Chapter 5

The Development of Technological Potential Map for Clean Coal Technology Dissemination in the East Asia Summit Region

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Chapter 5
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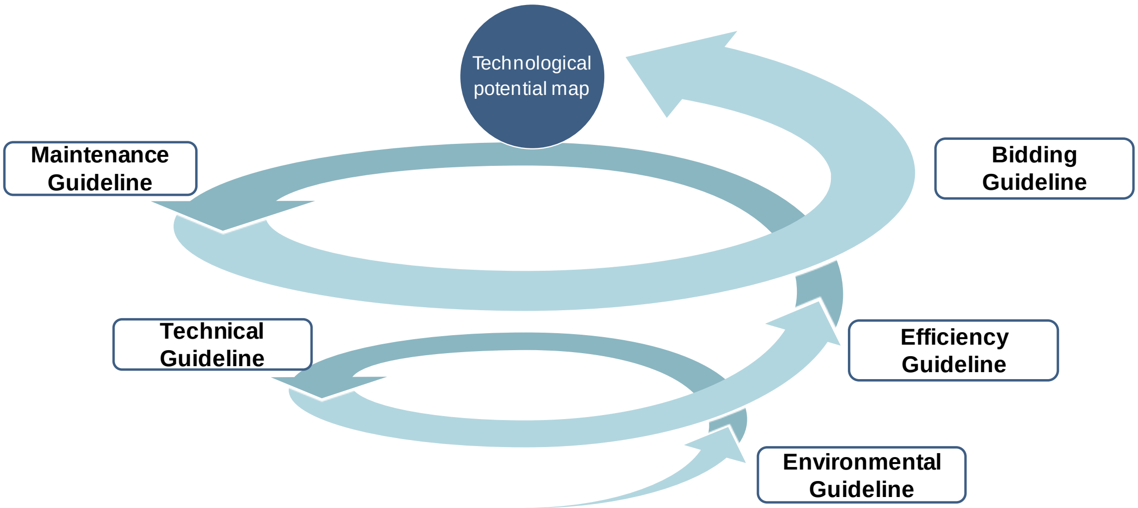
In order to stimulate investments in highly advanced generation technologies appropriately, several technological potential maps need to be formulated, respecting the different stages of economic development across East Asia Summit (EAS) member countries. Figure 5-1 shows the necessary guidelines which need to be included in the technological potential map. By providing a technological potential map that defines feasible efficiency levels as well as environmental performance and maintenance criteria of clean coal technology (CCT), EAS member countries are able to select and introduce the best CCT appropriate for their current stage of development.

Upon the completion of this research, a 'practical' technological potential map including the above-mentioned items will have been developed.

Figure 5-1. The Technological Potential Map



Source: Author's proposed road map.

5-1. Technological Guidelines

5-1-1. Factors impacting technological guidelines

The cost–benefit analysis results provide useful insights to setting technological guidelines for EAS countries. Table 5-1 displays results from the section on sensitivity analysis, which shows that ultra super critical (USC) is the most cost-competitive in almost every scenario. However, two important observations relevant to setting technological guidelines can be made, namely, the impact of coal prices and the impact of financing cost.

Fuel costs account for the largest share of total generation cost. As fuel costs are solely determined by coal prices, it is important to consider coal supply in EAS countries when setting technological guidelines. Countries with high domestic coal supply can typically procure coal at a much lower price than countries dependent on coal imports. For the former, cost divergence of USC and subcritical is smaller compared to coal-importing countries. As a result, USC may not be viable.

Financing costs also account for a significant share of total generation cost, depending on internal rate of return (IRR). In this analysis, two IRRs were included. Results show that USC loses cost-competitiveness when IRR is higher. For example, at coal prices of USS50/ton, USC is most cost-competitive (at US$6.77/kWh) when IRR is 9 percent. However, when IRR is increased to 15 percent, USC is less cost-competitive (at US$8.27/kWh) than super critical (SC) and subcritical. Therefore, USC may be less viable in countries which do not have access to low-interest loans.

