Asia-Pacific
Economic Cooperation

APEC Guideline for Quality Electric Power Infrastructure

Energy Working Group

October 2016

APEC Project: EWG 06 2015S

Produced by
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APEC#216-RE-03.2
ISBN 978-981-11-1544-8

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List of Acronyms

No.	Acronym	Full form
1	3E+S	Energy Security, Economic Efficiency, Environment + Safety
2	ACE	ASEAN Centre for Energy
3	AFC	Auto Frequency Load
4	APEC	Asia-Pacific Economic Cooperation
5	ASEAN	Association of South- East Asian Nations
6	BOD	Biochemical Oxygen demand
7	CC	Construction Cost
8	CCPP	Combined Cycle Power Plant
9	CCT	Clean Coal Technology
10	CO_2	Carbon Dioxide
11	COD	Chemical Oxygen Demand
12	DC	Disposal Cost
13	EAFxs	Equivalent Availability Factor excluding seasonal deratings
14	ECI	Early Contractor Involvement
15	EGAT	Electricity Generating Authority of Thailand
16	EPC	Engineering, Procurement, construction
17	ERO	Electric Reliability Organization
18	ESDH	Equivalent Seasonal Derated Hours
19	EUNDH	Equivalent Unit Derated Hours
20	FC	Fuel Cost
21	FERC	Federal Energy Regulatory Commission
22	FOH	Forced Outage Hours
23	FOR	Forced Outage Rate
24	HAPUA	Heads of ASEAN Power Utilities/Authorities
25	HRSG	Heat Recovery Steam Generator
26	IEA	International Energy Agency
27	IGCC	Integrated coal Gasification Combined Cycle
28	IoT	Internet of Things
29	IPP	Independent Power Producers
30	ISA	Industrial Safety Accident Rate
31	ITA	Instructions to Applicants
32	JV	Joint Venture
33	LCC	Life Cycle Cost
34	LCOE	Levelized Cost of Electricity
35	LFC	Load Frequency Control
36	MGO	Maximum Generation Output
37	MMPP	Mae Moh Power Plant
38	MO	Maximum Output
39	MSO	Maximum Sending Output

40	NEA	Nuclear Energy Agency
41	NERC	The North America Electric Reliability Organization
42	NOx	Nitrogen Oxide
43	O&M	Operation and Maintenance
44	OEM	Original Equipment manufacturer
45	OSHA	Occupational Safety and Health Administration
46	P/Q	Pre-Qualification
47	pH	potential of Hydrogen
48	PLF	Plant Load Factor
49	PM	Particulate Matter
50	QEPI	Quality of Electric Power Infrastructure
51	SA	Substation Automation
52	SC	Social Cost
53	SCADA	Supervisory Control And Data Acquisition
54	SOx	Sulfur Oxide
55	SS	Suspended Solid
56	TPG	Total Power Generation
57	USC	Ultra Super Critical

Introduction

APEC Guideline for Quality of Electric Power Infrastructure aims to provide basic concept, framework, lessons learned, best practices and case studies in securing the quality of electric power infrastructure.

Background & objectives

In the APEC region, electricity demand has soared mainly due to its rapid economic growth. Given the gravity of enough and stable electric supply on enhancing people's living standard and its economic activity, shortage of electricity, delayed start of operation and frequent outages are huge risks to the society. Maintaining and enhancing the quality of electric power infrastructure in this region is one of the most important and urgent tasks APEC economies are facing. It can be achieved by commencing operation of power plants as scheduled, supplying electric power stably and implementing effective operation and maintenance (O&M) throughout the duration of service.

Besides, as exemplified by the Paris Agreement at the 21st Congress of the Parties for the United Nations Framework Convention on Climate Change, it is globally shared that the increased efforts to reduce environmental load such as greenhouse gas emissions is an imminent task and thus it is highly encouraged for APEC economies to minimize environmental impact power infrastructure causes by implementing effective measures, which should be compliant to or more stringent than each economy's regulations. In this regard, taking into account not only cost-effectiveness but also social costs/externalities is also necessary.

In most countries around the world, there is a significantly increasing trend in the grid-connected distributed generation, and also decreasing trend in generation cost of renewable energy.

In October 2015, the APEC Energy Ministerial Meeting (EMM) affirmed the importance of "the quality of electric power infrastructure" in order to sustain economic growth, environmental sustainability, including transition to low-carbon economy, and power supply robustness against disasters. At the same time, the Ministers welcomed "APEC Initiative for Enhancing the Quality of Electric Power Infrastructure", which includes the formulation of a guideline helping APEC economies secure and promote its quality. This Guideline is compiled for those purposes.

This Guideline aims to undertake the following:

- Facilitate the readers understanding on how electric power infrastructure is built and operated.
- Share the best practice of electric power infrastructure between readers
- Provide and share useful suggestions of methodologies for securing the quality of electric power infrastructure to readers

Scope

The main target of this Guideline is electric power providers, including public utilities and independent power producers (IPPs), policy makers and relevant stakeholders such as firms providing goods, services and finances for power providers.

Taking into account the wide spectrum of power infrastructure from generators to national grid, it is necessary to specify the scope of infrastructure to be discussed in this Guideline for deeper analysis. This Guideline narrowed its focus on securing quality of individual “thermal power plant”. However, there are possibilities of further enhancement of the scope of this Guideline including renewable energy upon update in the future. We provides basic concept, performance indicators, metrics and methodologies. However, we think basic concept underlying is common to wide range of power infrastructure such as renewable energy and transmission, distribution and substation facilities.

Outline

The Guideline first defines “the quality of electric power Infrastructure” (Part I). The following Part II and Part III provide factors to be considered to secure the quality during feasibility study, planning and construction phase and at operation phase respectively. Throughout the Guideline, columns are provided to describe examples which can foster readers’ understanding. Four appendixes are also attached to support the technical discussion of Part II and Part III.

Part I: What is "the quality of electric power infrastructure (QEPI)"?

In order to contribute to sustainable development of the APEC economies, it is essential to ensure and enhance "the quality of electric power infrastructure (hereinafter referred to as "QEPI")" throughout the life cycle of the power plant. This part identifies and defines the QEPI.

1.1 Quality of infrastructure

"APEC Guidebook on Quality of Infrastructure Development and Investment" formulated in 2014 suggests three components of "the quality of infrastructure" as follows:

Components of " the quality of infrastructure" in general	Contents
Life cycle cost (LCC)	Initial cost, running cost, maintenance cost, etc.
Effect to the environment, etc.	Air emission (such as CO_2, nitrogen oxide (NOx), sulfur oxide (SOx), particle matters (PM)), waste water, waste treatment, etc.
Safety	Natural disaster tolerance, cyber security, etc.

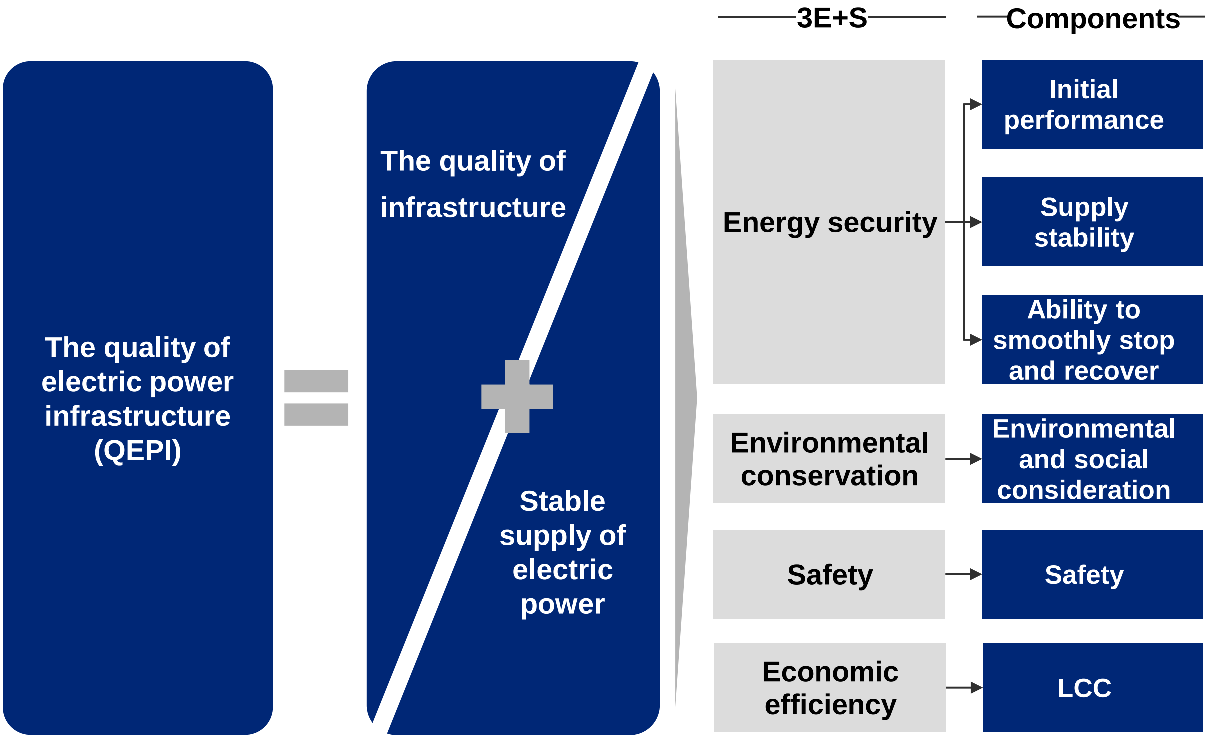
1.2 Quality of electric power infrastructure (QEPI)

In addition to the general components mentioned above, components unique to electricity should be added. They need to fit well with basic energy policy framework, namely "3E+S", Energy security, Economic efficiency and Environmental conservation simultaneously with Safety.

The Guideline defines the QEPI by adding "Stable supply of electric power" to the above-mentioned three general components. "Stable supply" is broken down into three concepts: initial performance, supply stability and ability to smoothly stop and recover. Consequently, the Guideline frames the QEPI as a composition of the following six components:

(1) Initial performance;
(2) Supply stability;
(3) Ability to smoothly stop and recover;
(4) Environmental and social consideration;
(5) Safety; and
(6) LCC.

Figure 1: Components of the QEPI



Not to mention, the quality of installed equipment such as boiler and turbine is the main determinant of the QEPI. However, since power infrastructure generally degrades over time, adequate maintenance and a mechanism to further enhance the QEPI during operation phase are also an essential element. The QEPI can be achieved through appropriate O&M cycle, which in this Guideline is defined as "Self-Elevating Mechanism for Sustainable Operation and Management Practice" (Refer to "3.2.1" for details).

1.3 Components of the QEPI

1.3.1 Initial performance

"Initial performance" is defined as the ability to commence operation of electric power infrastructure as initially planned and scheduled. It includes the ability to meet the scheduled completion date, the usability for O&M operators, compliance with specifications well-tailored for regional and project-specific characteristics and utilization of latest technologies. The electric power infrastructure is required to meet the performance specified in bidding specifications, when its contractor hands it over to its employer.

Early contractor involvement (ECI) may be an option. The ECI is a method available for enhancing the initial performance, especially when there exist technical difficulties and budget/schedule constraints on the project. Under the ECI, an employer, a design contractor and an engineering-procurement-construction (EPC) contractor collaborate to find optimal technology and incorporate it into the design. The EPC contractor can play a significant role in providing design proposals from the viewpoint of workability. It enables the employer to formulate a well-working design simultaneously with the working plan, which can result in time saving and minimization of design change in the middle of construction. It should be noted, however, that the employer needs to beware the fairness and transparency of the bidding process since the EPC contractor involved in ECI process has access to detailed information about the project before other applicants can have.

Column1: Example of ECI - ESK River Hydropower Project in New Zealand

Trustpower, a utility company in New Zealand, made a decision to construct a run-off-river hydro power plant located in ESK River. The planned construction site was located on a steep and unstable terrain, which made it quite difficult to transport construction equipment. Besides, budget and schedule were severely constrained. To overcome these issues, Trustpower decided to employ the ECI method, where Trustpower, a design contractor and an EPC contractor collaboratively implement the following undertakings:

- Flexible planning such as minimizing the volume of detailed geological survey and also performing construction work and detailed design simultaneously
- Well-thought anti-flood design of dam against excessive river flow
- Enhancement of quality of thrust blocks used to support the conduit pipe and minimization of transportation cost of fresh concrete, by utilizing a method which consist of precast concrete members

The construction completed without delay and the ESK River hydropower achieved over 16GWh generation compared to initially-planned 15.2GWh in the first year of service.

Although ECI in this case was used for the construction of a hydropower plant, ECI method can be applied to the construction project of thermal power plant.

(Reference: New Zealand Geotechnical Society Inc. (2015). *NZ GEOMECHANICS News December 2015*. New Zealand.)

1.3.2 Supply stability

"Supply stability" is defined as the ability for an electric power infrastructure to supply electric power stably. Generally speaking, the performance of electric power infrastructure degrades over time, primarily due to faulty construction and insufficient O&M. Retaining performance is extremely important as instable supply impairs not only utility company's profit but also social economic activity.

Three factors should be taken into account when attempting to mitigate the deterioration of electric power infrastructure. Firstly, adequate involvement of the employer in construction process needs to be considered to avoid faulty construction. Secondly, its operation needs to be optimized by taking the following actions: appropriate maintenance, continuous education of operators and maintenance engineers, continuous monitoring of operation by installing diagnosis equipment and performance evaluation based on actual data. Thirdly, adopting measures tailored to the location is indispensable since electric power infrastructure is subject to long term damages from the environment such as wind, salt, snow, lightning and earthquake. It is especially crucial to enhance its durability through appropriate selection of materials and timely cleaning in the regions where extreme salt damage is expected.

1.3.3 Ability to smoothly stop and recover

"Ability to smoothly stop" is defined as the ability to prevent forced outage to the extent possible as well as to safely halt the infrastructure without damaging the equipment. "Recover" is defined as immediate recoverability from forced outage. Forced outage in this case refers to shut down or output suppression except for scheduled and legally-required outage.

In order to minimize forced outage, it is important to properly detect signs from information such as operating data and the facility should be promptly halted as preventive measures when enough precursors of trouble are detected. It is also needed to weigh the status of the facility accurately, track down the true cause of troubles and come up with an appropriate repair plan to ensure facility stoppage is conducted at an optimal timing and in the shortest time possible. Damages to the facility due to emergency stop can be prevented not only by having the facility with enough physical strength but also by avoiding operation exceeding designed intensity and safety rate with reliable protective devices.

1.3.4 Environmental and social consideration

"Environmental and social consideration" is defined as the ability to prevent or suppress environmental damages attributable to electric power infrastructure and co-existence with local community.

As the construction and operation of an electric power plant can have a significant impact on the environment, it is crucial to implement effective measures to avoid or minimize it. This can be achieved by carefully examining features of the plants affecting the environment from the planning phase and properly implement necessary actions through carrying out procedures such as environmental assessment and the O&M enhancement. Implementing environmental preservation measures is also crucial from a finance perspective since many multinational development banks have already required borrowers to comply with the International Finance Corporation (IFC) performance standard as one of the conditions for financing. Air pollution, waste water, thermal discharge, waste, noise and vibration, and ecosystem are factors which need to be considered against environmental damages.

