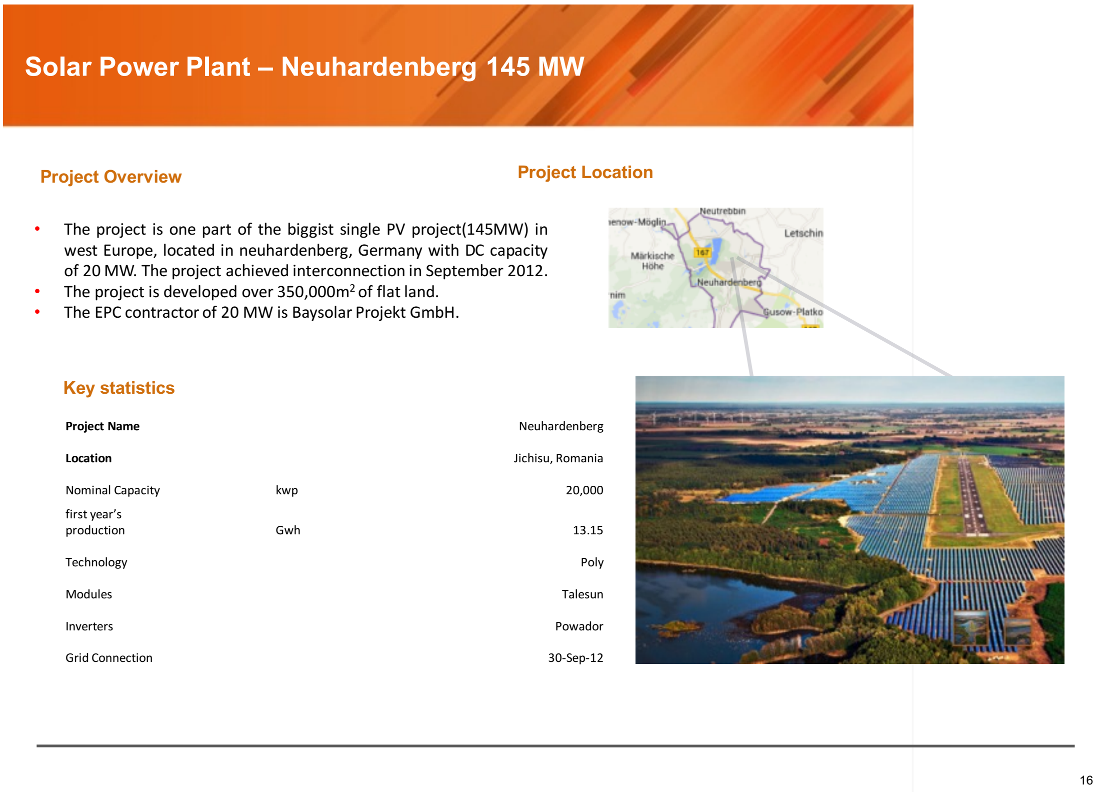



Fig. 1 One of the largest solar plants, generating 145MW (Germany) and presented by UNISUN JAPAN.

Required land area: 15,000m$^2$/MW x 220MW = 33,000,000m$^2$ (3,300ha). This area corresponds to dimensions of 150m × 22,000m and does not include the 22kV/154kV substation and control building.

Array design: 23 panels/string, 6.095kW/string

Solar panel quantity: 220,000kW ÷ 6.095kW/string = 36,095 strings

36,095 strings × 23 panels/string = 830,185 panels (219,999kW)

In the subsequent discussion, the following symbols are used: $V_{oc}$ (open circuit voltage), $V_{mp}$ (maximum peak voltage), $I_{sc}/A$ (short-circuit current), and $I_{mp}/A$ (maximum peak current).

The reasons for choosing 23 panels/string are as follows, considering that we will use a JA solar JAM6 (BK) 60-265/SI, which has $V_{oc}$ = 38.3V at 25°C and $V_{ppm}$ = 31.1V at °C. In the case of 23 series, 984.7V < $V_{oc}$ < 1000V at -10 °C and 554.2V > $V_{ppm}$ > 540V at

80°C.

3,960 panels ÷ 23 panels/string = 172 strings

172 strings × 9A ($I_{sc}/A$) = 1,548A

1,548A ÷ 16 feeders = 96.75A/feeder

Please refer to page 6 of the GO-A5ES-2014-001-A specifications.

The rated current of the power fuse is 160A, and the recommended current is 102A (160 ÷ 1.25 ÷ 1.25 = 102A), according to NEC690.8 (US electrical STD).

97A < 102A

The actual current is 11 parallel/box × 15 array boxes + 7 parallel/box = 16 incoming for one 750kW inverter.

∴ 11 × 9A = 99A

99A < 102A

The required number of inverters is as follows: 200MW ÷ 1.5MW/inverter = 133 inverters.

Local governments will be essential in building such immense solar parks. These power stations should be built on the ILC grounds by a business partnership, and the land should be supplied by the government for this enterprise. The company will pay taxes as well. In case the land is farmland or is protected forest by law, the local government will provide the necessary documentation and change the land category so that the power station can be built.

All of the generated power will be consumed by the ILC, and therefore no transmission capacity issues will occur. Tohoku-epco claimed that solar power will overflow sooner or later; however, their estimate assumed that all solar parks approved by the Ministry of Economy, Trade and Industry (METI) would generate power.

All of the nuclear power stations (NPSs) shown in Table 1 are operable. METI estimates that only 40% of approved solar parks will actually be commissioned, while the other 60% will be given up for some reason. The NPSs in Table 1 are all boiling water reactors (BWRs), which is same type of NPS as the Fukushima Daiichi NPS. Furthermore, some of them are very old, and therefore it would be quite unlikely for them all to be simultaneously operable before they are decommissioned. Thus, it can be concluded that Tohoku-epco's concern is needless.

The key is that local governmental support is necessary for this type of renewable energy system to be implemented. The land should be free, not only that used for the ILC main body, but also that for the Green ILC power stations. The government will perform all necessary legal work, such as changing forest land or farmland to miscellaneous lands.

As mentioned previously, there are no transmission capacity issues since the ILC will consume all of the generated power.

STEP3：検討断面における出力の想定：原子力 NPS p 6

安定供給のためには，ベースロード電源を一定量確保することが必要

↓

長期的な傾向を反映することとし，震災前過去30年（30年経過していない場合は運転開始後の全期間）［昭和56年度～平成22年度］の設備利用率平均を用いる 30 years capacity factor (CF) as average

| 原子力 Nuclear Power Station | |
|---|---|
| 供給力（万kW） Available Capacity (10kMW) | ※ ２３４．９ |
| 設備容量（万kW） Installed Capacity (10kMW) | ３８９．３ |
| 利用率（％） Capacity Factor (CF) | ６９．８ |

※ 福島第二は，東京電力の「新・総合特別事業計画」においても今後の扱いは未定としており，地元のご意向も踏まえて，接続可能量を算定する供給力には織り込んでいない。
仮に稼働した場合には，連系線に新たな南向き空き容量を確保できるため，その分を活用すれば，接続可能量には影響しない。 Fukushima Daini #3 & 4 are not include the capacity.

| 設備一覧［受電分］（10 MW） | | |
|---|---|---|
| 東通 | ５７．０ | Higashidori |
| 女川１ | ５２．４ | Onagawa |
| 女川２ | ８２．５ | |
| 女川３ | ４２．８ | |
| 柏崎刈羽１ | ５２．６ | Kashiwazaki Kariha |
| 東海第二 | ２１．１ | Toukai Daini |
| 大間 | ２８．１ | Ohma |
| 福島第二３ | ２６．４ | Fukushima Daini #3 |
| 福島第二４ | ２６．４ | |

Table 1. Nuclear power stations related to Tohoku-epco.

Concerning the economics, the feed-in tariff (FIT) price for solar power will be ¥27/kWh after June in FY2015. The FIT price has decreased from ¥42 in 2012 to ¥36 in 2013, ¥32 in 2014, and ¥29 until the end of June this year, after which it will be ¥27/kWh. In this paper, we will assume ¥20/kWh as the FIT price. The sunshine time in Iwate Prefecture is 1,888h/year, corresponding to a power generation of 234,110 MWh/year and an output price of 4.7 billion ¥/year. The Green ILC utility company will sell all of the power to Tohoku-epco, and about 10% of the income will be donated to the ILC. After the FIT has been paid off, control of the power plant will be transferred to the ILC, and thereafter, the ILC will be able to obtain free electricity for about 1,250 h/year.

The other government support requested of the METI Sendai office is that the licensed electrical engineer will maintain both the ILC and the Green ILC. Since the Fukushima Daiichi NPS disaster, there has been a heavy shortage of licensed electrical engineers.

3.Wind power generation

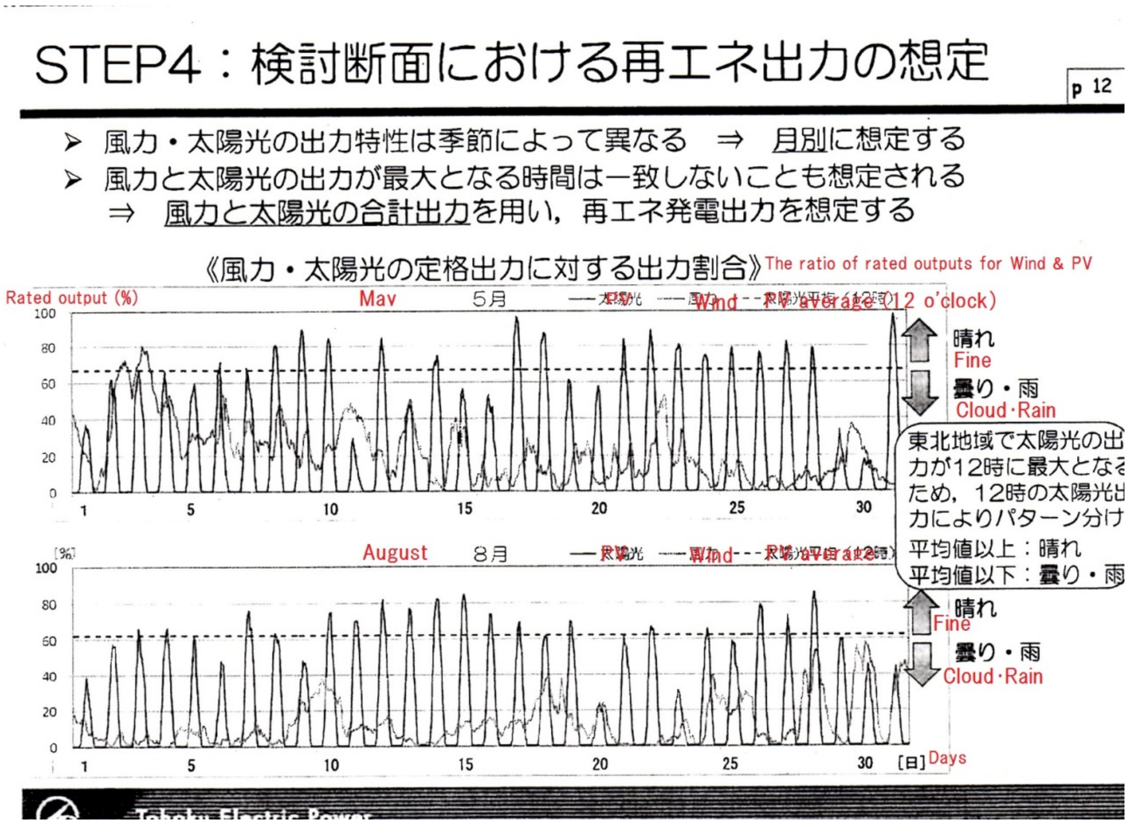
In the early stages of Japanese wind power generation, power stations were constructed by local governments with imported turbines. However, they did not well endure Japanese weather, and almost all were retired. The Japanese weather phenomena and problems that affect wind power are as follows.

1) The direction of the wind changes many times per day. For example, there may be sea breezes in the morning and mountain winds in the evening. Furthermore, mountain sides have irregular air flows.
2) Wind power generation requires an average wind speed of 6.5m/s. It is quite difficult for humans to live in locations that meet this requirement, so no access roads or transmission lines are available. Thus, utility costs will be high without a generator system. For instance, the Chiba Marine field is famous for its strong winds, and this baseball park has the only wind speed meter in Japan. However, the strong winds that are present at the ball park are not usable for power generations, as the winds that are defined as strong at this location only measure 3–4 m/s according to the wind speed meter. Figure 2 shows the Chiba Lotte Marines field.

Fig. 2 Home ground of Chiba Lotte Marines (QVC Marine field)

3) If people live nearby, low-frequency noise must be considered.
4) Typhoons and/or tornados generate winds over the design speed.
5) In Japan, thunderstorms occur more often than they do in other nations, and lightning may hit the turbine blades.
6) The center line of a turbine shaft is located very high (50–100m), making it difficult to maintain and repair.
7) Assessments of bird strikes and other environment factors take time (more than three years). Thus, it is difficult to judge whether or not to invest.

Even though there are many difficulties involved in wind power station construction, if locations are available that will yield more than 2MW/unit of power generation and if there is strong support from the local government, it is possible to build such stations. In addition, the FIT of ¥22/kWh will be maintained for 20 years, and according to Tohoku-epco, the peak power times of solar and wind power are different (Graph 1), so both generation systems can use same transmission lines and same locations. Thus, if a 200MW solar park is constructed at the ILC, then 72MW of wind power can be generated also. In this case, one generator unit would yield 6MW, which would be the greatest power generation in the world for a single unit. A total of 12 generator units will be located at the north end of the solar park. It is recommended that the local government study the average and maximum wind speeds at the ILC.




Graph 1. Peak output of solar cell and wind power generation reported by Tohoku-epco.

## 4.Geothermal power generation

Tohoku-epco and Toshiba explained geothermal power generation in another section of the Green ILC. Please refer to the above documents.

The Ministry of the Environment reported that the potential geothermal power generation is 33,100MW, while the recoverable amount is 14,200MW. This power is 17 times higher than that consumed by the ILC.

The author studied geothermal power generation at Japan Metals and Chemicals Co. Ltd. in Iwate Prefecture as a student 50 years ago. This company has more than 50 years of engineering knowledge and experience related to geothermal power generation.

The geothermal power generation capacity is 100MW in Iwate Prefecture, which is the second largest capacity in Japan. If an additional 100MW of geothermal energy were generated in Iwate, all of the power consumed by the ILC would be provided.

In addition, Japanese geothermal power generation manufacturers are very productive and get 70% of market share of the world. MHI (Fig. 3), Toshiba, and Fuji Electric always compete with one another to be the world's most productive geothermal power manufacturer.


Fig. 3 From MHI Graphic.

5. Hydro-power generation

Hydro-power will be generated at the base load authorized by METI. However, water rights issues appeared when the construction plan was proposed. Thus, local government support will be required.

Here we present the calculations of the energy generated by a 1MW solar power station and the requirements necessary to generate the same amount of energy hydraulically.

The energy generated by a 1MW solar power station is as follows:

1MW × 1,800h/year (insolation time) × 0.6 (ratio of sunshine: from sunrise to sunset) = 1.08GWh.

The construction cost is ¥200,000/kW (for the solar cells only), yielding a total cost of ¥200,000,000.

To achieve the same output by hydro-power:

1.08GWh ÷ 24h/day ÷ 365 days/year = 123kW

The hydro-power generation $P$ for a drop $H$ and water volume $Q$ is given by:
$P$ (kW) = 9.8 × $H$ (m) × $Q$ ($m^3$/s)
In order to achieve 123kW of power generation, if $Q$ = 1 $m^3$, then $H$ will be 12.6m:
123kW = 9.8 × 12.6m × 1$m^3$/s.
Considering the efficiencies of turbines and generators, $H$ should be about 14 m. The FIT price will be ¥34/kWh for 20 years (assuming a total output of not more than 200 kW), yielding a total income of ¥732,686,400 over 20 years. Hitachi and Toshiba also have catalogs of mine hydro-power.

6. Biomass power generation

MHI developed a biomass plant at the Koiwai ranch in Iwate Prefecture that uses methane gas from dung as fuel (Appendix 1). In addition, MHI and Hakutsuru Japanese Sake Brewing Industry Ltd. are researching how to produce liquid fuel from straws (Appendix 2).

In Japan, biomass generation is currently difficult economically; however, after the commissioning of the ILC, an international scientific project will be operational that will require a sewage treatment plant. Methane gas from this sewage treatment plant could be used as power-generator fuel. Biomass power centers can also produce fertilizer from sludge by using engine waste heat. The FIT for this system is ¥39/kWh for 20 years.

During construction, a great quantity of wooden boxes is generated as waste material. Similarly, forestry necessarily produces large amounts of wooden chips as waste. The best way to use these by-products is as raw material for the paper industry, and there are many paper factories in the Tohoku area. If they do not wish to receive these materials, the second option is to thermally recycle them. In this case, the waste would be used as fuel for boilers, turbines, and generators. This type of system is called a carbon-neutral power station. After construction, such a plant would be a waste-treatment plant for the city. The FIT for such as system ranges from ¥13/kWh to ¥20/kWh for 20 years.

7. Temperature-difference energy (waste heat recovery)

The author previously reported that the planned supply of waste heat from the Radioactive Isotope Beam Factory (RIBF) to the next-door 4th elementary school in Wako for heating in winter and for swimming pool temperature control was not working, demonstrating the difficultly of supplying energy outside.

Now we have a new technology, the binary turbine. Turbine systems are being introduced into the market by MHI and other companies. The energy sources will be RF power sources, He compressors, transformers, HVACs, and chillers for water-cooling systems. If the coolant outlet temperature is more than 60°C, and ideally as much as 80°C, electric power generation as well as waste heat recovery can be achieved. For this purpose, teams working on the accelerator and turbine should jointly consider and resolve the differences between the two arguments.

The 200MW electrical consumption of the ILC will be released as heat. If half of that amount can be controlled as waste heat and if the binary turbine system has an efficiency of 40%, the power generated by the turbine system will be 40MW, which is same as the consumption of the ILC control building. Furthermore, this amount is twice as high as RIKEN Wako campus's peak consumption from the utility company, Tokyo Electric Power Corporation (TEPCO).

## 8. Conclusion

The renewable energy sources that can be used in the ILC were explained in this paper. New energy plants cannot be established independently; they require support by local governments and/or utility companies. Without this support, it would be nearly impossible to build the Green ILC in addition to the ILC itself.

Only temperature-difference energy can be controlled by the team at the ILC, but the necessary system is one of most difficult to establish, as reconsideration of the decisions made by the accelerator builders would be required.

Nevertheless, there are numerous energy sources that could be implemented at the Green ILC. Therefore, only the selection of the preferred energy sources and concentration are necessary to realize the Green ILC.

## 9. Appendix

1) Mitsubishi heavy industry graph No.170 2013.1

2) Mitsubishi heavy industry graph No.163 2011.

# Power saving and use of New Energy at Riken RI Beam factory

(Tadashi Fujinawa, Riken)

## 1 Introduction

RI Beam Factory (following RIBF) of RIKEN Nishina Center for Accelerator-Based Science (hereinafter RNC) is a heavy ion cyclotron of the top in the world, was commissioned three months earlier than expected in December 2006, the superconducting ring cyclotron (hereinafter SRC) succeeded the initial beam extraction, then, a lot of the research results has been continued to report in various fields.

This time, in the WG of Green ILC where we consider energy saving and new energy, the efforts for the RIKEN of advanced energy-saving technologies are reported, such as the world's first combined heat and power system (CGS) installed in accelerator facility.

## 2 Co-Generation System

For the introduction of CGS, environmental measures are the largest purpose, as well as Green ILC. When we explained the RIBF plan in RIKEN of the Board, we received a proposition, as physicist, to think something contribution to make "world best accelerator facilities, which, of course, it is specialty of RIKEN accelerator, however, while an accelerator uses electricity and water as if we use public water, something ecology in accelerator, considering about the Kyoto Protocol has been studied." And we, studied various new energy, and concluded that CGS (also referred to as cogeneration) with the introduction of the gas turbine generator (GTG) as the main engine is the best in the RIBF.

In this method, by supplying electricity and heat at the same time, efficiency is greatly improved compared with the supply of electrical only or heat only. The GTG body is shown in Figure 1. Figure 2 photo shows periodic inspections. Figure 3 shows a flow diagram of CGS.

