ENERGY MARKET AUTHORITY

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ENERGY MARKET AUTHORITY

REVIEW OF VESTING CONTRACT TECHNICAL PARAMETERS

for the period of 1 January 2021 to 31 December 2022

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EXECUTIVE SUMMARY

WSP Consultancy Pre Ltd, Singapore has been engaged by Energy Market Authority (EMA) of Singapore to conduct a comprehensive review of the vesting price parameters set out in Section 2.3 of the published EMA's Procedures for Calculating the Components of the Vesting Contracts (Procedures) for the period 1 January 2021 to 31 December 2022. The vesting price parameters are categorized as technical and financial.

The LRMC parameters no 1 to 5 and 9 to 10 and 24a & 24b are determined by EMA and the values are given in table 1.2. The financial parameters no 17 to 23 are determined by KPMG and the values are given in separate financial report. The LRMC technical parameters no 6 to 8 and 11 to 16 are covered in this report prepared by WSP.

The recommended technical parameters for the period 1 January 2021 to 31 December 2022 (1 January 2021 to 31 December 2021 for items 7 and 8) are summarized in the below table.

Summary of recommended technical parameters for 2021-2022 review

Item	Description	Unit	2021-2022
6	Economic capacity of the most economic technology in operation in Singapore	MW	419.883
7	Capital cost of the plant identified in item 6	$US/kW	908.037
8	Land, infrastructure and development cost of the plant identified in item 6	$S million	159.913
11	HHV Heat Rate of the plant identified in item 6	Btu/kWh	6,999.7
12	Build duration of the plant identified in item 6	Months	31.5
13	Economic lifetime of the plant identified in item 6	years	25.0
14	Average expected utilisation factor of the plant identified in item 6, i.e. average generation level as a percentage of capacity	%	61.77%
15	Fixed annual running cost of the plant identified in item 6	$S million	22.232
16	Variable non-fuel cost of the plant identified in item 6	$S/MWh	7.340

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ABBREVIATIONS & ACRONYMS

AGC	Automated Generation Control
CCGT	Combined Cycle Gas Turbine
COD	Commercial Operation Date
CPI	Consumer Price Index
EMA	Energy Market Authority
EPC	Engineering, Procurement and Construction
EURO	Currency of Eurozone
GE	General Electric
GJ	Giga Joule
GT	Gas Turbine
HRSG	Heat recovery steam generator
ISO	International Organization for Standardization
kW	kilo Watt
kWh	kilo Watt hour
LRMC	Long Run Marginal Cost
LTSA	Long Term Service Agreement
MAS	Monetary Authority of Singapore
MJ	Mega Joule
MW	Mega Watt
NEMS	National Electricity Market of Singapore
OEM	Original equipment manufacturer
O&M	Operation and maintenance
WSP	WSP Consultancy Pte Ltd
PEACE	Plant Engineering and Construction Estimator
PLF	Plant load factor
Psm	Per square metre
RH	Relative humidity
RSC	Reference Site Conditions
SGD	Currency of Singapore
SPPG	Singapore Power PowerGrid
SRMC	Short Run Marginal Cost
ST	Steam Turbine
USD	Currency of USA
WACC	Weighted Average Cost of Capital
YoY	Year on year

1 INTRODUCTION

1.1 TERMS OF REFERENCE

In January 2004, the Energy Market Authority (**EMA**) of Singapore implemented Vesting Contracts as a tool to mitigate the exercise of market power by commercial generation companies (Gencos) in the National Electricity Market of Singapore (NEMS). Under the Vesting Contracts, Gencos are committed to sell a specified quantity of electricity at a specified price. This removes the incentive for large Gencos to withhold generation capacity in the market. The price under the Vesting Contracts is approximated with the Long Run Marginal Cost (LRMC) of a theoretical new generation entrant in the market, utilising the most economic generation technology in operation which contributes to more than 25% of total demand.

EMA has engaged WSP Consultancy Pte Ltd (**WSP**) to carry out the following tasks,

(a) Conduct a comprehensive review of the vesting price parameters set out in section 2.3 of EMAs procedures for calculating the components of vesting contracts, as follows

 (i). For items 6 and 11 to 24, the Consultant shall recommend the values of each parameter to be used for setting the vesting price for two (2) years period 1st January 2021 to 31st December 2022

 (ii). For items 7 and 8, the Consultant shall recommend the value for each parameter to be used for setting the vesting price for the one (1) year period 1st January 2021 to 31st December 2021

(b) Propose a methodology utilizing publicly available information (e.g., MAS core inflation index) to determine a capital cost index, as set out in section 3.8 (a) of the procedures that can be used to scale the parameter values for items 7 and 8 for setting the vesting price for one (1) year period 1st January 2022 to 31st December 2022. The methodology is provided in *Appendix D* of this report.

KPMG Services Pte Ltd (**KPMG**) has been engaged by WSP to review and provide the financial parameters.

1.2 FINANCIAL PARAMETERS

The financial parameters (as determined by KPMG in the financial parameters report) used in the technical parameter's analysis are shown in *Table 1.1*.

Table 1.1 Financial parameters used in technical parameter analysis

No	Parameters	Value for 2021-2022	Remarks
a	WACC	7.53% post-tax, nominal 9.29% pre-tax, real	Calculated financial parameters
b	Exchange rates	USD/SGD - 1.4197 EUR/SGD - 1.5538	Financial parameters; average of daily Bid / Ask rates for March to May 2020

1.3 EMA DETERMINED LRMC PARAMETERS

The LRMC parameters (as determined by EMA) used in the technical parameter analysis are shown in *Table 1.2*.

Table 1.2 EMA determined LRMC parameters used in technical parameter analysis

No	Parameters	Value for 2021-2022
1	Determination Date	1 June 2020
2	Base Month	May 2020
3	Application Date	1-Jan-2021 to 31-Dec-2022
4	Current Year	2020
5	Exchange Rate ($US per $Sing)	1.4197
9	Brent Index Price [US$/bbl]	25.515
10	LNG gas price [$Sing/GJ]	7.869
14	Average expected utilisation factor of the plant identified in Item 6	61.77%
24a	Carbon price ($S/tonne $CO_{2\text{-}e}$)	5.0
24b	Carbon emission factors [HHV basis]	50.03 kg/GJ

1.4 DISCLAIMER

This report has been prepared for the benefit of EMA for the purposes of setting the vesting contract price for the 2021 to 2022 period. This report may not be relied upon by any other entity and may not be relied upon for any other purpose.

2 PERFORMANCE PARAMETERS

The objective of this section is to estimate the technical performance parameters of the new entrant power plant in Singapore's electricity market.

2.1 NATIONAL ELECTRICITY MARKET OF SINGAPORE

Total registered capacity in National Electricity Market of Singapore (NEMS) is 12,451 MW[1] as on 31 December 2019 which has dropped by 8.2% as compared with previous year. The reduction in registered capacity came primarily from the retirement of three (3) ST units from YTL PowerSeraya and two (2) ST units from Senoko Energy. It is estimated that the CCGT/Cogen/Trigen technology contributes to 84.50% of total registered capacity in Singapore.

In Singapore, electricity generation is predominantly dominated by gas-based power generation using CCGT technology. The existing generation plant details are given below in *Table 2.1*.