In terms of the co-existence with local community, the primary factors are the employment of local residents and the procurement of local goods and services.

(1) Air quality control

The primary air pollutants from thermal power plants are NOx, SOx and PM. In case of coal-fired power plants, other substances such as heavy metal (e.g. mercury, arsenic, cadmium) may be emitted in smaller quantities. The measures against air pollutions include selecting more efficient and lower sulfur & nitrogen fuel, improving heat rate, introducing low NOx burners and staged combustion to improve combustion and establishing exhaust gas treatment facilities (e.g. NOx removal device, desulfurization equipment and precipitator). It is also important to request operators to regularly monitor and submit its record of emission at monitoring points such as chimney outlets and the surrounding areas.

CO_2 emissions reduction is also required to address global warming. Measures to reduce

CO_2 emissions include the introduction of a combined cycle and coal-fired thermal power plants with efficient heat rates such as ultra-supercritical (USC) and integrated gasification combined cycle (IGCC) power plants. Other measures include such as the selection of low carbon fuels such as natural gas.

Column 2: ASEAN Clean Coal Technology Handbook

In July 2014, ASEAN Centre for Energy (ACE) published “ASEAN Clean Coal Technology Handbook”, aiming to propel the sustainable use of coal-fired power plants. This handbook addresses the necessity of clean coal technology (CCT) and then explains the characteristics, benefits and applicability of CCT. The appendix of the Handbook explains the details of actual technologies including: USC, model driven control system, air preheater, consultation techniques regarding maintenance personnel, combustion simulation technologies, electric dust collector, desulfurization system, de-nitration system, continuous ship unloader, coal handling system, ash treatment facility, coal drying facility, carbon capture and sequestration (CCS), and IGCC.

(Reference: ACE. (2014). ASEAN *clean coal technology (CCT) handbook for power plant*. Indonesia.)

(2) Waste water measure

Thermal power plant discharges waste water through such processes as cleaning of oil-containing equipment, fly ash treatment, water production for boilers, desulfurization, daily water use by employees, and the maintenance and cleaning of equipment. The waste water contains a small quantity of acid, alkaline and suspended substances. The quality of water, which is measured by potential of hydrogen (pH), biochemical oxygen demand(BOD)/ chemical oxygen demand (COD), suspended solids (SS), total nitrogen, total phosphorus and other hazardous substances, should be adequately controlled, according to or exceeding each economy’s regulations. Waste water treatment should be conducted by utilizing technologies such as coagulating sedimentation, filtration, adsorption and neutralization. In addition, regular measurement and submission of the record should be requested to the operator in order to achieve continuous quality management of water generated from the plant.

(3) Heated effluent

In thermal power plants, steam used for driving the turbine is cooled by means of condensation using sea water and others. The condensed water is subsequently used in generating steam for driving the turbine again. It is important to consider the impact on surrounding aquatic habitats as the sea water used for cooling will be discharged as heated water. One of the measures available is designing a condenser to ensure the temperature difference between water intake and water discharge falls within a certain range. Other measures include minimizing the diffusion range of heated water through deep water intake and discharge, and suppressing heated effluent through the adoption of a closed circulation system in cooling towers and other facilities.

In addition, measures such as reduction of water flow and installation of technologies such as barrier nets should be taken, as water intake involves impingement and entrainment of aquatic habitats. In areas with scarce water resources, the risk of competing with other water uses such as agricultural irrigation and drinking water should also be considered.

(4) Waste measure

Wastes generated from thermal power plants include fly ash, which is mainly generated in coal-fired power plants, gypsum generated as a by-product of the flue gas desulfurization process and sludge from waste water. Waste management measures include effective reuse of cement raw materials, site preparation materials, gypsum boards and other materials. Otherwise it should be disposed appropriately. The effective use and appropriate disposal of fly ash, gypsum and sludge from coal-fired power plants are particularly important as they may contain small amounts of heavy metals such as trace cadmium, lead, mercury, arsenic and beryllium.

(5) Noise and vibration measure

Noise and vibration at generation facilities are generated from equipment such as boilers, turbines, transformers, pumps, fans, and coal pulverizers. Measures against noise include installing equipment indoor, securing sufficient distance from site boundary and introducing noise suppression covers, low-noise equipment and soundproof walls. Measures against vibration include installing vibration isolators, reinforcing the foundation of installed equipment and securing sufficient distance from site boundary. It is also important to require the operator to measure, record and submit the level of noise and vibration.

The same consideration should be applied to construction phase. The level of noise and vibration should be measured, recorded, submitted, etc. and appropriate countermeasures should be implemented by contractors in the same manner as the operation of generating facilities.

(6) Preservation of habitats during construction

The impact on habitats surrounding the construction site and the adoption of appropriate measures should be considered especially when it is developed on a new site.

(7) Employment of local residents and involuntary resettlement

The construction and operation of an electric power plant create a large scale of long-term employment. From the perspective of the co-existence with local community, employing a certain number of people from the local economy contributes to securing long-term employment, developing the local economy and also enhancing cultural and economic capability of local residents. This could be achieved, for instance, by requiring contractors and subcontractors to hire appropriate number of employees from the local community.

If involuntary resettlement is unavoidable for the construction of an electric power plant, the project should be well planned and executed so that the quality of life and livelihoods of those affected, particularly of vulnerable people, is well-restored, economic growth is enhanced and poverty is reduced as a result of economic growth. A well-thought involuntary resettlement plan should be formulated at the planning stage.

(8) Local procurement of goods

In order to stimulate local economy, it is desirable to make utmost efforts to procure a certain quantity of goods and services from the local community depending on the industrial level of the region to the extent where it does not harm the principle of free trade and the feasibility of the project. This could be achieved, for instance, by comparing the industrial level of local community with the quality required for the project and setting an appropriate and feasible ratio of goods and services to be procured.

1.3.5 Safety

"Safety" is defined as the ability to prevent or suppress damages to humans or facilities except for damages to the environment. It is a prerequisite to secure safety of surrounding residents, employees involved in the project and facilities by preventing external damages during both the construction and operation phase. "Safety" could primarily be classified into (1) disaster prevention, (2) information security and (3) crime prevention.

(1) Disaster prevention

Major risks in thermal power plants include fire, explosion, the leakage of hazardous objects or substances and industrial accidents such as electroshock. To prevent these risks and secure human and facility safety, it is essential to build a solid disaster prevention system and an appropriate working environment with the active involvement of related disaster prevention agencies.

Column 3: Safety and health regulations for workers at power plants in the United States

Occupational Safety and Health Administration (OSHA), an organization within the US Department of Labor (DOL) has set forth the "Safety and Health Regulations for Construction". It is intended to maintain safety of workers involved in the construction and contractors are required to comply with it. The regulation encompasses basic elements for ensuring the safety of workers, which include equipment and tools that should be used, handling of material and considerations for the construction of transformer substations. Besides, OSHA requires contractors to assess the following factors before commencing construction.

Required Contractor Assessment

Assessment Required	Type of Information
• Preauthorization requirements upon entering enclosed area • Whether air ventilation is adequate to feed the necessary volume and quality of air • Whether an adequate and safe distance for work place is being measured • Whether employees are exposed to hazards from flames or electric arcs • The estimated incident energy from an electric arc • Whether devices are designed to open or close circuits under load conditions • The known sources of electric energy (including known sources of back feed) supplying electric circuits	• Risks that may occur in enclosed areas and factors that may interfere during evacuation • The size of the enclosed space • Operating conditions for the value of the maximum transient overvoltage provided to the contract employer • Information on electric equipment, such as safety information provided by manufacturers, that relates to the required hazard assessment • The electrical parameters needed to calculate incident energy, such as maximum fault current, bus spacings, and clearing times • Load current for, and the opening and

• Whether protective grounds have adequate current-carrying capacity • Whether there is a possibility of hazardous transfer of potential should a fault occur • Whether overhead structures such as poles and towers are capable of sustaining stresses imposed by the work	closing ratings of, devices used to open and close circuits under load • All known sources of electric energy, including known sources of backfeed. • The maximum fault current and clearing time for the circuit • Potential rise on remote grounds under fault conditions • The design strength of the pole or structure

(Reference: Department of Labor. (2014). *Department of Labor Occupational Safety and Health Administration 29 CFR Parts 1910 and 1926.* The United States.)

(2) Information security

There exists an increasing threat and risk that cyber-attacks against operation systems of power plants may trigger a power failure and blackout. As a prevention measure, the following measures should be considered, but not limited to; to disjoint its control system from the IT system network, to install a firewall fitting well with each control systems' protocol, to create necessary manuals and to conduct appropriate employee training.

Column 4: Cyber security measures to protect power infrastructure in the United States

Federal Energy Regulatory Commission (FERC) is an organization within the US Department of Energy in charge of regulating commercial sales of electricity between states, transfer rate of oil and natural gas, hydropower projects and so on.

The North American Electric Reliability Corporation (NERC) is a non-governmental organization comprised of electric providers in North America and also a certified Electric Reliability Organization (ERO). ERO is given the responsibility and rights to make standards regulating power plants and to audit the compliance of power providers to the standard.

NERC has issued a standard, called Critical Infrastructure Protection (CIP), which is authorized by FERC. The standard requires all the users, owners and providers of trunk power system to comply with the following.

- Protection of physical/electronic access to control systems
- Protection of critical cyber assets, personnel training of those involved in security related work
- Reporting security related accidents
- Developing security policies related to restoration in the case of cyber accidents
- Developing plan and operating procedures

Basically, all operators must comply with this standard and undergo periodic audit by NERC.

(Reference: Federal Energy Regulatory Commission, (2008), *Mandatory Reliability Standards for Critical Infrastructure Protection,* Washington,: Federal Energy Regulatory Commission.)

Column 5: The trend of standardization in the field of control systems

The ISA-62443, originally developed by the International Organization for Standardization (ISO) ISA-99 (cyber security), is now in the process of standardization as IEC62443. It is aimed to procure and implement an appropriate control system that can safely enhance its confidentiality, integrity and availability. The ISA-62443 is divided into the following four categories:

IEC 63443-1: Terminology, concepts and models regarding security of control systems (Part 1-1 to 1-4)
IEC 62443-2: Establishment and operation of a secure control system (Part 2-1 to 2-4)
IEC 62443-3: Specifications of technical capabilities and requirements for systems used in automation and control (Part 3-1 to 3-3)
IEC 62443-4: Specifications of technical capabilities and requirements for individual components (Part 4-1 to 4-2)

(Reference: National Institute of Standard and Technology. (2011). *NIST (National Institute of Standards and Technology) Special Publication 800-82 guide to Industrial Control Systems (ICS) Security.* The United States.)

(3) Crime prevention

Crime actions against electric power infrastructure may cause large impact on citizens' life and socioeconomic activity, which makes it also important to establish necessary security measures against intrusion and any crime actions.

1.3.6 LCC

"LCC" is defined as the sum of the cost throughout life cycle, provided the electric power plant satisfies all the requirements of the other five components of the QEPI mentioned above. LCC can be roughly classified into construction cost and running cost including disposal cost. The ratio of the cash value of the two differ by the cost structure of each power source of the power infrastructure.

In the case of thermal power plant, fuel cost is a large component of running cost. Speaking of gas-fired thermal power plant in particular, the fuel cost composes an even larger portion of LCC. However, there are several other factors such as O&M cost and also additional cost caused by forced outage and the increase in heat rate. Preferably, social cost should be incorporated in LCC. Social cost refers to damages the facility directly or indirectly gives to the society and environment. For instance, the cost of CO_2 emission may not be recognized by operators as cost, but should be well considered in calculating LCC.

In general, running cost incurred over its life tends to exceed the construction cost in the case of a large scale infrastructure project. Large portion of the running cost is dependent on its initial design and quality of installed equipment, making it difficult to largely alter or reduce the cost after the operation commences. In order to optimize LCC, it is important for an employer to set an appropriate LCC calculation model in the specification, where the employer evaluates various factors affecting LCC calculation to select an appropriate contractor. It should be noted that the employer and the society may suffer huge loss if the employer chooses a contractor simply based on construction cost.

Although running cost and social cost are relatively difficult to accurately evaluate at the bidding stage, it is recommended to make efforts to estimate LCC by collecting precise information of actual value and projections supported by past performance data, or track records, to the extent possible. In the case of thermal power plant, per unit fuel cost largely varies and precise projection of fuel cost is difficult. Therefore, fuel cost projection should take into account the rise of quoting price and be done in a conservative manner, so as not to burden more cost than projected.

Generally speaking, power providers are required to recover their LCC through the energy bill revenue of the electric power infrastructure. Furthermore, energy bill revenue are heavily dependent on the power market structure of the region which they provide electricity. Therefore, the power market structure is very important in the viewpoint of considering the maximum value of LCC.

1.4 Components of the QEPI during each phase

The components of the QEPI will be defined separately for each phase, namely feasibility study, planning and construction phase, and operation phase. The good maintenance of the six components and the well-balanced coordination amongst them will enhance “3E+S”.

The definitions of the six components during each phase are provided in Figure 2.

Figure 2: Definitions of components during each phase

Components	Definition of the components during each phase: ① FS, Planning and Construction Phase	Definition of the components during each phase: ② Operation Phase
Initial performance	Ability to commence operation as scheduled	(As initial performance is a concept applicable only at the commencement of operation, this concept does not apply to operation phase)
Supply stability	Ability to establish a foundation for stable operation as scheduled	Ability to continue operation as scheduled
Ability to smoothly stop and recover	Ability to determine function and equipment to reduce forced outage	Ability to reduce downtime through immediate stoppage and recovery in case of trouble
Environmental and social consideration	Ability to secure environmental and social consideration during construction phase Ability to secure environmental and social consideration during operation phase	Ability to prevent and suppress external damages attributable to environment / co-existence with the local community
Safety	Ability to secure safety during construction phase Ability to secure safety during operation phase	Ability to suppress damages to human and facility due to factors not related to environment
LCC	Ability to configure the plant considering the total cost including consideration for the risk of social cost throughout life cycle	Ability to minimize the total cost including social cost while maintaining the other components of the "quality of electric power infrastructure"

Part II: Feasibility study, planning and construction phase

Adequate procurement of construction is vital to secure the QEPI. The first section of this Part clarifies methodologies to evaluate the QEPI, which should be secured during feasibility study, planning and construction phase. The second section describes basics for the appropriate bidding procedure, since the contractor plays a pivotal role in this phase.

2.1 Evaluation of the QEPI

2.1.1 Concept of the evaluation of the QEPI

Evaluating the QEPI during feasibility study, planning and construction phase is almost synonymous with evaluating the ability and responsibility of applicants.

It is often the case that the employer obtains knowledge related to the ability of applicants through the information submitted by the applicants and also the past track records the employer actually awarded to the same applicants. They are often not sufficient enough and thus it is recommended to share information with other employers who have worked with the applicants in the past. It is desirable to evaluate the applicants' capability with the information provided not only by the applicants but by the applicant's ex-employers.