Figure 1 GTG body, and the right side is the compressor, left turbine

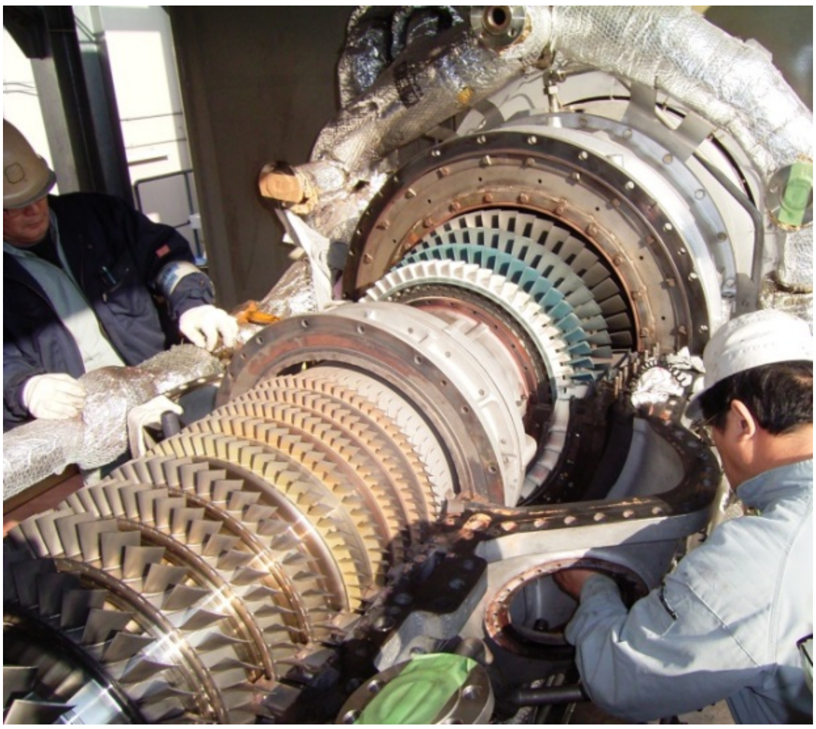


Figure 2 during annual inspection, the front is the compressor, rear is turbine

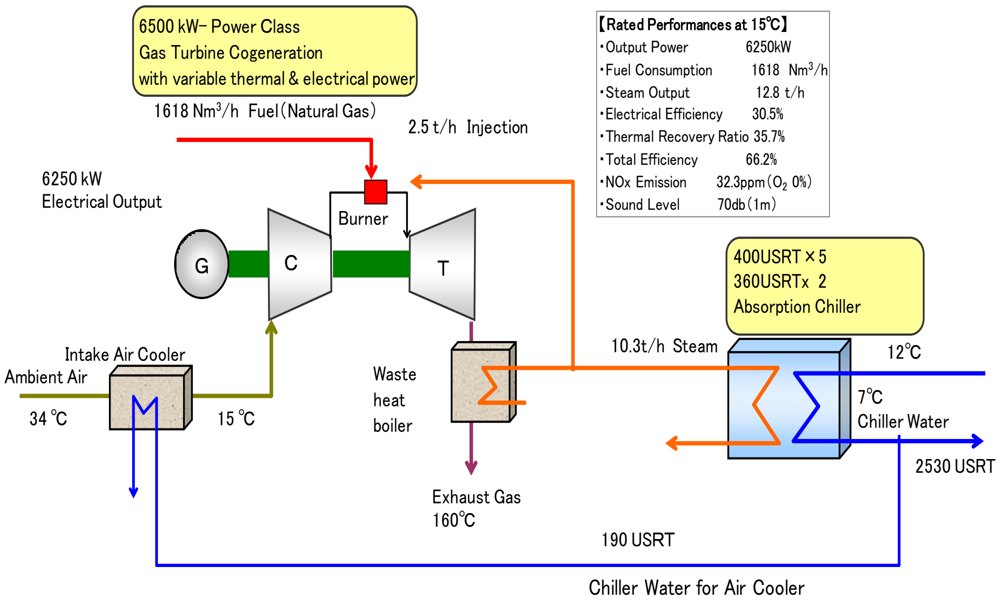



Figure 3 G is the generator, C shows the air compressor and a turbine, by generating saturated steam in the waste heat boiler, making it as a heat source of the absorption chiller cooling to make a cold water of 7℃, for the building cooling and the accelerator facility cooling, and is used for the intake-air cooling of the CGS.

This equipment has been introduced as an environmental measure, that is, as a response to the Kyoto Protocol as RIKEN. In fact, it also plays very important role into a function of accelerator facility as a large uninterruptible power supply at the same time.

CGS is using natural gas supplied from the Tokyo gas as fuel, the output of the generator is introduced and consumed in the RNC and the commercial lines of the Tokyo Electric Power Company (TEPCO) in parallel. If a problem in CGS has occurred, power is supplied to all of the accelerator from TEPCO uninterruptible.

If the instantaneous voltage drops (voltage sag) or power failure occurs in TEPCO, CGS disconnect the commercial line within one cycle, CGS provides power only to the critical loads such as helium refrigerator.

We believe that it is previous special situation to drive the accelerator, if the supply of TEPCO and Tokyo Gas will be disabled at the same time.

It should be noted that, for the power shortage due to the Fukushima Daiichi nuclear power plant accident in 2011, RIKEN CGS contributed to power supply to perform continuous operation until the end of the year.

For more information, accompanying CGS, you should refer the article in "accelerator" Vol.8, No.1, 2011(18-25) and "consideration of the large accelerator facilities for combined heat and power device as an uninterruptible power supply - RIKEN CGS-" [1].

For English article should be referred to a Proceedings[2] of ARW2013 and "RIKEN Accelerator Progress Report 36. (2003) ", "Cogeneration system for RI Beam Factory[3] ", Report 37 (2004) CGS operation[4].

Finally, as for the environmental effect, maximum efficiency is proud of the 68%, because the generator is located directly above the accelerator, there is no transmission loss. Natural gas is a very clean fuel compared to coal and oil. CGS absorption refrigerator is different from the typical refrigerator to repeat the compression-expansion by using a motor, there is an advantage of not using any ozone-depleting gas or greenhouse gases.

3. Energy saving and environment effect other than the CGS

It was already mentioned that minimization of transmission loss by placing the CGS just above the accelerator facilities. For commercial lines from TEPCO, the second special high voltage substation (the second extra-high voltage) was constructed at the top of the accelerator building, connected the 66kV underground line by the full-length 750 m from the first extra-high voltage substation in order to reduce the transmission loss. In the first floor basement, place the power supply room 2 to transform the high voltage (6.6kV) to low voltage (415, 220, 110V), further down below the power room 1 which houses the accelerator power was placed, in the next to the power room 1 the accelerator was arranged, in this way, the cable length was minimized.

In addition, high-voltage AC power supply of the experimental equipment SHARAQ (1MVA) and Rare-RI Ring (R3) 1.5MVA deployed to the accelerator room, with an effort to minimize the low-voltage cable length.

In the accelerator facilities, a lot of the electric motor in the cooling system being used, it is kept in mind the energy saving using a high efficiency electric motor actively.

It shows a photograph of a high-efficiency motor in Figure 4. Ordinary efficiency of the electric motor has a warship color in any manufacturer, gold color motor in the photo is made of Toshiba, a black color motor by Fuji Electric, they are descriptive.

Mitsubishi has two color motor, 31th US Navy warship color of GSI Creos Mr. HOBBY is high efficiency, 32th Japan Navy color (Yokosuka) is ordinary efficiency, to be difficult to determine the type. We suspect that there is a length of day advance in Toshiba and Fuji.

Figure 4 high-efficiency motors that are used in the cooling system (Toshiba)

Direct drive method was adopted for the motor start-up scheme considering helium compressor (315kW) as a main system, is a good start method for efficiency compared with the other start-up method (reactor, compared to Y- △ and inverter start-up).

High efficiency high/low voltage transformer is also adopted. Efficiency of the transformer are also advances year by year, the latest of a transformer for the RNC is the 99.4% of R3 (at rated 1.5MVA).

In addition, the transformer there is no worry of fire by using a dry-type transformers. As a result, carbon dioxide fire extinguishing equipment which has a risk of death is no longer needed. As harmonic voltage measures, we arranged the transformer alternately the winding △ - △ and the △ –Y, so as to obtain the same effect as three winding transformer. In CGS central control room, there is a harmonic monitoring device, and always shows the minimum value of the measurement limit. This is also that environment friendly design.

For more information, please refer to the English article [5) 6)].

4. New energy other not adopted

1) Solar cell: As the simplest new energy, solar power generation is raised. Since the energy density is low (a large area required), Wako of sunshine time is 1840 hours per year, even side-by-side solar cells on the existing Nishina Memorial Building roof, power generation capacity of about 40kW the maximum, there is unreasonable as the accelerator power. However, as a whole RIKEN, five places at the moment, we have total a 120kW of equipment. All generated power is a self-consumption, does not use fixed-price purchase system.

2) Wind power generation: suitable wind speed for wind power generation is 6 m per second, while average wind speed of Wako City is the 1 m. So it is not at all adapted.

3) Adsorption chillers: by changing the cooling water output temperature of the accelerator from 60 to 80℃, and making it as a heat source of the adsorption-type refrigerator, to give the cold water of 7℃ to be used for the air conditioning and cooling. As accelerator side, there is anxiety that the cooling water temperature is high, so we gave up.

4) Temperature difference energy[7)]: those are proposed in Wako City area new energy development committee, that waste heat of RIBF the (around 40℃), supplied to adjacent the Wako municipal fourth elementary school, for heating, hot water supply, and pool. It has been favorite proposal benefit to Wako areas as a result of the study over two years, however, a business entity did not appear, and did not reach to a realization, together with a problem of the education committee.

For more details, refer to the English documents.

5. Application to the ILC

High-efficiency equipment (electric motor, transformer, etc.) and so on, should be introduced for granted. It is necessary to note that it is slightly different even in the same high efficiency number by the manufacturer.

Next, as for the electric transmission and distribution, therefore it is very important and is described in a separate description. Please refer there.

Adsorption chillers with good improvement for performance in recent years, and worth considering because also possible to operate at a lower temperature.

CGS is an energy saving of the centerpiece of RIBF, but here it is necessary to pay attention.

The first, in planned construction site, there is no city gas, that is to lay the pressure pipe for CGS is required huge cost. In the case of RIKEN, because there was a medium pressure pipe next to the site of RIBF, so it was realized. Even if temporarily it is solved the problem of gas piping, because the ILC using 10 times the electricity of RIBF, by simply thinking, it requires 65MW of engine. For the gas engine it is too large, for the latest of composite power generation GTG it is too small.

Furthermore, absorption chiller which is key component of CGS has no noticeable progress in this more than 10 years. On the other hand, COP (Coefficient of Performance) of the motor drive refrigerators improving to 3 or more in the hot water supply, up to 6 or more in cooling, rather than a combined heat and power, combined cycle power generation (Combined Cycle; CC) can be used to convert to electricity, then to carry out the cooling and heating by the converted electricity. Those efficiency is good in the final end.

Temperature difference energy, it is to find a business entity who can build firstly with the investment.

6. Reference

1) "accelerator" Vol.8, No.1,2011 (18-25) record and consideration of the large accelerator facilities for combined heat and power device as an uninterruptible power supply - RIKEN RIBF of CGS-

2) ARW2013.Proceedings

3) RIKEN Accelerator Progress Report 36. (2003) Cogeneration system for RI Beam Factory

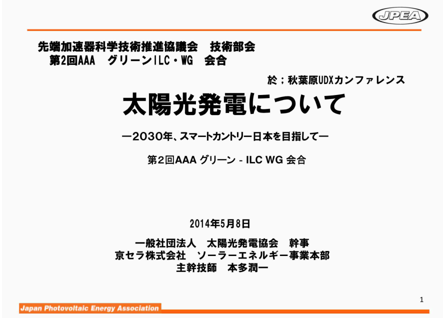
4) Report 37 (2004) CGS operation

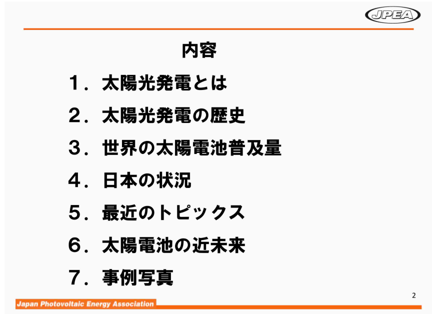
5) WAO07. DESIGN, INSTALLATION, OPERATION AND MAINTENANCE OF ELECTRICAL POWER SUPPLY FOR RI BEAM FACTORY

6) RIKEN Accelerator Progress Report 46 (2013) AC power system for Rare-RI Ring.

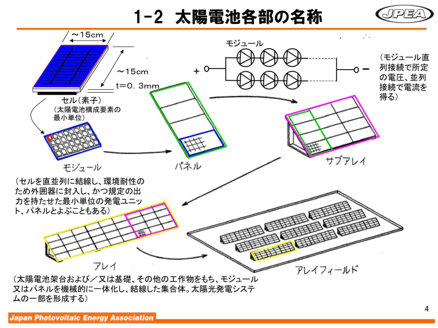
7) New Energy Establishment Committee of Wako City District and RIBF; RIKEN Accelerator Progress Report

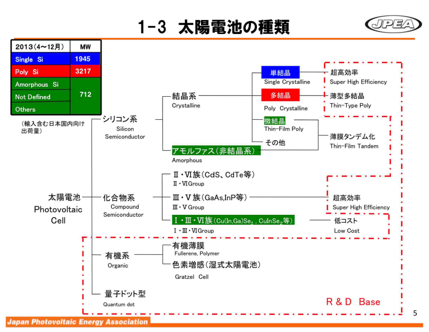
# Solar Power
# (Junichi Honda, Solar Power Association and Kyocera)

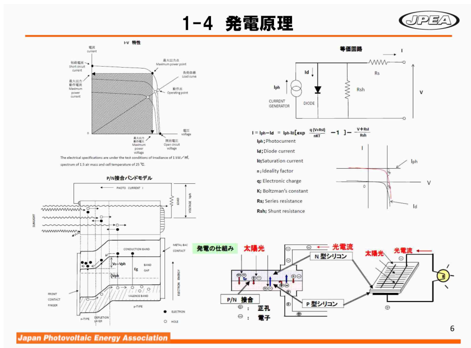


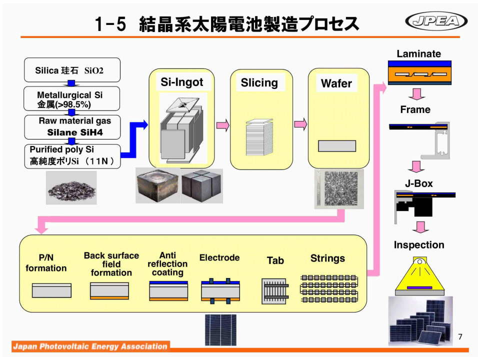



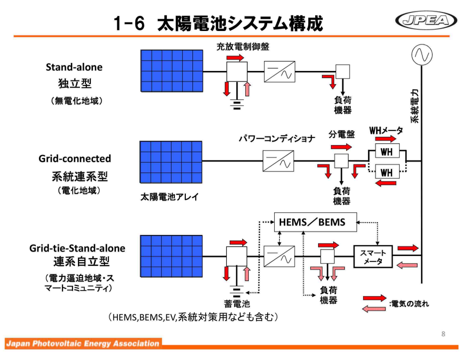


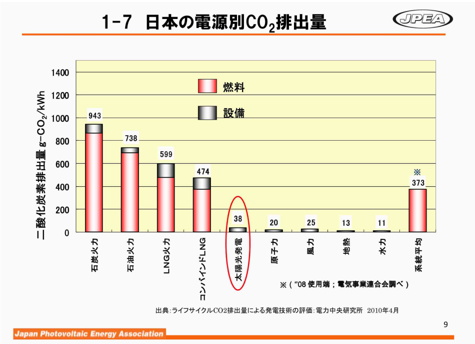



1-7 日本の電源別CO2排出量
JPEA
二酸化炭素排出量 g-CO2/kWh
燃料
設備
943
738
599
474
38
20
25
13
11
373
石炭火力
石油火力
LNG火力
コンバインドLNG
太陽光発電
原子力
風力
地熱
水力
系統平均
※（"08使用端；電気事業連合会調べ）
出典：ライフサイクルCO2排出量による発電技術の評価：電力中央研究所 2010年4月
Japan Photovoltaic Energy Association
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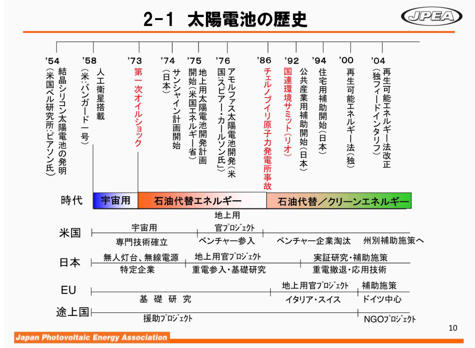
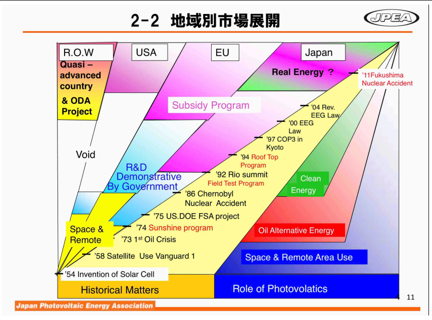
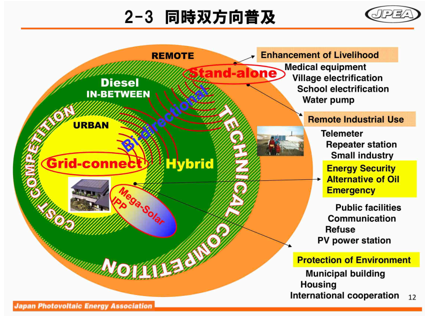
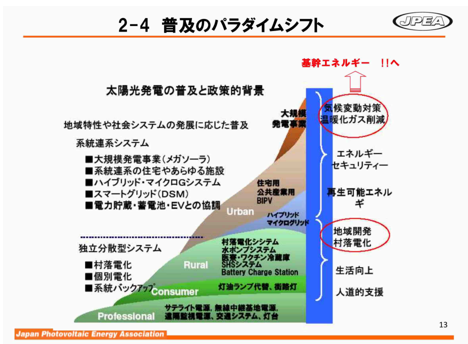
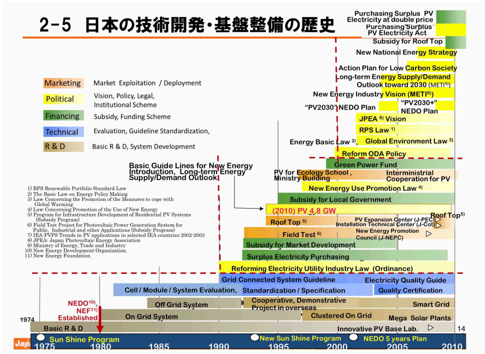
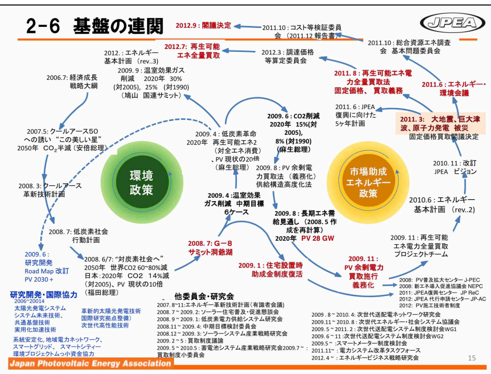

2-1 太陽電池の歴史
JPEA
'54 結晶シリコン太陽電池の発明（米国ベル研究所・ピアソン氏）
'58 人工衛星搭載（米・バンガード一号）
'73 第一次オイルショック
'74 サンシャイン計画開始（日本）
'75 地上用太陽電池開発計画開始（米国エネルギー省）
'76 アモルファス太陽電池開発（米国スピアー・カールソン氏）
'86 チェルノブイリ原子力発電所事故
'92 国連環境サミット（リオ）
'94 公共産業用補助開始（日本）
'00 住宅用補助開始（日本）
'04 再生可能エネルギー法（独）
再生可能エネルギー法改正（独フィードインタリフ）
時代
宇宙用
石油代替エネルギー
石油代替／クリーンエネルギー
米国
日本
EU
途上国
Japan Photovoltaic Energy Association
10


2-2 地域別市場展開
JPEA
R.O.W
USA
EU
Japan
Quasi – advanced country & ODA Project
Real Energy ?
'11Fukushima Nuclear Accident
Subsidy Program
Void
R&D Demonstrative By Government
Clean Energy
Oil Alternative Energy
Space & Remote
Space & Remote Area Use
Historical Matters
Role of Photovolatics
Japan Photovoltaic Energy Association
11


2-3 同時双方向普及
JPEA
REMOTE
Stand-alone
Diesel IN-BETWEEN
URBAN
Grid-connect
Hybrid
Bi-directional
Mega-Solar IPP
COST COMPETITION
TECHNICAL COMPETITION
Enhancement of Livelihood
Medical equipment
Village electrification
School electrification
Water pump
Remote Industrial Use
Telemeter
Repeater station
Small industry
Energy Security
Alternative of Oil
Emergency
Public facilities
Communication
Refuse
PV power station
Protection of Environment
Municipal building
Housing
International cooperation
Japan Photovoltaic Energy Association
12


2-4 普及のパラダイムシフト
JPEA
基幹エネルギー !!へ
太陽光発電の普及と政策的背景
地域特性や社会システムの発展に応じた普及
系統連系システム
■大規模発電事業(メガソーラ)
■系統連系の住宅やあらゆる施設
■ハイブリッド・マイクログリッドシステム
■スマートグリッド(DSM)
■電力貯蔵・蓄電池・EVとの協調
独立分散型システム
■村落電化
■個別電化
■系統バックアップ
気候変動対策 温暖化ガス削減
エネルギーセキュリティー
再生可能エネルギー
地域開発 村落電化
生活向上
人道的支援
Urban
Rural
Consumer
Professional
Japan Photovoltaic Energy Association
13


