Victorian Brown Coal Forum 2015
Material for the Forum (October 6, 2015)

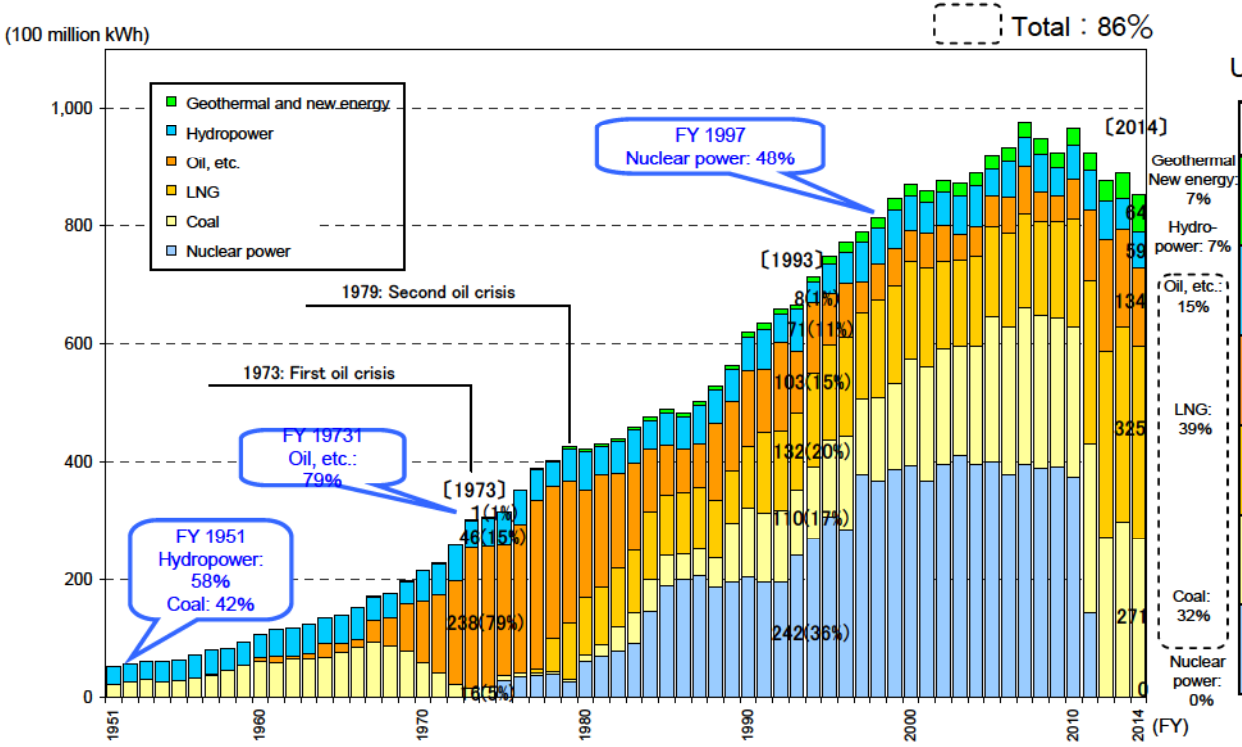
Development for Manufacture of Reformed Coal Derived from Victorian Brown Coal

October 6, 2015

Kyushu Electric Power Co., Inc.

1 Current Situation of Our Coal Power Generation

- Since the oil crises of the 1970s, we have concentrated on formulating the best mix of power sources in order to ensure long-term stability of energy, to respond to global environmental needs and to promote the use of various fuels, such as nuclear power, LNG and coal, and to develop sources of high-efficiency thermal power.
- Subsequent to the Great East Japan Earthquake, the rate of thermal power generation was increased to about 90% due to the long-term outage of nuclear power.
- At full operation and with the extension of periodic inspection and other measures, our coal power generation accounts for 32% of the total.