Column 6: Mechanism of information exchange among utility companies in ASEAN

Heads of ASEAN Power Utilities/Authorities (HAPUA), founded in 1981, is an institution comprised of utility companies and energy sector representatives from ASEAN countries. HAPUA holds council meetings, committee meetings, working groups and other meetings on a nonscheduled basis, to carry out actions such as exchanging information useful for upgrading the quality of power infrastructure. The agenda of the 31st council meeting included the following contents:

- Reaffirmed the importance of effort to secure sustainability (energy security, economical sustainability, and environmental sustainability)
- Report on the proceedings of projects related to enhancement of reliability and quality of power infrastructure
- Publishing handbooks that exemplify the best practices of asset management.

(Reference: HAPUA. (2015). *SUMMARY OF PROCEEDINGS OF THE 31st MEETING OF THE HAPUA COUNCIL.* Malaysia.)

2.1.2 Definition of the components of the QEPI

The components of the QEPI during feasibility study, planning and construction phase, which are almost synonymous with applicants' abilities to fulfill the QEPI, are as follows. Sufficient financial capability to complete the construction is also required.

Components of the QEPI	Definition during feasibility study, planning and construction phase
Initial Performance	• Ability to commence operation as

	scheduled
Supply Stability	• Ability to establish a foundation for stable operation as scheduled
Ability to Smoothly Stop and Recover	• Ability to determine functions and equipment to reduce forced outage
Environmental and Social Consideration	• Ability to secure environmental and social consideration during construction phase • Ability to secure environmental and social consideration during operation phase
Safety	• Ability to secure safety during construction phase • Ability to secure safety during operation phase
LCC	• Ability to construct a plant considering the total cost including consideration for the risk of social cost throughout life cycle

2.1.3 Performance indicators for ability an employer should require to applicants

The following are examples of performance indicators to evaluate applicants' ability particularly from the perspective of an employer. Detailed metrics of the indicators are provided in Appendix 1.

(1) Initial performance

It is critical to require a contractor to select appropriate facilities and equipment to obtain performance as agreed in the contract between the employer and the contractor. The contractor needs to construct it not only in compliance with the contract but also in enough consideration of its performance in actual operation. There already exist some mechanisms for preventing non-compliance such as imposing penalties against non-conformance with the required performance in performance test and delay in completion owing to contractors' fault. However, selecting an appropriate contractor through pre-qualification (P/Q) process is a far more cost-effective step to this effect. The performance indicators to evaluate the applicant's ability of realizing "initial performance" are as follows:

Performance indicators	Appendix 1
Number of construction completion	No.1
Conformity with specified performance	No.2
Record of contract termination	No.3
Track record of faulty construction including delay in completion	No.4

Column 7: P/Q standards regarding initial performance of thermal power plant in Malaysia

In Malaysia, best available techniques economically achievable (BAT) is adopted as P/Q standard for the initial performance of thermal power plant. Basically every new thermal power plant must achieve pre-determined base value regarding factors such as designed heat efficiency, control of NOx, dioxide, storage and pretreatment of fuel in order to commence construction in Malaysia.

(Reference: Department of Environment. (2014). *BEST AVAILABLE TECHNIQUES GUIDANCE DOCUMENT ON POWER GENERATION.* Malaysia.)

(2) Supply stability

Enough consideration for O&M should be paid even in designing the plant in the bidding phase in order to assure "supply stability". The design should include a system that enables collection and analysis of O&M log data and equipment to achieve optimization of O&M and other factors (refer to "3.2.2" for further details). The performance indicators to evaluate the applicant's ability of realizing "supply stability" is as follows:

Performance indicators	Appendix 1
Track record of faulty maintenance within the warranty period	No.5

Column 8 : Measures to improve the supply stability of thermal power plants in India

Central Electricity Regulatory Commission (CERC), the regulator of power sector in India has taken steps to improve the availability of thermal power plant. In New Delhi, if the plants' load factor exceeds 85%, they are allowed to mark up energy charge unit cost.

$$PLF = 10000 \times \sum_{i=1}^{N} SG_i / \{N \times IC \times (100 - AUX_n)\} (\%)$$

The definition of each item in the above formula is as follows:
PLF = Plant Load Factor
SG_i = Scheduled Generation in MW for the $_i$th time block of the period
N = number of time blocks during the period
IC = installed capacity of the generating station or unit in MW
AUX_n = Normative Auxiliary Energy Consumption as percentage of gross energy generation

(Reference: Central electricity regulatory commission. (2014). *Notification.* India.)

(3) Ability to smoothly stop and recover

In order to maintain "ability to smoothly stop and recover" during operation phase, it is necessary to take actions such as installing devices for early detection of defects and protection units as well as to ensure and enhance the easiness of maintenance. The performance indicator is as follows:

Performance indicators	Appendix 1
Track record of long term forced outage within the warranty period	No.6

(4) Environmental and social consideration

The contractor of a power plant is required to possess environmental protection capabilities conforming to, and preferably exceeding the regulations of the economy where it exists. A contractor who can barely surpass the regulations may lack allowance and margin for unexpected deviations from initial assumptions and thus impose high risks to the society. It is important to accurately evaluate the applicant's capabilities such as environmental capabilities. The performance indicators for "environmental and social consideration" are as follows, while the some of the indicators overlap with those for "initial performance".

Performance indicators	Appendix 1
Number of projects meeting the guarantee performance in relation to environmental performance (evaluated in "number of construction completion" under "Initial Performance")	No.1
Conformity with specified performance (evaluated in "conformity with specified performance" under "Initial Performance")	No.2
Track record in relation to non-conformance with the environment protection law	No.7
Track record in relation to employment from the economy	No.8

(5) Safety

"Safety" is evaluated from two perspectives: external factors during operation phase and internal factors during construction such as industrial accidents. The former can be evaluated in terms of preparedness against attacks and natural disasters from outside the thermal power plant. The latter can be evaluated in terms such as the preparedness against troubles and accidents in the construction site. As the contractor plays a pivotal role in minimizing/mitigating factors affecting its safety, the employer needs to carefully gauge contractor's ability and other aspects in this regard.

The performance indicators are as follows while some of the indicators for "safety" overlap with those for "initial performance".

Performance indicators	Appendix 1
Number of projects satisfying the guarantee performance in relation to safety (evaluated in "number of construction completion" under "Initial Performance")	No.1
Ability to meet required safety performance (evaluated in "conformity with specified performance" under "Initial Performance")	No.2
Track record of fatal accidents	No.9

Column 9 : Efforts to ensure workplace safety in Indonesia

PT PLN, a government owned utility company, complies with SMK3, a national standard for work place health and safety management system. Information dissemination, workshop, and training for employee need to be carried out according to the standard. The contractors of construction of PT PLN's thermal power plants, including their sub-contractors, are also subject to this SMK3, which is clearly mentioned in the P/Q requirements

(Reference: PT PLN. (2014). *Sustainability Report 2014.* Indonesia.)

(6) LCC

The employer needs to select an applicant with the ability to optimize LCC by evaluating information submitted by applicants with some reasonable assumptions, provided that thermal power plants satisfy all five other components. Although in the case of IPP projects, LCC is borne by the contractor, the entity purchasing electricity from the IPP operator is recommended to consider any associated social cost attributable to the plant in addition to the tariffs. The performance indicator to evaluate applicants' ability of realizing "LCC" is as follows:

Performance indicators	Appendix 1
LCC considering all other five components	No.10

Column 10 :Example of calculating LCC of power plants by international agencies

International Energy Agency (IEA) and Nuclear Energy Agency (NEA) together, have calculated generation costs of various power sources under a unified formula in order to compare the performances of various technologies such as coal-fired, gas-fired and renewables. The Levelized Cost of Electricity (LCOE) is a model used, which levelizes life time cost by means of discounted cash flow method. Its calculation formula is as follows.

$$\text{LCOE}\ (\text{US\$/MWh}) = \frac{\sum_t \left(CC + OC + FC + CO_2\ \text{emission cost} + DC\right) \times (1+r)^{-t}}{\sum_t \text{Net Electricity} \times (1+r)^{-t}}$$

CC = construction cost
OC = O&M cost
FC = fuel cost
DC = disposal cost
r = discount rate
t= year
CO_2 emission cost is fixed at US$30/t- CO_2

The underlying data such as serving years, PLF and disposal cost basically use unified projection values. For factors that can vary by economy, data provided by each economy are used. For example, in the case of coal-fired plant, 40 years of service, 85% PLF and 5% of construction cost for disposal cost are uniformly used, whereas costs such as construction cost, heat efficiency and fuel cost are based on data collected from each economy.

According to *Projected Costs of Generating Electricity-2015 edition*, the LCOEs of thermal power plants are calculated with three different discount rates (3%, 7%, and 10%) and falls in the following ranges.

3% discount rate: US $66/MWh~US$95/MWh
7% discount rate: US$76/MWh~US$107/MWh
10% discount rate: US$83/MWh~US$119/MWh

It should be noted, however, that the calculation of IEA and NEA based on the formula above uses a standardized PLF for the sake of practical convenience and it does not necessarily reflect the actual PLF that differs depending on economies and equipment.

(Reference: NEA, IEA. (2015). *Projected Costs of Generating Electricity-2015 Edition.*)

(7) Financial Capability

There remains a risk of a contractor's default during construction due to lack of funds and other reasons, even if the contractor satisfied all the performance indicators of the six components. Therefore, financial ability of the contractor should also be considered based on the information obtained through the financial statements for the past several years. The performance indicators for this factor are as follows:

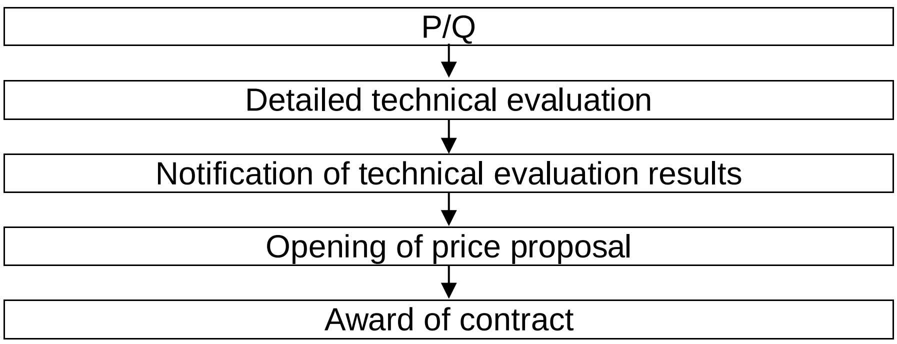
Performance indicators	Appendix 1
Turnover	No.11
Liquid asset	No.12
Soundness	No.13

2.2 Requirements of bidding to secure the QEPI

2.2.1 Bidding procedure for construction of electric power infrastructure

As mentioned in the previous section, it is important to conduct a sound bidding procedure for determining a contractor with the ability commensurate to satisfy all six components in order to secure the QEPI throughout the life cycle. The bidding procedure for a thermal power plant is provided in Figure 3. "Applicant" in this Guideline refers to someone that wishes to be the primary contractor with the employer by direct contract, and we exclude subcontractors from the definition of applicant.

Figure 3: General bidding procedure for a thermal power plant



Firstly, P/Q is conducted in order for an employer to determine applicants with sufficient ability to perform the contract. The evaluation at this stage will be conducted based on the applicants' track records and other relevant information including financial information.

Secondly, the employer provides technical specifications to screened applicants, and these applicants are required to submit a technical proposal along with the price bid proposal of the technical proposal simultaneously. If the time between notification of technical specifications and due date of submission of related proposals are too short, applicants will only have insufficient amount of time to prepare a technical proposal. Such proposal are subject to the risk of additional cost due to design alteration in the later phases of the project. Therefore, an adequate length of time should be secured in between by the employer. In the general case regarding construction of a large thermal power plant, six months period is indicative.

The results of the technical evaluation are notified, and the applicants with sufficient technical ability to perform the contract advance to the next stage.

Finally, some adjustments to the proposal of the eligible applicants are made. These adjustments will guarantee comparability and may include cost adjustments to reflect the deviation from the specifications and expected reduction in fuel cost as a result of proposing highly efficient equipment.

A contract is awarded to an applicant proposing the most economical price. The economical price in this case refers to the lowest bidding price with some adjustments mentioned above calculated by a formula defined by the employer.

The employer should, in order to guarantee the bid and redemption of contract, require a bid bond and performance bond to applicants and winning bidder respectively. Furthermore, even after conclusion of contract, the employer should carry out technical audit on certain phases of the construction to confirm that the contractor is adequately taking out construction in accordance with contract and rules, which indirectly secures QEPI.

Column 11: Bidding in comprehensive successful bid system for transmission line construction in Canada

Ontario Energy Board, located in Ontario, Canada, has adopted the comprehensive bid system with regard to the East-West Tie line construction project. The criteria set forth by the board were: (1) organization, (2) first nations and Métis participation, (3) technical capability, (4) financial capability, (5) proposed design, (6) schedule (development and construction phases), (7) cost (development, construction and operation phases), (8) landowner/community/municipal consultation, (9) first nations and Métis consultation. Applicants are ranked on a relative basis according to the nine categories above and scored according to their ranking. The scores are then aggregated and the applicant scoring the highest aggregate of the score is to be awarded the contract. Scores of each category is not weighted, meaning that "cost" is just one of the nine categories. Although this bidding system was used for the construction of a transmission line, the comprehensive bid system can be applied to the construction project of thermal power plant.

Details of each category

Organization	• Project organizational plan • Chart illustrating the organizational structure • Identification of the project management team with resumes for key management personnel

	• Overview of the applicant's experience with similar project
First nations and Métis participation	• Approach to first nations and Métis participation in the project
Technical capability	• Capability to plan, engineer, construct, operate and maintain
Financial capability	• Financial capability necessary to develop, construct, operate and maintain
Proposed design	• Feasibility
Schedule (development and construction phases)	• Overall project execution chart showing major milestones for both the development and construction phases of the project • Description of major risks of delays and plan to mitigate these risks
Cost (development, construction and maintenance phases)	• Estimated costs for the development, construction, and operation phases of the project
Landowner/community/municipal consultation	• Ability to conduct successful consultations with landowners, municipalities and local communities • Consultation plan including potential significant issues and mitigating measures
First nations and Métis consultation	• Ability to conduct successful First nation and Métis consultations and to provide a consultation • Approach to potential significant issues and mitigating measures

(Reference: Ontario Energy Board. (2013). *East-West Tie Line Designation Phase 2 Decision and Order.* Canada.)

2.2.2 Requirements of bidding procedure for the construction of electric power infrastructure

An employer prepares P/Q and bidding specifications which specify criteria of the QEPI a thermal power plant should satisfy, and selects applicants with sufficient ability to achieve the requirements.

Examples of the evaluation criteria for P/Q and bidding specification which a thermal power plant should secure are provided in Appendix 2 and Appendix 3 respectively.

2.3 Additional issues to consider

2.3.1 Requirements of employer and contractor communication for improved leadership and decision making

To achieve the QEPI, it is important for the employer to have appropriate technical and commercial skills to engage with the contractor. Upon establishing the employer's project team, is important to select staff possessing the skills and experience to provide the technical and commercial leadership for decision-making to appropriately manage funding, contracting and construction of the electric power infrastructure.
Although there may be a need to employ external project managers for specific senior roles, it is recommended for the employers' organization to use the feasibility study, planning and

construction phases of the project to allow its own staff to develop skills and gain experience and knowledge, through secondment to all the stages of the project.