Table 2.1 EMA determined parameters applied for LRMC calculation[2]

Large CCGT units	GT Model	Capacity	COD	License no
Keppel Merlimau Cogen				
GRF Unit 3	GT 26	420 MW	Mar - 2013	EMA/GE/006
GRF Unit 4	GT 26	420 MW	Jul - 2013	EMA/GE/006
PacificLight Power				
PACLBLK1	SGT5 - 4000F	400 MW	Jan - 2014	EMA/GE/005
PACLBLK2	SGT5 - 4000F	400 MW	Feb - 2014	EMA/GE/005
YTL PowerSeraya				
PSPS CCP1	V94.3A	368 MW	Oct - 2002	EMA/GE/016
PSPS CCP2	V94.3A	364 MW	Nov - 2002	EMA/GE/016
PSPS CCP3	SGT5 - 4000F	370 MW	Jul - 2010	EMA/GE/016
PSPS CCP4	SGT5 - 4000F	370 MW	Jul - 2010	EMA/GE/016
Sembcorp Cogen				
SKACCP1	GE 9FA	392.5 MW	Sep - 2001	EMA/GE/004
SKACCP2	GE 9FA	392.5 MW	Sep - 2001	EMA/GE/004
SKACCP3	GT 26	403.8 MW	Oct - 2014	EMA/GE/004
Senoko Energy				
SNK CCP1	V94.2	425	Jun - 1996	EMA/GE/012
SNK CCP2	V94.2	425	Sep - 1996	EMA/GE/012
SNK CCP3	GT 26	365	Feb - 2002	EMA/GE/012
SNK CCP4	GT26	365	Jul - 2004	EMA/GE/012
SNK CCP5	GT26	365	Dec - 2004	EMA/GE/012
SNK CCP6	M701F	431	Aug - 2012	EMA/GE/012
SNK CCP7	M701F	431	Aug - 2012	EMA/GE/012

[1] As per NEMS market report 2019
[2] https://www.ema.gov.sg/Licensees_Electricity_Generation_Company.aspx

Large CCGT units	GT Model	Capacity	COD	License no
Tuas Power Station				
Stage II CCP1	M701F	367.5	Nov - 2001	EMA/GE/009
Stage II CCP2	M701F	367.5	Jan - 2002	EMA/GE/009
TUACCP3	M701F	367.5	Jun - 2005	EMA/GE/009
TUACCP4	M701F	367.5	Sep - 2005	EMA/GE/009
TUACCP5	GT26	405.9	Apr - 2014	EMA/GE/009
Tuaspring				
TSPBLK1	SGT5-4000F	395.7	Mar - 2016	EMA/GE/015

2.2 GENERATION TECHNOLOGY

The Vesting Contract procedures[3] published by EMA indicate that:

The Energy Market Authority ("EMA" or the "Authority") implemented Vesting Contracts on 1 January 2004 as a regulatory instrument to mitigate the exercise of market power by the generation companies ("Gencos"). Vesting Contracts commit the Gencos to sell a specified amount of electricity (viz. the Vesting Contract level) at a specified price (viz. the Vesting Contract price). This removes the incentives for Gencos to exercise their market power by withholding their generation capacity to push up spot prices in the wholesale electricity market. Vesting Contracts are allocated only to the Gencos that had made their planting decisions before the decision was made in 2001 to implement Vesting Contracts.

And also:

The Allocated Vesting Price approximates the Long Run Marginal Cost (LRMC) of a theoretical new entrant that uses the most economic generation technology in operation in Singapore and contributes to more than 25% of the total demand.

The underlying concept of LRMC is to find the average price at which the most efficiently configured generation facility with the most economic generation technology in operation in Singapore will cover its variable and fixed costs and provide reasonable return to investors. The plant to be used for this purpose is to be based on a theoretical generation station with the most economic plant portfolio (for existing CCGT technology, this consists of 2 to 4 units of 370MW plants). The profile of the most economic power plants is as follows:

- *Utilizes the most economic technology available and operational within Singapore at the time. This most economic technology would have contributed to more than 25% of demand at that time.*
- *The generation company is assumed to operate as many of the units of the technology necessary to achieve the normal economies of scale for that technology.*
- *The plants are assumed to be built adjacent to one another to gain infrastructure economies of scale.*
- *The plants are assumed to share common facilities such as land, buildings, fuel supply connections and transmission access. The cost of any common facilities should be prorated evenly to each of the plants.*
- *The plants are assumed to have a common corporate overhead structure to minimize costs. Any common overhead costs should be prorated evenly to each of the plants.*

[3] EMA procedures for calculating the components of the vesting contracts April 2020 Version 2.8

The technology selected according to these criteria is CCGT units based on “F” class gas turbines. The existing large CCGT/Cogen plants in Singapore are based on “F” class gas turbine technology. Hence this review is focused on CCGT power plant with “F” class gas turbine technology.

2.3 THERMODYNAMIC MODELLING

WSP expects that any new power plant in Singapore would be optimized for performance at the Reference Site Conditions (RSC). For this review, reference site conditions are as follows:

- 32°C dry bulb air temperature
- 85% relative humidity
- 0 meters mean sea level
- 29.2°C[4] cooling water inlet temperature

The operation of any other ambient conditions or sea water temperature will be considered as an off-design operation. This includes operation at the ambient conditions specified in the Singapore Market Manuals for the Maximum Generation Capacity at an ambient temperature of 24.7°C.

Since this review is focused on "F" class gas turbine CCGT units, the following original equipment manufacturers (OEMs) are available in the market:

- Ansaldo Energia (Ansaldo)
- Siemens Energy (Siemens)
- GE Power (GE)
- Mitsubishi Hitachi Power System (MHPS)

The market for supply of such plants is competitive and it generally cannot be determined, without competitive bidding for a specific local project, which design is the most economic generation technology on an LRMC basis for new built plant. It is often the case for example that the configuration offered with the lowest heat rate is the bid with a higher capital cost. In order to model the performance of the most economic generator, it is recommended to consider all these OEMs’ appropriate "F" class CCGT configurations and to use an arithmetic average of the performance parameters of each of these OEM’s plants in CCGT configuration.

In order to estimate these performance parameters, the GTPro / GTMaster / PEACE[5] (Version 29.0 with updates until 4 June 2020) is used for the thermodynamic analysis. The output from the simulations is shown in *Appendix C* of this report.

2.4 CAPACITY PER GENERATING UNIT

The generation capacities of new entrant CCGT configurations on a clean-as-new condition and at the RSC of 32.0°C air temperature is given in *Table 2.2*. Note that upgrades of gas turbine technologies occur frequently, and judgement must be applied as to whether a new entrant developer would choose the very latest announced version of the gas turbine for a project in Singapore or not. In this review WSP has decided not to apply the very latest announced models of the Mitsubishi gas turbine (the 701 F5) but to instead select the variants that have been available in the market for a longer time (considering commercial operating experience).

New designs beyond “F” class technology are now available from most OEMs. For example, “H” and “J” classes. The procedure indicates that the Allocated Vesting Price approximates the LRMC of a theoretical new entrant that uses the most economic generation technology in operation in Singapore

[4] Based on previous review 2019 - 2020

[5] Software module developed by Thermoflow Inc. (https://www.thermoflow.com/)

and contributes to more than 25% of the total demand. Thus, it is interpreted that the procedure requires evaluation of “F” class units which are currently offered by the OEMs.

Table 2.2 Generation capacity of new entrant CCGT units @ 100% load condition

GT OEM / GT Model	Gross Power [MW]	Aux. Power [MW]	Net Power [MW]
Ansaldo / GT26	452.463	9.202	443.261
GE / 9F.05	431.242	9.213	422.029
MHPS / 701 F4	453.388	9.204	444.184
Siemens / SGT5-4000F	435.298	8.877	426.421
Average	**443.098**	**9.124**	**433.974**

The above performance parameters are based on the below conditions:

- Net power at HV side of main transformer
- GT in new and clean condition and operating at RSC
- Fuel gas compression is not considered
- Auxiliary power (including the main transformer losses) is estimated based on GT-Pro model
- 0% blowdown in HRSG

The details of auxiliary power estimated in GTPro model is given in the below *Table 2.3*.