Constituent ratio of power generation by power source
(including power received from other companies)

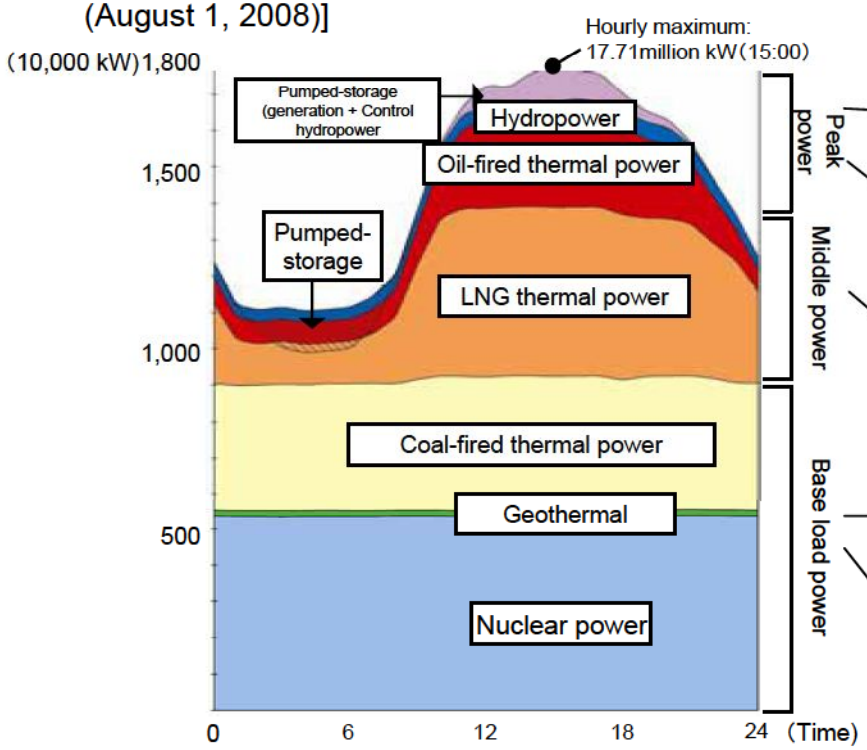
Upper: 100 million kWh, Lower: Constituent ratio

1973	1993	2010	2011	2012	2014
1 (1%)	8 (1%)	29 (3%)	31 (3%)	34 (4%)	64 (7%)
46 (15%)	71 (11%)	57 (6%)	66 (7%)	67 (8%)	59 (7%)
238 (79%)	103 (15%)	69 (7%)	120 (13%)	189 (21%)	134 (15%)
0 (0%)	132 (20%)	183 (19%)	276 (30%)	314 (36%)	325 (39%)
16 (5%)	110 (17%)	255 (26%)	286 (31%)	273 (31%)	271 (32%)
0 (0%)	242 (36%)	374 (39%)	145 (16%)	0 (0%)	0 (0%)

2 Concept of Our Coal Utilization

- Even if the strengths and weaknesses of power sources vary with environmental changes, we aim to ensure competiveness to allow for flexible responses, and to retain nuclear power, LNG, hydropower, geothermal and other forms of renewable energy.
- We utilize coal as a base load power source because of its abundant supply and excellent procurement stability and economic performance.

[Daily load curve at record-high power generation (August 1, 2008)]



[Positioning of main power sources]

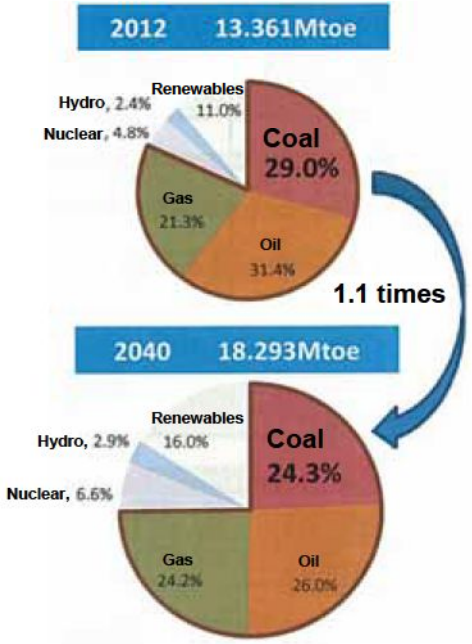
Pumped-storage hydropower	・Due to its fast startup and shutdown, it is utilized at power peaks and times of emergency.
Oil-fired thermal power	・It has a high generation cost and emits more CO2. ・Because it can respond flexibly to demand variation, it is utilized at power peaks and times emergency.
LNG thermal power	・It delivers environmental performance above that of oil-fired or coal-fired thermal power, and its output can be easily controlled. ・It has a low generation cost and is utilized as middle power.
Coal-fired thermal power	・It demonstrates excellent fuel procurement stability and economic performance. ・It is utilized as base load power, with due considerations to environment conservation.
Nuclear power	・It provides excellent fuel procurement stability, economic performance and environment conservation. ・It is utilized as dominant base load power, with the highest priority to safety.