A third factor, although not directly observed in the cost–benefit analysis is electricity demand and grid capacity. Large USC units may not be viable for countries where electricity demand is relatively low. In addition, if electricity demand is low, there may not be enough grid capacity to accommodate a USC unit. Instead, a smaller SC unit may be more suitable.

Table 5-1. Generation Cost by Boiler Type and Coal Price

		Boiler Type		
		Ultra Super Critical (USC)	Super Critical (SC)	Sub-critical
Capacity		1,000 MW		
Coal CV / Price		4,000 Kcal/kg (GAR) / 50 USD/ton		
Thermal Efficiency (LHV)		42.1%	41.1%	38.2%
Initial Cost (million USD)		1,931	1,897	1,787
Coal Consumption (tons/year)		3,578,263	3,665,326	3,943,583
CO2 Emission (tons/year)		5,102,914	5,227,073	5,623,893
Generation Cost (USD cent/kWh) (@USD60/ton)	IRR= 9.5%	7.29	7.33	7.43
	IRR=15.0%	8.79	8.80	8.81
Generation Cost (USD cent/kWh) (@USD50/ton)	IRR=9.5%	6.77	6.79	6.85
	IRR=15.0%	8.27	8.26	8.24
Generation Cost (USD cent/kWh) (@USD40/ton)	IRR=9.5%	6.25	6.26	6.27
	IRR=15.0%	7.75	7.73	7.66

Source: Author's assumption and calculation.

5-1-2. Country categorisation

EAS countries are divided into three categories under the technological guidelines considered in the previous section: Group A, Group B, and Group C. Country characteristics, current technology focus, and future technology focus are summarised in Figure 5-2.

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(1) Group A

For countries in group A, it is assumed that coal prices are sufficiently high due to high import dependence, low financing costs, and high electricity demand. In addition, USC has already been widely introduced and necessary know-how is available.

Current technology focus should be to utilise USC as standard technology. Future technology focus should be introduction of advanced USC (A-USC) and/or Integrated Coal Gasification Combined Cycle (IGCC).

(2) Group B

For countries in group B, coal prices are also assumed to be relatively high, low interest loans can be provided, and electricity demand is high. The main difference with countries in group A is the current level of USC diffusion.

Current technology focus is to further promote USC diffusion, rather than SC and subcritical. In the future, the aim should be to replace older inefficient units and make USC the standard technology.

(3) Group C

Countries in group C are characterised by factors potentially making USC unviable. This may be due to abundant and cheap domestic coal supply, high financing costs, or low electricity demand and grid capacity.

Therefore, SC may be more viable where domestic coal prices are cheap or where financing costs are high. For countries where electricity demand and grid capacity are low, smaller SC units may be more suitable. However, future technology focus should still be on introducing USC where possible.

Figure 5-2. Technological Guidelines: Country Characteristics and Technology Focus

	■Country Characteristics	■Current technology focus	■Future technology focus
Group A	✓ High GDP/capita ✓ High coal import dependency ✓ Low financing costs. ✓ High electricity demand ✓ USC technology and know-how is already available	✓ USC should be the standard technology.	✓ Promotion of A-USC and /or Integrated Gasification Combined Cycle (IGCC)
Group B	✓ High coal import dependency ✓ Low-interest loans are available ✓ Sufficient electricity demand	✓ USC diffusion should be further promoted.	✓ USC should be become the standard technology, replacing older inefficient units.
Group C	✓ Cheap domestic coal supply and no import dependence ✓ High financing cost ✓ Low electricity demand ✓ Low grid capacity	✓ SC units may be more viable in countries with abundant domestic coal supply. ✓ Smaller SC units may be more viable if domestic electricity demand is low, and grid capacity is limited.	✓ USC should be promoted where possible.