Table 2.3 Estimated auxiliary loads within GTPro models @ 100% load condition

List of aux. power consumers [MW]	AE GT26	GE 9F.05	MHPS 701 F4	SGT5-4000F
GT fuel compressors	0.000	0.000	0.000	0.000
HRSG feed pumps	2.993	3.280	3.030	3.004
Condensate pumps	0.318	0.300	0.298	0.272
Cooling water pumps	1.463	1.379	1.367	1.321
Aux. from PEACE running motor/load list	1.204	1.160	1.266	1.146
Miscellaneous gas turbine auxiliaries	0.646	0.635	0.667	0.659
Miscellaneous steam turbine auxiliaries	0.091	0.087	0.082	0.081
Miscellaneous plant auxiliaries	0.226	0.216	0.227	0.218
Program estimated overall plant auxiliaries	6.940	7.057	6.937	6.700[6]
Transformer losses	2.262	2.156	2.267	2.177
Total aux. power consumption	**9.202**	**9.213**	**9.204**	**8.877**[6]

There is no need for further allowances to be made to the above performance numbers except the following factors:

- Adjustment for degradation
- Adjustment for gas compression

2.4.1 ADJUSTMENT FOR DEGRADATION

The capacities and heat rates of operating gas turbine and CCGT power plants degrade from the time the plant is new and clean.

[6] the calculation would not tally due to rounding

The following parameters are the primary drivers for performance degradation:

- Fouling
- Erosion
- Roughening of the gas turbine compressor blades
- Material losses in the turbine section

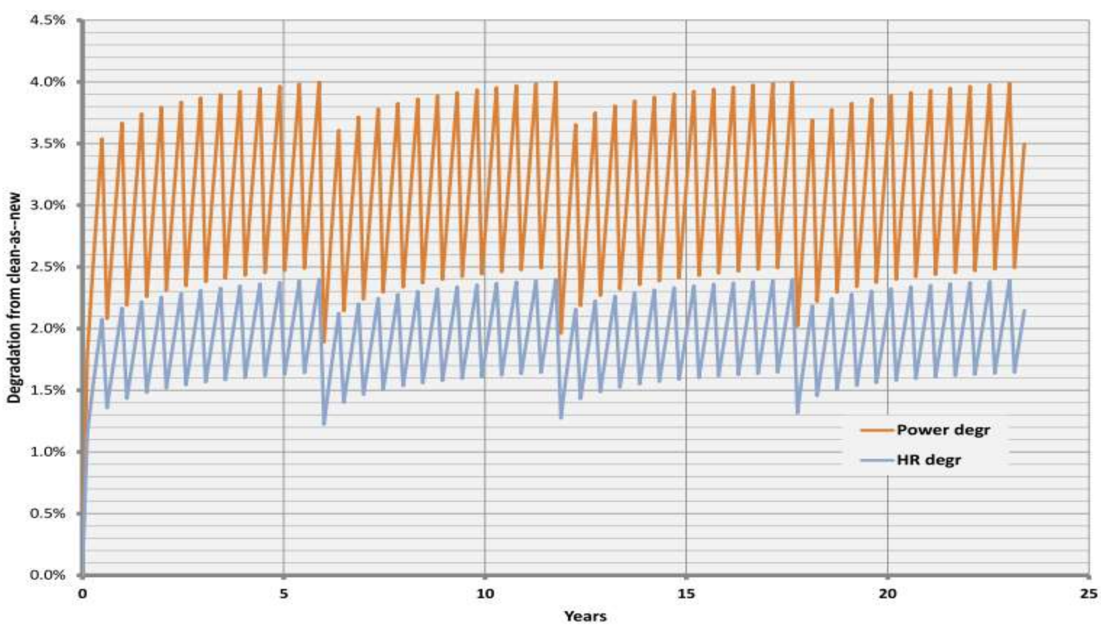
Any CCGT power plant has a slightly reduced degradation profile than a simple cycle gas turbine installation due to partial recovery of the losses suffered by the gas turbine in the steam cycle, and that the gas turbine only comprises approximately two thirds of the plant output. This degradation effect is typically described as having two components:

- **Recoverable degradation:** The degradation of capacity and heat rate that occurs to the plant which can be recovered during the scheduled inspection (overhaul cycle). Recoverable degradation can be substantially remediated by cleaning of air inlet filters, water washing of the compressor, condenser tube cleaning and the like. These cleaning activities are typically undertaken several or many times within a year depending on the site characteristics and the economic value of performance changes.
- **Non-recoverable degradation:** The degradation caused by the impacts of temperature, erosion and corrosion of parts within the plant. This type of degradation is typically substantially remediated at overhaul when damaged parts are replaced with new or refurbished parts. Because the typical industry repair philosophy uses an economic mix of new and refurbished parts within overhauls, it is typically the case that not all of the original clean-as-new performance is recovered at the overhauls.

The average capacity reduction due to recoverable degradation is estimated at 1%. That is, the degradation amount varies from approximately zero to approximately 2% over the cleaning cycle.

Additional to this, an allowance for the non-recoverable degradation of capacity should be made. These typically have the form similar to that shown in *Figure 2-1*. Degradation rates for base and intermediate loaded CCGT units are not considered to be materially affected by load factor or capacity factor.

Figure 2-1: Form of CCGT recoverable and non-recoverable degradation



Based on plants operating up to 93.2%[7] of hours in the year, the average power degradation allowance of 3.06% is suggested.

2.4.2 *ADJUSTMENT FOR GAS COMPRESSION*

Gas compression is considered for new entrant “F” class CCGT plants in Singapore.

Three of the CCGT configurations use natural gas at approximately 30 barg and one configuration (the GT26) uses natural gas at approximately 50 barg. The gas compressor power requirements calculated for the relevant gas turbines at varying gas pressures are shown in *Figure 2-2*. An additional 7 barg pressure drop allowance from the system pressure measurement point to the site boundary (as included in GTPro) is included in the calculation.

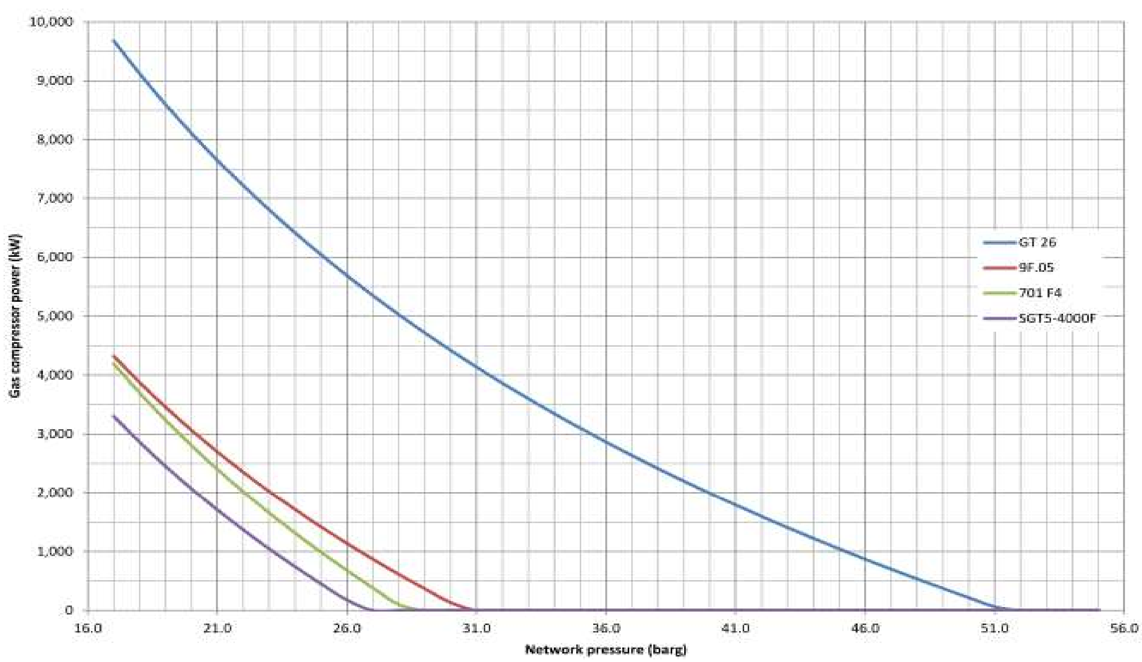
Data for gas pressures in the Tuas area of Singapore is shown in *Figure 2-3* and *Table 2.4*, for the period from January 2012 to March 2020. The Network 1 pressure may be downstream of a regulator in which case the upstream pressure will be higher.