3 Need for Utilization of Low rank Coal

■ Coal demand prospects

Coal demand accounts for about 1/4 of the total energy demand worldwide, and is expected to be about 1.1 times larger in 2040 than in 2012.
With coal demand expanding rapidly in emerging countries such as China and India, the supply-demand balance is expected to be tight in the long and medium terms.

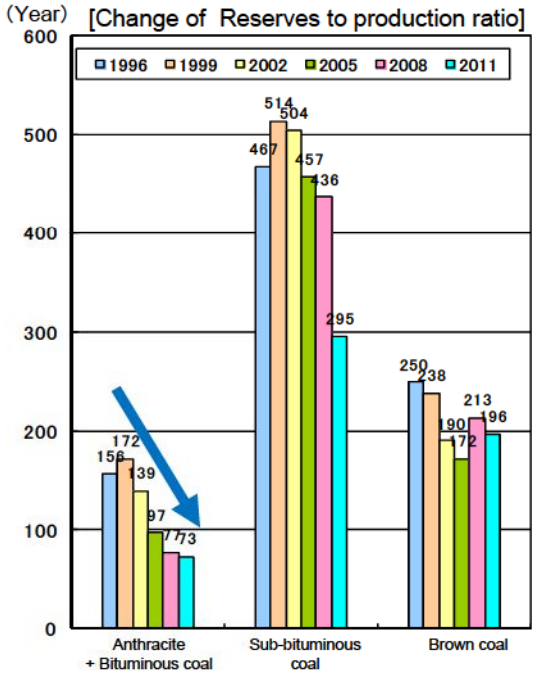
[Global long-term prospects of energy supply and demand]



Source: IEA "World Energy Outlook 2014"

■ Recoverable reserves & Reserves to production ratio of coal

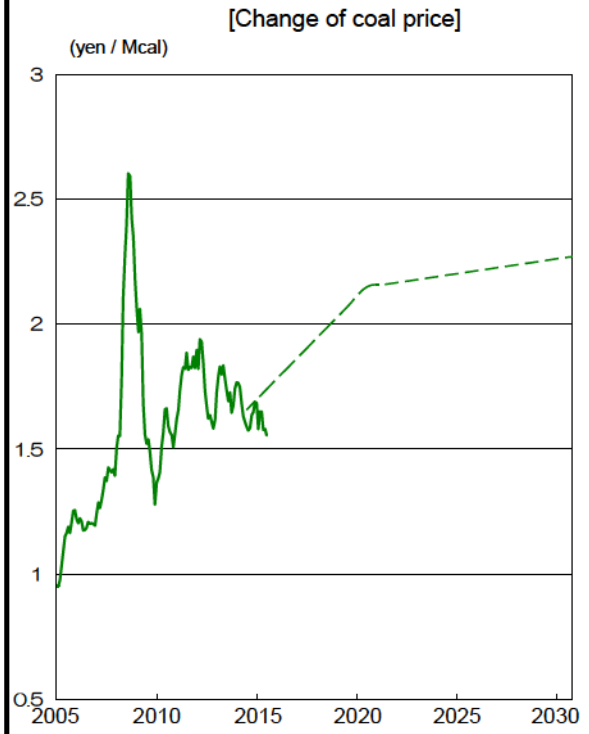
One half of recoverable reserves of coal consist of low rank coal. The Reserves to production ratio of high rank coal such as bituminous coal which is the fuel of current thermal power plants, have been sharply reduced.