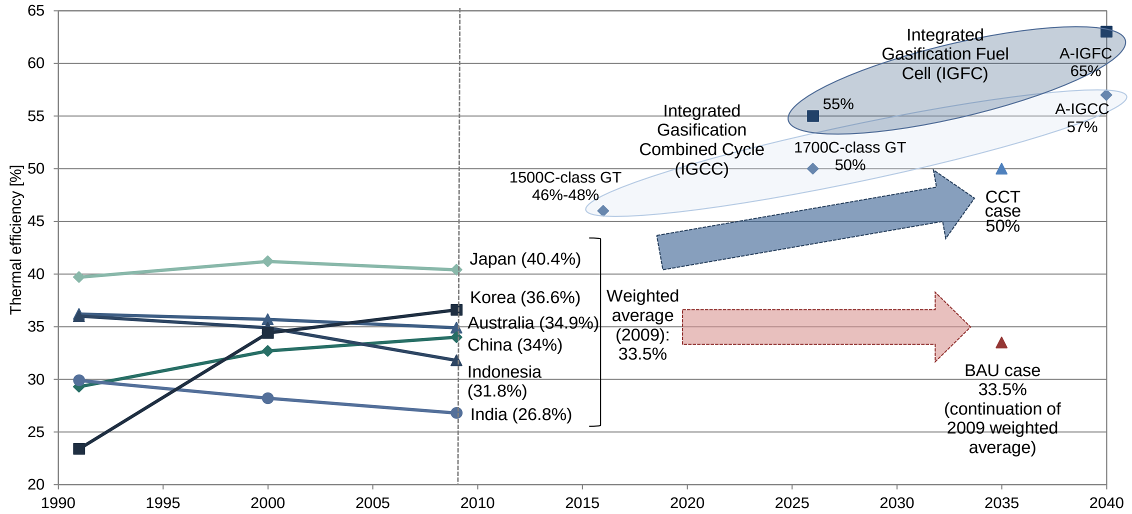
Source: Author's proposed road map

5-2. Efficiency Guidelines

Thermal efficiency of coal-fired power stations varies greatly across Asia, leaving room for improvement in some Asian countries. Japan and South Korea have incentives to adopt efficient technologies from an investment point of view (in order to decrease coal imports) as well as from a social and environmental point of view. A policy package in other countries to increase the investment benefits would accelerate the adoption of more efficient technologies and close the thermal efficiency gap.

In the first-year study, the benefits of providing a road map for CCT technologies were quantified in two assumed scenarios: the CCT case and the (business as usual) BAU case. Figure 5-3 illustrates the two scenarios and the technology road map as well as the history of thermal efficiency values. In the CCT case, it is assumed that a thermal efficiency of 50 percent will be attained by 2035, through the introduction of CCT. In the BAU case, it is assumed that the weighted average thermal efficiency (based on electricity generation in TWh) in 2009 will remain unchanged at 33.5 percent up to 2035.

Figure 5-3. Thermal Efficiency History and Road Map



Source: Japan International Cooperation Agency (JICA), 2012, Final report of 'The Project for Promotion of CCT in Indonesia.

The ERIA energy savings research project estimates that by 2035, an annual production of 13,497.8 TWh of electricity will be generated from coal for both CCT and BAU cases. Coal heating value and coal prices were assumed at 6,000 kcal/kg and US$90.89/ton according to Newcastle FOB prices for 6,000 kcal/kg coal for January 2013. Annual requirement for coal in the CCT case was 1,905 MT lesser than in the BAU case and US$173 billion in coal procurement costs were saved per year in the CCT case. Moreover, the reduction of coal necessary for power generation will reduce CO_2 emissions. Assuming that 2.30 kg–CO_2/kg-coal was emitted, a massive 4.39 billion tons of CO_2 emissions can be avoided annually.