2-5 日本の技術開発・基盤整備の歴史
Marketing
Political
Financing
Technical
R & D
Sun Shine Program
New Sun Shine Program
NEDO 5 years Plan
1975
1980
1985
1990
1995
2000
2005
2010
14


2-6 基盤の連関
JPEA
環境政策
市場助成エネルギー政策
研究開発・国際協力
他委員会・研究会
Japan Photovoltaic Energy Association
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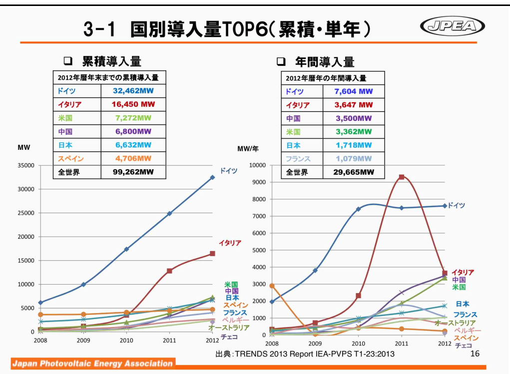
3-1 国別導入量TOP6(累積・単年)
JPEA
累積導入量
年間導入量
ドイツ 32,462MW
イタリア 16,450 MW
米国 7,272MW
中国 6,800MW
日本 6,632MW
スペイン 4,706MW
全世界 99,262MW
ドイツ 7,604 MW
イタリア 3,647 MW
中国 3,500MW
米国 3,362MW
日本 1,718MW
フランス 1,079MW
全世界 29,665MW
出典：TRENDS 2013 Report IEA-PVPS T1-23:2013
Japan Photovoltaic Energy Association
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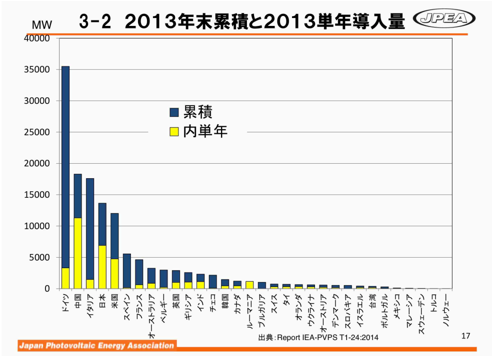
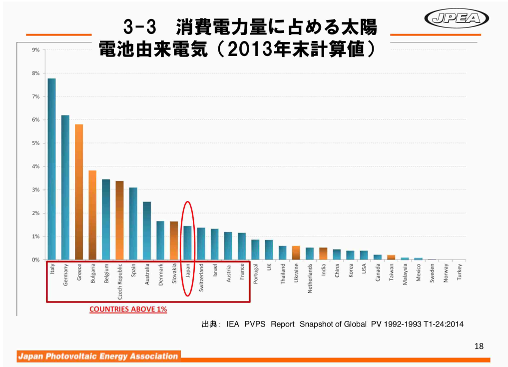

3-2 2013年末累積と2013単年導入量
MW
累積
内単年
出典:Report IEA-PVPS T1-24:2014
Japan Photovoltaic Energy Association
17


3-3 消費電力量に占める太陽電池由来電気（2013年末計算値）
COUNTRIES ABOVE 1%
出典: IEA PVPS Report Snapshot of Global PV 1992-1993 T1-24:2014
Japan Photovoltaic Energy Association
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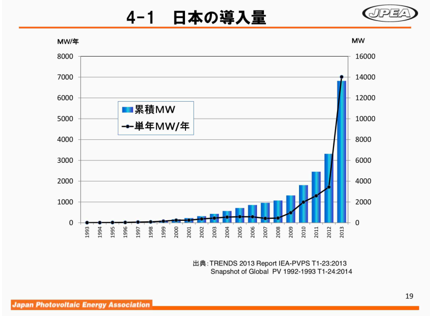
4-1 日本の導入量
累積MW
単年MW/年
出典: TRENDS 2013 Report IEA-PVPS T1-23:2013
Snapshot of Global PV 1992-1993 T1-24:2014
Japan Photovoltaic Energy Association
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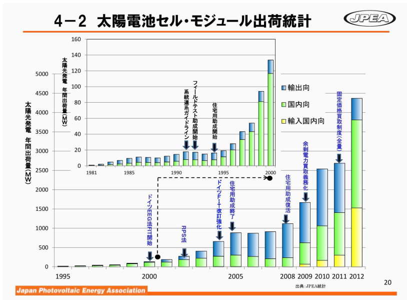
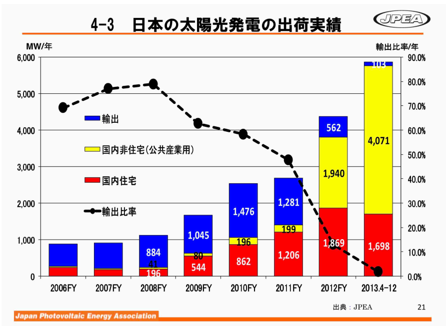
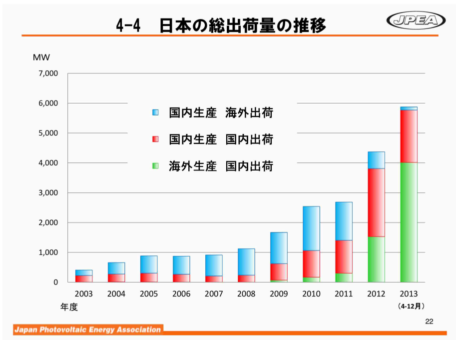

4−2 太陽電池セル・モジュール出荷統計
輸出向
国内向
輸入国内向
Japan Photovoltaic Energy Association
20


4-3 日本の太陽光発電の出荷実績
MW/年
輸出比率/年
輸出
国内非住宅(公共産業用)
国内住宅
輸出比率
2006FY
2007FY
2008FY
2009FY
2010FY
2011FY
2012FY
2013.4-12
出典：JPEA
Japan Photovoltaic Energy Association
21


4-4 日本の総出荷量の推移
MW
国内生産 海外出荷
国内生産 国内出荷
海外生産 国内出荷
年度
(4-12月)
Japan Photovoltaic Energy Association
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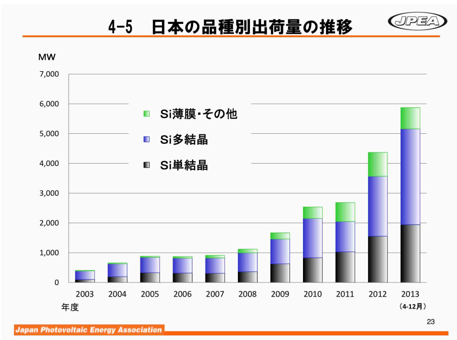
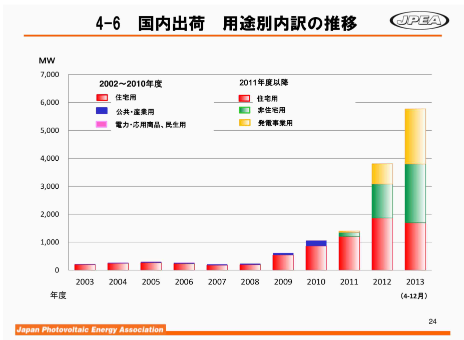

4-5 日本の品種別出荷量の推移
MW
Si薄膜・その他
Si多結晶
Si単結晶
年度
(4-12月)
Japan Photovoltaic Energy Association
23


4-6 国内出荷 用途別内訳の推移
MW
2002～2010年度
住宅用
公共・産業用
電力・応用商品、民生用
2011年度以降
住宅用
非住宅用
発電事業用
年度
(4-12月)
Japan Photovoltaic Energy Association
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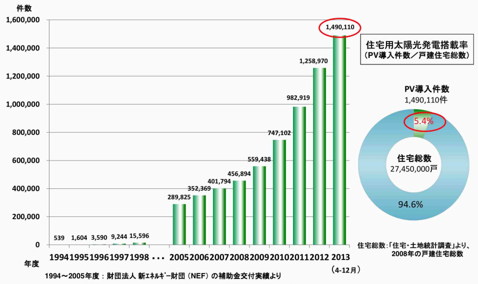
## 4-7　住宅用太陽光発電導入件数（累計）




1994～2005年度：財団法人 新ｴﾈﾙｷﾞｰ財団（NEF）の補助金交付実績より
2006～2008年度：一般社団法人 新ｴﾈﾙｷﾞｰ導入促進協議会（NEPC）による調査より
2008年度～現在：太陽光発電普及拡大ｾﾝﾀｰ（J-PEC）での補助金交付決定件数より JPEA集計

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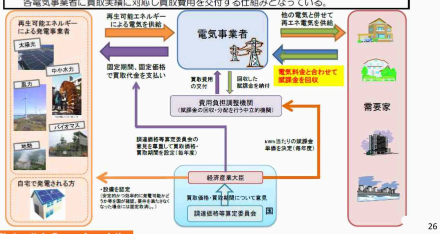
## 5-1　固定価格買取制度

固定価格買取制度の基本的仕組み　経済産業省 資源エネルギー庁

- 固定価格買取制度は、電気事業者に対し、経済産業大臣が定めた買取価格と買取期間により、再生可能エネルギー電気を買取ることを義務づける制度。
- 再生可能エネルギー電気の買取りに要した費用は、電気料金と併せて毎月、電気の使用者に対し使用電力量に応じた賦課金の負担を求め、費用負担調整機関がそれをいったん回収した後、各電気事業者に買取実績に対応し買取費用を交付する仕組みとなっている。

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## 5-2　固定価格買取制度　買取価格・期間

（下表以外に地熱、水力、バイオマスが定められている）

| 太陽光 | | | | 風力 | | | |
|---|---|---|---|---|---|---|---|
| 年度 | 26 | 25 | 24 | 年度 | 26 | 25 | 24 |
| 10KW以上（20年間） | 32円+税 | 36円+税 | 40円+税 | 20KW以上（20年間） | 22円+税 | 22円+税 | 22円+税 |
| 10KW未満（10年間） | 37円 | 38円 | 42円 | 20KW未満（20年間） | 55円+税 | 55円+税 | 55円+税 |
| 10KW未満ダブル発電（10年間） | 30円 | 31円 | 34円 | 洋上風力※（20年間） | 36円+税 | | |

※建設及び運転保守のいずれの場合にも船舶等によるアクセスを必要とするもの

◆ 買取価格及び買取期間は、経済産業大臣が毎年度、当該年度の開始前に定める。
（施行の日から起算して三年間を限り、調達価格を定めるに当たり、特定供給者が受けるべき利潤に特に配慮するものとする。）
（エネルギー基本計画が変更されるごと又は少なくとも三年ごとに、・・・必要な措置を講ずる。）
◆ 経済産業大臣は、買取価格及び買取期間を定めようとするときは、調達価格等算定委員会の意見を聴き、その意見を尊重する。
◆ ・・・法律の施行後平成三十三年三月三十一日までの間に、この法律の施行の状況等を勘案し、この法律の抜本的な見直しを行うものとする。

●買取単価決定要素：年間発電量、発電劣化率、敷地造成費用、EPC価格、昇圧費用、電源線費用、O&M費用、土地リース代、販促費用、主任技術者人件費、貸付金利、償却年数、事業税、固定資産税、法人税、買取期間、撤去費、IRR（内部収益率）

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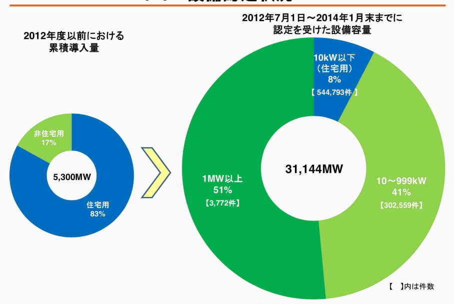
## 5-3　設備認定状況




経済産業省 News Release より

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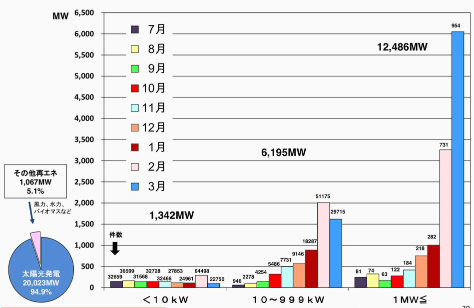
## 5-4　設備認定の推移（2012年7月～2013年3月）




経済産業省 News Release より

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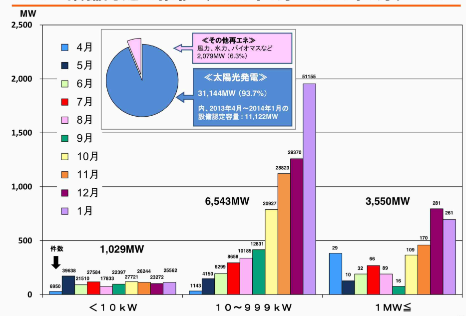
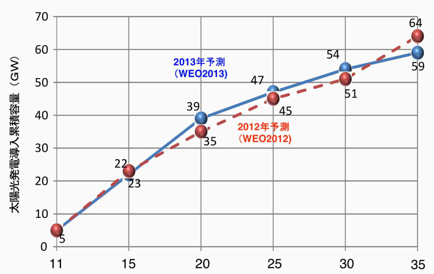
## 5-5　設備認定の推移（2013年4月～2014年1月）




経済産業省 News Release より

Japan Photovoltaic Energy Association　30

## 6-1　IEAによる日本の太陽光発電導入量予測




出典：IEA World Energy Outlook 2013

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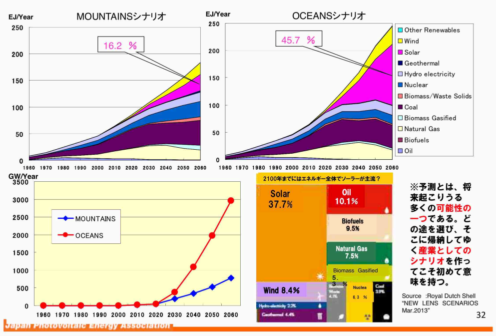
## 6-2　シェルシナリオ、最終消費電力電源別




※予測とは、将来起こりうる多くの可能性の一つである。どの道を選び、そこに帰納してゆく産業としてのシナリオを作ってこそ初めて意味を持つ。

Source：Royal Dutch Shell "NEW LENS SCENARIOS Mar.2013"

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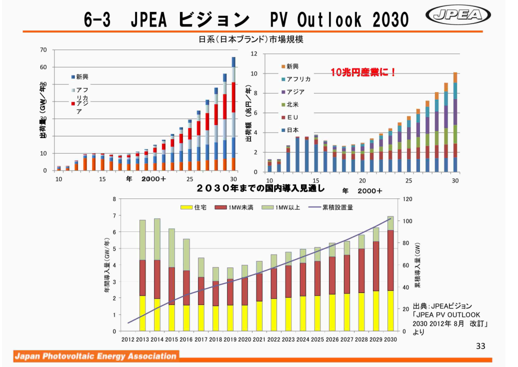
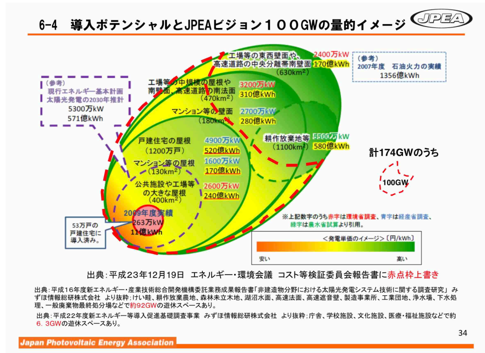
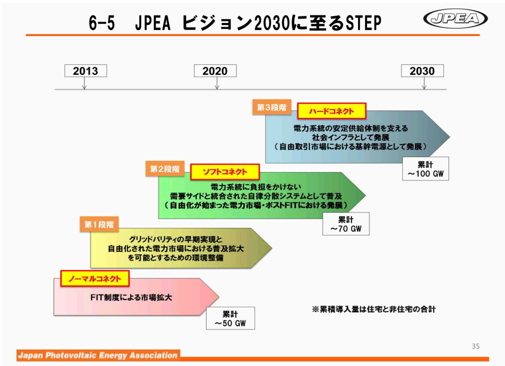
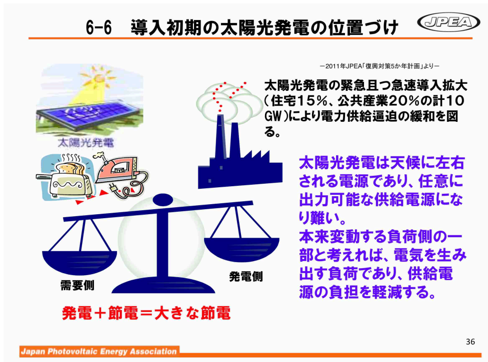
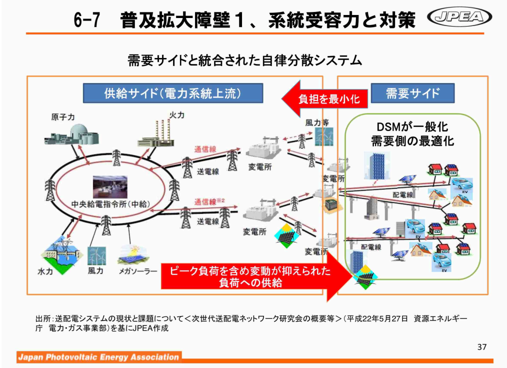
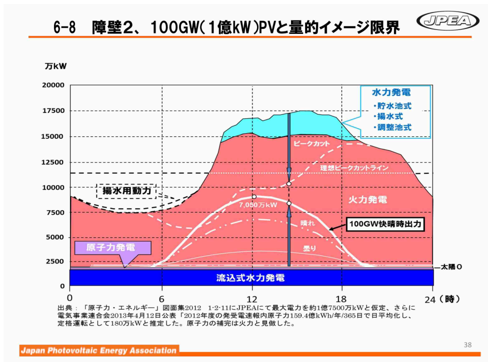


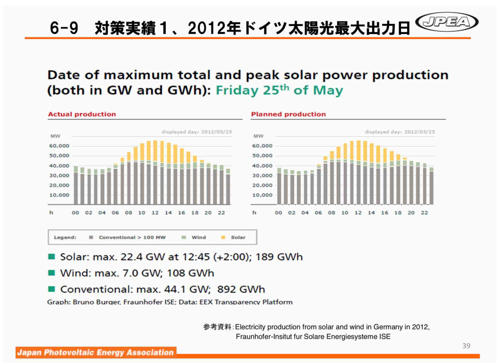



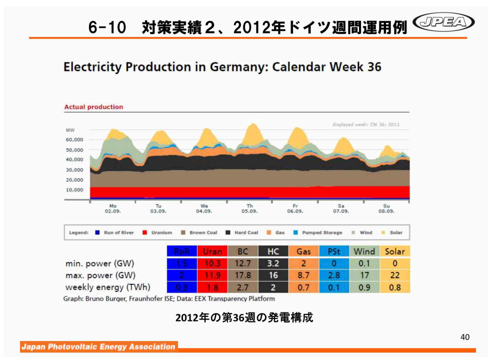



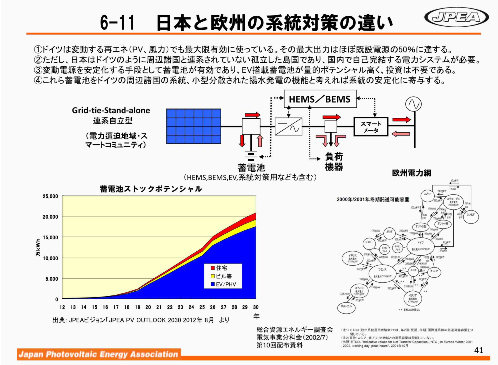




| | RoR | Uran | BC | HC | Gas | PSt | Wind | Solar |
|---|---|---|---|---|---|---|---|---|
| min. power (GW) | 1.9 | 10.3 | 12.7 | 3.2 | 2 | 0 | 0.1 | 0 |
| max. power (GW) | 2 | 11.9 | 17.8 | 16 | 8.7 | 2.8 | 17 | 22 |
| weekly energy (TWh) | 0.3 | 1.9 | 2.7 | 2 | 0.7 | 0.1 | 0.9 | 0.8 |