The data indicates that gas compression is sometimes required under current conditions. Should the system pressures reduce further (e.g. because of load growth) then gas compression would be required more often.

For the purposes of this review it is assumed:

- Gas compressors would be incorporated in a new plant in the Tuas View vicinity
- The specification of the compressors would allow for further reductions in local gas pressures from those presently seen. It is assumed they would be capable of operating from a site boundary gas pressure of 16 barg
- The average pressure at the site boundary during operation is 38.72 barg in the relevant period, being the average pressure in the Network 2 in 2020

Figure 2-2: Gas compressor power requirements for relevant gas turbine



[7] WSP estimated available capacity factor for the plant

Figure 2-3: Gas network pressure; Networks 1 and 2 for 2019 and 2020

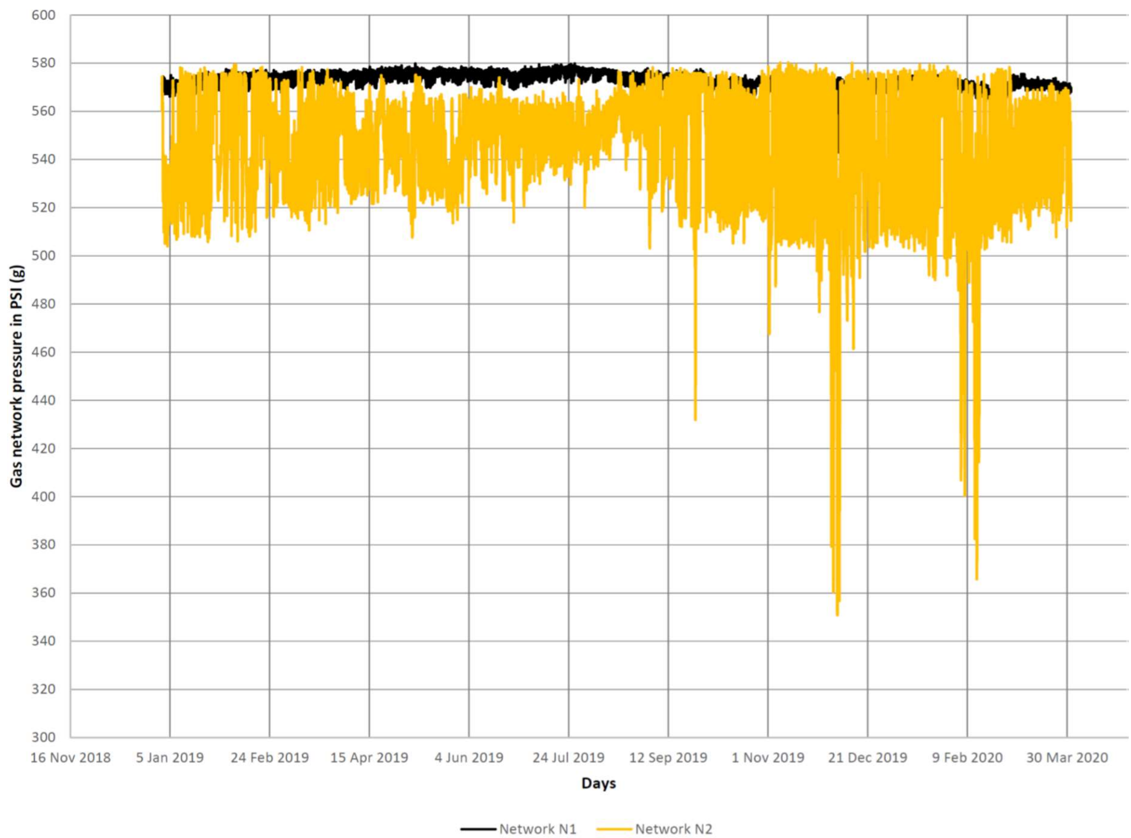


Table 2.4 Estimated auxiliary loads within GTPro models @ 100% load condition

Year	TUAS Network N1				TUAS Network N2			
	Minimum		Average		Minimum		Average	
	PSI (g)	Bar (g)	PSI (g)	Bar (g)	PSI (g)	Bar (g)	PSI (g)	Bar (g)
2012	547.20	37.73	565.63	39.00	349.02	24.06	510.20	35.18
2013	558.30	38.49	570.79	39.35	343.65	23.69	508.90	35.09
2014	277.80	19.15	569.27	39.25	453.28	31.25	548.10	37.79
2015	560.29	38.63	569.88	39.29	464.31	32.01	561.60	38.72
2016	557.56	38.44	569.80	39.29	506.69	34.94	558.34	38.50
2017	557.09	38.41	557.09	38.41	423.37	29.19	542.00	37.37
2018	563.04	38.82	563.04	38.82	490.95	33.85	552.30	38.08
2019	543.10	37.45	573.25	39.52	350.91	24.19	546.21	37.66
2020*	564.00	38.89	570.70	39.35	366.07	25.24	538.58	37.13

* indicated gas pressures are up to 31st March 2020

On this basis the calculated average gas compressor auxiliary / parasitic load impact is 0.532 MW per unit based on the average pressure requirements of the four gas turbine models under consideration.

2.4.3 RESULTS

The resulting net capacity calculation after considering the above factor is given in *Table 2.5*.

Table 2.5 Generation capacity of new entrant CCGT units

Parameters / Factors	Capacity [MW]
Gross power @ RSC & clean as new	443.098
Adjustment for auxiliary power	- 9.124
Adjustment for gas compression	- 0.532
Adjustment for degradation	- 13.559
Net Capacity	**419.883**

2.5 HEAT RATE OF THE GENERATING UNIT

The heat rates of new entrant CCGT configurations, on a clean-as-new condition, and at the Reference Conditions of 32°C air temperature is given in below *Table 2.6*.

Table 2.6 Generation capacity of new entrant CCGT units @ 100% load condition

GT OEM / GT Model	Net LHV HR (kJ/kWh)	Net HHV HR (kJ/kWh)	Net HHV HR (Btu/kWh)[8]
Ansaldo / GT26	6,136.0	6,792.6	6,438.1
GE / 9F.05	6,170.0	6,830.2	6,473.8
MHPS / 701 F4	6,172.0	6,832.4	6,475.9
Siemens / SGT5-4000F	6,091.0	6,742.7	6,390.9
Average	6,142.3[9]	6,799.5[9]	6,444.7[9]

This thermodynamic modelling includes all corrections (within GTPro) necessary for,

- RSC and average sea water temperature of 29.2°C
- Boiler blow-down
- Step-up transformer losses

No further allowances need to be made for these factors except as discussed below,

- Adjustment for degradation
- Adjustment for part load factor
- Adjustment for starts gas usage
- Adjustment for gas compression

2.5.1 ADJUSTMENT FOR DEGRADATION

As noted in Section 2.4.1 above, heat rates for CCGT plants are also subject to degradation. The average heat rate degradation 1.93% is suggested.

2.5.2 ADJUSTMENT FOR PART LOAD FACTOR

Whenever the power plant is operated at less than the Maximum Continuous Rating (MCR) of the plant at the reference site conditions, the heat rate is affected. The modelled variation in heat rate with part

[8] 1.0 kJ/kWh = 0.94781712 Btu/kWh
[9] the calculation would not tally due to rounding

load factor of the new entrant units and average of the new entrant units is shown on *Figure 2-4*. The part load adjustment factor is given in *Table 2.7*.