In addition, coal consumption and CO_2 emission of USC, SC, and subcritical plant were estimated. A higher efficiency plant has less coal consumption and CO_2 emissions than lower efficiency plant.

Therefore, plant efficiency should be considered in the introduction and promotion of CCT from both economic and environmental views.

5-3. Environmental Guidelines

5-3-1. Environmental standards

Table 5-3 gives an overview of regulations related to coal-fired power stations in various countries in the EAS region with the European Union (EU) and the US as references. Environmental regulations on emissions from coal-fired power stations are already in place in most countries. The main difference is the stringency of the emission regulations with developing countries often having less stringent regulations compared to developed countries.

On the contrary, regulations on the thermal efficiency of coal-fired power generators generally have not been implemented in either the developing countries or developed countries. In liberalised markets such as Europe (and US, to some extent, and depending on the state), the economic rationale for efficient technologies is set by the market and therefore the most efficient and economical technologies are usually deployed. In Asia, most markets remain regulated and coordination of policies is necessary to promote the deployment of more advanced generation technologies.

Table 5-3. Regulations of Coal-Fired Power Stations

	Australia	China	India	Indonesia	Japan	Korea	Thailand	Viet Nam	EU	US
CO2 Regulation	Carbon tax: Start 2012 Repeal 2014				Oil and coal Tax				CO2 certificate	Proposed: 1000lb/kWh
NOx and SOx regulation		(mg/m3) NOx 100 W-type, CFB 200 SOx New 100 Existing 200 Key region 50	None	(mg/m3) NOx 750 SOx 750	(ppm) Regulation is determined by local government. Newest and most sever standards are follows; NOx<13 SOx<10	(ppm) NOx 80 SOx 80	(ppm) NOx 350 SOx >500MW 320 300-500MW 450 <300MW 640	(mg/m3) Cmax=C x Kp x Kv C: NOx >VM10% 650 <VM0% 1000 SOx :500 Kp(Scale factor) <300 MW : 1 300-1200MW: 0.85 >1200MW:0.7 Kv(Reginal factor): 0.6 ~1.4	(mg/m3) NOx 500 until 2015 then 200 SOx New 200 Old 400	(mg/m3) NOx New 117 NOx and SOx 160 (1997-2005) 640 (before '96)
Particulate matter regulation (mg/m3)		30 Key region 20	>210MW 150 <210MW 350	100	5 (Newest and most sever standards)	>500MW 20 <500MW 30	120	C: 200	50	22.5
Mercury regulation		0.03	None			None			0.03 (Germany)	0.001 0.002

Sources: Author's compilation from various sources.

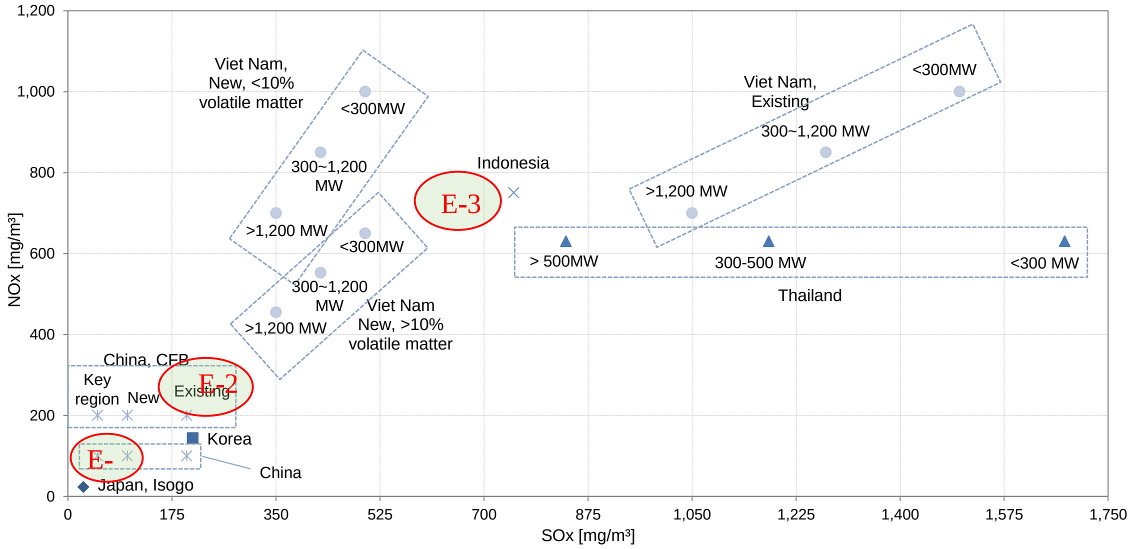
SOx and NOx regulations are already implemented in many EAS countries but CO_2 regulations have not been introduced yet in most EAS countries.