2.3.2 Requirements of the employer for financial success of the electric power infrastructure

The funding of electric power infrastructure is complex and involves the participation of a range of organizations and specialists to achieve outcomes not limited to construction and commissioning of projects, but also their financial success over long periods of time. Decisions at the start of the project will influence the success of the project in later years. It is also important to identify hold points and performance targets of both technical and financial aspects to address any unfavorable deviation at an early stage so as to quickly recover the situation.

In order to ensure succession of both construction and financial outcome throughout the life cycle, multi-disciplinary project teams with technical, economical and commercial capability are necessary. An example of team members to fulfill the above includes staff with economic, financial, accounting, managerial, engineering, operational and organizational skills.

2.3.3 Identification of required human resources of each phase

Construction of a large electric power infrastructure will be a complex project with a long expected life. The range of skills, experience and knowledge required to ensure a successful project varies over the phases of the project, and understanding the difference between phases is important. Each phase of the life of the large electric power infrastructure project should clearly identify the objectives of each stages of the project and ensure the skills, experience and knowledge of the staff match the needs of the project to achieve its objectives. Good practice requires extensive documentation such as training manuals and operating instructions during period of staff transition for assisting new appointees.

Part III: Operation phase

Realizing stable operation in the mid to long term by conducting effective O&M is important. Effective O&M can be realized through application of “Self-Elevating Mechanism for Sustainable Operation and Management Practice” by O&M operators. This mechanism can contribute to maintaining and enhancing the QEPI which will otherwise be subject to aging deterioration. The O&M operators here refer to utility companies or consigned vendors. The first section of this Part clarifies the QEPI, which should be enhanced during operation phase. The second section sets out management system to enhance O&M operation.

3.1 Evaluation of the QEPI

3.1.1 Basic concept for the evaluation of the QEPI

Evaluating the QEPI during operation phase is synonymous with self-checking of performance and quality of O&M by operators.

3.1.2 Definition of the components of the QEPI

The components constituting the QEPI of a thermal power plant during operation phase, in other words, the ability of an O&M operator, are as follows:

Components of the QEPI	Definition during operation phase
Initial performance	(As initial performance is a concept applicable only at the commencement of operation, this concept does not apply to operation phase)
Supply stability	Ability to continue operation as scheduled
Ability to smoothly stop and recover	Ability to reduce downtime through immediate stoppage and recovery in case of trouble
Environmental and social consideration	Ability to prevent and suppress external damages attributable to environment / co-existence with the local community
Safety	Ability to suppress damages to human and facility due to factors not related to environment
LCC	Ability to minimize the total cost including social cost while maintaining the other components of the QEPI

3.1.3 Performance indicators of the QEPI

The performance indicators that are used by O&M operator for appropriate measurement of the QEPI are as follows. Details of the measurement approaches are provided in Appendix 4.

(1) Initial performance

As initial performance is a concept applicable only to the commencement of operation, this concept does not apply to operation phase.

(2) Supply stability

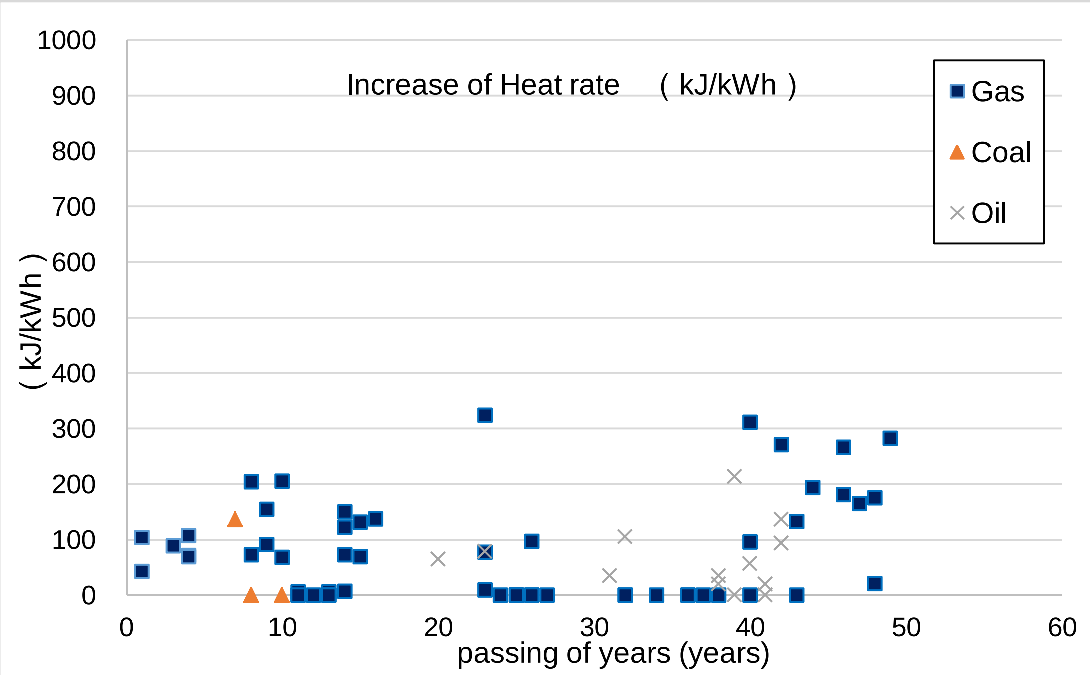
As the operation of a thermal power plant can last for several decades, conducting effective O&M and maximizing generation time through monitoring the increase of heat rate are the most important. In addition, the plant's ability to sufficiently and promptly adjust to fluctuating demand is also gaining much attention partly due to the expansion of intermittent renewable energy such as solar power and wind. Performance indicators for the ability to realize "supply stability" in operation phase are as follows:

Performance indicators	Appendix 4
Availability	No.1
Increase of heat rate	No.2
Ability to adjust power supply and demand	No.3

Column 12: The measurement of increase of heat rate in Japan

In general, the performance of a generation facilities degrade as time passes by, resulting in increase of heat rate. Since increase of heat rate has huge impact on LCC, it is vital to undertake O&M properly and sustain and control the heat rate.

TEPCO Fuel & Power, Inc., a Japanese utility company, regularly measures heat rate in order to minimize fuel costs. The graph below shows the results of its power plants' heat rate increase (in relation to designed heat rate) measured at performance tests conducted for the period from December 2011 to February 2015.



(Reference: *Graph courtesy of TEPCO Fuel & Power, Inc.,*)

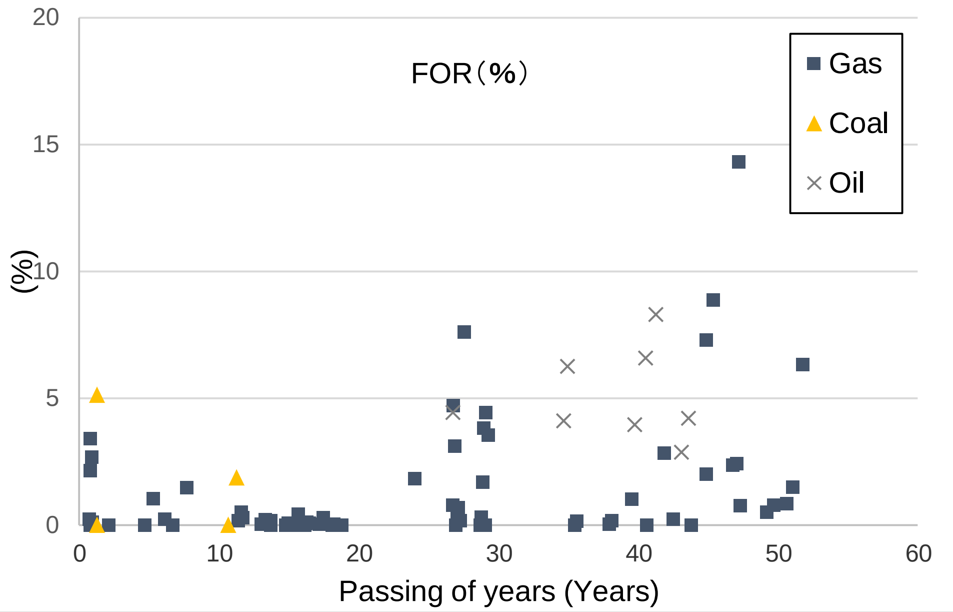
(3) Ability to smoothly stop and recover

The ability to smoothly stop and immediately recover from shutdown is a requirement for enhancing the QEPI. The performance indicators for the "ability to smoothly stop and recover" are as follows:

Performance indicators	Appendix 4
Forced outage rate (FOR)	No.4
Long-Term FOR	No.5

Column 13: The measurement of actual FOR in Japan

TEPCO Fuel & Power Inc. aims to minimize FOR through active O&M in accordance with safety control and inspection regulations imposed by a Japanese law. The results of FOR of generating facilities of TEPCO Fuel & Power, Inc., during the period from April 2014 to March 2015, are as follows:



(Reference: *Graph courtesy of TEPCO Fuel & Power, Inc.*)

(4) Environmental and social consideration

A thermal power plant must be appropriately evaluated based on its environmental performance and track record of operation. Not to mention, the impact on the surrounding environment through operation should be kept at a minimal, considering the economic rationale. The performance indicators for "environmental and social consideration" are as follows:

Performance indicators	Appendix 4
SOx and NOx discharge rate	No.6
CO_2 emissions rate	No.7
Water quality	No.8
Noise/vibration	No.9
Waste recycling rate	No.10
Employment rate from an economy concerned	No.11

(5) Safety

Since a thermal power plant handles a large amount of combustibles and hazardous substances and requires large scale engineering works such as periodic inspections, it is important to secure "safety" to prevent industrial accidents. The performance indicator for "safety" is as follows:

Performance indicators	Appendix 4
Number of casualties caused by industrial accidents	No.12

(6) LCC

It is important to reduce not only initial cost but running cost to optimize LCC, as the operation of a thermal power plant tend to last up to several decades. In order to reduce running cost, it is important to optimize operation cost taking into account all five other components of the QEPI. The performance indicator for the optimization of "LCC" is as follows:

Performance indicators	Appendix 4
LCC considering all other five components	No.13

3.2 Requirements to sustainably enhance the QEPI

3.2.1 Concept of the Self-Elevating Mechanism for Sustainable Operation and Management Practice

As reiterated, enhancing the quality of O&M is a decisive element to sustain and further enhance the QEPI. The O&M operators are recommended to implement a management cycle, which we call "Self-Elevating Mechanism for Sustainable Operation and Management Practice" (see Figures 4 and 5), to sustain and further enhance the quality over the years. The mechanism comprises of six O&M requirements shown below.

O&M requirements	Definition
Measuring ability	Ability to measure and collect data
Data control ability	Ability to comprehensively record, manage and store data
Analytical ability	Ability to identify problems through comprehensive consideration and interpretation of the collected data
Problem-solving ability	Ability to identify and solve causes of unexpected problems/risk factors through use of analytical data
Organizational reiteration Ability	Ability to reiterate the entire process from measuring data to problem-solving
Sustainable management ability	Ability to design an organization and other factors which maximizes the QEPI

Figure 4: Self-Elevating Mechanism for Sustainable Operation and Management Practice – operation phase

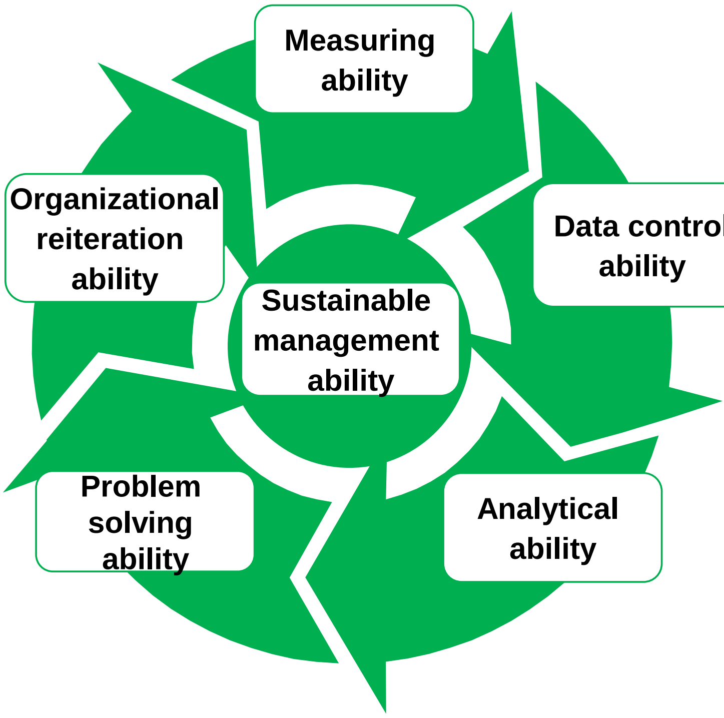
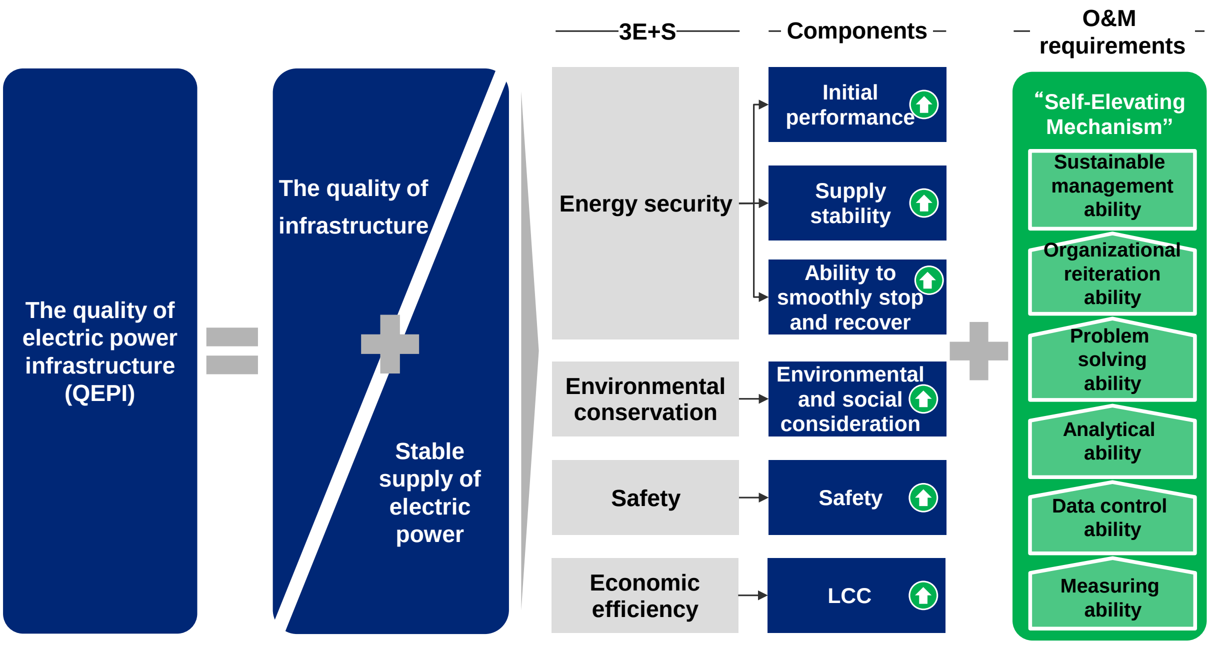


Figure 5: Realization of the enhancement of the QEPI by "Self-Elevating Mechanism for Sustainable Operation and Management Practice"



3.2.2 O&M requirements of electric power infrastructure

Provided below are details of the six O&M requirements for successful Self-Elevating Mechanism for Sustainable Operation and Management Practice.