6-11　日本と欧州の系統対策の違い
JPEA
①ドイツは変動する再エネ(PV、風力)でも最大限有効に使っている。その最大出力はほぼ既設電源の50%に達する。
②ただし、日本はドイツのように周辺諸国と連系されていない孤立した島国であり、国内で自己完結する電力システムが必要。
③変動電源を安定化する手段として蓄電池が有効であり、EV搭載蓄電池が量的ポテンシャル高く、投資は不要である。
④これら蓄電池をドイツの周辺諸国の系統、小型分散された揚水発電の機能と考えれば系統の安定化に寄与する。
Grid-tie-Stand-alone
連系自立型
HEMS／BEMS
蓄電池
負荷機器
(HEMS,BEMS,EV,系統用なども含む)
欧州電力網
蓄電池ストックポテンシャル
出典：JPEAビジョン「JPEA PV OUTLOOK 2030 2012年 8月」より
総合資源エネルギー調査会
電気事業分科会(2002/7)
第10回配布資料
Japan Photovoltaic Energy Association
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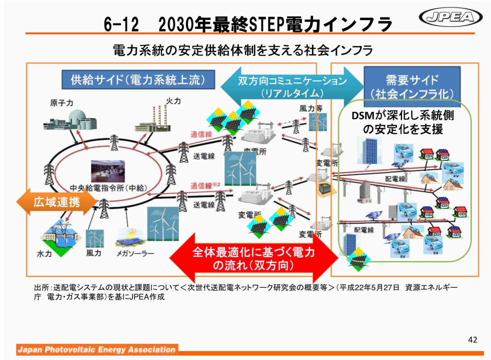
6-12　2030年最終STEP電力インフラ
JPEA
電力系統の安定供給体制を支える社会インフラ
供給サイド(電力系統上流)
双方向コミュニケーション
(リアルタイム)
需要サイド
(社会インフラ化)
原子力
火力
風力等
DSMが深化し系統側
の安定化を支援
通信線
送電線
変電所
配電線
中央給電指令所(中給)
広域連携
水力
風力
メガソーラー
全体最適化に基づく電力
の流れ(双方向)
出所：送配電システムの現状と課題について＜次世代送配電ネットワーク研究会の概要等＞(平成22年5月27日　資源エネルギー庁　電力・ガス事業部)を基にJPEA作成
Japan Photovoltaic Energy Association
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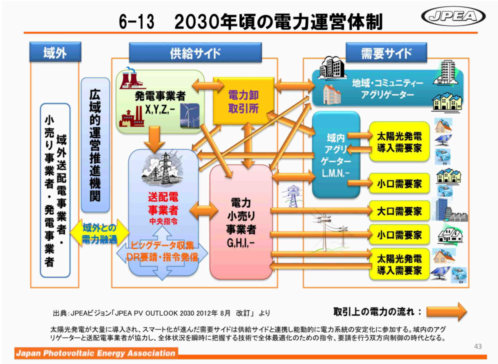
6-13　2030年頃の電力運営体制
JPEA
域外
供給サイド
需要サイド
小売り事業者・発電事業者
域外送配電事業者・
広域的運営推進機関
発電事業者
X.Y.Z.−
電力卸取引所
地域・コミュニティーアグリゲーター
域内アグリゲーター
L.M.N.−
太陽光発電導入需要家
小口需要家
大口需要家
小口需要家
太陽光発電導入需要家
送配電事業者
電力小売り事業者
G.H.I.−
域外との電力融通
ビッグデータ収集
DR要請・指令発信
出典：JPEAビジョン「JPEA PV OUTLOOK 2030 2012年 8月 改訂」より
取引上の電力の流れ：
太陽光発電が大量に導入され、スマート化が進んだ需要サイドは供給サイドと連携し能動的に電力系統の安定化に参加する。域内のアグリゲーターと送配電事業者が協力し、全体状況を瞬時に把握する技術で全体最適化のための指令、要請を行う双方向制御の時代となる。
Japan Photovoltaic Energy Association
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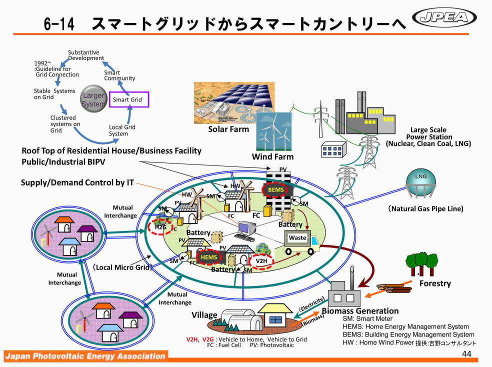
6-14　スマートグリッドからスマートカントリーへ
JPEA
Substantive Development
1992~ :Guideline for Grid Connection
Smart Community
Stable Systems on Grid
Larger System
Smart Grid
Clustered systems on Grid
Local Grid System
Solar Farm
Wind Farm
Large Scale Power Station (Nuclear, Clean Coal, LNG)
Roof Top of Residential House/Business Facility
Public/Industrial BIPV
Supply/Demand Control by IT
Mutual Interchange
(Natural Gas Pipe Line)
(Local Micro Grid)
Forestry
Village
Biomass Generation
V2H, V2G : Vehicle to Home, Vehicle to Grid
FC : Fuel Cell　PV: Photovoltaic
SM: Smart Meter
HEMS: Home Energy Management System
BEMS: Building Energy Management System
HW : Home Wind Power 提供:吉野コンサルタント
Japan Photovoltaic Energy Association
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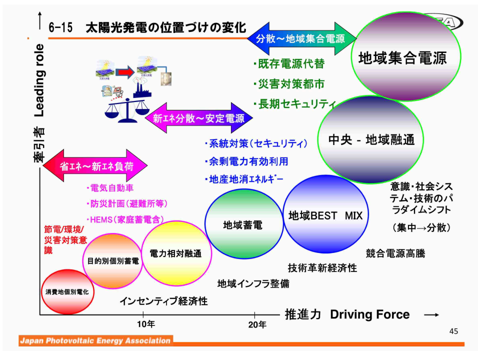
6-15　太陽光発電の位置づけの変化
牽引者　Leading role
分散～地域集合電源
地域集合電源
・既存電源代替
・災害対策都市
・長期セキュリティ
新エネ分散～安定電源
中央－地域融通
・系統対策(セキュリティ)
・余剰電力有効利用
・地産地消エネルギー
省エネ～新エネ負荷
・電気自動車
・防災計画(避難所等)
・HEMS(家庭蓄電含)
意識・社会システム・技術のパラダイムシフト
(集中→分散)
節電/環境/災害対策意識
地域蓄電
地域BEST MIX
目的別個別蓄電
電力相対融通
競合電源高騰
技術革新経済性
地域インフラ整備
インセンティブ経済性
推進力　Driving Force
10年
20年
Japan Photovoltaic Energy Association
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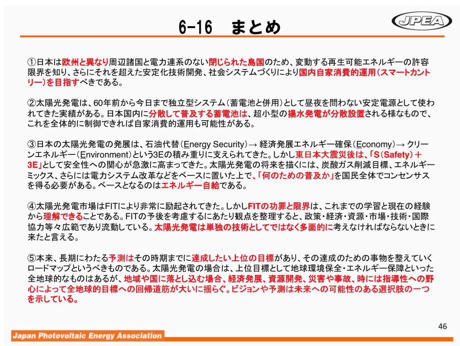
6-16　まとめ
JPEA
①日本は欧州と異なり周辺諸国と電力連系のない閉じられた島国のため、変動する再生可能エネルギーの許容限界を知り、さらにそれを超えた安定化技術開発、社会システムづくりにより国内自家消費的運用(スマートカントリー)を目指すべきである。
②太陽光発電は、60年前から今日まで独立型システム(蓄電池と併用)として昼夜を問わない安定電源として使われてきた実績がある。日本国内に分散して普及する蓄電池は、超小型の揚水発電が分散設置される様なもので、これを全体的に制御できれば自家消費的運用も可能性がある。
③日本の太陽光発電の発展は、石油代替(Energy Security)→ 経済発展エネルギー確保(Economy)→ クリーンエネルギー(Environment)という3Eの積み重りに支えられてきた。しかし東日本大震災後は、「S(Safety)＋3E」として安全性への関心が急激に高まってきた。太陽光発電の将来を描くには、炭酸ガス削減目標、エネルギーミックス、さらには電力システム改革などをベースに置いた上で、「何のための普及か」を国民全体でコンセンサスを得る必要がある。ベースとなるのはエネルギー自給である。
④太陽光発電市場はFITにより非常に励起されてきた。しかしFITの功罪と限界は、これまでの学習と現在の経験から理解できることである。FITの予後を考慮するにあたり観点を整理すると、政策・経済・資源・市場・技術・国際協力等々広範であり流動している。太陽光発電は単独の技術としてではなく多面的に考えなければならないときに来たと言える。
⑤本来、長期にわたる予測はその時期までに達成したい上位の目標があり、その達成のための事物を整えていくロードマップというべきものである。太陽光発電の場合は、上位目標として地球環境保全・エネルギー保障といった全地球的なものはあるが、地域や国に落とし込む場合、経済発展、資源開発、災害や事故、時には指導性への野心によって全地球的目標への回帰道筋が大いに揺らぐ。ビジョンや予測は未来への可能性のある選択肢の一つを示している。
Japan Photovoltaic Energy Association
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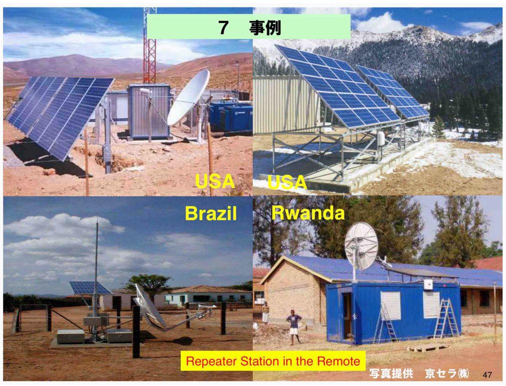
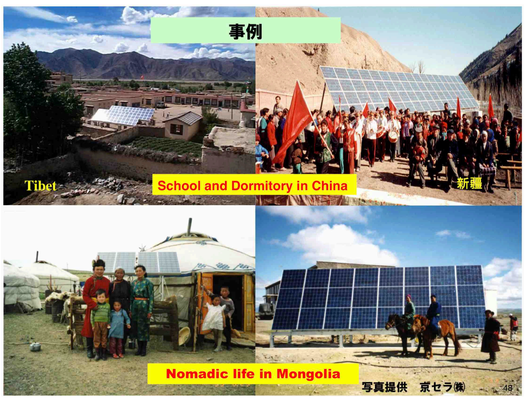

7　事例
USA
USA
Brazil
Rwanda
Repeater Station in the Remote
写真提供　京セラ㈱
47


事例
Tibet
School and Dormitory in China
新疆
Nomadic life in Mongolia
写真提供　京セラ㈱
48


事例
JPEA
For Basic Human Needs
Japan Photovoltaic Energy Association
写真提供　京セラ㈱ 49


事例
住宅用太陽光発電の事例
写真提供　京セラ㈱ 50


事例
NEXCO中日本　名二環
（名古屋第二環状自動車道）　2MW
㈱ベネッセコーポレーション　720kW
浜中町農業協同組合
計1050kW(105戸計)
イオン伊丹昆陽　960kW(全体1160kW)
写真提供　京セラ㈱
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事例
MAZDA　Zoom-Zoom
スタジアム広島　100kW
東北電力仙台太陽光発電所
九州電力メガソーラー大牟田発電所3MW
馬路村農業共同組合200KW
写真提供　京セラ㈱
52


事例
JPEA
Italy 2.5MW
Czech 1.2MW
Thailand 6 MW
Italy 1MW
写真提供　京セラ㈱
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Japan Photovoltaic Energy Association


事例
JPEA
タイ国最大のプロジェクト
250MW+ 計画
6MW×20サイト
120MW　完成式
タイ　メガソーラー
54
Japan Photovoltaic Energy Association
写真提供　京セラ㈱


事例
JPEA
太陽電池　450KW
パワーコンディショナ　500KW
連系盤
京セラ佐倉ソーラーセンター
写真提供　京セラ㈱
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Japan Photovoltaic Energy Association


事例
JPEA
出力：約70MW
PCS：500KW×144
敷地面積；約127万㎡
年間予想発電量：一般家庭の電力使用量約2万2000世帯分相当
鹿児島　七つ島メガソーラー
写真提供　京セラ㈱
57
Japan Photovoltaic Energy Association


JPEA
Renewable Japan !
What a Wonderful Job!
むすび
太陽光発電は巨大技術開発でも最新のテクノロジーでもない。60年ほど前に発明された小さな光電変換素子が原理的には今も使われている。都度途中成果が実用に生かされ、単純な技術でありながら、いつまでたっても限界の見えない、かつ色褪せない稀有な技術である。資源小国の日本で純国産のエネルギー確保は重要であり、孤立した島国でスマートカントリーを目指せば世界のエネルギー安全保障の範ともなりうる。太陽電池がそのキーテクノロジーになれば。
for The People・for The Earth･from Japan
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Japan Photovoltaic Energy Association

# Biomass power generation using ILC exhaust heat
(Mituo Takeda, Kabuki, Hitachi-cement, Nihon-premium, Mizuing)

1. Introduction

Since International Linear Collider: ILC, become one of the foundation industry for the region, it will be intended to integrate to regional management unification. If the facility is operational once, a number of researchers and their families from abroad will visit and stay, then how the effective use of the waste generated from there is a theme as a national project. Furthermore, it is considered necessary to indicate the way of next generation waste disposal incorporation with the entire region is developed.

By operating the linear accelerator of 30km or more as the main ILC facilities, a large amount of heat is generated. By utilizing the exhaust heat, it is possible to ensure the thermal energy source, which accounts for significant costs in organic waste treatment at low cost. Biomass power generation, although a wide variety of methods have been taken, as simple as possible is good, by using an inexpensive heat, direct combustion power plants which accept any type of organic waste are proven, and can be expected.

2. Biomass direct combustion power generation plant

(1) the value of biomass direct combustion power generation plant

· It is possible to generate electricity by using animal and vegetable waste generated in the region.

- By using the waste heat of the ILC facility, it is possible to dry them with costs cheaper

- Along with the drying → incineration → power generation is simple line, also accepted any kind of organic waste.

And disposal destination of sewage sludge and organic waste will expand.

- Reduction of the incineration plant of each municipality is measurably proceed.

(2) flow of direct combustion power plant

In biomass direct combustion power plant flow as shown in Figure 1, it is to accept all of the biomass from the high moisture content livestock manure to as low as rice straw, is to dry by the ILC exhaust heat and recovered heat. Then burned directly, and then the power generation by the steam, use the full generated power at the ILC facilities.

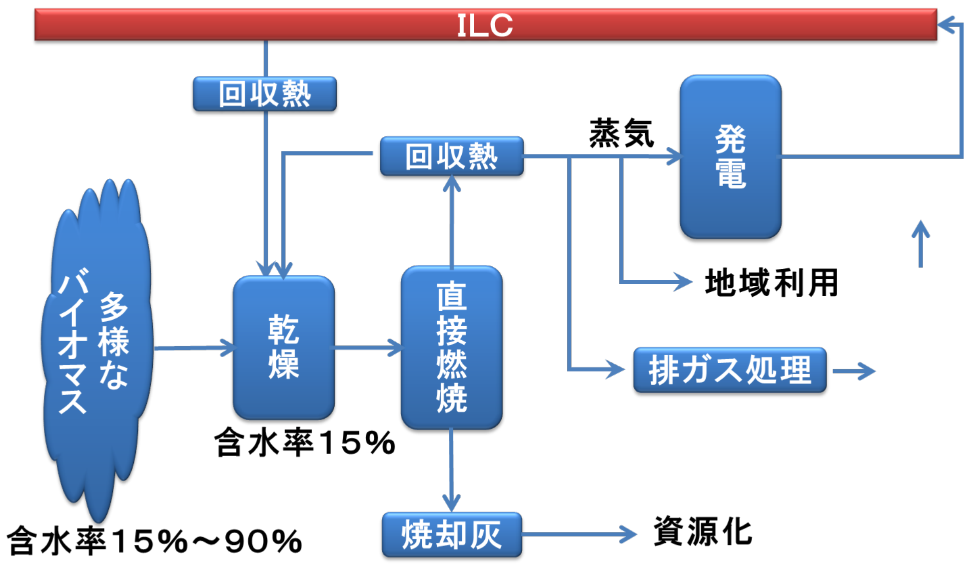



Figure 1 biomass direct combustion power generation plant flow

(3) Considerations of direct combustion power plant

<Notes of dry>

· For drying machine, the rotary dryer type is safe to cope with the wide variety of biomass.

· When the oxygen concentration is high, it is necessary to lower the oxygen concentration replaced with steam (turbine extraction steam) and the exhaust gases, since there is likely to be burned in a dryer.

· In order to keep the dry exhaust as much as possible, it will be exhausting and dehumidified in the wet scrubber, re-heating by the ILC recovered heat, and recycling and re-using some part.

· Surplus exhaust, you can either use as combustion air of incinerator, or on the deodorizing process, then dissipated to the atmosphere.

<Incinerator type>

· By taking into account the nature, input amount, fluctuation range of input, the optimum furnace type should be selected from stoker, fluidized bed, and the other.

· Review of the post-process of the exhaust gas treatment.

3. Power generation amount expected by biomass direct combustion

(1) Biomass endowment amount and effectiveness available amount

In the Tohoku region (Iwate, Miyagi Prefecture) and Kyushu region (Saga, Fukuoka Prefecture), each of the biomass endowment amount and effectiveness available amount can be estimated from NEDO data, as shown in Table 1.

Table 1 Biomass endowment amount and effectiveness available amount

| | | 林地残材 | | 切り捨て間伐材 | | 果樹剪定材 | | タケ | | 稲作残渣・稲わら | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 有効利用可能量 DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 |
| 東北地区 | 岩手県 | 4,980 | 90,142 | 5,982 | 127,390 | 5,214 | 59,956 | 1,475 | 18,432 | 39,315 | 534,690 |
| | 宮城県 | 1,316 | 24,627 | 2,167 | 46,155 | 3,117 | 35,847 | 4,644 | 58,055 | 51,075 | 694,617 |
| 九州地区 | 佐賀県 | 746 | 13,495 | 477 | 10,148 | 7,733 | 88,935 | 17,311 | 216,383 | 18,752 | 255,031 |
| | 福岡県 | 402 | 7,282 | 1,757 | 37,423 | 12,614 | 145,056 | 29,999 | 374,992 | 27,493 | 373,900 |

| | | 稲作残渣・籾殻 | | 麦わら | | その他の農業残渣 | | ササ | | ススキ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 有効利用可能量 DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 |
| 東北地区 | 岩手県 | 4,790 | 68,022 | 1,444 | 19,638 | 9,455 | 102,111 | 2,417 | 32,876 | 135,516 | 1,843,020 |
| | 宮城県 | 5,416 | 76,909 | 971 | 13,208 | 9,146 | 98,779 | 0 | 0 | 28,703 | 390,362 |
| 九州地区 | 佐賀県 | 2,309 | 32,791 | 8,109 | 110,288 | 12,201 | 131,770 | 54 | 738 | 3,998 | 54,367 |
| | 福岡県 | 4,504 | 63,962 | 7,706 | 104,805 | 8,079 | 87,249 | 18 | 239 | 27,714 | 376,913 |

| | | 国産材製材廃材 | | 外材製材廃材 | | 建築廃材 | | 新・増築廃材 | | 公園剪定枝 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 有効利用可能量 DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 |
| 東北地区 | 岩手県 | 12,459 | 225,502 | 2,699 | 48,846 | 2,742 | 49,625 | 2,467 | 44,659 | 14,815 | 87,487 |
| | 宮城県 | 6,154 | 111,394 | 4,462 | 80,109 | 10,114 | 183,068 | 725 | 13,117 | 2,652 | 30,503 |
| 九州地区 | 佐賀県 | 1,640 | 29,683 | 162 | 2,938 | 3,896 | 70,511 | 291 | 5,266 | 611 | 7,022 |
| | 福岡県 | 1,547 | 27,996 | 1,045 | 18,919 | 4,007 | 72,535 | 2,246 | 40,650 | 3,562 | 40,965 |

| | | 乳用牛糞尿 | | 肉用牛糞尿 | | ぶた糞尿 | | 採卵鶏糞尿 | | ブロイラー糞尿 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 有効利用可能量 DW-t/年 | 有効利用熱量GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 |
| 東北地区 | 岩手県 | 6,642 | 39,690 | 14,815 | 87,487 | 6,642 | 39,690 | 2,847 | 32,739 | 13,686 | 223,060 |
| | 宮城県 | 5,578 | 32,132 | 13,198 | 77,927 | 3,973 | 23,750 | 1,262 | 14,505 | 1,096 | 17,866 |
| 九州地区 | 佐賀県 | 1,133 | 6,521 | 8,581 | 50,669 | 1,582 | 9,449 | 467 | 5,364 | 2,489 | 40,560 |
| | 福岡県 | 4,112 | 23,683 | 3,382 | 19,977 | 1,077 | 6,443 | 3,706 | 42,624 | 524 | 8,523 |

| | | 下水汚泥（濃縮汚泥） | | し尿浄化槽・余剰汚泥 | | 集落汚水汚泥 | | 食品加工廃棄物 | | 家庭系厨芥類 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 有効利用可能量 DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 | 有効利用可能量DW-t/年 | 有効利用熱量 GJ/年 |
| 東北地区 | 岩手県 | 680 | 6,046 | 309 | 2,992 | 623 | 6,297 | 200 | 576 | 18,311 | 373,577 |
| | 宮城県 | 0 | 0 | 241 | 2,332 | 463 | 4,678 | 4,400 | 12,672 | 34,234 | 698,455 |
| 九州地区 | 佐賀県 | 0 | 0 | 372 | 3,602 | 190 | 1,922 | 2,561 | 7,374 | 11,744 | 239,609 |
| | 福岡県 | 3,562 | 31,687 | 818 | 7,920 | 142 | 1,437 | 1,800 | 5,184 | 69,199 | 1,411,822 |

| | | 事業系厨芥類 | |
|---|---|---|---|
| | | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 |
| 東北地区 | 岩手県 | 7,567 | 154,388 |
| | 宮城県 | 14,740 | 300,728 |
| 九州地区 | 佐賀県 | 4,922 | 100,427 |
| | 福岡県 | 31,011 | 632,706 |

＊バイオマス推計方法の定義

(1)賦存量

賦存量は、バイオマスの利用の可否に関わらず理論上1年間に発生、排出される量とした。なお、本定義によらないものは個別に定義してた。

(2)有効利用可能量

有効利用可能量とは、賦存量よりエネルギー利用、堆肥、農地還元利用等、既に利用されている量を除き、さらに収集等にに関する経済性を考慮した量を利用可能量とした。

(3)熱量

賦存量と有効利用可能量について、熱量の推計を行った。熱量はバイオマス種により直接燃焼またはメタン発酵により発生するメタンの熱量として算出を行った。

Summarizing the results, the number are shown in Table 2.