Figure 5-4 gives an overview of SOx and NOx emissions standards applied in countries that operated coal-fired power stations as well as the SOx and NOx emissions of the new Isogo plant in Japan. As can be seen in the figure, standards vary greatly across countries. Therefore, harmonisation of emission standards across Asia is necessary. Furthermore, a road map for future emissions standards is crucial.

Within the EAS region, Australia was the only country that introduced carbon tax in 2012, which was repealed in 2014. In Japan, CO_2 emissions are indirectly regulated through a tax on coal and oil. The tax on coal is higher, accounting for higher CO_2 emissions from coal use. In other EAS countries, CO_2 emissions are not regulated.

If CO_2 emission regulations would be implemented in countries across the EAS region, deployment of more advanced technologies such as CCS, A-USC, or IGCC in addition to USC and SC would be incentivised and commercialisation of such technologies could be accelerated.

Figure 5-4. Comparison of SOx and NOx Emission Standards from Coal-Fired Power Stations



NOx = nitrogen oxide, SOx = sulphur oxide.

Note: A regional factor applies to power stations in Viet Nam ranging from 0.6 (urban areas) to 1.4 (remote areas). Factor 1 is applied in this figure.

Source: Author's compilation from various sources.

5-3-2. Environmental guidelines: environmental standards and available technology

As previously stated, efforts should be made to develop high-efficiency and low-emission CCT, and improve the environment in the future based on harmonised and stringent environmental standards. However, present environmental standards vary from country to country depending on the introduction and promotion of coal-fired power station. Thus, the environmental guideline classified environmental standard targets into three stages: E-1, E-2, and E-3. This is in consideration of the electricity demand and the introduction/promotion of coal-fired power generation facilities in each country, as shown in Figure 5-4. The environmental targets and applicable technologies of pertinent country groups are summarised in Table 5-4.

(1) Environmental standard target 1 (E-1)

This target applies to countries that are already implementing USC and have plans for promoting high-efficiency CCT such as A-USC and IGCC. Those countries belong to group A mentioned in section 5.1.2. This environmental target aims to achieve the levels of standards in Japan and South Korea, and calls for the utilisation of high-efficiency desulphurisation, denitrification, and electrostatic precipitation technologies. In the near future, it will be necessary to introduce technologies for the removal of mercury and other heavy metals and for the reduction of CO_2 emissions using CCS.

(2) Environmental standard target 2 (E-2)

This target is for countries belonging to group B that are already operating coal-fired power plant and have implemented or are planning to implement SC and/or USC. Further deployment of USC is expected in those countries in the future. The environmental target is to attain the level of standard in China where USC has been utilised and is being promoted. Although desulphurisation, denitrification, and electrostatic precipitation technologies are required to achieve the target, it is desirable to design facilities that meet the standards with a large margin. In view of CO_2 emissions reduction in the future, these countries should consider introduction of CCS-ready power stations.