(1) Measuring ability

"Measuring ability" is defined as the ability of an O&M operator to measure and collect data. It is a critical element for sustaining the O&M quality to develop a system to measure necessary and sufficient data on a timely basis. The requirements to fulfill this capability are as follows:

Classification	Details of the requirement
Measure/Collect	• System in place to enable timely measurement • Clarity of the points to measure • Optimal measuring frequency • Appointment of personnel responsible for measuring and monitoring • Ability to determine an appropriate measuring method

(2) Data control ability

"Data control ability" is defined as the ability of an O&M operator to comprehensively record, manage and store data. Organizational, physical and technical measures regarding safety handling of data must be fulfilled. The requirements to fulfill this capability are as follows:

Classification	Details of the requirement
Organizational measures	• Improved system and clarification of the authority and responsibility for protecting information
Physical measures	• Physical protection (e.g. lock, stipulation of criteria for taking data out) of equipment and device for preventing data leakage and damage
Technical measures	• Technical protection (e.g. access authorization, introduction of an antivirus software) of system for preventing data leakage

(3) Analytical capability

"Analytical capability" is defined as the ability of an O&M operator to comprehensively interpret the measured data and identify the true causes of troubles. Administrating and accumulating collected data alone is not sufficient enough. Analyzing and interpreting the data is a critical process for identifying what needs to be solved. The requirements to fulfill this capability are as follows:

Classification	Details of the requirement
Hiring personnel with analytical capability	• Hiring employees with high analytical capability and appointing to appropriate positions
Equip analytical tools	• Provision of tools necessary to conduct data analysis

(4) Problem solving ability

"Problem solving ability" is defined as the ability of an O&M operator to solve and eliminate the true causes of unexpected problems/risk factors through the maximum use of analytical data. After analyzing the data and identifying the potential risks, the next step required is to solve problems. Important processes required are to forecast unexpected situations, to prepare reaction plans and to take appropriate preventive and mitigation actions based on the analysis. The requirements to fulfill this capability are as follows:

Classification	Details of the requirement
Reaction to sign of risk	• Prompt identification of the sign of risk • Selection/planning/implementation of appropriate measures to cope with identified cause of signs • Implementation of appropriate preventive measures to cope with the identified risk factors in the future • Monitoring the effectiveness of remedy/recurrence prevention measures, sharing the progress with relevant stakeholders
Reaction to realized risk	• Prompt identification of causes • Selection/planning/implementation of appropriate measures to cope with identified causes • Implementation of appropriate preventive measures to cope with identified causes of the problem in the future • Monitoring the effectiveness of remedy/recurrence prevention measures, sharing the progress with relevant stakeholders

(5) Organizational reiteration ability

"Organizational reiteration ability" is defined as the ability of an O&M operator to reiterate the entire process from the measurement of data to problem solving. Having measured, controlled, analyzed, and solved problems, the next step required is to establish the system to maintain this cycle. Maintaining this cycle is difficult if the system is overly dependent on workers' experience and knowledge. Procedures should be made replicable as a whole organization. Know-how, which is intact knowledge, need to be converted to explicit knowledge to the extent possible and to be utilized for human resource development. The requirements to fulfill this capability are as follows:

Classification	Details of the requirement
Transfer of know-how through systemized explicit knowledge	• Establishment, update and usage of database with sets of O&M know-how
Transfer of know-how through human resource development	• Systematic implementation of human resource development programs aimed at measuring capability, data control capability, analytical capability and problem-solving capability (refer to 3.2.3 for further details)

(6) Sustainable management ability

"Sustainable management ability" is defined as the ability of an O&M operator to design an organization to maximize the potential of an electric power infrastructure. In order to maintain and continuously elevate QEPI, measurement, data control and analysis, usage of data, problem solving and reiteration must be made repeatable by incorporating it in the organizational structure. The requirements for fulfilling this ability are as follows:

Classification	Details of the requirement
Corporate execution system	• Establishment of a management system/chain of command regarding the QEPI, O&M requirement, and efficient operation of several power plants considering relevant factors • Operating a power plant efficiently, while maintaining compliance to various O&M requirements.

3.2.3 Training for O&M workers

Developing the capability of the operation and maintenance workers involved is vital in realizing high quality O&M. To enhance the workers' capability, it is imperative to provide sufficient initial training as well as to formulate a mid to long term training plan and develop the capability of the workers involved on a daily basis. It is also needed to prepare a training manual for O&M, train the workers based on the manual and periodically reflect any issues solved through "Self-Elevating Mechanism for Sustainable Operation and Management Practice".

Training from a remote location through the use of Internet of Things (IoT) may be made possible in the future (refer to 3.2.4 for further details).

Column14: Training employees in thermal power plants in Thailand

Mae Moh Power Plant (MMPP) of Electricity Generating Authority of Thailand (EGAT) utilizes a practical organization management system that leads to an integration of operation process.

The strategic objectives and action plan of MMPP are aligned to meet the needs of customers and stakeholders. The progress of each action plan is continuously monitored at a meeting named "Mae Moh Cockpit" held at each plant, consisting of every layer of corporation. Should deviation from the plan occur, persons responsible must take corrective measures. The accomplishment of progress in each employee is directly linked to personnel evaluation, and motivates employees to learn continuously and enhance their capabilities. Any quality control information is aggregated at the knowledge management department.

(Reference: EGAT. (2012). *Mae Moh Power Plant Electricity Generating Authority of Thailand.* Thailand.)

3.2.4 Utilization of IoT

O&M can be optimized by standardizing O&M based on the analysis of various log data produced through the equipped system. In addition, it is required to timely convey the optimal O&M procedure to O&M workers. In other words, the QEPI can be maximized through the conversion of closed internal knowledge within an employee to systematic and explicit knowledge by utilizing IoT. Furthermore, enhancement of O&M skills and accumulation/succession of knowledge will be realized through appropriate training towards the O&M workers utilizing IoT.

3.3 Additional issues to consider

3.3.1 Retaining skills and knowledge gained during the feasibility study, planning and construction phases for the operation phase

It is of value to the overall project for the skills and knowledge gained during the feasibility study, planning and construction phase to be retained to assist the commissioning and the operation. This can be achieved by the O&M operator employing workers from the feasibility study planning and construction phase, or by seconding future O&M workers into the feasibility study planning and construction project teams. This issue should be considered during the preparation of contracts for the project to ensure the involvement of the appropriate employer's workers from the early stages of the feasibility study, planning and construction phase is included in contractual agreements.

3.3.2 Improving leadership and decision-making for the O&M phase

Following the final commissioning of the thermal power plant, the operation phase could last up to several decades. It is important for the thermal power plant to ensure that workers with the appropriate knowledge, experience and skills are available to operate and maintain as well as undertake major upgrade projects over the life of the plant. In particular, the control and instrumentation systems on thermal power plant are likely to be upgraded several times over the life of the asset. The leadership and decision-making processes require wider skills in addition to technical O&M. The cost of each of these intra-asset lifetime reinvestments can represent large sum of the total cost. The economic cost benefit analysis is a vital tool that requires skill and experience of the O&M team members.

3.3.3 Financial capability to identify operational funding

While the major investment cost in a large thermal power plant is the initial planning and construction costs, the cost of maintenance and reinvestment to the asset to maintain or enhance its capability over its lifetime could exceed the original investment cost. Therefore, it is vital for the on-going incremental investments receive all due care from the feasibility study to operation phases, to ensure the thermal power plant meets its reliability, efficiency and cost minimization objectives. This process requires personnel with economic analysis, commercial and accounting skills, as well as the expected technical skills of the O&M team. These broader skills are not required on a permanent basis and can be obtained from internally or externally from the organization as required.

Appendix 1: Metrics of performance indicators during feasibility study, planning and construction phase

<table>
<tr><td>No.</td><td>1</td><td>Performance indicator</td><td colspan="2">Number of construction completion</td></tr>
<tr><td colspan="2">Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td>Evaluation period</td></tr>
<tr><td colspan="2">Initial performance</td><td>Number of constructions</td><td>Applicant</td><td>Most recent 10 years (Optional)</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To confirm that the applicant has sufficient capability to construct a thermal power plant satisfying the required specification</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• Request the applicant to submit a relevant track record and confirm the facts with the operator</td></tr>
<tr><td colspan="5">Measurement methodology (method to accumulate information of the indicator/component to be evaluated)</td></tr>
<tr><td colspan="5">• Formula for number of construction completion
Number of completed thermal power plant projects (*1) using similar equipment (*2) in which the applicant participated as an EPC contractor outside its domicile economy/region

*1: Definition of completed thermal power plant projects
(1) Boiler/steam turbine plant
For equipment with a steam temperature below 593 degrees C: Substantial operation record of more than xx hours outside the domicile economy/region
For equipment with a steam temperature above 593 degrees C: Substantial operation record of more than xx hours outside the domicile economy/region
(2) Gas turbine, combined cycle plant: Operation record in relation to a gas turbine of the similar class (above the class of the planned equipment)
(3) Environmental equipment: Substantial operation record of more than xx hours outside the domicile economy/region

*2: Definition of similar equipment
(1) Boiler/steam turbine plant: Output (greater than the planned equipment), steam temperature/pressure (greater than the planned equipment), fuel properties (anthracite, lignite, high- ash coal, etc.)
(2) Gas turbine, combined cycle plant: Similar class
(3) Environmental equipment (NO_x, SO_x, PMs):
Efficiency of environmental equipment (= (Value at an inlet of the equipment - Value at an outlet of the equipment) ÷ (Value at an inlet of the equipment) × 100) (greater than the planned equipment)</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
• It is necessary to create a place to share information with operators having track records.</td></tr>
</table>

No.	2	Performance indicator	Conformity with specified performance
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Initial performance	%	Applicant	Most recent 10 years (Optional)
Purpose of evaluation			
• To confirm that the applicant has sufficient capability to construct a thermal power plant satisfying the required specification			
Evaluation method/Evaluation logic			
• Request the applicant to submit a guarantee sheet and confirm the facts with the operator			
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)			
• Formula for conformity with specified performance (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and that satisfied all performance requirements (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100 *1: Definition of projects that satisfied all performance requirements Projects which satisfied all the requirements indicated in the guarantee sheet outside its domicile economy/region			
Note			
• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc. • It is necessary to create a place to share information with operators having track records.			

No.	3	Performance indicator	Record of contract termination
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Initial performance	%	Applicant	Most recent 10 years (Optional)
Purpose of evaluation			
• To confirm that the applicant has sufficient technical capability to fulfil the contract			
Evaluation method/Evaluation logic			
• Request the applicant to submit a relevant track record and confirm the facts with the operator			
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)			
• Formula for terminated contracts (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and which were terminated due to the applicant's fault (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100 *1: Definition of projects which were terminated due to the applicant's fault Projects in which the applicant substantially made monetary payment to the employer (e.g. liquidation damage)			
Note			
• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc. • It is necessary to create a place to share information with operators having track records.			

No.	4	Performance indicator	Track record of faulty constructions including delay in completion	
Component		**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Initial performance		%	Applicant	Most recent 10 years (Optional)
Purpose of evaluation				
• To confirm that the applicant has sufficient technical capability to fulfil the contract				
Evaluation method/Evaluation logic				
• Request the applicant to submit a relevant track record and confirm the facts with the operator				
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)				
• Formula for track record of faulty construction including delay in completion (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and which were deemed faulty due to the applicant's fault (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100 *1: Definition of projects deemed faulty due to the applicant's fault Projects in which the applicant substantially made monetary payment to the employer (e.g. liquidation damage attributable to non-conformance with the required performance, liquidation damage for delay in construction)				
Note				
• Precise evaluation standards shall be determined by the employer based on the size and complexity of the project. • It is necessary to create a place to share information with operators having track records.				

No.	5	Performance indicator	Track record of faulty maintenance within the warranty period
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Supply stability	%	Applicant	Most recent 10 years (Optional)

Purpose of evaluation

- To confirm that the applicant has sufficient capability to fulfil the maintenance of the thermal plant delivered

Evaluation method/Evaluation logic

- Request the applicant to submit a relevant track record and confirm the facts with the operator

Measurement methodology (method to accumulate information of the indicator/component to be evaluated)

- Formula for track record of faulty maintenance within the warranty period (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and of which the maintenance was deemed faulty due to the applicant's fault (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100

*1: Definition of maintenance deemed faulty due to the applicant's fault
Projects in which the applicant substantially made monetary payment to the employer within the warranty period (e.g. forfeiture of retention ,liquidation damage attributable to non-conformance with the required performance)

Note

- Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
- It is necessary to create a place to share information with operators having track records.

No.	6	Performance indicator	Track record of long term forced outages within the warranty period
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Ability to smoothly stop and recover	%	Applicant	Most recent 10 years (Optional)
Purpose of evaluation			
• To confirm that the applicant has sufficient capability to construct a thermal power plant with good quality not to cause long-term forced outage			
Evaluation method/Evaluation logic			
• Request the applicant to submit a relevant track record and confirm the facts with the operator			
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)			
• Formula for track record of long term forced outages within the warranty period (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and which experienced long term forced outages due to factors excluding wars, civil wars, insurrection, disasters, etc. (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100 *1: Definition of projects which experienced long term forced outages Projects which experienced Forced Outage Hours (FOH) equal to 30 consecutive days or longer (the same definition as provided in *IEEE Std 762TM-2006*).			
Note			
• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc. • It is necessary to create a place to share information with operators having track records.			

No.	7	Performance indicator	Track record in relation to non-conformance with the environment protection law
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration	%	Applicant	Most recent 10 years (Optional)

Purpose of evaluation

- To confirm that the applicant has sufficient capability to construct a thermal power plant while preserving the surrounding environment

Evaluation method/Evaluation logic

- Request the applicant to submit a relevant track record and confirm the facts with the operator

Measurement methodology (method to accumulate information of the indicator/component to be evaluated)

- Formula for track record in relation to non-conformance with the environment protection law
  (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and which experienced non-conformance with the environment protection law (*1)) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100

*1: Definition of projects which experienced non-conformance with the environment protection law
Projects in which the applicant or the applicant's board of directors or project manager received public prosecution or administrative disposition relating to the local environment protection law

Note

- Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
- It is necessary to create a place to share information with operators having track records.

No.	8	Performance indicator	Track record in relation to employment from the economy
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration	%	Applicant	Most recent 10 years (Optional)

Purpose of evaluation

- To confirm that the applicant has sufficient capability to construct a thermal power plant while returning value to the local economy through creation of employment

Evaluation method/Evaluation logic

- Request the applicant to submit a relevant track record and confirm the facts with the operator

Measurement methodology (method to accumulate information of the indicator / component to be evaluated)

- Formula for track record in relation to employment from the economy
  (Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region with the rate of employment from the local economy (within the construction site during the contract period) (*1) of xx % or more) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside the applicant's domicile economy/region) × 100

*1: Definition of the rate of employment within the construction site during the contract period
(Total working hours of employees possessing the project economy's nationality at the construction site during the contract period) / (Total working hours of employees at the construction site during the contract period) × 100

Note

- Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
- It is necessary to create a place to share information with operators having track records.