Table 2　Summary table

| | | 有効利用可能量DW-t/年 | 有効利用熱量GJ/年 |
|---|---|---|---|
| 東北地区 | 岩手県 | 318,092 | 4,279,248 |
| | 宮城県 | 209,847 | 3,041,795 |
| 計 | | 527,939 | 7,321,043 |
| 九州地区 | 佐賀県 | 112,331 | 1,488,343 |
| | 福岡県 | 252,026 | 3,964,889 |
| 計 | | 364,357 | 5,453,232 |

(2) The expected amount of power generation from biomass direct combustion

After calculating the total amount of heat per year from each of the effective use possible amount of both regions,

Tohoku district: 7,321,043GJ/year ≒ 2,033,623,055kwh

Kyushu district: 5,453,232GJ/year ≒ 1,514,786,650kwh

Power generation amount in the case of use all the effective utilization heat quantity by the efficiency 20% of the power generation system,

Tohoku district: 2,033,623,055kwh × 0.2 = 406,724,611kwh

Kyushu district: 1,514,786,650kwh × 0.2 = 302,957,330kwh

Output in the case of the power generation equipment that runs the power generation per year 7,000 hours,

Tohoku district: 406,724,611kwh ÷ 7,000h = 58,104kw

Kyushu district: 302,957,330kwh ÷ 7,000h = 43,280kw

When there is an effective available amount of about 10 to 20%, it can be expected that the following output.

Tohoku district: 58,104kw × 10 ~ 20% = 6,000 ~ 10,000kw

Kyushu district: 43,280kw × 10 ~ 20% = 5,000 ~ 10,000kw

(3) Amount of heat required for biomass fuel drying

Required amount of heat to dry the biomass waste, is calculated as follows.

① Effective available capacity

If drying the moisture content from 60% → 15%, water evaporation amount W is,

W = effective use possible amount × (1- solids ratio before drying / solids ratio dried)

Tohoku district W = 527,939t/year × (1-40% / 85%) = 279,497t-$H_2O$/year

Kyushu W = 364,357t/year × (1-40% / 85%) = 192,895t-$H_2O$/year

② The necessary amount of heat to dry

Latent heat of vaporization at 70℃ (qj) = 2,332kJ/kg, and the drying efficiency (n) = 60%.

$$q = W \times qj / n$$

Tohoku district q = 237,572 × 2,332 / 0.6 = 924GJ/year

Kyushu district q = 192,895 × 2,332 / 0.6 = 750GJ/year

③ If you have 10 to about 20% of the effective possible amount of use

Tohoku district 924GJ/year × 10 ~ 20% = 100 ~ 200GJ/year

Kyushu district 750GJ/year × 10 ~ 20% = 75 ~ 150GJ/year

4. Challenges for biomass direct combustion power generation

(1) Collection challenges

· How much ensured biomass collection amount is, from location issues?

· It was assumed 10 to about 20% of the effective use possible amount, as a planning.

· Local understanding can be obtained in broad-based way?

(2) Issues of plant installation

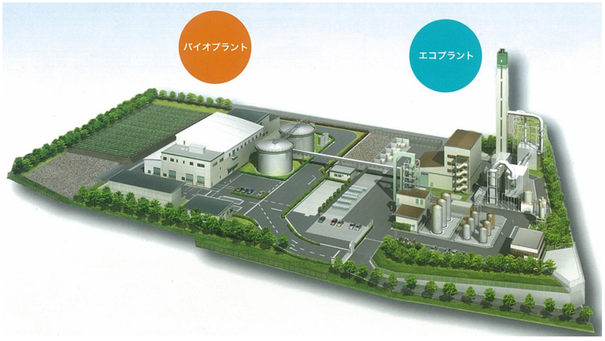
· ILC facility adjacent is favor, but challenges such as landscape and smell issue remain.

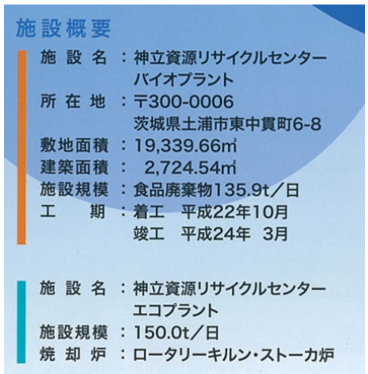
· Whether it is possible to underground plant including the cost?

· What is extent of temperature, amount, operating time, and period of the tunnel exhaust heat?

· Recycling of incinerator ash? or final disposal method?

5. Reference Case (Hitachi cement)
Biomass methane fermentation plant




This project, has large part at the joint venture with local governments and the private sector, in a sense might also say PPP (Public Private Partnership) civil cooperation. There is a need to local governments to be a prerequisite to gain certification of Biomass Town, confirmation of intention is important (Figure 2).


Figure 2 Tsuchiura Biomass Town Initiative

(1) Overview of biomass utilization business

Framework of the business is as follows, the gas by methane processing mainly from food waste (general waste, industrial waste) is used as a co-combustion gas of the cement burning fuel. Further it features a composting facility, by utilizing a part of, such as digestion solution from the methanation facility, perform the manufacture and sale of compost (Figure 3). In this project, there is also a merit of burden reduction, such as a reduction in the size of the incinerator, in local government.

As for business scale, it becomes 100t/day of methane gas reduction facility, and 30t/day composting facility.

The facility of summary flow is shown in Figure 4. By acceptance of garbage, animal and plant residues in biomass in the building, after removal of the fermentation unsuitable material at fracture separation, it is fed to the methane fermentation tank through the solubilization, anaerobic fermentation process is performed.

Biogas obtained by methane fermentation process, is used as auxiliary fuel substitute of the existing incineration facilities, also makes use of the surplus steam boilers of the existing incineration facility as a heat source of the methane fermentation tank and dryer of the new plan facility.

Digestion solution after methane fermentation is to solid-liquid separation at the dehydrator. Dehydration residue is subjected to aerobic fermentation process in the later stage of fermentation composting facility, to provide compost to the regional farmers and citizens. Filtrate after dehydration processed by water treatment to the sewage discharge standards, then it will be discharged into the sewer.

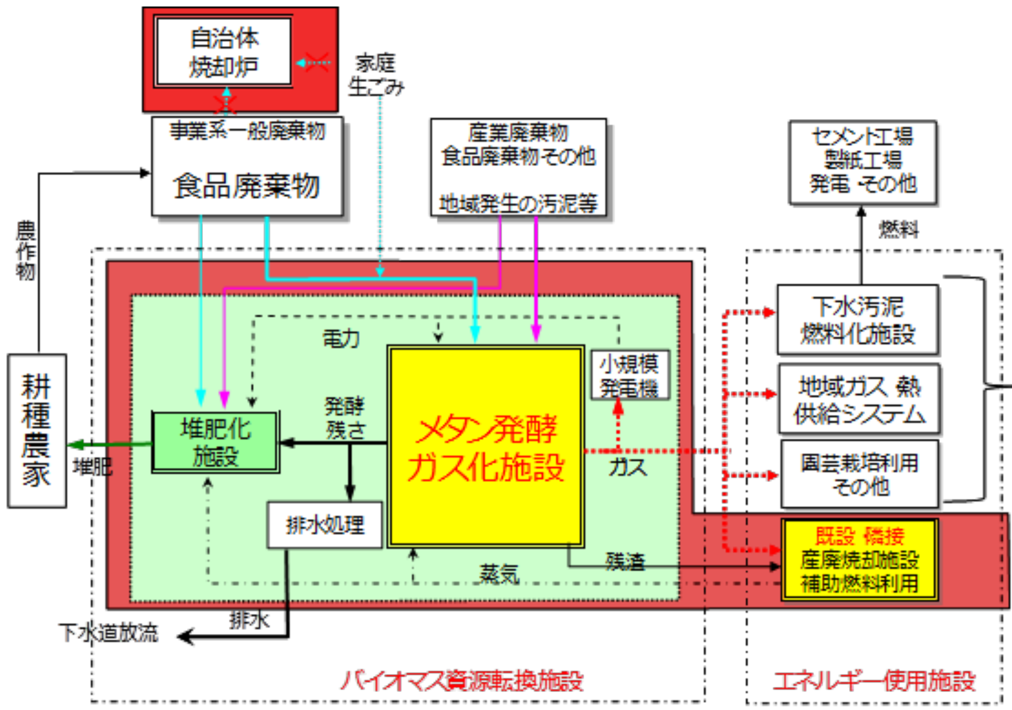



Figure 3 framework of business

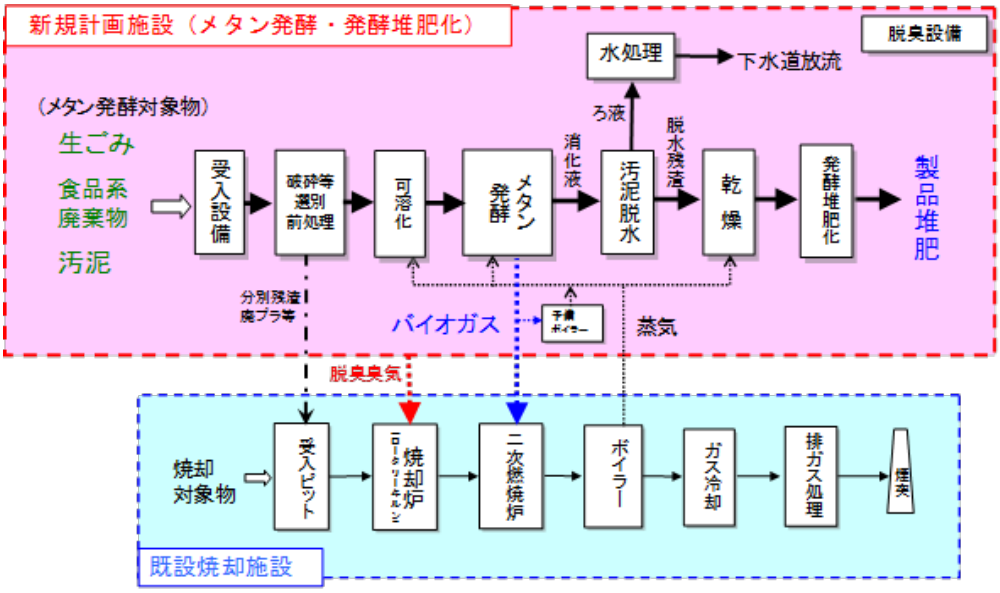
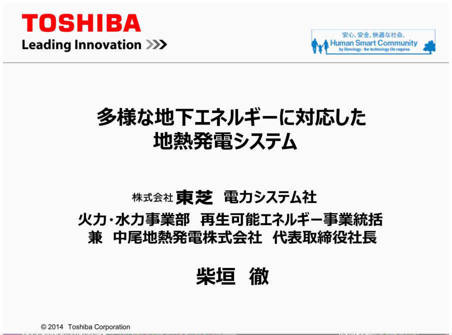
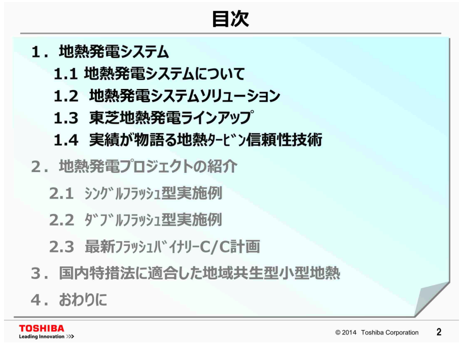
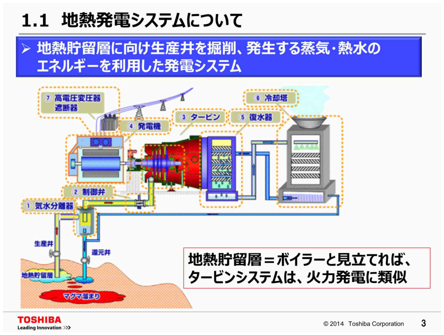



Figure 4 the processing flow of methane gas

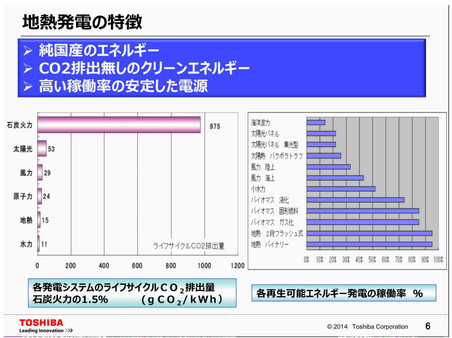
# Geo-thermal Power Generation System using variety of under-ground energy　(Toru Shibagaki, Toshiba)

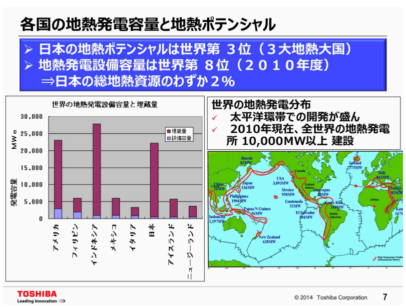


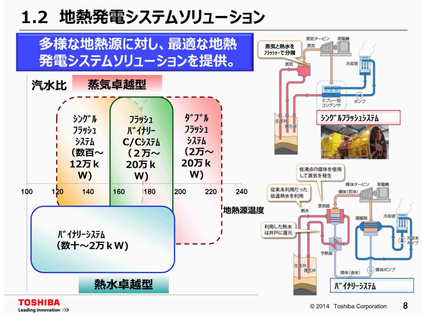



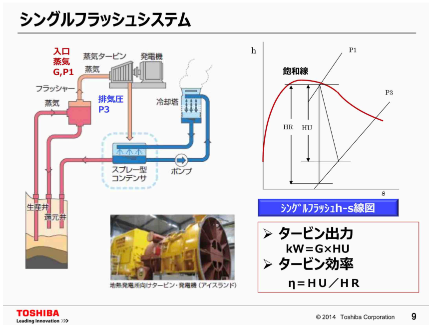






シングルフラッシュシステム
入口
蒸気
G,P1
蒸気タービン
発電機
蒸気
フラッシャー
蒸気
排気圧
P3
冷却塔
スプレー型
コンデンサ
ポンプ
生産井
還元井
地熱発電所向けタービン・発電機（アイスランド）
h
P1
飽和線
P3
HR
HU
s
ｼﾝｸﾞﾙﾌﾗｯｼｭh-s線図
タービン出力
kW＝G×HU
タービン効率
η＝HU／HR
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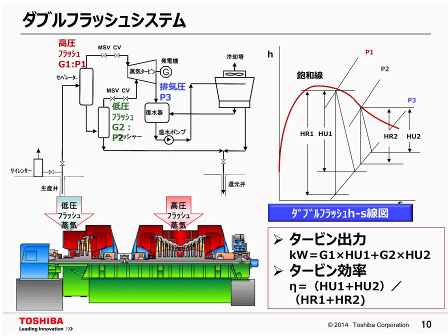
ダブルフラッシュシステム
高圧
フラッシュ
G1:P1
低圧
フラッシュ
G2：
P2
排気圧
P3
生産井
還元井
低圧
フラッシュ
蒸気
高圧
フラッシュ
蒸気
h
P1
P2
飽和線
P3
HR1
HU1
HR2
HU2
ﾀﾞﾌﾞﾙﾌﾗｯｼｭh-s線図
タービン出力
kW＝G1×HU1＋G2×HU2
タービン効率
η＝（HU1＋HU2）／（HR1＋HR2）
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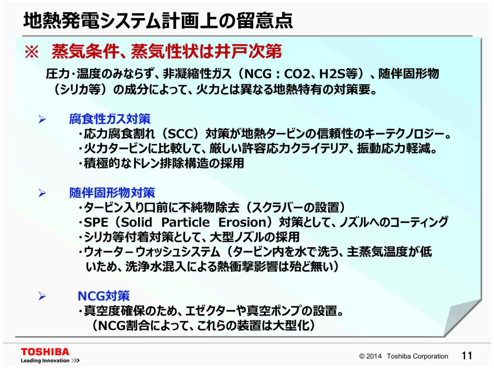
地熱発電システム計画上の留意点
※ 蒸気条件、蒸気性状は井戸次第
圧力・温度のみならず、非凝縮性ガス（NCG：CO2、H2S等）、随伴固形物（シリカ等）の成分によって、火力とは異なる地熱特有の対策要。
腐食性ガス対策
・応力腐食割れ（SCC）対策が地熱タービンの信頼性のキーテクノロジー。
・火力タービンに比較して、厳しい許容応力クライテリア、振動応力軽減。
・積極的なドレン排除構造の採用
随伴固形物対策
・タービン入口前に不純物除去（スクラバーの設置）
・SPE（Solid Particle Erosion）対策として、ノズルへのコーティング
・シリカ等付着対策として、大型ノズルの採用
・ウォーター・ウォッシュシステム（タービン内を水で洗う、主蒸気温度が低いため、洗浄水混入による熱衝撃影響は殆ど無い）
NCG対策
・真空度確保のため、エゼクターや真空ポンプの設置。
（NCG割合によって、これらの装置は大型化）
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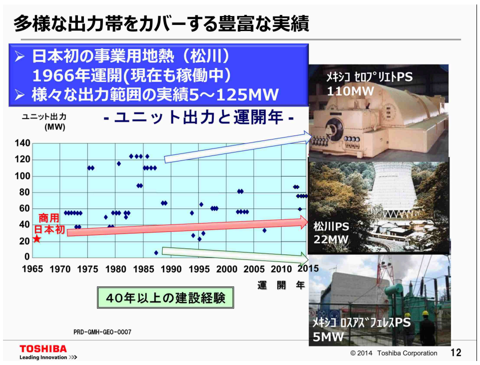
多様な出力帯をカバーする豊富な実績
日本初の事業用地熱（松川）
1966年運開(現在も稼働中)
様々な出力範囲の実績5～125MW
ユニット出力
(MW)
- ユニット出力と運開年 -
140
120
100
80
60
40
20
0
商用
日本初
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
運開年
40年以上の建設経験
ﾒｷｼｺ ｾﾛﾌﾟﾘｴﾄPS
110MW
松川PS
22MW
ﾒｷｼｺ ﾛｽｱｽﾞﾌｪﾚｽPS
5MW
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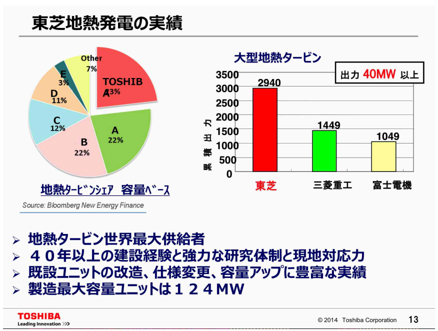
東芝地熱発電の実績
Other 7%
E 3%
D 11%
C 12%
B 22%
A 22%
TOSHIBA 23%
地熱ﾀｰﾋﾞﾝｼｪｱ 容量ﾍﾞｰｽ
Source: Bloomberg New Energy Finance
大型地熱タービン
出力 40MW 以上
実績出力
3500
3000
2500
2000
1500
1000
500
0
2940
1449
1049
東芝
三菱重工
富士電機
地熱タービン世界最大供給者
４０年以上の建設経験と強力な研究体制と現地対応力
既設ユニットの改造、仕様変更、容量アップに豊富な実績
製造最大容量ユニットは１２４MW
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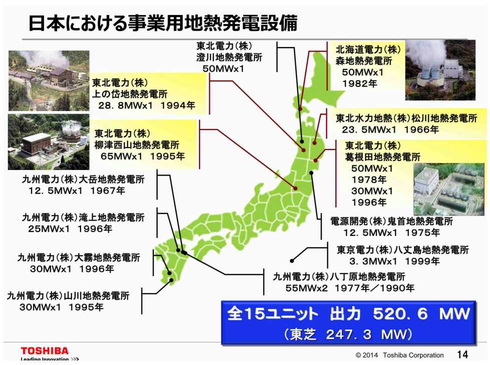
日本における事業用地熱発電設備
東北電力(株)
澄川地熱発電所
50MWx1
北海道電力(株)
森地熱発電所
50MWx1
1982年
東北電力(株)
上の岱地熱発電所
28. 8MWx1 1994年
東北水力地熱(株)松川地熱発電所
23. 5MWx1 1966年
東北電力(株)
柳津西山地熱発電所
65MWx1 1995年
東北電力(株)
葛根田地熱発電所
50MWx1
1978年
30MWx1
1996年
九州電力(株)大岳地熱発電所
12. 5MWx1 1967年
九州電力(株)滝上地熱発電所
25MWx1 1996年
電源開発(株)鬼首地熱発電所
12. 5MWx1 1975年
九州電力(株)大霧地熱発電所
30MWx1 1996年
東京電力(株)八丈島地熱発電所
3. 3MWx1 1999年
九州電力(株)八丁原地熱発電所
55MWx2 1977年／1990年
九州電力(株)山川地熱発電所
30MWx1 1995年
全15ユニット 出力 520. 6 MW
(東芝 247. 3 MW)
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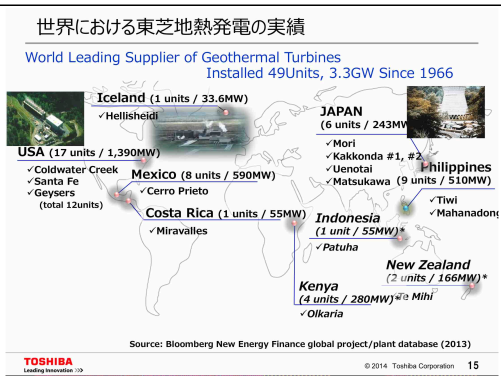
世界における東芝地熱発電の実績
World Leading Supplier of Geothermal Turbines
Installed 49Units, 3.3GW Since 1966
Iceland (1 units / 33.6MW)
✓Hellisheidi
USA (17 units / 1,390MW)
✓Coldwater Creek
✓Santa Fe
✓Geysers
(total 12units)
Mexico (8 units / 590MW)
✓Cerro Prieto
Costa Rica (1 units / 55MW)
✓Miravalles
JAPAN
(6 units / 243MW)
✓Mori
✓Kakkonda #1, #2
✓Uenotai
✓Matsukawa
Philippines
(9 units / 510MW)
✓Tiwi
✓Mahanadong
Indonesia
(1 unit / 55MW)*
✓Patuha
New Zealand
(2 units / 166MW)*
✓Te Mihi
Kenya
(4 units / 280MW)*
✓Olkaria
Source: Bloomberg New Energy Finance global project/plant database (2013)
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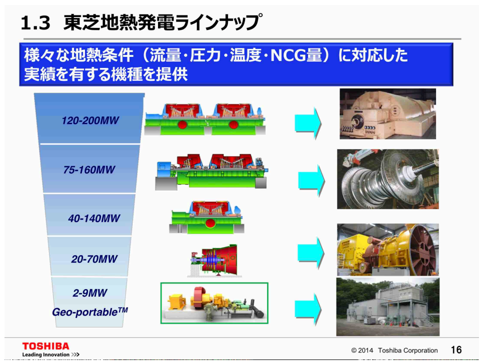
1.3 東芝地熱発電ラインナップ
様々な地熱条件（流量・圧力・温度・NCG量）に対応した
実績を有する機種を提供
120-200MW
75-160MW
40-140MW
20-70MW
2-9MW
Geo-portable™
TOSHIBA
Leading Innovation
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## 1.4 実績が物語る地熱ﾀｰﾋﾞﾝ信頼性技術