(3) Environmental standard target 3 (E-3)

This target is applicable to countries in group C that have no coal-fired power plants but only have small-scale coal-fired power plants. However, increases in demand for electricity are expected to spur the introduction of SC or USC in those countries. The environmental target is to achieve the environmental standards in Thailand and Indonesia where coal-fired power plants are already in use. Thus, desulphurisation and electrostatic precipitation facilities are required. Although it is desirable to use denitrification facilities for NOx reduction, employment of boilers equipped with low-NOx burners can provide the necessary performance.

Table 5-4 Environmental Guideline: Environmental Standard Targets and Applicable Technologies

Country Group		Group A	Group B	Group C
Guideline		E-1	E-2	E-3
Environmental Target (mg/m3)	SO x	<50	<250	<700
	NO x	<50	<250	<700
	PM	<10	<50	<100
Applicable Technology	SO x	FGD	←	←
	NO x	deNOx Unit	←	Low NOx Burner
	PM	High efficiency EP	EP	←
	Others	Removal of heavy metal elements		
	CO_2	CCS	CCS-ready	

Source: Author's proposed road map.

5-4. Maintenance Guidelines

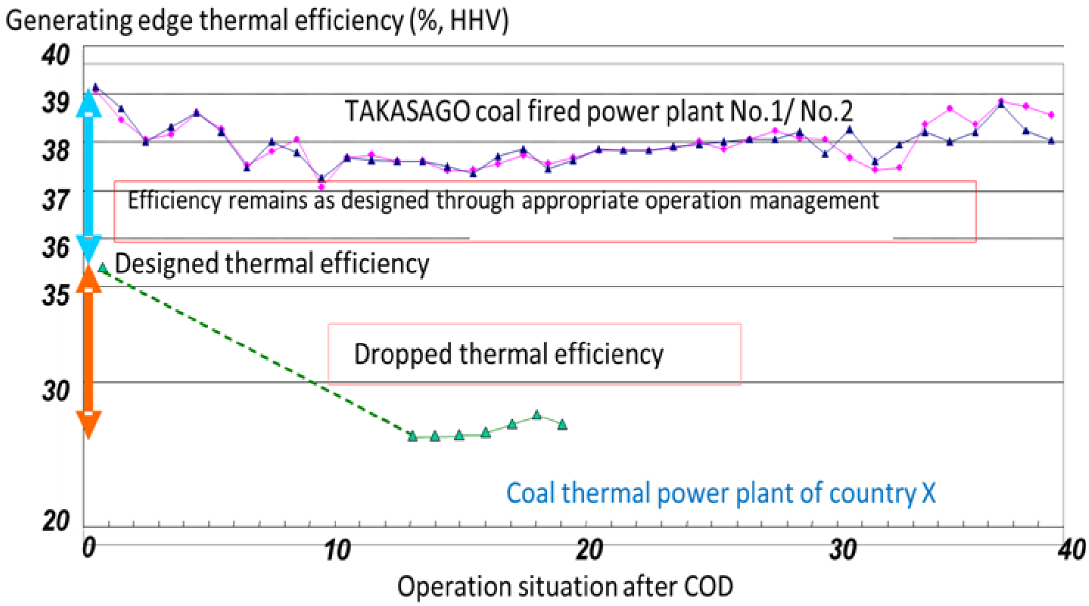
5-4-1. Importance of maintenance

Clean coal technology such as USC has higher efficiency and lower emission compared to conventional coal utilisation technology. The advantage of introducing USC is realising fuel cost reduction and CO_2 emissions reduction over the increment of construction cost.

Figure 5-5 shows the decrease of plant thermal efficiency of coal-fired power plants in ASEAN and Japan. Takasago units #1 and #2 indicated in the figure is an old subcritical power plant with individual unit capacity of 250 MW while the efficiency of country X consists of average data of subcritical plants whose outputs are 300 MW.

The figure shows that the decrease of plant thermal efficiency in country X is down to 10 percent at 10 years into commercial operation. On the other hand, the Takasago power plant in Japan has maintained its designed efficiency for over 40 years and the decrease in plant thermal efficiency is one to two percent only.