Source : WEC, "Survey of Energy Resources 1998, 2001, 2004, 2007, 2010 ", " World Energy Resources 2013 Survey"

■ Price trend of coal

Due to the increased consumption of worldwide energy and the reduction of high rank coal resources, the future supply-demand balance of coal is expected to be tight and triggering serious price hike.



Source: Prepared based on the Trade Statistics of the Ministry of Finance, data of the WG for Verification of Generation Costs, Advisory Committee for Natural Resources and Energy of METI, etc.

Need for utilization of low rank coal

4 Characteristics of Victorian Brown Coal

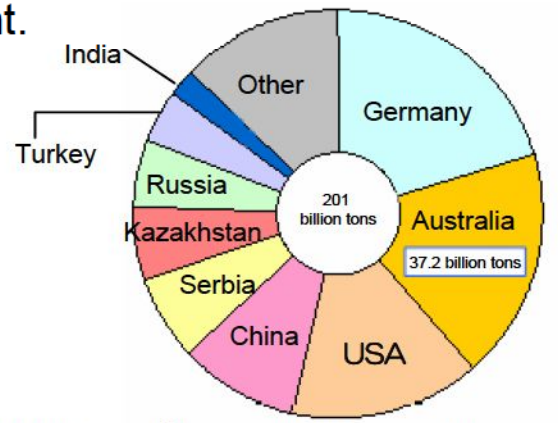
- The development of Victorian brown coal in the State of Victoria is beneficial in terms of ensuring long-term stability of resources procurement, such as abundant resources and the local government's strong expectation regarding coal development.

➢ Abundant resources

o More than 95% of brown coal resources in Australia occur in Victoria.

Source: Survey report of CRIEPI (Y13012)

⇒ Stable long-term procurement



Global Proved Recoverable Brown coal Reserves
Source: WEC, "World Energy Resources 2013 Survey"

➢ High-quality properties

o Low ash content

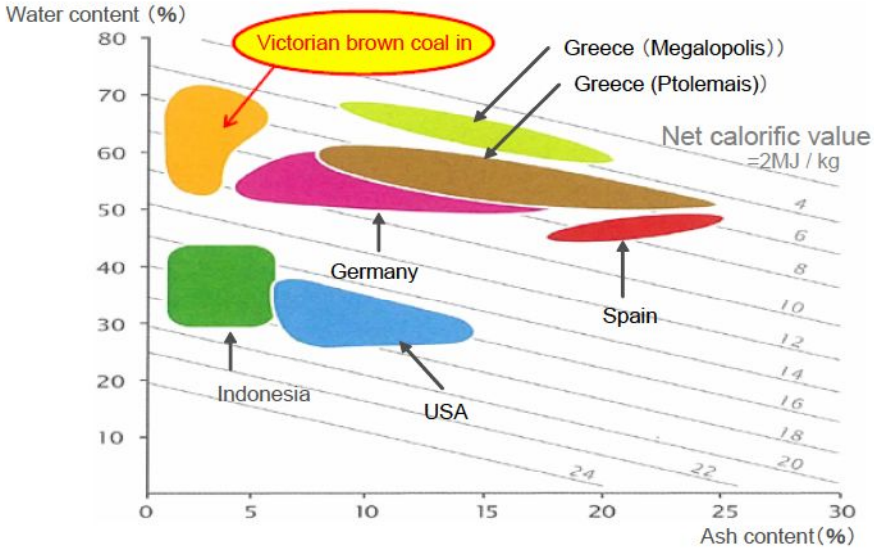
⇒ Reducing the load of ash treatment

➢ Positive attitude and stability of Victoria

o The utilization of brown coal is currently limited to power generation at local mining sites. The government of Victoria State strongly expects the development of the coal to contribute to regional economic growth and employment through exports and commercial use of the coal.

o The State of Victoria is geographically close to Japan, and politically stable.