### 東芝最新地熱タービン技術の信頼性を実証

Calpine 11号機,14号機(ｶﾞｲｻﾞｰｽ・ｶﾘﾌｫﾙﾆｱ) ｽｰﾊﾟｰﾛｰﾀｰ化

- 地熱タービンに耐腐食最新技術を適用（2002年ﾘﾌﾟﾚｰｽ）

結果 ：１１号８年間、１４号10年間連続運用、開放点検 良好

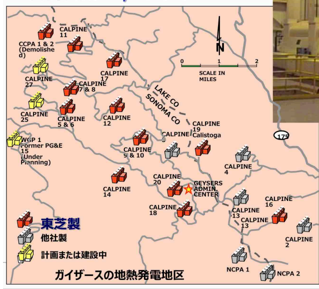
効果 ：CO2削減：年間約60万ton/台（対石炭）
稼働率向上による収入増、ﾒﾝﾃﾅﾝｽ費最小化：約３０億円改善／10年





## ガイザース, 米国カリフォルニア

１９７１年以来
１７ユニット建設
合計出力 １，３９０MW




*Calpine 19 : Calistoga Unit 1*

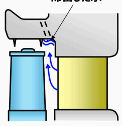
- SCDF-26”
- 定格出力 48.5MW
- 最大出力 88.0MW
- １ケーシング当り最大出力ユニット



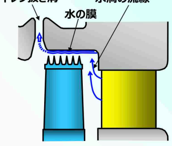
## ｶﾞｲｻﾞｰｽﾘﾊﾋﾞﾘ工事 信頼性向上技術

### ドレン排出 性向上（腐食対策）

- **従来設計**
  - 大粒の水滴は、外壁のフィンにより堰き止められる
  - 滞留した水は、高速蒸気流によってポケット内で回転し、フィンを損傷させることがある




- **最新技術**
  - ノズル後縁から剥がれた大粒の水滴は、遠心力によって、ノズル－羽根間のスペースを外壁へと流出
  - これら水滴はダイヤフラム外壁のひさしに沿って膜状に流れ、段落出口のドレン抜き溝からスムーズに排出。

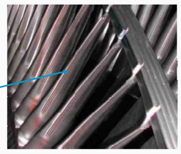


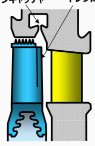



## ｶﾞｲｻﾞｰｽﾘﾊﾋﾞﾘ工事 信頼性向上技術

### 湿分除去羽根（腐食対策）

・ﾄﾞﾚﾝを積極的に排除し、耐エロージョン性を向上



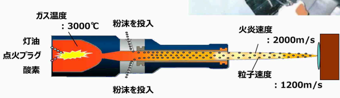




## ｶﾞｲｻﾞｰｽﾘﾊﾋﾞﾘ工事 信頼性向上技術

### ロータへのコーティング（腐食対策）

- 処理ﾌﾟﾛｾｽ：HP-HVOF
- 特徴：強力な接着力を有する精細なコーティング層を形成



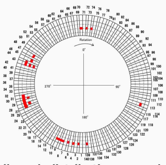



## ｶﾞｲｻﾞｰｽﾘﾊﾋﾞﾘ工事 信頼性向上技術

### 耐SCC設計クライテリア（腐食対策）

**オリジナル設計**

ガイザース20号およびカリストガ1、2号機の15年間の実運用データから、ホィール部のSCC発生データを蓄積
これらのデータから、“ Crack Occurrence Rate”, を確立し、SCC発生防止のクライテリアを確立

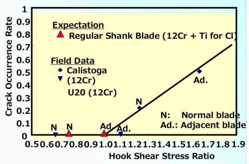


Dovetail crack distribution on a wheel

**スーパーロータ設計**

実機データをもとに、下図のクライテリアにて強度設計を実施。

10年連続運用において、耐SCC性を実証



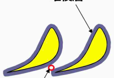

COR of 1st stage dovetail for First Generation SuperRotor



## ｶﾞｲｻﾞｰｽﾘﾊﾋﾞﾘ工事 信頼性向上技術

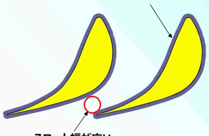
### シリカ堆積物による閉塞に対する耐性向上

- **従来設計**
  - 動翼振動応力低減のため、動翼固有振動数離調を優先に設計。
  - 段落によって、ノズル枚数を増加要シリカによる閉塞のため、性能低下などにより、蒸気通路の清掃のためにしばしば開放要。





- **ﾗｰｼﾞｺｰﾄﾞ（大型）ﾉｽﾞﾙの採用**
  - ｽﾅｯﾊﾞ翼による振動応力低減により、大型ﾉｽﾞﾙの採用が可能。ｽﾛｰﾄ幅増加により、ｼﾘｶ堆積層の影響を受けにくい。
  - この大型の構造は、長期に渡って高い性能レベルを維持可能。




2.1 最近のシングルフラッシュ地熱トピック
ケニア OLKARIA地熱発電所
第四発電所
型式 単車室２流式
出力 4 x 75MW(発電端)
主蒸気圧力 第一発電所4.8bara(2台) 第四発電所5.8bara(2台)
主蒸気温度 150℃/158℃
2014年9月 第四発電所運転開始 第一発電所試運転中
Save the Date
KenGen
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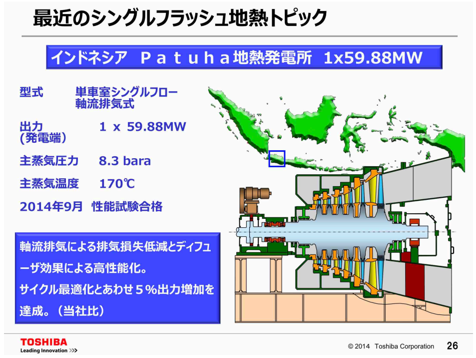
最近のシングルフラッシュ地熱トピック
インドネシア Ｐａｔｕｈａ地熱発電所 1x59.88MW
型式 単車室シングルフロー 軸流排気式
出力 (発電端) 1 x 59.88MW
主蒸気圧力 8.3 bara
主蒸気温度 170℃
2014年9月 性能試験合格
軸流排気による排気損失低減とディフューザ効果による高性能化。
サイクル最適化とあわせ５%出力増加を達成。（当社比）
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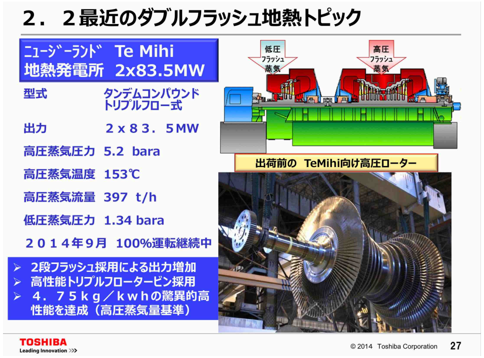
２．２最近のダブルフラッシュ地熱トピック
ﾆｭｰｼﾞｰﾗﾝﾄﾞ Te Mihi 地熱発電所 2x83.5MW
低圧フラッシュ蒸気
高圧フラッシュ蒸気
型式 タンデムコンパウンド トリプルフロー式
出力 ２ｘ８３．５MW
高圧蒸気圧力 5.2 bara
高圧蒸気温度 153℃
高圧蒸気流量 397 t/h
低圧蒸気圧力 1.34 bara
２０１４年９月 100%運転継続中
出荷前の TeMihi向け高圧ローター
2段フラッシュ採用による出力増加
高性能トリプルフロータービン採用
４．７５ｋｇ／ｋｗｈの驚異的高性能を達成（高圧蒸気量基準）
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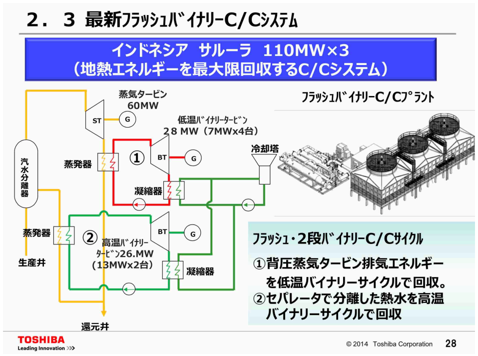
２．３ 最新ﾌﾗｯｼｭﾊﾞｲﾅﾘｰC/Cｼｽﾃﾑ
インドネシア サルーラ 110MW×3
（地熱エネルギーを最大限回収するC/Cシステム）
蒸気タービン 60MW
低温ﾊﾞｲﾅﾘｰﾀｰﾋﾞﾝ 28 MW（7MWx4台）
ﾌﾗｯｼｭﾊﾞｲﾅﾘｰC/Cﾌﾟﾗﾝﾄ
冷却塔
汽水分離器
蒸発器
凝縮器
高温ﾊﾞｲﾅﾘｰﾀｰﾋﾞﾝ26.MW (13MWx2台)
生産井
還元井
ﾌﾗｯｼｭ・2段ﾊﾞｲﾅﾘｰC/Cｻｲｸﾙ
①背圧蒸気タービン排気エネルギーを低温バイナリーサイクルで回収。
②セパレータで分離した熱水を高温バイナリーサイクルで回収
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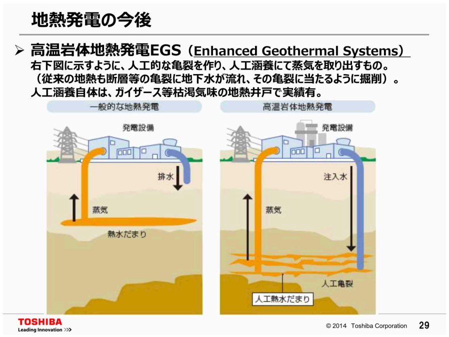
地熱発電の今後
高温岩体地熱発電EGS（Enhanced Geothermal Systems）
右下図に示すように、人工的な亀裂を作り、人工涵養にて蒸気を取り出すもの。
（従来の地熱も断層等の亀裂に地下水が流れ、その亀裂に当たるように掘削）。
人工涵養自体は、ガイザース等枯渇気味の地熱井戸で実績有。
一般的な地熱発電
高温岩体地熱発電
発電設備
排水
蒸気
熱水だまり
注入水
人工亀裂
人工熱水だまり
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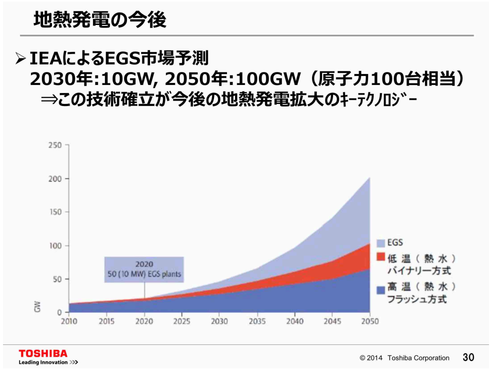
地熱発電の今後
IEAによるEGS市場予測
2030年:10GW, 2050年:100GW（原子力100台相当）
⇒この技術確立が今後の地熱発電拡大のｷｰﾃｸﾉﾛｼﾞｰ
2020 50 (10 MW) EGS plants
EGS
低温（熱水）バイナリー方式
高温（熱水）フラッシュ方式
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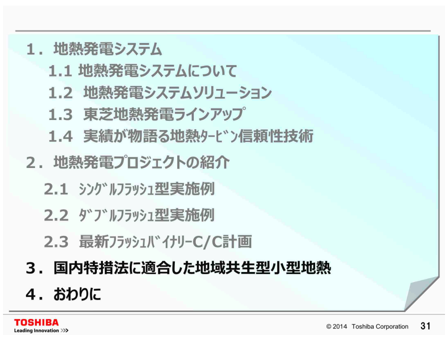
１．地熱発電システム
1.1 地熱発電システムについて
1.2 地熱発電システムソリューション
1.3 東芝地熱発電ラインアップ
1.4 実績が物語る地熱ﾀｰﾋﾞﾝ信頼性技術
２．地熱発電プロジェクトの紹介
2.1 ｼﾝｸﾞﾙﾌﾗｯｼｭ型実施例
2.2 ﾀﾞﾌﾞﾙﾌﾗｯｼｭ型実施例
2.3 最新ﾌﾗｯｼｭﾊﾞｲﾅﾘｰC/C計画
３．国内特措法に適合した地域共生型小型地熱
４．おわりに
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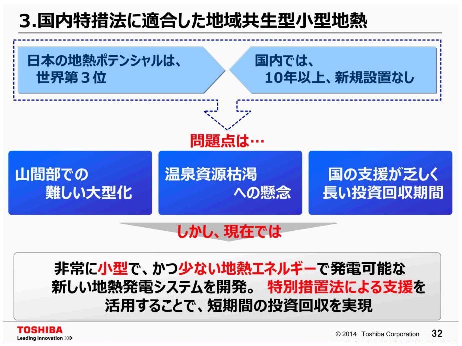
3.国内特措法に適合した地域共生型小型地熱
日本の地熱ポテンシャルは、世界第３位
国内では、10年以上、新規設置なし
問題点は…
山間部での難しい大型化
温泉資源枯渇への懸念
国の支援が乏しく長い投資回収期間
しかし、現在では
非常に小型で、かつ少ない地熱エネルギーで発電可能な新しい地熱発電システムを開発。 特別措置法による支援を活用することで、短期間の投資回収を実現
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## 地熱発電事業　事業性検討

- **建設コスト**：開発地点により下記要因で大きく初期コストが変化
  ①井戸掘削コスト（深さ、蒸気噴出量、掘削期間）
  ②送電線コスト（山間地のため、系統連系点までの距離、容量）
  ③補機コスト（蒸気条件、性状により、補機容量が変化）
- **地元理解**：候補地は温泉地に隣接、温泉枯渇危惧の払拭要
  ①地熱開発における周辺温泉へのモニタリング
  ②地域との共同事業化：休止又は老朽温泉井戸の代替掘削による湯煙発電、余剰熱水を温泉へ供給
- **耐久性**：地熱蒸気の枯渇や、腐食、固形物堆積による出力減
  ⇒適正メンテナンス費の計上、代替生産井の計画
- **発電単価**：燃料不要であるが、大容量化が難しく高い発電単価
  ⇒日本においては、固定買取制度により、数MWでも事業採算性向上（地熱開発千歳一遇のチャンス到来）

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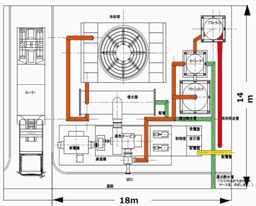
## 地域共生型　小型地熱発電所計画

### 2000kW級　標準レイアウト（発電所敷地300m²以下）




小型地熱発電所

- 蒸気量24～30ton/hで2000kWの発電が可能（生産井戸1～2本相当）
- 発電に使用しない熱水は、温泉向けとして供給
- 発電所は300m²の敷地（百坪発電所）
- 特別措置法を活用、40円/kWhで売電することで、投資回収は、5年未満

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## 奥飛騨中尾地区小型地熱開発事例

### 奥飛騨温泉郷

- 奥飛騨温泉は５ヵ所（平湯温泉、新平湯温泉、福地温泉、新穂高温泉、中尾温泉）の総称であり、130軒の温泉旅館で構成されています。
- 一方、バブル以降、年間の集客数はピーク時から減少傾向であり、地域活性化が求められています。

### 環境省再エネ事業業務委託

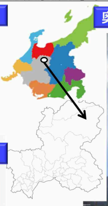

株式会社東芝
火力・水力事業部
再生可能エネルギー事業統括
柴垣 徹 殿

環境省地球環境局長
関 荘一郎

平成24年度再生可能エネルギー事業のための緊急検討委託業務
応募案件の採否について

平成24年度再生可能エネルギー事業のための緊急検討委託業務にご応募いただいた貴提案については、平成24年度再生可能エネルギー事業のための緊急検討委託業務に係る提案書審査検討会における審査の結果、下記の内示額を上限に採択となりましたので、お知らせします。
なお、当該内示額については、契約の際に事業趣旨及び公募要領に照らし内容を再精査していただく場合もありますので、ご承知置きください。

内示額：　49,644,431　円



### 奥飛騨地熱井掘削

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# Summary of Geo-thermal power generation of Tohoku Electric Power

(Kentaro Otuki, Tohoku Electric Power)

1. Mechanism and characteristics of geothermal power

○ Mechanism of geothermal power generation

The steam of low temperature that has finished work in a steam turbine becomes condensed water in the condenser, is back from the reinjection wells in the basement. (Figure 1)