<table>
<tr><td>No.</td><td>9</td><td>Performance indicator</td><td colspan="2">Track record of fatal accidents</td></tr>
<tr><td colspan="2">Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td>Evaluation period</td></tr>
<tr><td colspan="2">Safety</td><td>%</td><td>Applicant</td><td>Most recent 10 years (Optional)</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To confirm that the applicant has sufficient capability to construct a thermal power plant while securing the labour safety and the safety of the construction site and surrounding citizens</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• Request the applicant to submit a relevant track record and confirm the facts with the operator</td></tr>
<tr><td colspan="5">Measurement methodology (method to accumulate information of the indicator / component to be evaluated)</td></tr>
<tr><td colspan="5">• Formula for track record of fatal accidents
(Number of similar thermal power plant projects in which the applicant participated as an EPC contractor outside its domicile economy/region and which experienced fatal accidents attributable to construction work (*1) outside the applicant's domicile economy/region) / (Number of similar thermal power plant projects the applicant received as an EPC contractor outside its domicile economy/region) × 100

*1: Definition of fatal accidents attributable to construction work
Accidents which involved one or more deaths and were caused by workers of the construction work (whether caused by the applicant, sub-contractor, or vendor etc., and within or outside the construction site)</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
• It is necessary to create a place to share information with operators having track records.</td></tr>
</table>

No.	10	Performance indicator	LCC considering all other five components
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
LCC	(US$ or local currency) / kWh	Applicant	30 years after construction (Optional)

Purpose of evaluation

- Evaluate the LCC of the power equipment that will be realized through the applicant, and evaluate whether if the LCC falls below pre-determined value

Evaluation method/Evaluation logic

- Request the applicant to submit the LCC amount and the calculation procedures based on various assumptions made by the employer

Measurement methodology (method to accumulate information of the indicator / component to be evaluated)

- LCC considering all five other components = (Total power generation cost + Social cost) / Total power generation (details provided in the note below)

The definition of each item in the above formula is as follows:
Total power generation cost: Construction cost (CC), fuel cost (FC), O&M cost and disposal cost (DC).
Social cost (SC): External cost such as CO_2 emission cost is evaluated quantitatively
Total power generation (TPG): Net maximum capacity (MWHr)

Note

- It is necessary to create a place to share information with operators having track records.
- The construction cost of the power equipment include not only the cost which is directly required to construct the power equipment but also transportation cost of material and equipment, custom duties, customs fee, insurance premium, etc.
- The disposal cost of the power equipment is to be assumed (for example) as a constant rate of construction cost as disposal cost is significantly immaterial in comparison to other costs
- Applicant sets up and shall guarantee the values at the construction completion regarding construction cost, rated output and heat rate
- Employer sets up the values of each of the applicants regarding availability, increase of heat rate per year and Forced Outage Hours per year according to the applicant's actual results, to the extent possible
- Employer will calculate the value of LCC considering all five other components based on values set by the employer and the applicant
- LCC considering all five other components shall be evaluated on the whole period from construction to disposal
- Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.

LCC considering all five other components is as follows:

$$\frac{(1)\ \Sigma(CC, FC, O\&M cost, SC, DC)}{(2)\Sigma\ TPG}$$

*The future cost and the future portion will be discounted to the present value.

Explanation of each item

[(1)]

$$\sum_{y}\left(CC + FC(a) + O\&M\ cost(b) + SC(c)^{*1,2} + DC\right) \times (1+r)^{-y}$$

(a). FC in y year

Fuel consumption Fuel (y) (MJ) × Fuel unit price ($/MJ))

(b). O&M cost in y years

O&M cost: (Example: Power generation in y years (MWh) × O&M cost per power generation ($/MWh))

(c). SC in y years

Example : Fuel consumption Fuel (y) (MJ) × CO_2 emission cost ($/MJ)

The definition of each item in the above formula is as follows:

$$\text{Fuel consumption Fuel}(y)(MJ) = P(MW) \times \left(8760(h/year) \times A(\%) - FOH(h/year)\right) \times \left(\varepsilon(MJ/MWh) + n(MJ/MWh \cdot year) \times y\right)$$

P: Applicant sets up and shall guarantee Rated output of the power equipment (MW) on construction completion

A: Employer sets up the value of availability (%) of the power equipment of each applicants based on past actual results, to the extent possible

r: Discount rate (determined based on the interest rate on the economy's government bond and other risk factors such as currencies)

FOH: Employer sets up FOH per year (h/year) *3 of power equipment of each applicants based on past actual results to the extent possible

ε: Applicant sets up and shall guarantee the value of heat rate of the power equipment on the day of completion (MJ/MWh)

n: Employer sets up the value about increase of heat rate per year (MJ/MWh) of the power equipment of each applicant based on past actual results to the extent possible

y: Year

*1 Social cost should be derived based on the appropriate unit cost and coefficient. An example of the CO_2 emission cost calculation is as follows

(1) CO_2 emission unit cost: US $8.3/t - CO_2 (*EU-ETS ICE 31/12/2015 ending price*)

(2) CO_2 emission coefficient: 94.6t - CO_2 /TJ-coal (*2006 IPCC Guidelines for National Greenhouse Gas Inventories*)

*2 It is desirable to include NOx emission cost, SOx emission cost, PM, emission cost, water disposal cost and external cost that is caused by the forced outages into social cost to the extent possible

*3 Same definition as *IEEE Std 762TM-2006*

[(2)]

- Power generation in y year

$$TPG = P(kW) \times \left(8760(h/year) \times A(\%) - FOH(h/year)\right) \times (1+r)^{-y}$$

No.	11	Performance indicator	Turnover	
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**	
Financial capability	$ or local currency	Applicant	Most recent 5 years (Optional)	
Purpose of evaluation				
• To confirm that the applicant has sufficient financial capability to fulfil the contract of thermal power plant construction				
Evaluation method/Evaluation logic				
• Request the applicant to submit audited income statement or if not required by the law of the applicant's economy, other financial statements acceptable to the employer for the last 5 years				
Measurement methodology (method to accumulate information of the indicator / component to be evaluated)				
• Formula for turnover The average annual turnover (indicated in the income statement) for the past 5 years				
Note				
• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.				

No.	12	Performance indicator	Liquid asset	
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**	
Financial capability	$ or local currency	Applicant	Most recent year	
Purpose of evaluation				
• To confirm that the applicant has sufficient financial capability to fulfil the contract of thermal power plant construction				
Evaluation method/Evaluation logic				
• Request the applicant to submit the evidence that applicant has rights to liquid asset				
Measurement methodology (method to accumulate information of the indicator / component to be evaluated)				
• Formula for liquid asset The amount of liquid asset (*1) that is demonstrated by the applicant *1: Definition of liquid asset Current assets which are highly convertible to cash (e.g. cash and cash equivalents, accounts receivable, notes receivable, securities held for trading purposes)				
Note				
• Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.				

No.	13	Performance indicator	Soundness	
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**	
Financial capability	%	Applicant	Most recent year	

Purpose of evaluation

- To confirm that the applicant has sufficient financial capability to fulfil the contract of thermal power plant construction

Evaluation method/Evaluation logic

- Request the applicant to submit audited balance sheets or if not required by the law of the applicant's economy, other financial statements acceptable to the employer for the last 1 year

Measurement methodology (methods to accumulate information of the indicator / component to be evaluated)

- Formula for soundness (e.g. net assets)
  Net assets (*1) derived from the latest balance sheet

*1: Definition of net assets
The difference between total assets and total liabilities

Note

- Precise evaluation standards shall be determined by the employer based on the size, complexity of the project, etc.
- As the minimum requirement, an applicant's net assets calculated as the difference between total assets and total liabilities should be positive.

Appendix 2: Examples of evaluation criteria for P/Q

	Subject	Requirement	Remarks
1. Eligibility			
1.1	Conflict of interest	The applicant has no conflicts of interest in accordance with Instructions to Applicants (ITA).	
1.2	Ineligibility	The applicant has not been declared ineligible by the employer as described in ITA.	
2. Historical contract non-performance			
2.1	History of non-performing contracts	Non-performance of a contract did not occur within the last xx years prior to the deadline for application submission based on all the information on the fully settled disputes or litigation. Fully settled disputes or litigation mean disputes or litigation that have been resolved in accordance with the dispute resolution mechanism under the respective contract and for which the applicant's right to appeal to the court of second instance has been expired.	
2.2	Pending litigation	All pending litigation shall in total not represent more than xx% of the applicant's net worth and shall be treated as resolved against the applicant.	
3. Financial situation			
3.1	Financial performance	The applicant shall submit audited balance sheets or, if not required by the law of the applicant's economy, other financial statements acceptable to the employer for the last xx years to demonstrate the current soundness of the applicant's financial position and its prospective long term profitability. As the minimum requirement, the applicant's net assets calculated as the difference between total assets and total liabilities shall be positive.	Financial capability: "Soundness"
3.2	Average turnover	The applicant shall submit audited income statement or, if not required by the law of the applicant's economy, other financial statements acceptable to the employer for the last xx years and the minimum average turnover calculated based on the total certified payments received for contracts in progress or completed during the last xx years need to be USD xx or equivalent.	Financial capability: "Turnover"

Notes:
3.1 Financial performance

1) In contracts for procurement of works, applicants will be required at the bidding stage to demonstrate their construction cash flow to verify the soundness and stability of their financial circumstances. The construction cash flow should be calculated by following the procedure below, and the requirement clearly indicated by the employer at the bidding stage:
"Indicate the construction cash flow for a number of months (to the nearest half-month), determined as the total time needed by the employer to pay a contractor's invoice, allowing for (a) the actual time consumed for construction, from the beginning of the month invoiced, (b) the time needed by the engineer to issue the monthly payment certificate, (c) the time needed by the employer to pay the amount certified, and (d) a contingency period of one month to allow for unforeseen delays. The total period should not exceed xx months. The assessment of the monthly amount should be based on a straight-line projection of the estimated cash flow requirement, over the particular contract period, neglecting the effect of any advance payment and retention monies, but including contingency allowances in the estimated contract cost."

2) Financial information provided by an applicant should be of the applicant or partner of Joint Venture (JV) and not of sister or parent companies.

3) The financial statements provided by applicants should be carefully reviewed for proper evaluation, and the judgement for acceptance or rejection from financial circumstances should be determined based on such proper evaluation. If any abnormality which may cause financial issues occurs, the employer should seek reviews and interpretations from experts.

4. Applicant's qualification

4A. Experience

4.1	General construction experience	The applicant shall have experience under a construction contract in the role of a contractor, management contractor or subcontractor for at least the last xx years prior to the application submission deadline.	
4.2	Specific construction experience	The applicant shall have experience exclusively in the role of an EPC contractor in at least xx contracts which have been successfully completed outside the Applicant's domicile economy/region within the last xx years and that are similar to the proposed works. The similarity shall be based on the physical size (more than xx MW capacities in one Combined-Cycle Power Plant (CCPP) unit, including any type of CCPP configuration), complexity, methods/technology or other characteristics as described in scope of works. In addition, the applicant is required to submit performance test results to ensure its compliance with the performance required by the employer. The applicant is required to have satisfied all the performance requirements by the employer for at least xx% of the projects	Initial performance: "Track record in relation to construction completion" and "Conformity with specified performance"

		delivered.	
4.3	Specific operating experience	At least xx of the contracts provided by the applicant as a track-record shall have successful operation experience of more than xx hours as a total plant at the P/Q application closing date. The technical data and information on the contracts are to be provided with contract details of the end-users. The applicant shall submit the original certificate issued by the end-user (free form) at the time of bid submission.	Initial performance: "Track record in relation to construction completion"
4.4	Past record in relation to termination of a contract	The applicant shall have no record of termination in a contract due to the applicant's fault within the last xx years, with respect to the similar contracts conducted outside the its domicile economy/region as an EPC contractor.	Initial performance: "Record of contract termination"
4.5	Track record of faulty construction including delay in completion	The ratio of construction deemed faulty (contracts in which the applicant substantially made monetary payment to the employer at completion) shall be less than xx%, with respect to the similar contracts in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	Initial performance: "Track record of faulty construction including delay in completion"
4.6	Track record of faulty maintenance within the warranty period	The ratio of maintenance deemed faulty (contracts in which the applicant substantially made monetary payment to the employer during the warranty period) shall be less than xx%, with respect to the similar contracts in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	Supply stability: "Track record of faulty maintenance within the warranty period"
4.7	Track record of long-term forced outages within the warranty period	The ratio of projects experiencing long term forced outages due to reasons other than wars, civil wars, insurrection, disasters, etc. (projects experiencing FOH equivalent to 30 days or more within the warranty period (as defined in *IEEE Std 762TM-2006*)) shall be less than xx%, with respect to the similar projects in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	Ability to Smoothly Stop and Recover: "Track record of long-term forced outage within the warranty period"
4.8	Track record in relation to non-conformance with the environment protection law	The ratio of projects experiencing non-conformance with the environment protection law (projects in which the applicant or the applicant's board of directors received public prosecution or administrative disposition relating to the local environment protection law) shall be less than	Environmental and social consideration: "Track record in relation to non-conformance with the

		xx %, with respect to the similar projects in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	environment protection law”
4.9	Track record in relation to employment from the economy	The ratio of projects with xx% or more of workers hired from the economy ((Total working hours of employees possessing the project economy’s nationality at the construction site during the contract period / Total working hours of employees at the construction site during the contract period) x 100) shall be more than xx%, with respect to the similar projects in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	Environmental and social consideration: “Track record in relation to employment from the economy”
4.10	Track record in relation to fatal accidents	The ratio of projects experiencing fatal accidents attributable to the construction work (accidents which involved one or more deaths, whether caused by the applicant, sub-contractor or other vendor and within or outside the construction site) shall be less than xx%, with respect to the similar projects in which the applicant participated as an EPC contractor outside its domicile economy/region within the last xx years.	Safety: “Track record of fatal accidents”
4B. Equipment capabilities			
4.11	Operating experience of reference gas turbines	The gas turbine shall be supplied by an original equipment manufacturer (OEM) of the gas turbine to be proposed who has developed, designed and manufactured and be able to technically and substantially support the maintenance. The number of the reference gas turbines shall be xx and their total successful commercial operating hours shall be more than xx hours with the longest operating hours’ unit of more than xx hours at the P/Q application closing date. The data and information on the reference gas turbines are to be provided with contract details of the end-user. The applicant shall submit the original certificate from the end-user (free form) at the time of bid submission.	