⇒ Stable long-term procurement



Low rank coal constituents worldwide
Source : Data by Allardice Consulting

5 Technical Issues of Use of Victorian Brown Coal

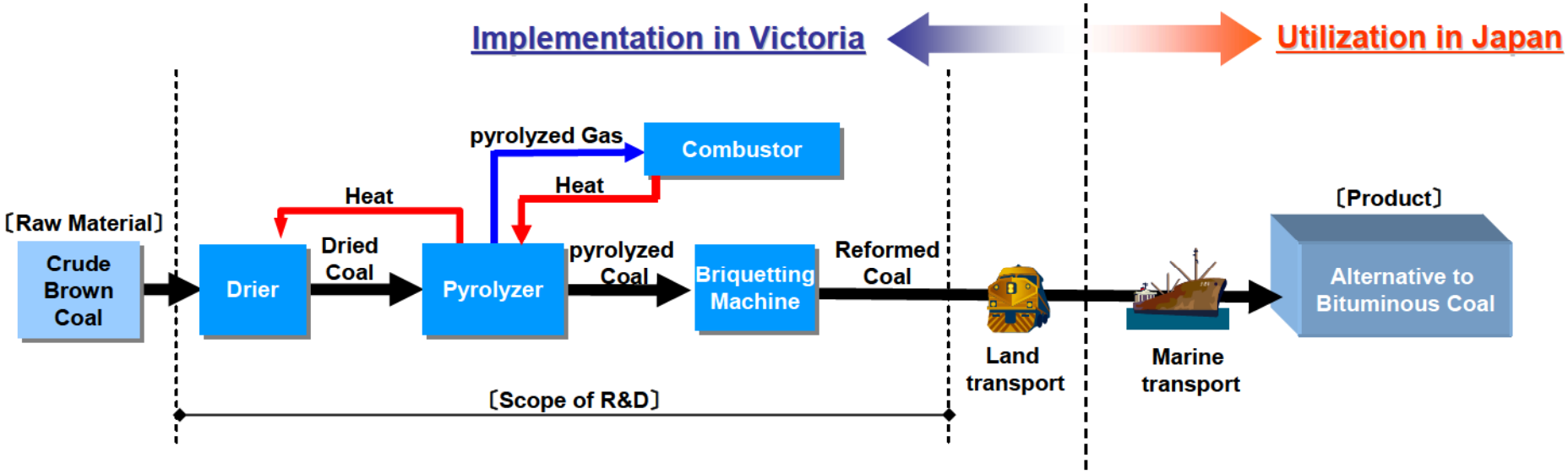
- Victorian brown coal, characterized by an abundant resources and low-ash content, can be procured stably over the long term, reducing the load of ash treatment as the fuel for coal-fired power generation.
- On the other hand, it is difficult to transport raw brown coal to Japan and to use it due to its high water content and high spontaneous combustibility.
- The reforming of brown coal potentially produces high-value coal having the quality of the same kind as bituminous coal.

→ It is necessary to develop a technology for locally reforming of brown coal.

Technical issues	Direction of technical development
Due to its high water content, brown coal has a low calorific value per weight, and poor transport efficiency.	Drying raw coal at low cost and increase the calorific value per weight.
Due to its high volatile matter content, even when dried, it still have a low calorific value.	Controlling its volatile matter content through Pyrolysis, and increase its calorific value, making it the same as that of bituminous coal.
Its high spontaneous combustibility makes storage and long-distance transport difficult.	Controlling spontaneous combustibility through Pyrolysis and Briquetting.