Figure 5-5. Thermal Efficiency of Coal-Fired Power Plants in Japan and Asia



Source: Japan International Cooperation Agency (JICA), 2012, Final report of 'The Project for Promotion of CCT in Indonesia.

Table 5-5 shows the cost impact analysis of the decline of plant thermal efficiency and plant load factor (JICA, 2012). Data is based on 1,000MW USC. When plant thermal efficiency decreases by one percent than the base case, then demerit of construction cost becomes US$82/kW. In other words, a decrease of one percent in thermal efficiency is equivalent to US$82/kW of construction cost. Furthermore, when plant load factor decreases by 10 percent than base case due to an outbreak or to unachieved rated output, then the equivalent construction cost is US$76/kW.

Therefore, an assessment of degradation in plant thermal efficiency, plant load factor, and a comparison of the construction cost become indispensable in USC technology.

Table 5-5. Cost Impact Analysis of the Decline of Plant Load Factor and Plant Efficiency

Rated Plant outputs / Plant efficiency degradation	100%	99% (▲1%)	95% (▲5%)	90% (▲10%)
0%	base	8	38	76
▲1%	82	90	120	158
▲2%	168	176	206	244
▲3%	259	267	297	335

Source: Japan International Cooperation Agency (JICA), 2012, Final report of 'The Project for Promotion of CCT in Indonesia.'

5-4-2. Maintenance guidelines

A decrease in plant thermal efficiency and plant load factor overtime due to deterioration affects the economic benefit of CCT and, therefore, a stable and suitable operation and maintenance (O&M) is required in the long term. In order to enjoy the merits of CCT such as USC, IGCC, and other highly efficient power generation facilities, it is necessary to have advanced operation control technologies and to ensure the appropriate maintenance and management of the facilities. To this end, it is also important to start providing personnel with training, such as an on-the-job training on O&M, from construction stage so that relevant personnel can acquire necessary technological know-how.

O&M in consideration of these facts should be implemented as follows.

- Before CCT introduction
  - ✓ Development of O&M engineers via education and training.
- After CCT introduction and operation
  - ✓ Establishment of a training centre to provide education and training on the use of power plant simulators and other training facilities
  - ✓ Development of engineers having advanced O&M skills in training centre
  - ✓ Implementation of daily check and using operation monitoring system combined with periodic inspection for maintaining the stable operation.

5-5. Bidding Guidelines

A bidding system is generally used to select the contractor for a large-scale public facility such as a power plant from the standpoint of fairness. In a bidding process, the bidding winner is determined based on the results of examination of bidders' proposal documents including cost estimations, details of design, and construction plan based on designated technical specifications of the facility as well as the bidders' past track records. However, the highest priority is often placed on the assessment of cost estimations. Therefore, if a bidder with insufficient engineering capability wins a bid, various problems can result and hinder the smooth execution of the project.

Indonesia experienced considerable delay of the two-phased national Fast Track Power (FTP) Development Program, which was caused by prolonged period of construction, mechanical troubles during commissioning or post-commercial operational date (COD). A bidding policy with overwhelming priority on proposed cost rather than on technical appropriateness of a proposal is observed to be blamed for the situation that has ultimately affected the entire power supply security.

Seemingly high-priced, CCT is excellent in terms of efficiency and economy, and will be able to provide a sustainable and high-efficiency operation of a power plant.

In closing, bids should consider the details and other guidelines listed below:

- Apart from cost/price, technology to be employed and technical specification (including efficiency) should be accounted for.
- A minimum one-year performance guarantee period should be imposed so that troubles during commissioning or post-COD period may be addressed.
- A training centre with power plant operation simulator in combination with O&M training at construction phase is recommended.
- Cost evaluation is better conducted only after technology assessment for both independent power producer (IPP) and private–public partnerships (PPP) projects.