4.12	Similarity of proposed gas turbine	The proposed gas turbine shall be technically similar to the reference gas turbines specified above. The "technically similar" shall mean xx-type machine and shall denote that it has the same configuration with the same dimensions, the same design parameters and the same or better materials as the reference gas turbines.	
4.13	Heat Recovery Steam Generator (HRSG)	Each manufacturer shall have the commercial experiences of at least xx reference heat recovery steam generators with a capacity of more than xx t/h of steam generation which were put into operation in last xx years. The proposed HRSG shall be of similar configuration to the reference HRSGs.	
4.14	Steam turbine	Each manufacturer shall have the commercial experiences of at least xx reference steam turbines with a capacity of more than xx MW which were put into operation in last xx years. The proposed steam turbine shall be of similar configuration to the reference steam turbines.	
4.15	Gas turbine generator	Each manufacturer shall have the commercial experiences of at least xx reference gas turbine generators with a capacity of more than xx MVA which were put into operation in last xx years. The proposed gas turbine generator shall be of similar configuration to the reference gas turbine generators.	
4.16	Boiler	Each manufacturer shall have the commercial experiences of at least xx reference boilers with a capacity of more than steam temperature xx degrees and steam pressure xx MPa which were put into operation in last xx years. The proposed boilers shall be of similar configuration to the reference boilers.	
4.17	Desulfurization equipment	Each manufacturer shall have the commercial experiences of at least xx reference desulfurization equipment with a capacity of more than desulfurization efficiency xx % which were put into operation in last xx years.	
4.18	NOx removal device	Each manufacturer shall have the commercial experiences of at least xx reference NOx removal devices with a capacity of more than NOx removal efficiency xx % which were put into operation in last xx years.	
4.19	Precipitator	Each manufacturer shall have the commercial experiences of at least xx reference precipitators with a capacity of more than precipitation	

		efficiency xx % which were put into operation in last xx years.	
4.20	Draft & recirculating fan system	Each manufacturer shall have the commercial experiences of at least xx reference ventilation equipment with a capacity of more than xx m3/min which were put into operation in last xx years.	

Notes:
4.1 General construction experience
A management contractor is a firm which takes on the role of contract management as a general contractor of sort could do. It does not normally perform directly the construction work(s) associated with the contract. Rather, it manages the work of other (sub) contractors while bearing full responsibility and risk for price, quality, and timely performance of the work contract.

4.2 Specific construction experience
Experience information provided by an applicant should be of the applicant or partner of JV and not of sister or parent companies.

Appendix 3: Examples of qualification criteria in bidding specification

<table>
<tr><th>Requirement</th><th>Remarks</th></tr>
<tr><td colspan="2">1. Update of information</td></tr>
<tr><td>The applicant and applicant's subcontractors shall continue to meet the criteria including data proposed by the applicants used at the time of P/Q.</td><td></td></tr>
<tr><td colspan="2">2. Financial resources</td></tr>
<tr><td>Using the attached bidding forms, the bidder shall demonstrate that it has access to, or has available, liquid asset, unencumbered real assets, lines of credit and other financial means (independent of any contractual advance payment) sufficient to meet:

a) The cash flow requirements estimated to be USD xx for the subject contract. In case of JV, all partners combined shall meet the above requirement: each partner shall meet at least xx% of the above requirements; one partner shall meet at least xx% of the above requirement.
b) The cash flow requirements on works currently in progress and for future contract commitments. In case of JV, all partner combined shall satisfy the above requirement.</td><td>Financial capability: “Liquid asset”</td></tr>
<tr><td colspan="2">3. Personnel</td></tr>
<tr><td>The applicant must demonstrate that it will have the personnel for the key positions that meet the following requirements:

<table>
<tr><th>NO</th><th>Position</th><th>Total work experience (years)</th><th>Similar work experience (years)</th></tr>
<tr><td>1</td><td>Project manager</td><td>xx</td><td>xx</td></tr>
<tr><td>2</td><td>Lead engineering manager</td><td>xx</td><td>xx</td></tr>
<tr><td>3</td><td>Lead engineering civil works</td><td>xx</td><td>xx</td></tr>
<tr><td>4</td><td>Lead engineering mechanical works (power block)</td><td>xx</td><td>xx</td></tr>
<tr><td>5</td><td>Lead engineering mechanical works Balance of Plant (BoP)</td><td>xx</td><td>xx</td></tr>
<tr><td>6</td><td>Lead engineering electrical works</td><td>xx</td><td>xx</td></tr>
<tr><td>7</td><td>Lead engineering Instrumentation and Control (I&C)</td><td>xx</td><td>xx</td></tr>
<tr><td>8</td><td>Lead engineering substation</td><td>xx</td><td>xx</td></tr>
<tr><td>9</td><td>Lead engineering transmission line</td><td>xx</td><td>xx</td></tr>
<tr><td>10</td><td>Site manager</td><td>xx</td><td>xx</td></tr>
<tr><td>11</td><td>Lead site engineer Gas Turbine (GT)</td><td>xx</td><td>xx</td></tr>
<tr><td>12</td><td>Lead site engineer Steam Turbine (ST)</td><td>xx</td><td>xx</td></tr>
<tr><td>13</td><td>Lead site engineer HRSG</td><td>xx</td><td>xx</td></tr>
<tr><td>14</td><td>Lead site engineer BoP</td><td>xx</td><td>xx</td></tr>
<tr><td>15</td><td>Lead site engineer electrical</td><td>xx</td><td>xx</td></tr>
<tr><td>16</td><td>Lead site engineer I&C</td><td>xx</td><td>xx</td></tr>
</table></td><td></td></tr>
</table>

17	Lead site engineer civil	xx	xx
18	Lead site engineer substation	xx	xx
19	Lead site engineer transmission line	xx	xx
20	Accident prevention officer	xx	xx

The applicant shall provide details of the proposed personnel and their experience records using the forms provided in the bidding documents.

4. Equipment

The applicant must demonstrate that it will have access to the key Contractor's equipment listed below:

NO	Equipment type and characteristics	Minimum number required
1	xx	xx
2	xx	xx
3	xx	xx
4	xx	xx

The applicant shall provide further details of the proposed items of equipment using the forms provided in the bidding documents.

5. Subcontractors/manufacturers

Subcontractors/manufacturers for major items of supply or services identified in the P/Q document must meet or continue to meet the minimum criteria specified therein for each item.

Subcontractors/manufacturers which provide the following additional major items of supply or services must meet the following minimum criteria each of the items:

NO	Description of item	Minimum criteria to be met
1	Steam turbine generator	The manufacturer shall have at least xx reference generators with a capacity of more than xx MVA which were put into operation in the last xx years. The proposed generator shall be of similar type to reference generators.
2	Cooling tower	The manufacturer shall have the commercial experience of at least xx cooling towers with a capacity of more than xx m3/h which were put into operation in the last xx years.
3	Demineralized water treatment system	The manufacturer shall have the commercial experience in combined cycle power plants of at least xx demineralized water treatment systems with a capacity of more than xx ton/day/train which were put into operation in the last xx years.
4	Waste water	The manufacturer shall have the commercial

	measure system	experience in combined cycle power plants of at least xx waste water treatment systems which were put into operation in the last xx years.
5	Feedwater pumps	The manufacturer shall have xx sets and xx years of successful operation experience with the same or larger capacity and pressure.
6	Boiler	The manufacturer shall have xx sets and xx years of successful operation with the similar steam conditions and capacity. And the proposed boiler shall be of similar configuration to reference boilers.
7	Desulfurization equipment	The manufacturer shall have desulfurization equipment with a capacity of more than desulfurization efficiency xx % and xx projects that satisfied all performance requirements and more than xx years of successful operation experience.
8	NOx removal device	The manufacturer shall have NOx removal device with a capacity of more than NOx removal efficiency xx % and xx projects that satisfied all performance requirements and more than xx years of successful operation experience.
9	Precipitator	The manufacturer shall have precipitator with a capacity of more than precipitation efficiency xx % and xx projects that satisfied all performance requirements and more than xx years of successful operation experience.
10	Draft & recirculating fan system	The manufacturer shall have xx sets and xx years of successful operation experience with the same or larger capacity.
11	DCS	The offered model shall have at least xx years of trouble free operation in the combined cycle power plant and shall have commitment from OEM for spare parts/service support at least for xx years from the date of bid closing.
12	Relays	Relays shall be identical to the proposed relays with xx years of proven field experiences. xx (company name (made in xx)), xx (company name (made in xx)) or equivalent.
13	Substation Automation (SA)	The SA supplier (manufacturer) shall have more than xx years of design, supply and successful operation experiences similar to the Project.
14	Substation up to	The substation contractor responsible for

	xx kV	engineering, management, supervision, procurement, installation and quality assurance of all substation works shall have successfully completed xx project as a main substation contractor, complying with the following requirements: - The contract was made within the last 10 years. The contract must be for substations of similar complexity.
15	Transmission line up to xx kV	The transmission line contractor, responsible for engineering, management, supervision, procurement, installation and quality assurance of all transmission line works shall have successfully completed xx projects as a main Transmission line contractor, complying with the following requirements: - The contract was made within the last xx years. The contract must be for transmission lines of similar complexity.
16	Supervisory Control And Data Acquisition (SCADA)	The SCADA contractor responsible for engineering, management, supervision, procurement, installation and quality assurance of all SCADA works shall have successfully completed xx project as a main SCADA contractor, complying with the following requirements - The contract was made within the last xx years. The contract must be for SCADA project of similar complexity.
17	Civil, building & structural works	The subcontractor shall have general experience under contracts in the role of a contractor, sub-contractor, or management contractor for civil, building and structural works for at least the last xx years prior to the bid submission deadline and have specific experience in participating as a contractor, management contractor or sub-contractor in at least xx contracts for civil, building and structural works for power plant projects of similar methods or complexity within the last xx years that have been successfully or are substantially completed.

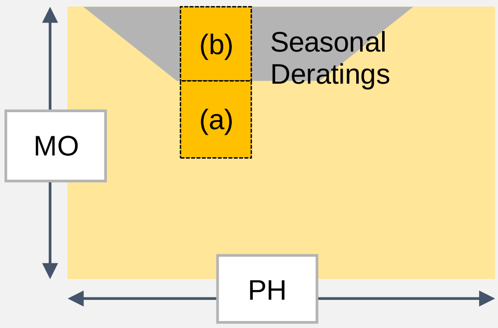
Failure to comply with this requirement will result in the rejection of the subcontractor. In the case of an applicant who supplies and installs major items of supply that the applicant did not manufacture or produce, the applicant shall provide manufacturer's authorization indicating that the

applicant has been duly authorized by the manufacturer or producer of the related plant and equipment or components to supply and/or install such items in the employer's economy. The applicant is responsible for ensuring that the manufacturer or producer complies with the requirement of the bidding specification and meets the minimum criteria listed above for such items.	
6. Additional experiences certificates	
The applicant shall submit the original certificate submitted by the end-user (free form) if the same was not submitted during the P/Q stage.	

(Reference) The evaluation of the applicant's ability to realize "LCC" will be based on the bidding price defined by the employer. The relevant performance indicator during feasibility study, planning and construction phase for "LCC" is the "LCC considering all five other components".

Appendix 4: Metrics of performance indicators in operation phase

<table>
<tr><th>No.</th><th>1</th><th>Performance indicator</th><th colspan="2">Availability</th></tr>
<tr><th colspan="2">Component</th><th>Measurement unit</th><th>Scope of evaluation</th><th>Evaluation period</th></tr>
<tr><td colspan="2">Supply stability</td><td>%</td><td>Power equipment</td><td>Most recent year</td></tr>
<tr><th colspan="5">Purpose of evaluation</th></tr>
<tr><td colspan="5">• To evaluate the quality of periodic maintenance and operating capability and equipment as a power plant by computing the availability of the power equipment</td></tr>
<tr><th colspan="5">Evaluation method/Evaluation logic</th></tr>
<tr><td colspan="5">• Compute the Equivalent Availability Factor excluding seasonal deratings (EAFxs) of the reference power equipment</td></tr>
<tr><th colspan="5">Measurement methodology (method to accumulate information of the indicator / component to be evaluated)</th></tr>
<tr><td colspan="5">• Formula for EAFxs
EAFxs = (AH - EUNDH)) / PH × 100 (*)
The definition of each item in the above formula is as follows:
AH: Available Hours (*)
EUNDH: Equivalent Unit Derated Hours (*)
(Equivalent Seasonal Derated Hours (ESDH) is not included)
PH: Period Hours (*)

(*) Same definition as IEEE Std 762TM-2006</td></tr>
<tr><th colspan="5">Note</th></tr>
<tr><td colspan="5">• The Maximum Output (MO) is defined as Maximum Sending-End Output (MSO) and the standard of MO is the rated value stipulated in the specification as a basis.
• The fixed rate regulated by NERC may be used to convert the Maximum Generating-End Output (MGO) to MSO.
• No bonus will be added (mark-up of the numerator) even if operation above the MO is possible due to seasonal factors.
• In principle, ESDH is not included in EUNDH. However, if it is difficult to separate the two factors, ESDH may be included.
(1) Principle: EUNDH = Electric power equivalent to (a) [MWh] / MO [MW]
(2) Exception: EUNDH = Electric power equivalent to ((a) + (b)) [MWh] / MO [MW]
The decline in availability due to regulatory inspection may be indicated separately (e.g. EAFxs =xx % (+yy%: For Regulatory Inspection)).

</td></tr>
</table>

No.	2	Performance indicator	Increase of heat rate	
Component		**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Supply stability		MJ/MWh	Power equipment	Most recent 5 years (Optional)

Purpose of evaluation

- To evaluate the adequacy of operation and maintenance in relation to the retention of heat rate of the power generation facility

Evaluation method/Evaluation logic

- Compute the difference between heat rate of the previous year and the designed value at construction
- Both the figures measured from the actual operation and figures based on the performance tests conducted within the last 5 years (optional) should be used as a performance test, in general, is conducted periodically at the time of periodic maintenance.

Measurement methodology (method to accumulate information of the indicator / component to be evaluated)

- Formula for increase of heat rate (both (1) and (2))
  (1) (Heat rate of a performance test during the evaluation period - Designed heat rate specified in the specification)
  (2) (Actual heat rate during the evaluation period - Designed heat rate specified in the specification)

- Formula for heat rate (based on the formula provided by the IEA)
  HR = I [MJ] / P [MWh]

The definition of each item in the above formula is as follows:
HR: Heat rate
P: Power generation from power equipment
I: Fuel input for power equipment

Note

- Both the actual figure and figure from the performance test should be indicated as heat rate for these two figures differ in many cases.

No.	3	Performance indicator	Ability to adjust power supply and demand	
Component		Measurement unit	Scope of evaluation	Evaluation period
Supply stability		%	Power equipment	Most recent year

Purpose of evaluation

- To evaluate the ability of the power generation facility to adjust output based on the changes in daily power supply and demand within the electricity supply network

Evaluation method/Evaluation logic

- Compute the percentage of the time that the supply and demand adjustment ability is functioning to the total time of parallel operation

Measurement methodology (method to accumulate information of the indicator/component to be evaluated)

- Formula for ability to adjust power supply and demand
  Ability to adjust power supply and demand = (1 - Time that the supply and demand ability is restricted / Time of parallel operation) × 100

- The "time that the supply and demand ability is restricted" is the sum of the time provided in (1) and (2) below.
  (1) The time that the use of Auto Frequency Control (AFC) or Load Frequency Control (LFC) was restricted due to unplanned causes
  (2) The time that the power generation of the facility was constant due to unplanned causes
- The time of parallel operation is defined as the time that the power generation facility is connected to the electricity supply network and generating electricity.
- AFC is defined as the adjustment of power output using AFC devices to maintain the frequency of the electric system within a standard value.
- LFC is defined as detecting frequency variations and interconnected power variations caused by load variations and controlling the output to maintain the frequency and power flow within standard values during the normal operation.