6 Outline of Technical Development

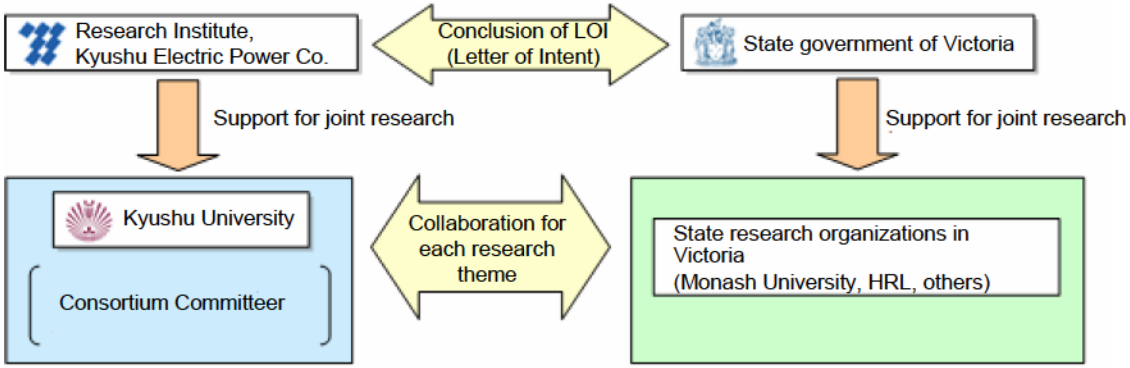
- Victorian brown coal with its characteristics of high water content, high spontaneous combustibility and low ash content will be locally reformed so that it can be utilized in Japan, transported to Japan in a safe manner, and used as a fuel for thermal power generation.



- Drying: Removing water from Crude Brown Coal to reduce moisture content to appropriate level.
- Pyrolysis: Adjusting proportion of volatile matter content to fixed carbon content in Dried Coal.
- Briquetting: Reducing powder coal and improving the portability.

7 Framework of International Cooperation between Japan and The State of Victoria, and Status of Technical Development

- FY2009: Concluded the Letter of Intent (LOI) concerning strategic R&D of brown coal with the State Government of Victoria, Department of Primary Industries, and established a framework of international cooperation between Japan and The State of Victoria.



It was confirmed through our joint research with Kyushu University (3 years of laboratory tests) that Reformed Coal provided the quality of the same kind as bituminous coal.

- FY2010: Implemented the NEDO project and conducted an outline evaluation of project feasibility (2 years).
- FY2013: Conducted a pilot test for the practical application in Japan in cooperation with other coal users. Joined the Reformed Coal WG for NEDO project together with other coal users, and estimated cost for producing Reformed Coal.
- FY2014: Implemented the NEDO project “Review Concerning Possibility of Low Rank Coal Use Promotion Project,” jointly with other coal users, and reviewed the possibility of practical application of Reformed Coal production.
- FY2015: Will work to solve technical issues over 2 years from FY2015 in the NEDO project “Low Rank Coal Use Technological Development,” which aims to establish a basic technology toward practical application of Reformed Coal production.

8 Status of Technical Development toward Practical Application

- Implemented technical development with respect to each process with the goal of practical use of technology for producing alternative coal for power generation based on Reforming of Victorian brown coal.

Optimization of overall process through careful assessment of element technologies

	Drying	Pyrolysis	Briquetting	Safety	Combustibility
Goal	To establish a technology for drying that will be able to be demonstrated.	To establish a technology for Pyrolysis that aims at a combination of safety and productivity.	To establish a briquetting technology that satisfies the requirements of transportation and storage (grain size and strength) of Reformed coal.	To confirm the safety of final packing form of Reformed coal.	To confirm the possibility of use of an actual boiler by determining the combustion or ash-adhesion characteristics of Reformed coal.
Implementation	Specification of optimal drying technology and evaluation through test operation of prototype equipment	Production of pyrolyzed coal with targeted quality, and confirmation of production process	Production of samples using briquetting test machine and confirmation of briquette strength	Analysis and evaluation of self-heating of Reformed Coal samples with targeted quality	Implementation of combustibility testing in coal combustibility test furnace

Low-temperature drying test equipment

Dried coal

Pyrolysis test equipment

Dry-distillated coal

Dried Coal

pyrolyzed Coal

Dried Coal

pyrolyzed Coal

Briquetting test machine

Dried Coal (Briquetted coal)