Figure 2-4: Variation of heat rate to part load factor

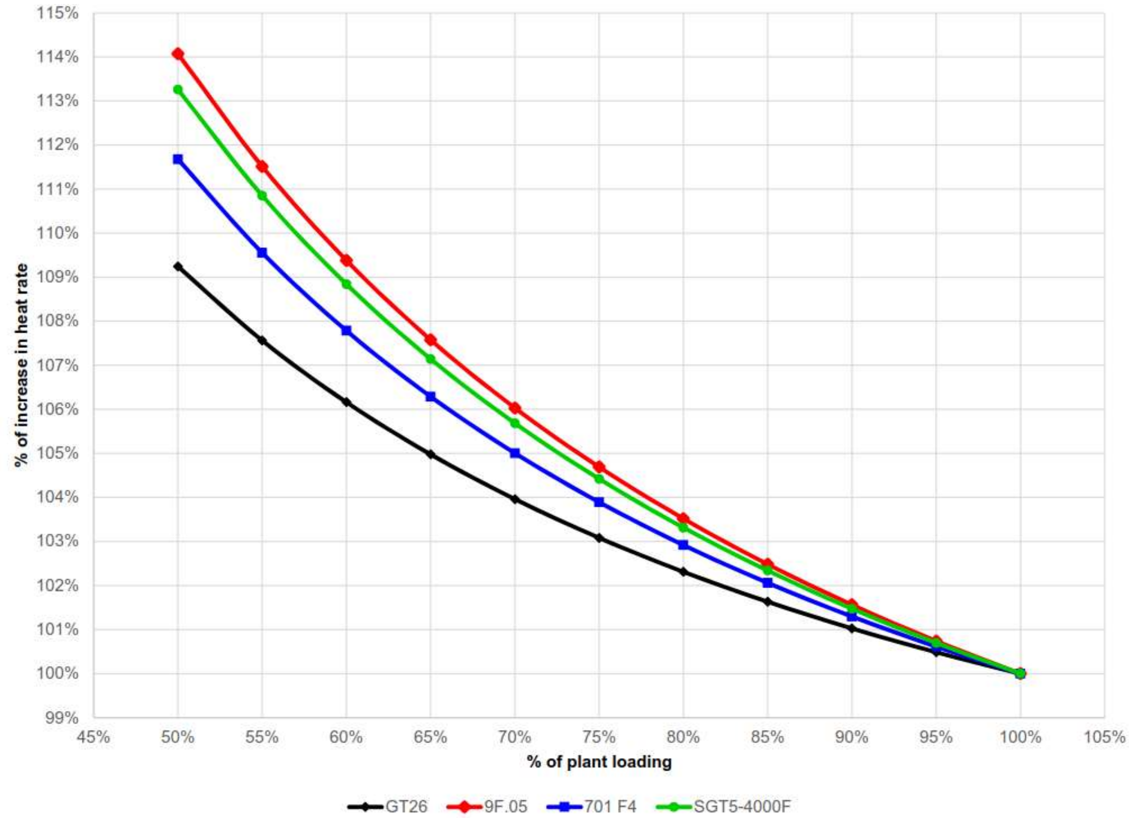


Table 2.7 Variations of average HHV heat rate of new entrant CCGT

% of CCGT load	Average HHV heat rate relative to 100 % load
100%	100.00%
95%	100.63%
90%	101.34%
85%	102.13%
80%	103.02%
75%	104.02%
70%	105.17%
65%	106.50%
60%	108.04%
55%	109.87%
50%	112.06%

In the 2020-2021 review the plant load factor of the new plant was determined from the average historical capacity factor of the existing F class plant for the 12 months leading up to the base month.

For consistency with the previous review, the actual historic capacity factor for the previous 12 months is applied. This value has been advised by EMA to be 61.77%.

The part load factor is to be calculated based on the plant load factor of 61.77%. Applying the Available Capacity Factor of 93.2% (i.e. planned and unplanned outage rate is 6.8%) and assuming there are no economic shuts or part load conditions, the calculated part load factor is 61.77% / 93.2% = 66.28%.

The apparent part load factor for the plant performance is slightly reduced since the registered capacity would only be 98.5% of the nominal capacity. The resulting overall part load factor is 65.28% for which the part-load factor for heat rate adjustment would be 6.42%.

2.5.3 ADJUSTMENT FOR START GAS USAGE

An additional adjustment is made to reflect the natural gas used in starts through the year. The gas usage for starts is estimated at 10 hours of full-load operating equivalent, or 0.1%. In reviews prior to 2010, an additional allowance on account of regulation service is added to the heat rate (+0.5%). However, AGC requirement in Singapore is not considered to be materially different from other jurisdictions, where minor perturbations of output on account of AGC (for those units in the system providing AGC service) or on droop-control are part of normal operations for which no specific extra allowance is considered appropriate. Note that the impact of operating the plant at part-load on account of the need for regulation and contingency reserve ancillary services is already accounted for within the load factor correction.

2.5.4 ADJUSTMENT FOR GAS COMPRESSION

An adjustment is applied to account for the gas compressor auxiliary load. As noted in Section 2.4.2, the auxiliary load of the gas compression has an impact on net output and also on net heat rate.

The average pressure at the site boundary during operation is 38.72 barg in the relevant period, being the average pressure in the Network 2 in 2020. The adjustment for gas compression is estimated as 10.41 kJ/kWh (HHV basis).

2.5.5 RESULTS

The resulting net capacity calculation after considering the above factor is given in *Table 2.8*.

Table 2.8 Generation capacity of new entrant CCGT units

Parameters / Factors	Net HHV heat rate
Net HHV heat rate @ RSC & clean as new	6,799.5 kJ/kWh
Adjustment for degradation	131.6 kJ/kWh
Adjustment for overall part load factor	436.6 kJ/kWh
Adjustment for start gas usage	7.0 kJ/kWh
Adjustment for gas compression	10.4 kJ/kWh
Final HHV net heat rate	7,385.1 kJ/kWh
	6,999.7 Btu/kWh[8]

3 CAPITAL COST

3.1 INTRODUCTION

The items considered in the capital cost of the power plant are listed below and in *Figure 3-1*. Details are further described in the subsequent sections.

- The main power island of the CCGT power plant in a single shaft configuration, each unit comprising of gas turbine generator, HRSG and steam turbine
- The balance of plant facility costs (ancillary buildings, water treatment and demineralization plant, gas compression system, sea water intake / outfall structures, emergency fuel unloading jetty and storage tanks
- Civil works for the plant, erection and assembly, detailed engineering and start-up costs, and contractor soft costs
- Additional spares and security measures as required by the authorities
- Discounted through life capital cost
- Land lease, water frontage and site preparation
- Grid connection facility and gas receiving facilities
- Owner's costs before and after achievement of Financial Close

Figure 3-1: Overview of capital costs considered on this review

Total Overnight Costs

Initial Plant Costs

- Main power plant
- Balance of plant
- Building and structures
- Engineering and plant start-up
- EPC contractors soft & miscellaneous costs
- Transportation to site
- Erection cost
- Gas compression system
- Cooling water system
- Fuel unloading jetty and facilities
- Additional security measures
- Additional spares (air filters)
- Adjustment of civil and foundations

Owners Costs

<u>Pre-financial close</u>

- Permits, licenses and fees
- Legal and financial advisors
- Owners engineers and in-house costs

<u>Post-financial close</u>

- Owners engineers' costs
- Owners minor items
- Initial spares
- Start-up costs
- Construction related insurance

Through life capital costs

Land lease, Water frontage fees and Site preparation costs

Connection Costs

- Grid connection charge
- Switchgear and underground cables
- Gas receiving facilities

3.2 METHOD OF ASSESSMENT

The method of assessment for the estimated capital cost of the new entrant power plant uses the same approach as the previous review. This includes the following:

1. Modelling the plant as discussed in Section 2.0 (a two-unit single shaft "F" class CCGT built with shared common facilities) using the latest version of the PEACE software included with the GTPro software suite. This model is used to generate the initial capital cost of the turnkey project with an EPC contracting strategy for each of the machine type. The average of the PEACE output of the four (4) machine types is taken and adjusted to the plant output considered in this review. The PEACE software has in-built current regional cost factors (labour, equipment, currency) to adjust the costs to be region specific to reflect the market condition. The PEACE cost generated is on an "overnight basis".
2. Assessment of recent CCGT power projects in the region and WSP in-house data.
3. Assessment of published price indicators: Power Capital Cost Index (PCCI) North America and the widely used Gas Turbine World Handbook to gauge the change in price trends of power plants since the last mid-term review. The values are provided in *Table 3.1* and *Figure 3-2*.
4. Cost of additional facilities and equipment required for the power plant that are not typically included in a turnkey project and captured by PEACE are computed using costs from the previous review adjusted by the BCA tender price index for construction components of civil / structural nature and the MAS core index for plant machinery and equipment. This method is consistent with the previous reviews. The indices are provided in *Figure 3-3* and *Figure 3-4*.