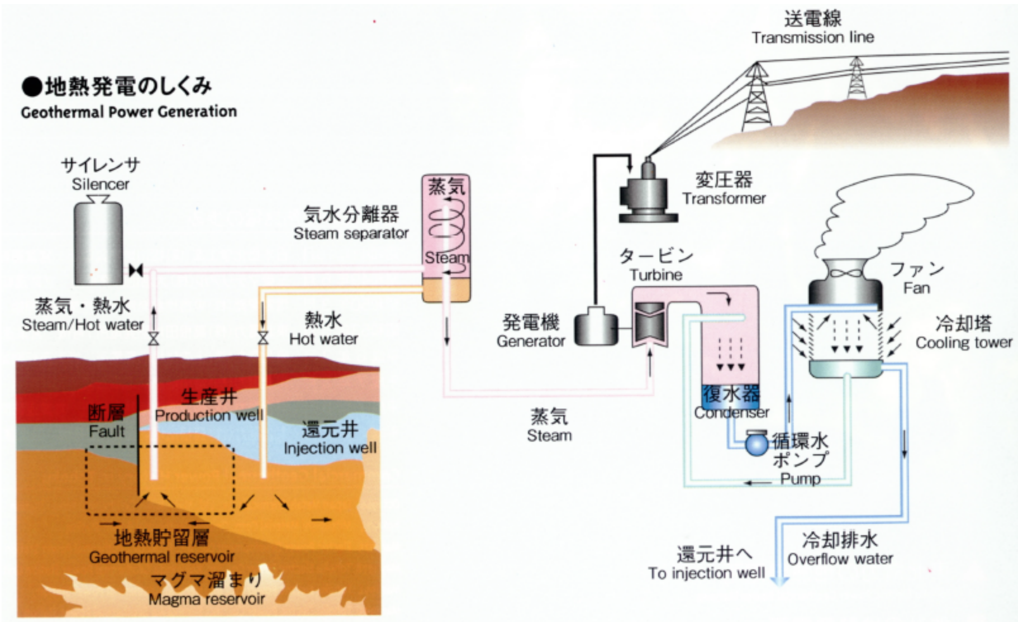



Figure 1 mechanism of geothermal power generation

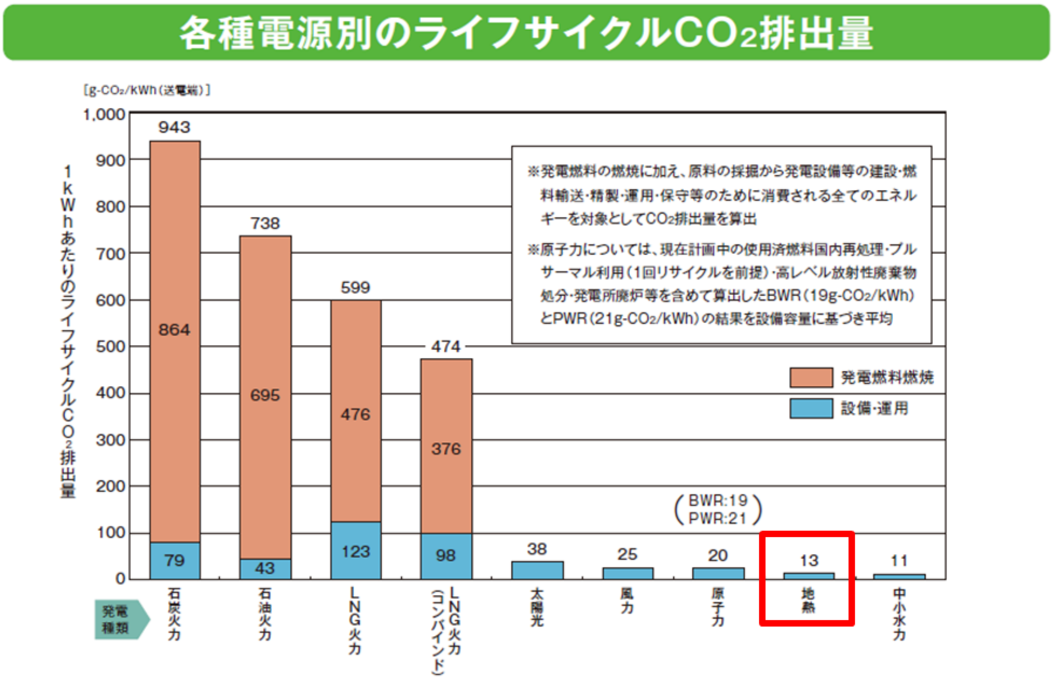
○ Features of geothermal power generation

Features of geothermal power generation is as follows.

- Net domestic energy that does not rely on imports
- Renewable energy
- Stable power supply in the natural energy
- Environmental load is small, $CO_2$ emissions is small
- Multi-purpose use is possible (agriculture, forestry and fisheries, tourism, etc.)
- Share is not very large in the world

Life cycle $CO_2$ emissions of geothermal power generation has become a low level compared to other power sources.

Also, compared to other renewable energies, as high as about 80% facility usable rate, there are many power generation can be characterized by the same output. (Figure 2)




<Source> Federation of Electric Power Companies of Japan, "Nuclear energy drawings collection 2014"

□電源別の設備利用率

| | |
|---|---|
| 地熱 | 約80% |
| 風力 | 約20% |
| 太陽光 | 約12% |

<出典>コスト等検証委員会報告書
(内閣府：平成23年12月19日)

Figure 2 life cycle $CO_2$ emissions, each power supply facility usable ratio

2. World and Japan's geothermal power generation

○ History of geothermal power generation

1904 Driving a generator using natural steam by Jiriko Conti Duke in Italy Larderello (output 0.75 hp)

1913 The world's first geothermal power plant in Italy Larderello (output 250kW)

1918 Vice Admiral Toshiharu Yamauchi started excavation at Oita Prefecture Hayami District Asahi village Tsurumi 950-1. The success of excavation in 1919. (Pore size 4 suns, depth 80 shaku)

1925 Mr. Osamu Tachikawa of Tokyo electric light Ltd. Institute, took over the business

of Yamauchi et al, named "Tsurumi fumaroles", after number of test results, the first successful geothermal power generation in Japan by the turbine. (Output 1.12kW)
1947 Geological survey was started for research on the selection of geothermal development area.
1948 Tone bowling Ltd. succeeded in power generation by steam turbine in Shizuoka Prefecture Joto village Yunosawa laboratory. (3kW)
1951 The geothermal power generation succeeded in Industry and Technology Agency Beppu test site. (Output 30kW)
1958 The world's first start of operation of geothermal power plants in hot water separation type in New Zealand Wairakei. (Output 6,500kW)
1960 Start of operation of private geothermal power generation at Fujita Kanko Inc. Hakone Kowakien. (Output 30kW, 1965 obsolete)
1966 Start a geothermal power generation by Japan Metals & Chemicals Co., Ltd. At Matsukawa geothermal power plant at the first time in Japan. (Output 9,500kW)
1967 Start a geothermal power generation by Kyushu Electric Power Co., Ltd. At Otake power plant. (Hot water separation type, output 11,000kW)
1996 Geothermal power output 500 000 kW achieved.
2006 Japan's first binary power plant (Hatchobaru, 2,000kW) was in operation.
2012 feed-in tariff (FIT) was started.

○ Geothermal power generation facilities in the world

Japan is located in the volcanic zone of the Pacific Rim, abundance of geothermal is said to be third largest after the United States, and Indonesia, however, the introduction amount is not as many than other countries. (Figure 3, Figure 4)

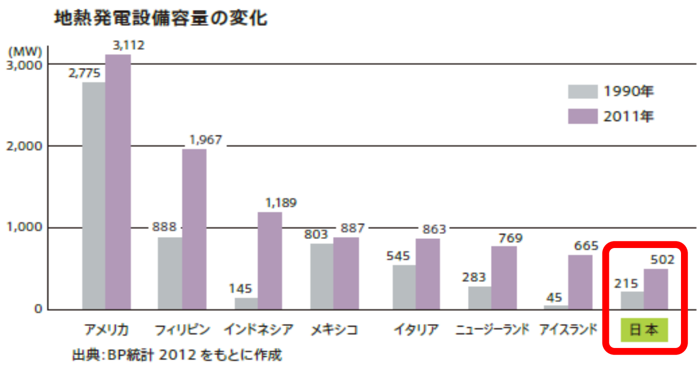

<Source> National Institute of Oil, Gas and metal mineral resources mechanism "geothermal pamphlet"

Figure 3 The world geothermal power generation capacity

**世界各国の主な地熱資源量**

| 順位 | 国名 | 資源量 (万kW) |
|---|---|---|
| 1 | アメリカ | 3,900 |
| 2 | インドネシア | 2,700 |
| 3 | 日本 | 2,300 |
| 4 | フィリピン | 600 |
| 5 | メキシコ | 600 |
| 6 | アイスランド | 580 |
| 7 | ニュージーランド | 370 |
| 8 | イタリア | 150 |

※ 1万kW = 10MW
出典:村岡洋文、OHM、2011.7をもとに作成




<Source> National Institute of Oil, Gas and metal mineral resources mechanism "geothermal pamphlet"

Figure 4 World major geothermal resource amount of each country, and the change in the geothermal power generation capacity

○ situation of geothermal development in the world

Geothermal development in countries around the world is accelerating aggressively. (Figure 5)

単位：万kW

| 米国 | 2005年 | 2010年 | 2015年（見込み） |
|---|---|---|---|
| | 256.4 | 309.3 | 540 |

（注）主な地熱発電所：ガイザーズ（カリフォルニア州、14基、出力127.3万kW）等

| インドネシア | 2005年 | 2010年 | 2015年（見込み） |
|---|---|---|---|
| | 79.7 | 119.7 | 350 |

（注）主な地熱発電所：サラク（西ジャワ州、6基、出力37.5万kW）等

| ニュージーランド | 2005年 | 2010年 | 2015年（見込み） |
|---|---|---|---|
| | 43.5 | 62.8 | 124 |

（注）主な地熱発電所：タウポ（ニュージーランド北島、11基、出力17.5万kW）等

| アイスランド | 2005年 | 2010年 | 2015年（見込み） |
|---|---|---|---|
| | 20.2 | 57.5 | 80 |

（注）主な地熱発電所：ヘリシェイディ（アイスランド南西部、5基、出力30.3万kw）等

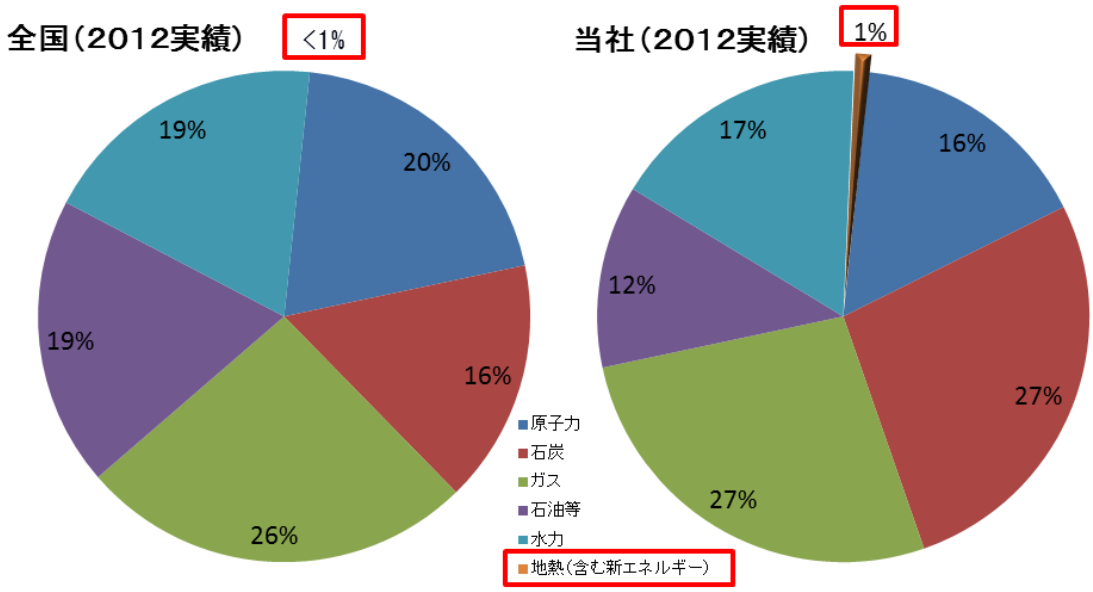
<出典> Ruggero Bertani : Geothermal power generation in the world 2005-2010 update report

Figure 5 status of the world's geothermal development

3. The proportion of power generation scale of nationwide and our company

○ Power configuration ratio based on power generation capacity

As for our company's geothermal power generation, it is about 1% of power generation installed capacity in our company inside, and it is a minority and less than 1% in Japan. (Figure 6)

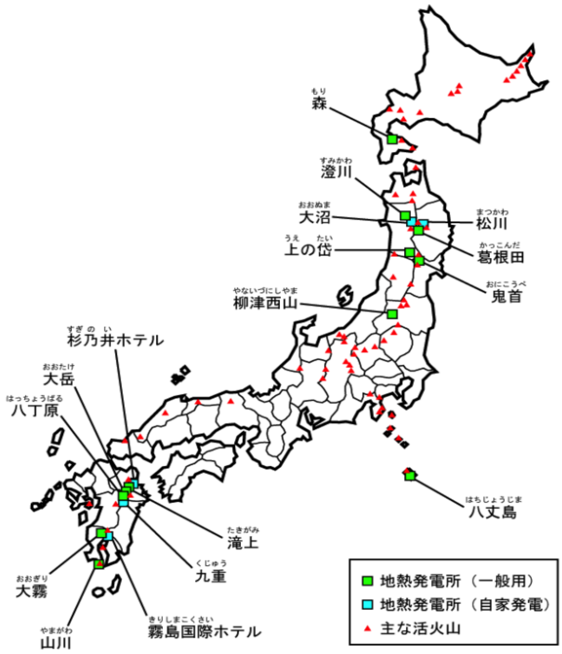



<Source> Federation of Electric Power Companies of Japan, "Nuclear energy drawings Collection 2014" (national data only)

Figure 6 Power supply configuration ratio in accordance with power generation installed capacity (nationwide, our company)

○ Power generation scale of geothermal power

Currently, geothermal power generation in Japan has been developed in the17 points, most of which have been installed in the Tohoku and Kyushu. (Figure 7)




<Source> "Japan's geothermal power plant" Industrial Scienc and Technology Institute HP

| | 全国 | 東北電力 |
|---|---|---|
| 地点数 | 17地点 | 5地点 |
| 認可出力（万kW） | 51. 509 | 24. 730（48%） |
| 発電電力量（億kWh） | 26. 2 | 10. 3（39%） |

<Source> geothermal power generation of the current status and trends 2013

Figure 7 Japan's geothermal power plant and the power generation amount

## 4. Features and efforts of our geothermal power

○ Overview of the geothermal power plant of our company

Our Company has 5 power plant 6 generators including a cooperating group, total authorized output accounts for about 48% of the geothermal power plant of Japan. (Figure 8)

Our company’s (including a group of companies) geothermal power plants are, relatively, located in the vicinity of the ILC candidate site. (Figure 9)

| 発電所名 | 所在地 | 号機 | 設備容量（kW） | 運転開始 | 蒸気供給会社 |
|---|---|---|---|---|---|
| 葛根田 | 岩手県雫石町 | 1号<br>2号 | 50,000<br>30,000 | S53.5.26<br>H8.3.1 | 東北水力地熱㈱<br>（旧）日本重化学工業 |
| 上の岱 | 秋田県湯沢市 | ― | 28,800 | H6.3.4 | 東北水力地熱㈱<br>（旧）秋田地熱エネルギー |
| 澄　川 | 秋田県鹿角市 | ― | 50,000 | H7.3.2 | 三菱マテリアル㈱ |
| 柳津西山 | 福島県柳津町 | ― | 65,000 | H7.5.25 | 奥会津地熱㈱ |
| 小　計 | | | 223,800 | | |
| 松　川 | 岩手県八幡平市 | ― | 23,500 | S41.10.8 | 東北水力地熱㈱ |
| 合　計 | | | 247,300 | | |

Figure 8 Overview of the Company's geothermal power generation


Figure 9 position of the geothermal power plant of the Company (including a group of companies)

○ Our geothermal power generation organization

The steam production and reduction are conducted by steam supply company. We adopted a joint development system for generating electric power by purchasing the steam (about Matsukawa, consistently operated by Tohoku Hydropower Geothermal Co., Ltd. [group of companies]). (Figure 10)

※ Matsukawa geothermal power plant, consistently operated by Tohoku Hydropower Geothermal Co., Ltd. (group of companies)

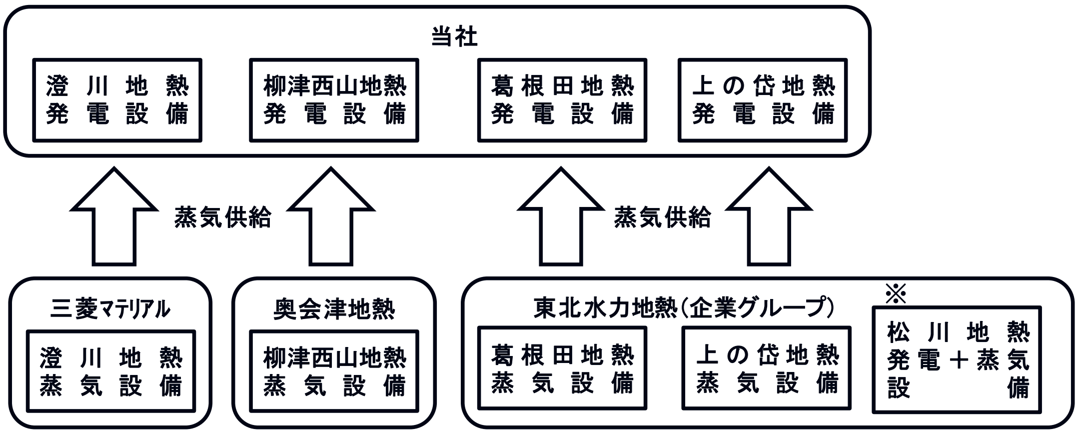



Figure 10 Our company's geothermal power generation organization

○ Features of our geothermal power plant

Geothermal power plants have a simple structure without such a boiler compared to thermal power plants.

From this reason, we have adopted the remote operating system to monitor and control in the monitoring room of 10-30 km away from each geothermal power plant.

Our company has proceeded further rationalization from 2000 fiscal year, to employ a centralized monitoring and controlling of 5 geothermal power generators of four power plants locations from Akita thermal power plants.

(Figure 11, Figure 12)

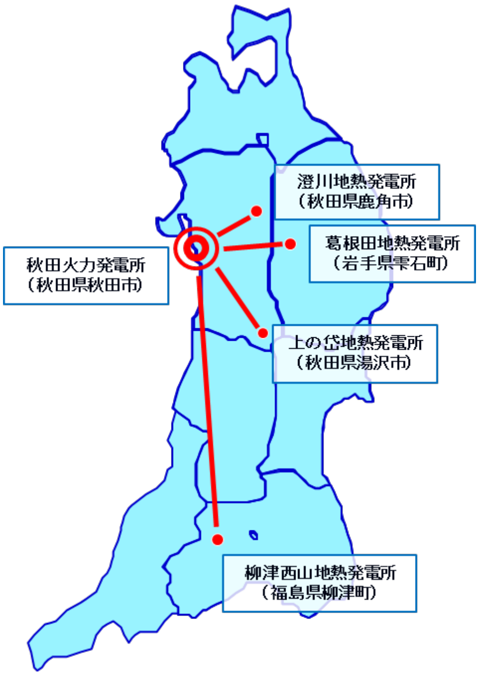



Figure 11 centralized remote monitor control system

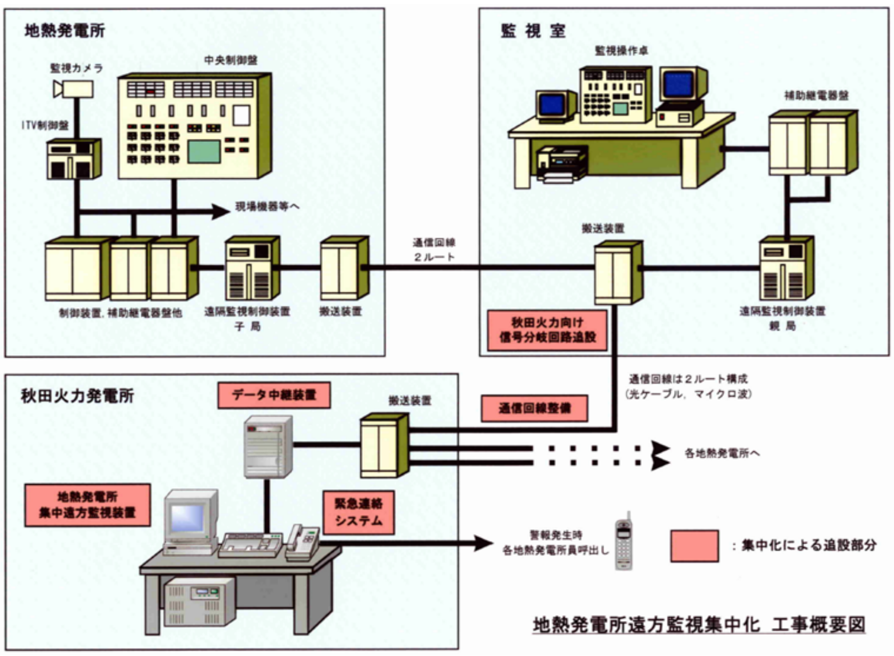



Figure 12 Overview of centralized remote monitor control system

○ Changes in year average output

Our geothermal power plants, there is a high performance experience, after the operation of Kakkonda Unit 1 (1978). In 1990 or later, we have sequentially started the operation of Uenotai, Sumikawa, Yanaizu-Nishiyama, and Kakkonda No.2. Initially, although the output power was the order of 70-80 percent in about 5-10 years, and significant vapor reduction was happened in 10 years passed, and the output power became about 50 percent in about 15 years and now. After that, it is almost stable at this level.