Safety analysis equipment

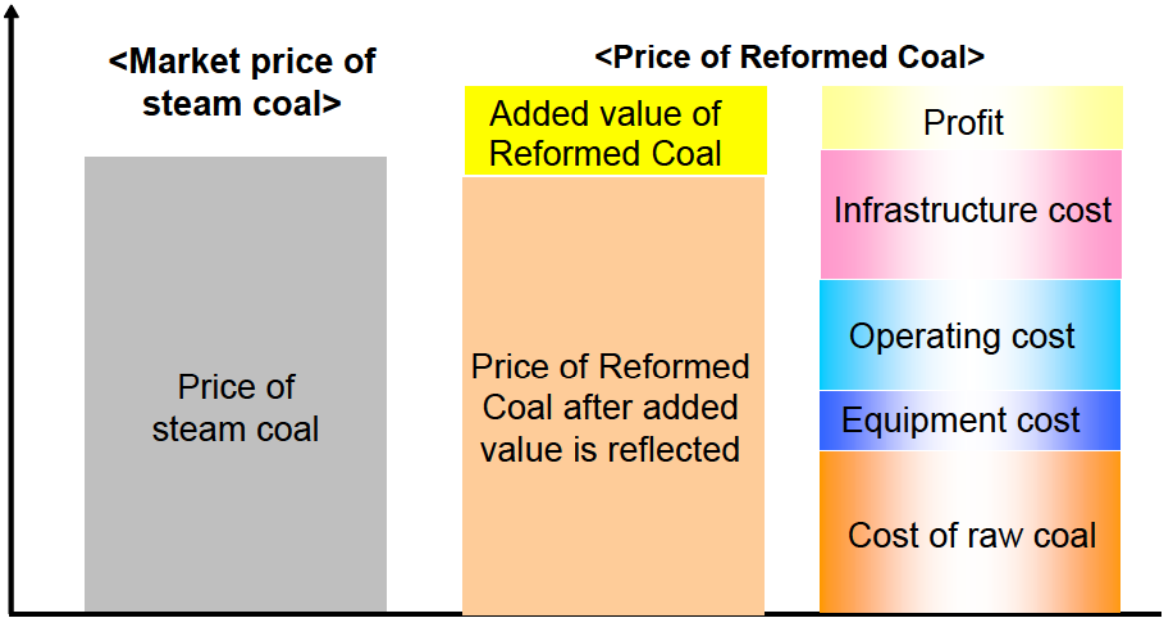
Raw Coal

Raw coal sample (Victorian brown coal)