3.2.1 RESULTS OF ANALYSIS

In PEACE cost estimates, there is a slight increase in the specialised equipment[10] price and the balance of plant equipment, such equipment packages are subcontracted out to local contractors to remain competitive. The estimated initial plant capital costs are provided in *Table 3.3*. The resulting initial plant capital cost was compared with recent CCGT projects in the region to provide a sanity check.

Also, the price trends from the various sources like PCCI and GTW handbook are consulted to provide an indication of the global power market for CCGT plants. Theses specific costs are not used in the 2021-2022 review calculation as there is a time lag between the published data and actual market conditions.

As mentioned in Gas Turbine World Handbook, the power market in globally is very competitive and EPC prices has reduced as provided in the Gas Turbine World Handbook. However, there are various qualifications given in the GTW Handbook which needs to be considered while evaluating the data[11]. As seen from GTW Handbook prices in *Table 3.1*, the unit cost of the F-class CCGT plants increased from 2013 to 2014-15 and have not varied significantly since then. The upward trend from 2013 to 2014 is supported by North American PCCI which then shows reduction and increase in the last quarter of 2019.

Table 3.1 Gas Turbine World Handbook budget plant prices for CCGT units, USD/kW$_{ISO}$

Single shaft CCGT price	Vol. 34 [2019]	Vol. 33 [2018]	Vol. 32 [2016-17]	Vol. 31 [2014-15]	Vol. 30 [2013]
Ansaldo / GT 26	653	683	667	675	N/A
GE / 9F.05	649	N/A	660	667	572

[10] Main power island equipment consisting of gas turbine, steam turbine-generator, HRSG, condenser, DCS, CEMS and transformers.
[11] These are "bare bones" standard plant designs and exclude design options such as dual fuel and project specific requirements, are for sites with minimal transportation costs, site preparation and with non-union labour, and there can be a wide-range of prices for combined cycle plants depending on geographic location, site conditions, labour costs, OEM marketing strategies, currency valuations, order backlog and competitive situation

Single shaft CCGT price	Vol. 34 [2019]	Vol. 33 [2018]	Vol. 32 [2016-17]	Vol. 31 [2014-15]	Vol. 30 [2013]
MHPS / 701 F4	659	659	659	670	560

Figure 3-2: PCCI price trends of power plants (without nuclear)

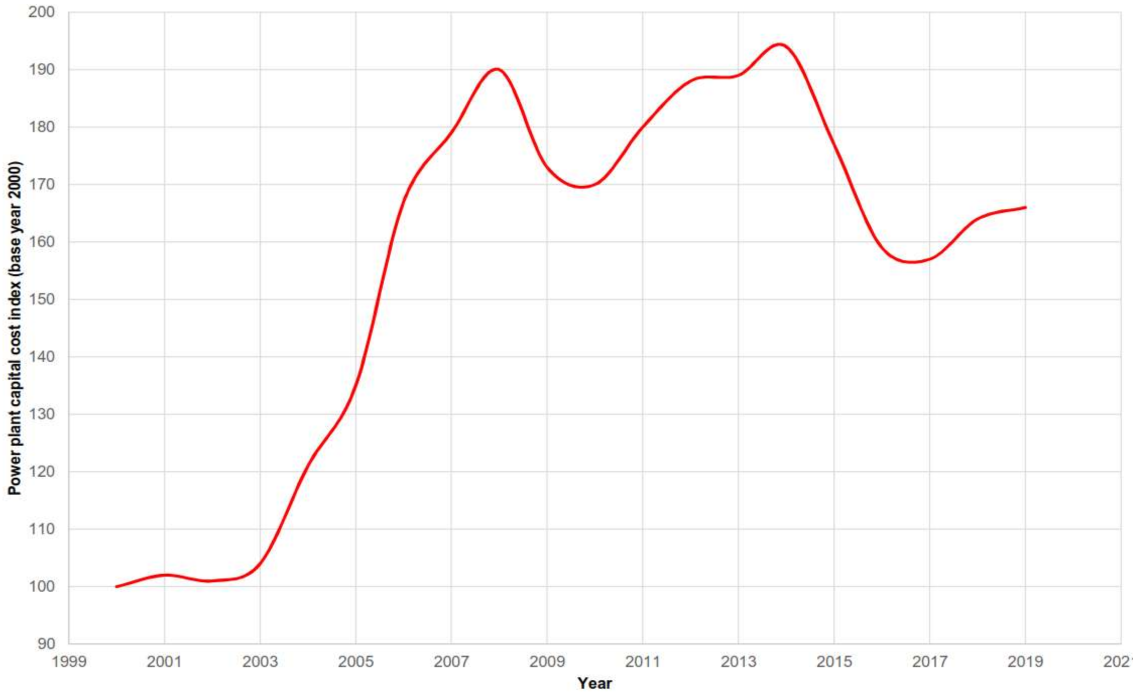
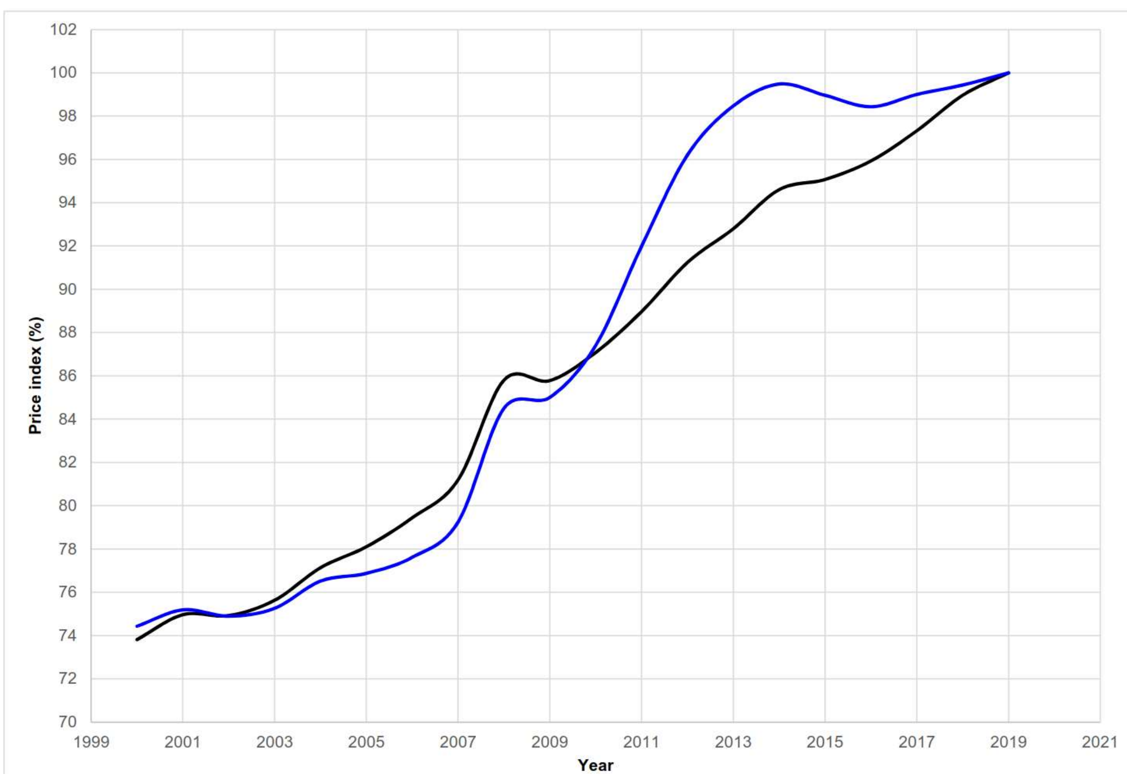