As annual average output (red line) is close to approval output (blue line), it shows a high investment performance. (Figure 13)

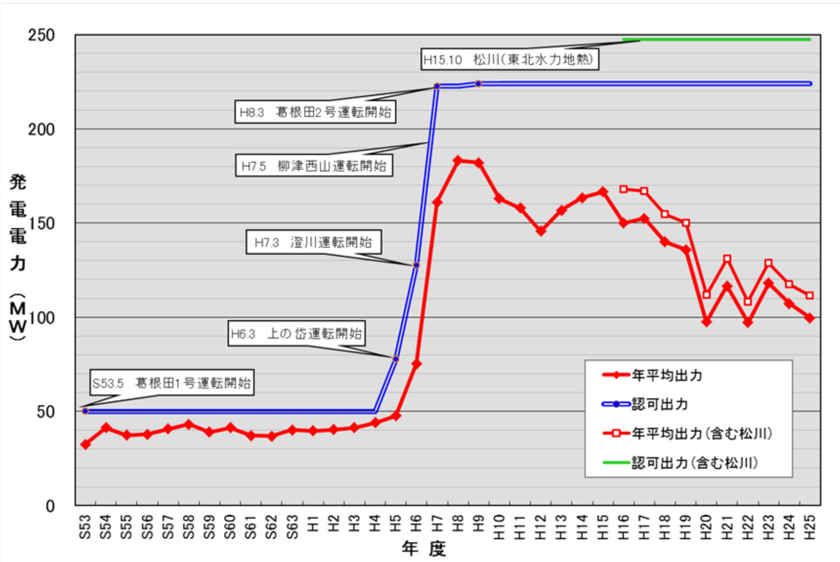



Figure 13 Trends in year average output

○ Transition of power generation time utilization

Transition of power generation time utilization ratio of each power plant can be divided to two groups; Uenotai and Sumikawa of high utilization (70-90 percent) group even 15 years after the start of operation, and Kakkonda, Yanaizu-Nishiyama and Matsukawa of low utilization (50% or less) group. You can see the difference in investment performance point by point. (Figure 14)

The power generation time utilization ratio is the percentage ratio of the amount of power generated during the fiscal year, with the amount of power that can be obtained within the actual power generation time at the rated output.

$$\text{発電時間利用率(\%)} = \frac{\text{年度の発電電力量(kWh)}}{\text{定格出力(kW)} \times \text{年度の発電時間(h)}} \times 100$$

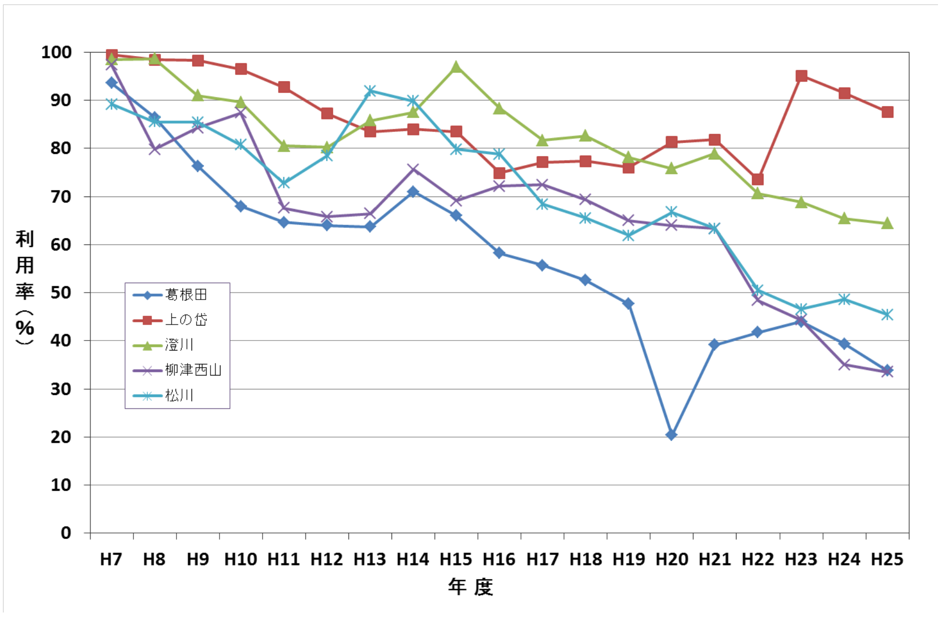



Figure 14 Transition of power generation time utilization ratio

○ Challenge of geothermal power plant operation

"Steam well attenuation", "scale", and "hydrogen sulfide" are the issues as big factors that reduce the output (operating ratio) in geothermal power plant operations.
Our company has implemented for the operating rate improvement efforts.

○ Operating ratio improvement efforts

In Uenotai and Sumikawa geothermal power plant of our company, it has gained a certain degree of success by drilled the replenishment well into the natural park, by receiving benefits of a deregulation of Japan. (Figure 15, Figure 16)

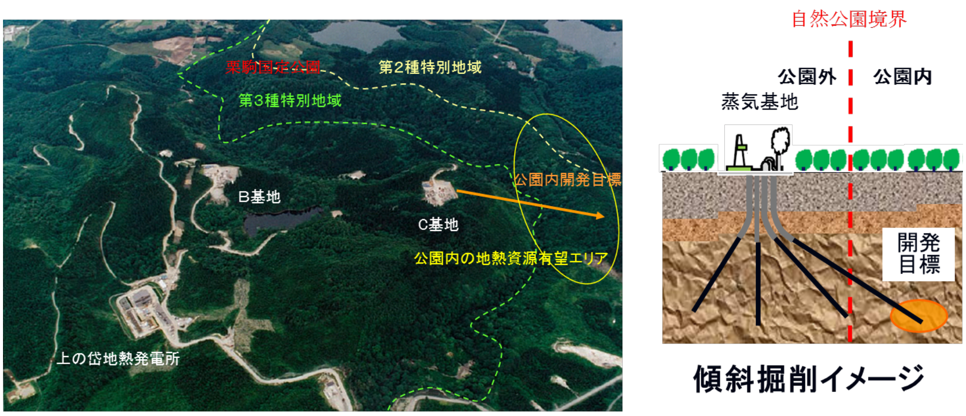



Figure 15 the example of Uenotai thermal power plant replenishment well T-56

Figure 16 The situation of fumaroles of inclination well in the National Monument Park (replenishment production well T-56)

○ Geothermal reservoir recharge project

There is a case that the power generation output is fluctuating in a geothermal power plant by being unable to collect the required amount of steam and hot water stably.

By performing the supply of water to the heat source of the underground more appropriately, JOGMEC (National Institute of Oil, Gas and metal mineral resources) is developing a technology to achieve optimization and stabilization of the collected amount of steam and hot water at Yanaizu-Nishiyama geothermal power plant. (Figure 17)

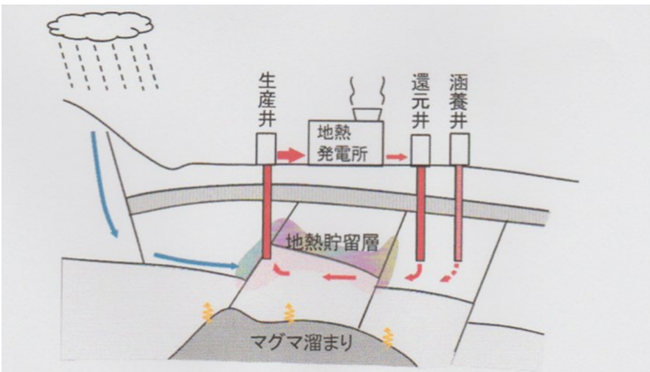



Figure 17 Schematic of geothermal reservoir recharge project

5. Challenges and the Japan's support system for geothermal power generation

○ Challenges geothermal power generation

· Single machine capacity is small.
  In business power generation facilities in Japan, 3,300kW ~ 65,000kW
  In Japan of private power generation 100kW ~ 23,500kW

· Research ~ development ~ commercial operation take time.

National-wide survey ~ wide area survey ~ rough survey ~ fine survey ~ development survey ~ power plant construction.
(Example: on Uenotai took 23 years)

· Number of new power plant construction is limited.
Since promising areas are unevenly distributed in the Tohoku and Kyushu, and since about half of the possible development area are located in a special area on the Natural Parks Law, new development is difficult.

○ For support measures in geothermal development process
Auxiliary support of Japan related to geothermal development (JOGMEC) has been provided in stages. (Figure 18)


<Source> Agency for Natural Resources and Energy, "the current state of geothermal resources development (September 2014)."

Figure 18 Support measures in geothermal development process

○ Geothermal development point of nationwide
Figure 19, is a situation of geothermal development sites nationwide.
We in the corporate group are being carried out the early stages of the investigation "Kijiyama - Shimonotai (Akita Prefecture Yuzawa City) area".


<Source> Agency for Natural Resources and Energy, "the current state of geothermal resources development (September 2014)."

Figure 19 status of geothermal development sites nationwide

○ Geothermal power plant that was operating since FIT

The operational geothermal power generation facilities after FIT (feed-in tariffs) were five plants and total output of about 250kW. At the moment it is mostly small-scale plant. (Figure 20)

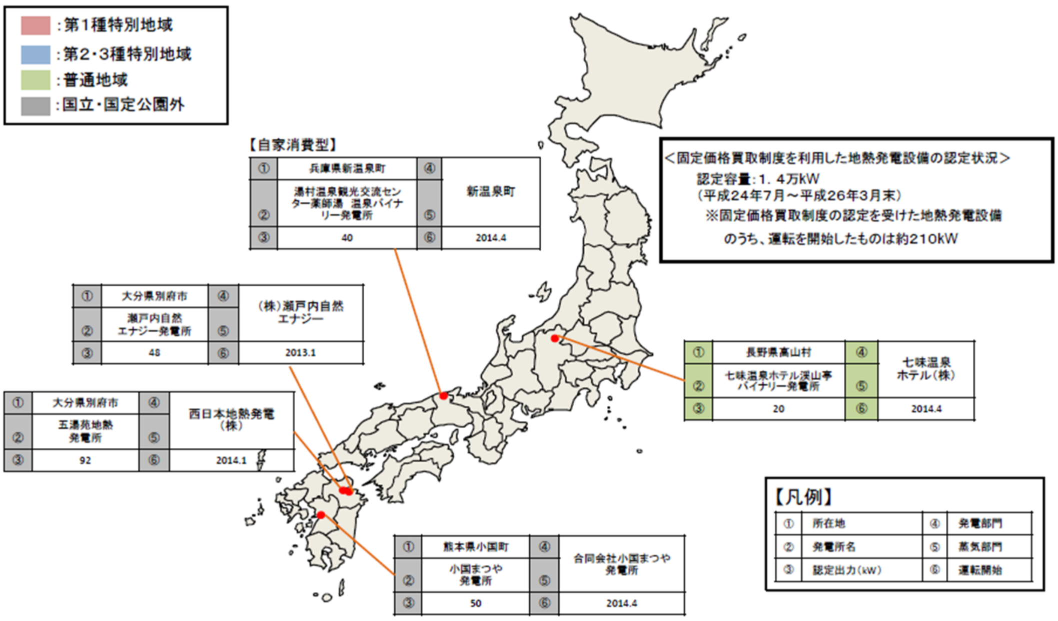



Figure 20 geothermal power plant that has operated since FIT

6. Efforts to geothermal development of our company's corporate group

○ Kijiyama, Shimonotai regional geothermal resource development research projects

Our group of companies "Tohoku Hydropower Geothermal" is making the geothermal resource survey of the early stages, in the adjacent land of Uenotai thermal power plant "Kijiyama, Shimonotai".

In the area of Kijiyama and Shimonotai, up to now, we conducted the ground survey, exploration well two, and monitoring well single drilling, then make ongoing the overall analysis. (Figure 21, Figure 22)

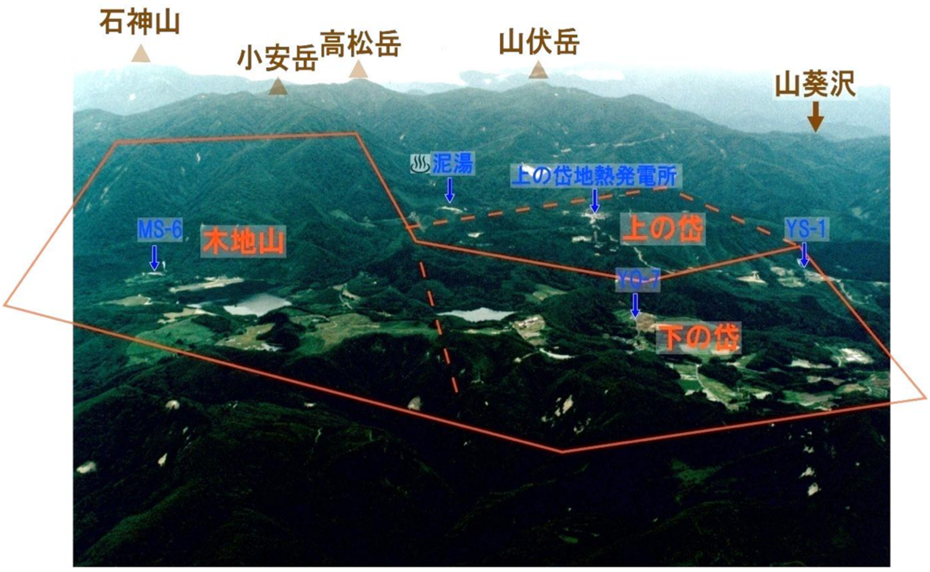



Figure 21 bird's-eye view of Kijiyama, Shimonotai area

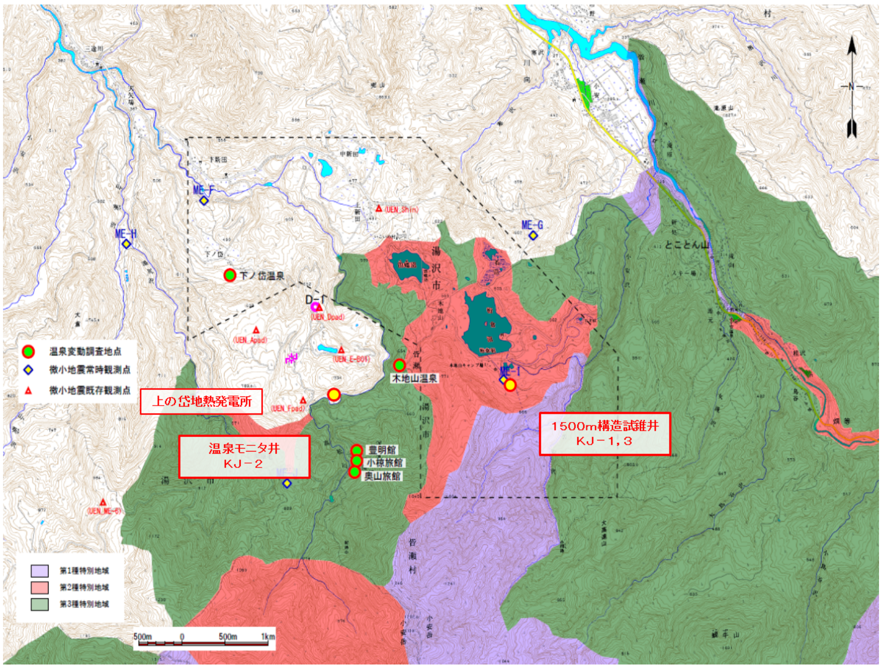



Figure 22 Kijiyama-Shimonotai regional position

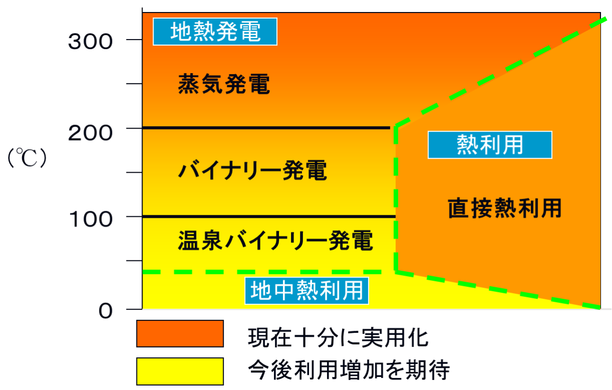
○ Kijiyama, Shimonotai region geothermal development research results and planning
Kijiyama - Shimonotai survey schedule is below.
Continues a similar survey to 2015 fiscal year, and to review and evaluate the commercialization potential on it, is expected to plan an investigation after the 2016 fiscal year. (Figure 23)

| 年度 | H22 | H23 | H24 | H25 | H26 | H27 |
|---|---|---|---|---|---|---|
| 調査位置づけ | 地熱構造調査 | 地熱構造モデル作成 | 地熱構造モデル見直し | 地質構造調査・モニタリングデータ収集 | | |
| 地表調査坑井掘削他 | ・地質調査<br>・地化学調査<br>・電磁探査<br>・重力探査<br>・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・温泉変動ﾓﾆﾀﾘﾝｸﾞ<br>・微小地震観測 | ・電磁探査<br>・自然電位探査<br>・フラクチャ解析<br>・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・温泉変動ﾓﾆﾀﾘﾝｸﾞ<br>・微小地震観測 | ・電磁探査<br>・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・温泉変動ﾓﾆﾀﾘﾝｸﾞ<br>・微小地震観測 | ・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・構造試錐井掘削<br>・温泉ﾓﾆﾀﾘﾝｸﾞ井掘削<br>・温泉変動ﾓﾆﾀﾘﾝｸﾞ 他 | ・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・構造試錐井掘削<br>・ﾄﾚｰｻｰ試験 | ・坑井圧力ﾓﾆﾀﾘﾝｸﾞ<br>・隣接貯留層との関係評価他<br>・事業化可能性の検討 |

Figure 23 Kijiyama, Shimonotai investigation schedule

7. Utilization of geothermal energy

○ Effective utilization of geothermal energy due to the difference in the temperature
We are utilizing the area of the steam power generation, but in recent years has spread the movement to take advantage of geothermal resources in the binary power generation. (Figure 24)

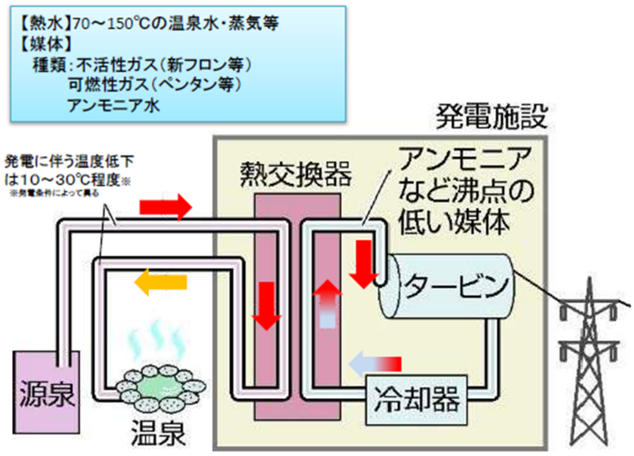



<Source> New Energy Foundation brochure
Figure 24 Geothermal energy area and the availability

○ Mechanism of geothermal binary power generation (hot spring power generation)

Binary power generation is a system for generating electricity by turning a turbine generator, using a medium having a lower boiling point than water boiled in hot spring of heat (70℃ ~ 150℃). (Figure 25)

If the order of several hundred kW is required, it is possible to develop in a short period of about 2-3 years.




<Source> Agency for Natural Resources and Energy, "the current state of geothermal resources development (September 2014)."

Figure 25 mechanism of geothermal binary power generation

○ Case Study of geothermal resources

Matsukawa geothermal power plant (Tohoku Hydropower Geothermal Co., Ltd., Iwate Prefecture Hachimantai) warmed condensed water after power generation by the addition of steam, and sold to Hachimantai Industrial Promotion of the third sector. It has been used in Hotels and cottage villa, and in greenhouses with a hot water supply contract. (Figure 26)

(In the 2010 fiscal year, 70 ℃, up to 260t/h)

供給先

| | | | | | |
|---|---|---|---|---|---|
| ・ホテル等 | ３８軒 | ・保養所 | ２５軒 | ・別荘 | ６１３軒 |
| ・商店 | １５軒 | ・貸別荘施設 | １軒 | ・病院 | １軒 |
| ・老人ホーム | １軒 | ・日帰り温泉施設 | １軒 | | |
| ・農業用ハウス | ９５棟（冬期のみ） | | | | |

Figure 26 Matsukawa condensed water supply destination after geothermal power plant power generation

End.

# 7 Editor words

High efficiency energy conversion in International Linear Collider (ILC) is an inevitable issue among advanced accelerator project. ILC should be the model for use of high-efficiency equipment, and the use of sustainable and renewable energy sources. The Technology Group of the Association of Adavanced Accelerator Science and Technology Promotion began a study of this issue. This report is a summary about the technology being studied which has been proposed at green ILC Working Group in February 2014 to March 2015. Technical study is intended to make continued even after April 2015, but the present report is the first stage of the study results, which will be a help document at the time of ILC detailed design stage in the near future. We would like to keep both the Japanese and English version of this report in the ILC-related web-page.

Individual presentations at the working group can be found at;

https://aaa-sentan.org

See the member pages of the inside.

Editor
May 27, 2015