Coal combustibility test furnace

9 Economical Evaluation

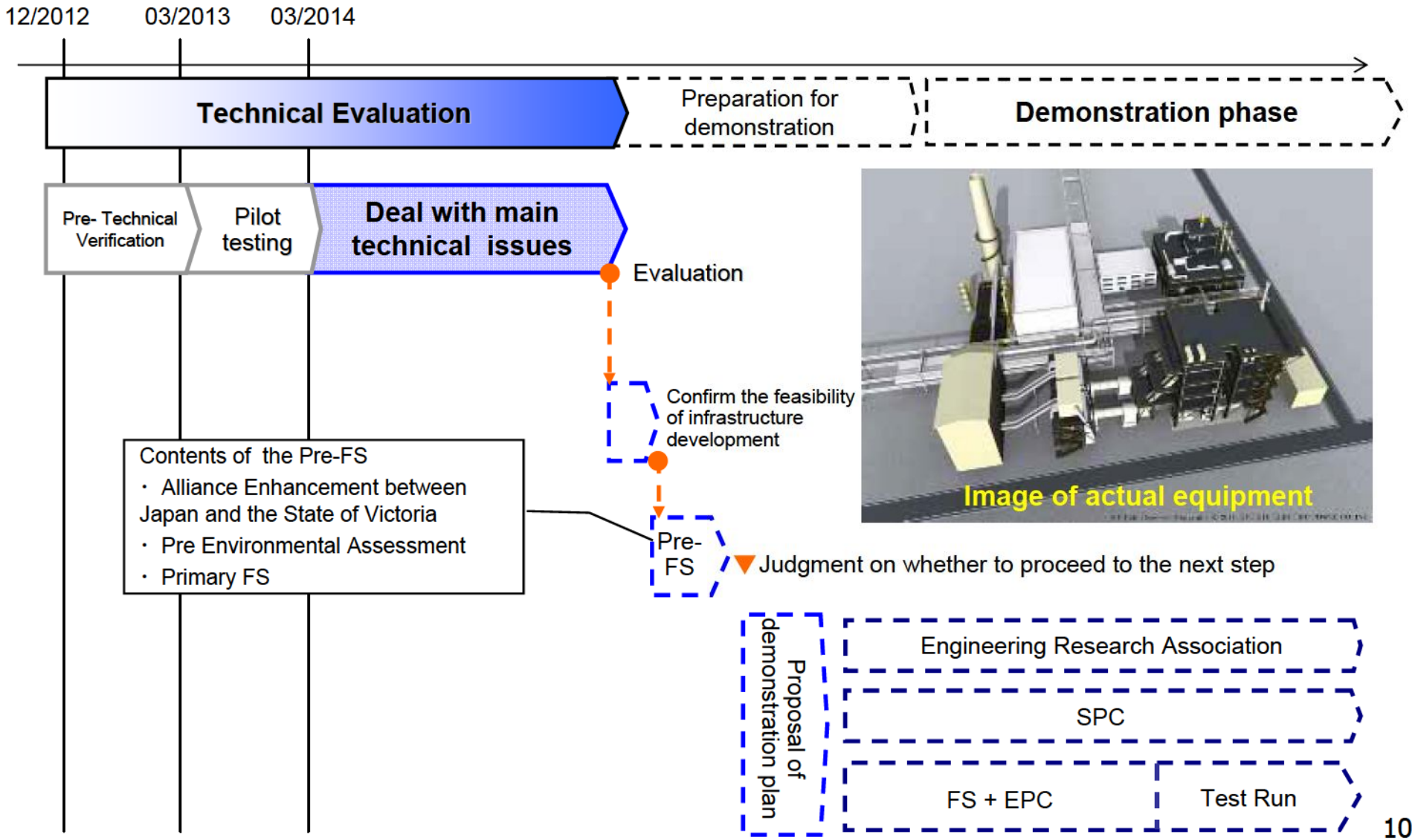
- Brown coal mined in the State of Victoria, Australia, has a low ash content. Consequently when Refoemed Coal is used in coal-fired power plants in Japan, ash-treatment costs will be reduced. In addition, because Reformed Coal has less hydrogen than the steam coal and high combustibility, it is expected to increase boiler efficiency.
- Based on the Reformed Coal's added value against steam coal, such as the values mentioned above, Reformed Coal is expected to be competitiveness against steam coal, while the costs for the raw coal and infrastructure are dominant for the price of Reformed Coal.
- For practical use of the Reformed Coal, it is necessary not only to reduce production cost through technical development but also to procure raw coal at a reasonable price based on mining costs and to provide low-cost transportation infrastructure within the State of Victoria.



Overview of the cost of Reformed Coal

10 Overall Schedule

- We will continue to move toward solutions to technical issues for the practical application of the production process for Reformed Coal, and toward the next step (demonstration phase→commercialization).



11 Conclusion

- The development of Victorian brown coal in the State of Victoria is beneficial in terms of ensuring long-term stability of resources procurement, such as abundant resources and the local government's strong expectation regarding coal development.
- It is difficult to transport raw brown coal to Japan and to use it due to its high water content and high spontaneous combustibility, but the reforming of brown coal potentially produces high-value coal having the quality of the same kind as bituminous coal.
- We are concentrating on technical development jointly with major coal users including other electric power companies. This also enables us to review the technologies on actual coal operations.
- Because the Reformed Coal derived from Victorian Brown Coal has the characteristics of high combustibility and low-ash content, it is expected to use of Reformed Coal in combination with various types of coal. We will continue to move toward solutions to technical issues for the practical application of the production process for Reformed Coal.

Thank for your kind attention