Appendix 4: Metrics of performance indicators in operation phase

No.	1	Performance indicator	Availability	
Component		Measurement unit	Scope of evaluation	Evaluation period
Supply stability		%	Power equipment	Most recent year

Purpose of evaluation

- To evaluate the quality of periodic maintenance and operating capability and equipment as a power plant by computing the availability of the power equipment

Evaluation method

- Compute the Equivalent Availability Factor excluding seasonal deratings (EAFxs) of the reference power equipment

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

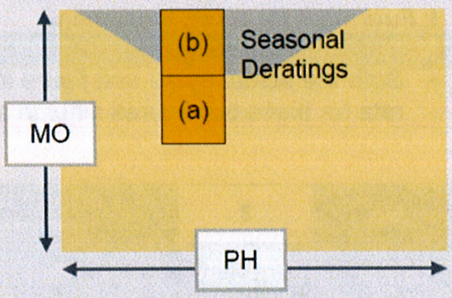
- Formula for EAFxs
  EAFxs = (AH - EUNDH)) / PH × 100 (*)

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*

Note

- 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)).



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

- 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

- 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			
• 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			
• 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)

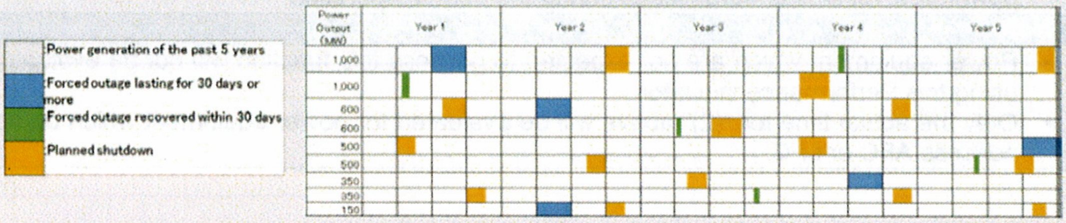
- Formula for Long-Term FOR

  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

- 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

No.	7	Performance indicator	CO_2 emissions rate
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration	kg- CO_2 /kWh	Power equipment	Most recent year
Purpose of evaluation			
• To evaluate the quality of environmental consideration by evaluating the impact of CO_2 based on the actual operation			
Evaluation method			
• 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.			
Measurement methodology (methods to accumulate information of the indicator/component to be evaluated)			
• Formula for CO_2 discharge rate CO_2 discharge rate = Annual CO_2 emission (kg) / Annual power generation (kWh)			
Note			
• 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.			

No.	8	Performance indicator	Water quality
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration	pH, mg/l, MPN/100ml	Power plant	Most recent year
Purpose of evaluation			
• To evaluate the quality of environmental consideration by evaluating the impact of water quality based on the actual operation			
Evaluation method			
• 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			
Measurement methodology (method to accumulate information of the indicator/component to be evaluated)			
• Examples of the items to be measured are pH, BOD, COD, N-hexane, total nitrogen, total phosphorus, SS and Escherichia coli			
Note			
• The water discharge from power plants includes water discharge attributable to employees working at the power plant.			

No.	9	Performance indicator	Noise / vibration
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and	dBA, dB	Power plant	Most recent year

social consideration			

Purpose of evaluation

- To evaluate the quality of environmental consideration by evaluating the impact of noise and vibration based on the actual operation

Evaluation method

- 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

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

- Examples of the items to be measured are the levels of noise (dBA)/vibration (dB)

Note

None

No.	10	Performance indicator	Waste recycling rate
Component	**Measurement unit**	**Scope of evaluation**	**Evaluation period**
Environmental and social consideration	%	Power plant	Most recent year

Purpose of evaluation

- To evaluate the quality of environmental consideration by evaluating the impact of waste on the environment

Evaluation method

- 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

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

- Formula for waste recycle rate

Waste recycle rate = Σ Waste recycled from the power plant (t) / Σ Waste generated at the power plant (t)

Note

None

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

- 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			
• 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	$ 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

- 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 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]

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

*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]

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

(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:

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

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

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