Note

- Power equipment which are not expected to possess this function will not be evaluated using this Performance indicator.
- Only the actual time for "(2)" above will be evaluated for power equipment which do not possess AFC or LFC.

No.	4	Performance indicator	Forced Outage Rate (FOR)	
Component	Measurement unit	Scope of evaluation	Evaluation period	
Ability to smoothly stop and recover	%	Power equipment	Most recent year	
Purpose of evaluation				
• To evaluate the power generation facility's reliability and its ability to recover through O&M				
Evaluation method/Evaluation logic				
• Compute the FOR of the power equipment				
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)				
• Formula for FOR FOR = FOH / (SH + FOH) × 100 (*) The definition of each item in the above formula is as follows: SH: Service Hours (*) (*) Same definition as *IEEE Std 762TM-2006*				
Note				
None				

No.	5	Performance indicator	Long-Term FOR
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Ability to smoothly stop and recover	%	Power equipment	Most recent 5 years (Optional)

Purpose of evaluation

- To evaluate the power equipment’s reliability and its ability to recover through O&M from large scale troubles

Evaluation method/Evaluation logic

- Compute the percentage of the amount of power loss due to a long term forced outage (30 days or more) within the last 5 years to the total power generation

Measurement methodology (method to accumulate information for the indicator/component to be evaluated)

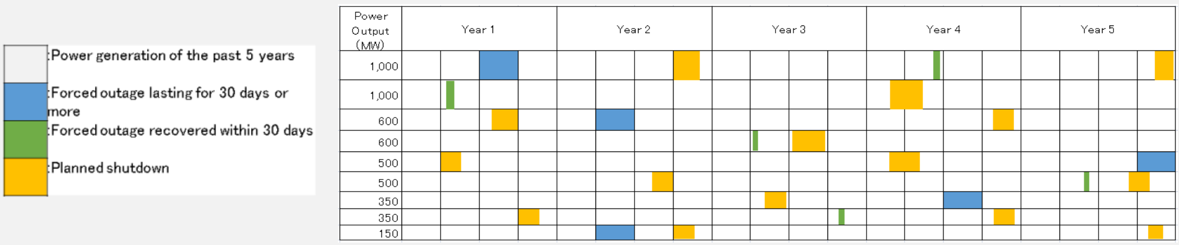
- Formula for Long-Term FOR

  Long-Term FOR = Σ(FOH30 ×MO) / (Σ(SH ×MO) + Σ(FOH30 ×MO)) × 100

The definition of each item in the above formula is as follows:

Σ(FOH30 ×MO) [MWh]: Sum of the total power loss (for 5 years) (= Stoppage time ×MO) due to a long forced outage (30 days or more)

Σ(SH ×MO) [MWh]: Sum of the maximum output during parallel operation (for 5 years)



Note

- Indicate the number of outages lasting for 30 days or more as well as their causes in addition to the Long-Term FOR

No.	6	Performance indicator	SOx and NOx discharge rate	
Component		**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration		g/kWh	Power equipment	Most recent year
Purpose of evaluation				
• To evaluate the quality of environmental consideration by evaluating the impact on the atmospheric environment based on the actual operation				
Evaluation method/Evaluation logic				
• Evaluate initiatives other than those for the effectiveness of the exhaust gas treatment facility (e.g. adoption of low NOx burners, low-sulfur/nitrogen fuel) by computing the discharge rate • The evaluation will be based on MGO as MSO may be affected by the auxiliary power. • SOx will be computed based on the sulfur concentration of the fuel as sulfur concentration has a high impact on SOx. • NOx will be computed based on the results of a regular gas exhaust measurement. If the measurement is conducted multiple times a year, the average will be computed. • Load frequency may have an impact, but this will not be considered as the impact could be considered minimal.				
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)				
• Formula for SOx discharge rate SOx discharge rate = Annual SOx emission (g) / Annual power generation (kWh) • Formula for NOx discharge rate NOx discharge rate = Annual NOx emission (g) / Annual power generation (kWh) The definition of each item in the above formulas is as follows: Annual SOx emission = Σ Sulfur concentration of the fuel (monthly) × Fuel consumption (monthly) × (1 - Desulfurization efficiency) Annual NOx emission = NOx concentration (mean value) × Annual fuel consumption × Gas exhaustion (per unit)				
Note				
None				

<table>
<tr><td>No.</td><td>7</td><td>Performance indicator</td><td colspan="2">CO_2 emissions rate</td></tr>
<tr><td colspan="2">Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td>Evaluation period</td></tr>
<tr><td colspan="2">Environmental and social consideration</td><td>kg- CO_2 /kWh</td><td>Power equipment</td><td>Most recent year</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To evaluate the quality of environmental consideration by evaluating the impact of CO_2 based on the actual operation</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• The evaluation will be based on MGO as MSO may be affected by auxiliary power.
• The annual CO_2 emission will be derived from factors based on each economy's computation methodology such as annual fuel consumption.</td></tr>
<tr><td colspan="5">Measurement methodology (methods to accumulate information of the indicator/component to be evaluated)</td></tr>
<tr><td colspan="5">• Formula for CO_2 discharge rate
CO_2 discharge rate = Annual CO_2 emission (kg) / Annual power generation (kWh)</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">• In general, the CO_2 discharge rate differs depending on the element composition of the fuel, even if heat rate of a power equipment is equal.</td></tr>
</table>

<table>
<tr><td>No.</td><td>8</td><td>Performance indicator</td><td colspan="2">Water quality</td></tr>
<tr><td colspan="2">Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td>Evaluation period</td></tr>
<tr><td colspan="2">Environmental and social consideration</td><td>pH, mg/l, MPN/100ml</td><td>Power plant</td><td>Most recent year</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To evaluate the quality of environmental consideration by evaluating the impact of water quality based on the actual operation</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• The evaluation will be based on the measurement of water quality (discharge concentration)
• If the measurement is conducted multiple times a year, the average will be computed</td></tr>
<tr><td colspan="5">Measurement methodology (method to accumulate information of the indicator/component to be evaluated)</td></tr>
<tr><td colspan="5">• Examples of the items to be measured are pH, BOD, COD, N-hexane, total nitrogen, total phosphorus, SS and Escherichia coli</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">• The water discharge from power plants includes water discharge attributable to employees working at the power plant.</td></tr>
</table>

<table>
<tr><td>No.</td><td>9</td><td>Performance indicator</td><td colspan="2">Noise / vibration</td></tr>
<tr><td>Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td colspan="2">Evaluation period</td></tr>
<tr><td colspan="2">Environmental and social consideration</td><td>dBA, dB</td><td>Power plant</td><td>Most recent year</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To evaluate the quality of environmental consideration by evaluating the impact of noise and vibration based on the actual operation</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• The measurement will be conducted at the border of the power plant to understand the environmental impact on the surroundings
• Other sources of noise and vibration in the surrounding area should be considered
• If the measurement is conducted multiple times a year, the average will be computed</td></tr>
<tr><td colspan="5">Measurement methodology (methods to accumulate information of the indicator/component to be evaluated)</td></tr>
<tr><td colspan="5">• Examples of the items to be measured are the levels of noise (dBA)/vibration (dB)</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">None</td></tr>
</table>

<table>
<tr><td>No.</td><td>10</td><td>Performance indicator</td><td colspan="2">Waste recycling rate</td></tr>
<tr><td colspan="2">Component</td><td>Measurement unit</td><td>Scope of evaluation</td><td>Evaluation period</td></tr>
<tr><td colspan="2">Environmental and social consideration</td><td>%</td><td>Power plant</td><td>Most recent year</td></tr>
<tr><td colspan="5">Purpose of evaluation</td></tr>
<tr><td colspan="5">• To evaluate the quality of environmental consideration by evaluating the impact of waste on the environment</td></tr>
<tr><td colspan="5">Evaluation method/Evaluation logic</td></tr>
<tr><td colspan="5">• The recycle rate of waste that the operator is responsible for disposing of (e.g. fly ash, desulfurized gypsum, sludge from waste water) should be computed per power plant
• Recycle includes material recycle, thermal recycle and sales of recycled items</td></tr>
<tr><td colspan="5">Measurement methodology (method to accumulate information of the indicator/component to be evaluated)</td></tr>
<tr><td colspan="5">• Formula for waste recycle rate
Waste recycle rate = Σ Waste recycled from the power plant (t) / Σ Waste generated at the power plant (t)</td></tr>
<tr><td colspan="5">Note</td></tr>
<tr><td colspan="5">None</td></tr>
</table>

No.	11	Performance indicator	Employment rate from an economy concerned	
Component	Measurement unit	Scope of evaluation	Evaluation period	
Environmental and social consideration	%	Power plant	Most recent year	
Purpose of evaluation				
• To evaluate the perspectives of creation of employment and return of value to the local economy				
Evaluation method/Evaluation logic				
• The local employment rate is defined as the percentage of the total number of employees from the local economy to the total employees working at the power plant • If the employee turnover is high, the evaluation will be based on the number of employees at the end of the fiscal year • Employees hired from the economy refer to employees possessing the nationality of the economy at which the power plant is located				
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)				
• Formula of employment rate from the economy Employment rate from the economy (%) = (Number of employees hired from the economy) / (Total number of employees working at the power plant) x 100				
Note				
• The evaluation of the local employment of subcontractors should be reported using each operator's reporting format (e.g. Annual Report).				

No.	12	Performance indicator	Number of casualties caused by industrial accidents
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Safety	Number of people	Power plant	Most recent year

Purpose of evaluation

- To evaluate the adequacy of measures taken within the power plant in relation to natural disasters, equipment troubles and industrial accidents of the workers working in the power plant

Evaluation method/Evaluation logic

- The evaluation will be based on Industrial Safety Accident Rate (ISA) defined by the World Association of Nuclear Operators (WANO)

Measurement methodology (method to accumulate information of the indicator / component to be evaluated)

- Formula for ISA
  ISA = (Number of lost-time + Restricted time accidents + Fatalities) / Number of station man-hours worked × H

The definition of each item in the above formula is as follows:
Number of lost-time: Number of workers who were unable to work for more than one day from the day after the industrial accident occurred
Restricted time accident: Number of workers who had restriction in work for more than one day from the day after the industrial accident occurred
Fatalities: Number of deaths from industrial accidents
Number of station man-hours worked: Total man-hours worked within the power plant
H: 200,000 man-hours worked or 1,000,000 man-hours worked

Note

- The number of employees should include all employees working at the power plant as well as all the subcontractors.
- Restriction in work will be calculated based on the regulations and customs followed by each operator.

No.	13	Performance indicator	LCC considering all other five components
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
LCC	US$ or local currency/kWh	Power plant	30 years after construction (Optional)

Purpose of evaluation

- To evaluate the balance of total benefit (total power generation) and total cost (sum of total power generation cost and social cost) of power equipment

Evaluation method/Evaluation logic

- Evaluate the adequacy and economical efficiency of both equipment and O&M by considering the total power generation and social cost (environmental impact) in the indicator

Measurement methodology (method to accumulate information of the indicator/component to be evaluated)

- LCC considering all five other components = (Total power generation cost + Social cost) / Total power generation (details provided in the note below)

The definition of each item in the above formula is as follows:
Total power generation cost: Construction cost (CC), fuel cost (FC), O&M cost and disposal cost (DC).
Social cost (SC): External cost such as CO_2 emission cost is evaluated quantitatively
Total power generation (TPG): Gross maximum capacity. Actual power generation will be used for operations carried out in the past

Note

- The construction cost of the power equipment include not only the cost which is directly required to construct the power equipment but also transportation cost of material and equipment, custom duties, customs fee, insurance premium, etc.
- The disposal cost of the power equipment is to be assumed (for example) as a constant rate of construction cost as disposal cost is significantly immaterial in comparison to other costs.
- The evaluation period may be either of the following:

A: If LCC for the period throughout the operation is evaluated (LCC (total)), the evaluation will be based on the periods from the construction of the power equipment to the disposal of the power equipment

LCC considering all five other components (total) is as follows:

$$\frac{(1)\text{Past cost} + (2)\text{Future cost of } \Sigma(\text{CC.FC,O\&M cost,SC,DC})}{(3)\text{Past portion} + (4)\text{Future portion of } \Sigma\,\text{TPG}}$$

*The future cost and the future portion will be discounted to the present value. The past cost and the past portion will be the accumulated value of actual results and no adjustments such as price levels determination will be made.
*When conducting relative evaluation, assumptions such as adjustments for price levels and currencies and social costs should be adequately uniformed to obtain best effect.

B: If LCC for the future operation is the only factor evaluated (LCC (Future)), the evaluation period will include the current period operation and all future operation.

LCC considering all five other components (future) is as follows:

$$\frac{(2)\text{Future cost of } \Sigma(\text{CC.FC,O\&M cost,SC,DC})}{(4)\text{Future portion of } \Sigma\,\text{TPG}}$$

*The future cost and the future portion will be discounted to the present value.

Explanation of each item

[(1) Actual cost]

$$\Sigma\left(CC + FC + O\&Mcost + SC^{*1,2}\right)$$

*[1] SC should be derived based on the appropriate unit cost and coefficient. An example of the CO_2 emission cost calculation is as follows.

(1) CO_2 emission unit cost: US $8.3/t - CO_2 (*EU-ETS ICE 31/12/2015 ending price*)

(2) CO_2 emission coefficient: 94.6t - CO_2 /TJ-coal (*2006 IPCC Guidelines for National Greenhouse Gas Inventories*)

*[2] It is desirable to include NOx emission cost, SOx emission cost, PM emission cost, water disposal cost and external cost that is caused by the forced outages into SC to the extent possible

[(2) Future cost]

$$\sum_{y}\left(FC(a) + O\&Mcost(b) + SC(c) + DC\right) \times (1+r)^{-y}$$

(a). FC in y years
  Fuel consumption Fuel (y) (MJ) × Fuel unit price ($/MJ))

(b). O&M cost in y years
  O&M cost (Example: Power generation in y years(MWh) ×O&M cost per power generation($/MWh))

(c). SC in y years
  Example : Fuel consumption Fuel (y) (MJ) × CO_2 emission cost ($/MJ)

The definition of each item in the above formula is as follows:

$$\text{Fuel consumptio n Fuel}(y)(MJ) =$$
$$P(MW) \times \left(8760(h/year) \times A(\%) - FOH(h/year)\right) \times \left(\varepsilon(MJ/MWh) + n(MJ/MWh \cdot year) \times y\right)$$

P: Capacity of the power equipment (MW)
A: Availability of the power equipment (%) (refer to performance indicator No.1)
r: Discount rate (determined based on the interest rate on the economy's government bond and other risk factors such as currencies)
ε: Current heat rate of the power equipment (MJ/MWh),
n: Increase of heat rate of the power equipment (MJ/MWh·year)
FOH: Actual FOH per year (h/year)*[3]
*[3] Same definition as *IEEE Std 762TM-2006*

[(3) Actual power generation]
Sum of power generation from the start of operation until the present

[(4) Future power generation]
Sum of power generation from present onwards
- Power generation in y year

$$TPG = P(kW) \times \left(8760(h/year) \times A(\%) - FOH(h/year)\right) \times (1+r)^{-y}$$