Figure 3-3: MAS core index and CPI (2019 as base year)



For plant machinery and equipment which are outside of the EPC contractor scope, the cost estimates have been escalated using the MAS core index which reflects the cost of goods in Singapore, excluding accommodation and private road transport. The previous index used in the 2019-2020 review was 100.34 and the current value is 99.78 (average of 3 months up to May 2020). This reflects a decrease of 0.56.

The apparent local construction costs have slightly increased from the previous review as reflected by the construction material prices and the BCA Tender Price Index. For the previous review of 2019-2020, the index used was 98.600 (adjusted to base year 2010=100 as implemented by BCA in 2015) and the latest value used in this report is 101.0 up to 15th May 2020 quarterly data published.

Thus, the adjustment factor applied is 1.0243 from the previous review.

3.3 INITIAL PLANT CAPITAL COST

The initial plant capital cost includes the following modifications applied to a typical two-unit CCGT plant. This is done to reflect the design features required for a power plant in Singapore. Where plant equipment or infrastructure is shared between the two units, the costs are halved.

- Gas compression system (two trains per unit)
- Once-through cooling system with the civil costs added separately on a shared (two-unit) basis
- Dual fuel firing system for the gas turbines and fuel forwarding system from the tanks
- Fuel unloading jetty and associated facilities on a shared (two-unit) basis
- Fuel tanks with on-site storage capacity at not less than sixty days on a shared (two-unit) basis
- Civil costs are calculated on a two-unit station basis and then 60% cost considered for one (1) unit
- Building and structures costs are calculated for a two-unit station and then 88% cost considered for one (1) unit
- Adjustment is made for additional security measures as allowed in previous reviews
- Additional inlet filter spares considering the requirements of the Transmission Code clause 9.2.5

The resulting initial plant cost for the plant (excluding external connections) is S$535.696 million per unit as shown in *Table 3.2*. This cost is on an "overnight" basis[12].

Table 3.2 Initial plant capital costs summary and compared with previous reviews (1 unit)

No	Item	2015-16 [kSGD]	2017-18 [kSGD]	2019-20 [kSGD]	2021-22 [kSGD]
1	Specialized Equipment	214,780	242,377	219,495	231,088
2	Other Equipment	11,389	11,489	30,866	17,666
3	Civil	25,802	31,771	30,352	34,879
4	Mechanical	33,580	37,470	41,297	41,473
5	Electrical Assembly & Wiring	7,123	8,905	9,875	8,784
6	Buildings & Structures (shared except turbine hall)	9,717	5,617	8,572	14,009
7	Engineering & Plant Start-up	20,074	15,966	26,545	29,694
8	Contractor's Soft & Miscellaneous Costs	69,715	76,936	103,124	96,084
9	Transport	Included	Included	Included	Included
10	Gas compression system	14,831	11,597	Included	11,453
11	Cooling water system	7,277	6,809	6,637	6,799
12	Fuel unloading jetty and facilities	8,690	8,130	7,925	8,118
13	Fuel tanks	21,700	22,814	27,128	26,792
14	Additional security measures and cyber security measures	2,635	2,886	3,025	2,897
15	Air filters	82	150	154	147
16	Adjustment for civil/foundations	N/A	5,530	5,675	5,813
Total initial plant cost excl. connection costs		**447,395**	**488,447**	**520,670**	**535,696**[13]

[12] Overnight basis does not include interest during construction.
[13] The calculation would not tally due to rounding

The initial plant capital cost estimate for this review is approximately 2.89% higher than the 2019-2020 review due to higher construction costs (considering CoVID-19) in the construction market as observed in *Table 3.1* and *Figure 3-2*.

Thus, the total initial plant cost is S$535.696 million for one unit or S$1,071.392 million for two units.

3.4 THROUGH-LIFE CAPITAL COST

Additional capital costs are incurred through the project's life. Actual costs incurred vary considerably and are based on progressive assessments made of plant condition through the plant's life. The recommended estimates for this review are given in Table 3.3. However, the maintenance costs incurred for the overhaul cycles of the gas turbine and steam turbine are included in the Operating Cost Sections 4.1 and 4.2.

Table 3.3 Through life capital costs (1 unit)

No	Item	Unit	Calculation	2021-22
1	**Distributed Control System (DCS)**			
	Time to replacement	[years]	15 years or 150,000 EoH	
	Cost of replacement	[S$m]	7.0 [real value]	
	Discounted value of costs	[S$m]	@ pre-tax real WACC of 9.29%	**1.85**
2	**Gas Turbine Rotor**			
	Time to replacement	[years]	15 years or 150,000 EoH	
	Cost of replacement	[S$m]	13.854 [real value] considering 10.0 USDm	
	Discounted value of costs	[S$m]	@ pre-tax real WACC of 9.29%	**3.75**
	Total through life costs (1 unit)	**[S$m]**		**5.59**[14]

The cost of the DCS upgrade depends on the level of obsolescence of related items such as field instrumentation and associated wiring.

Towards the end of the notional technical life of the plant, if market studies indicated that the plant may still be economic, studies would be undertaken to evaluate extending the plant's life. The studies and the resulting costs and resulting life extensions are not included.

3.5 LAND AND SITE PREPARATION COST

The land and site preparation cost exclude,

(i) Facility costs (ancillary buildings, demineralisation plant, sea water intake / outfall structures, constructing the jetty for emergency fuel unloading facility and gas receiving facilities)

(ii) Emergency fuel facilities

These costs have been included under capital cost for the current review.

The site area for building the two units remains unchanged from the previous review at 12.5 Ha and a waterfront requirement of 200m. Based on data published by JTC Corporation’s Land Rents and Prices, the land price for 30-year lease at Tuas View is between $184 and $231 psm and taking the midpoint value of S$207.5 psm, the total land lease cost is S$25.94 million.

The published water frontage fees range from $984 to $1,478 per metre per year and using the midpoint annual cost at a pre-tax discount rate of 9.29% over 25 years; this gives an equivalent cost of $2.36 million. Therefore, the total cost assuming mid-point land cost is S$28.30 million.

[14] The calculation would not tally due to rounding

For site preparation cost at the same site location as the previous review, the BCA tender price index have been applied to the previous mid-term review cost of S$2.03 million which results in site preparation cost of S$2.08 million. The total land and site preparation costs are summarised and compared with the previous reviews in *Table 3.4*.

Table 3.4 Current review land costs compared with previous reviews (2 units)

No	Item	Units	2017-18	2019-20	2021-22
1	Land cost for 30-year lease at Tuas View	[S$m]	31.75	25.96	25.94
2	Equivalent water frontage cost	[S$m]	3.68	2.91	2.36
3	Site preparation cost	[S$m]	2.11	2.03	2.08
Total land and site preparation cost (2 units)		**[S$m]**	**37.54**	**30.90**	**30.38**

For the current review, the total land and site preparation costs is $30.38 million for two units or S$15.19 million per unit.

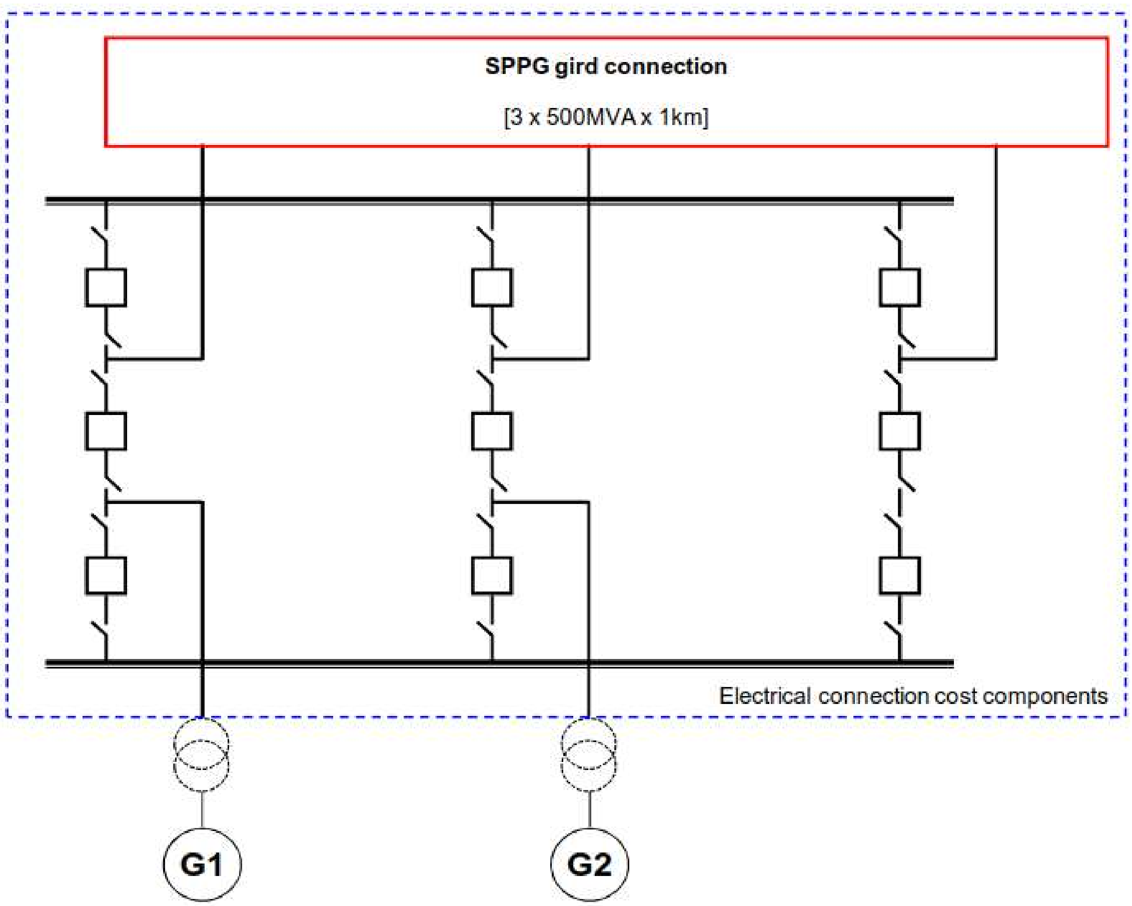
3.6 CONNECTION COST

The connection costs for electrical and gas connections to the electricity grid and gas network respectively are considered in this section.

3.6.1 ELECTRICAL CONNECTION COST

For the electrical connection cost, the components considered are shown in *Figure 3-4* and itemized in *Table 3.5*.

Figure 3-4: Assumed electrical connection configuration



The electrical connection configuration assumed in this review is consistent with the previous review where the 3x500 MVA arrangement is selected from the options of a 3x500 MVA or 2x1000 MVA connection. The sizing of the 230kV GIS equipment, 230kV cables have been sized for export of the plant total net output at 24.7°C of 925.034 MW.

Table 3.5 Electrical connection costs (2 units)

No	Item	Units	2021-22
1	Total SPPG generation connection charge	S$ m	45.21
1a	Plant output at 24.7°C	MW	904.140
1b	Unit cost of SPPG generation connection charge	S$/MW	50,000
2	230kV Switchgear GIS and underground cables - Includes switch house but excludes generator transformer which is included in power plant cost 3 x 500 MVA circuits, 1km direct buried cables	S$ m	31.85
	Total electricity connection cost (2 units)	**S$ m**	**77.06**

From Singapore Power PowerGrid (SPPG), the unit cost of the generation connection charge is at S$50,000/MW and the total net plant capacity at 24.7°C is 904.140 MW. This gives a total generation connection charge of S$45.21 million. Using escalation from previous review, the cost of the 230kV switchgear GIS and underground cables are estimated to be S$31.85 million. The total electricity connection cost for the power plant is S$77.06 million for two units and S$38.53 million per unit.

3.6.2 GAS CONNECTION COST

Given the location of the new entrant plant is the same as the last review at Tuas View area and the gas requirements of the power plant, the gas connection cost is escalated from the previous review using MAS core inflation index and BCA's tender price index for equipment/materials and civil costs respectively. This gives a gas connection cost of S$14.66 million for two units or S$7.33 million per unit.

The total connection cost is S$91.72 million for two units or S$45.86 million per unit. *Table 3.6* provides the connection costs compared with the previous reviews.

Table 3.6 Current review connection costs compared with previous reviews (1 unit)

No	Item	Units	2017-18	2019-20	2021-22
1	SPPG generation connection charge	S$ m	21.99	24.40	22.60
2	230kV Switchgear GIS and underground cables	S$ m	17.03	15.40	15.92
3	Gas connection cost	S$ m	7.08	7.30	7.33
	Total connection cost (1 unit) *(numbers may not add up due to rounding)*	**S$ m**	**46.09**	**47.10**	**45.86**
	Total connection cost (2 units)	**S$ m**	**92.18**	**94.20**	**91.72**

3.7 OWNERS COST AFTER FINANCIAL CLOSE

The Owner's costs incurred from Financial Close to the Commercial Operation Date of the plant are typically calculated as a percentage of the initial plant capital costs and connection costs. The allowances recommended are shown in *Table 3.7*.

Table 3.7 Owner's cost after Financial Close

No	Item	% of initial plant cost and connection cost	2021 - 2022 (S$m)
1	Owner's engineer	3%	17.45
2	Owner's minor items	3%	17.45
3	Initial spares	2%	11.63
4	Start-up costs	2%	11.63

No	Item	% of initial plant cost and connection cost	2021 - 2022 (S$m)
5	Construction related insurance, etc.	1%	5.82
	Total Owner's cost post Financial Close (1 unit)		**63.97**[15]

The Owner's cost items considered after Financial Close are consistent with the previous reviews. Owner's engineering costs are the costs to the owner for in-house and external engineering and management services after financial close, including inspections and monitoring of the works, contract administration and supervision, project management and coordination between the EPC contractor, connection contractors and contractors providing minor services, witnessing of tests and management reporting.

Minor items include all the procurement costs to the owner outside of the primary plant EPC costs and the electricity and gas connections. This includes permits / licenses / fees after financial close, connections of other services, office fit-outs and the like. This also reflects any site specific optimisation or cost requirements of the plant above those of a "generic" standard plant covered in Section 3.3.

Start-up costs include the cost to the owner of bringing the plant to commercial operation (the actual commissioning of the plant is within the EPC contractor's scope). The owner is typically responsible for fuels, water and consumables used during testing and commissioning, recruiting, training and holding staff prior to commercial operations commencing, and for establishing systems and procedures. The construction related insurance cost borne by the owner has also been considered in the owner's total cost after Financial Close.

The initial working capital, including initial working capital for liquid fuel inventory and for accounts receivable versus payable, are not included (these are an ongoing finance charge included in the fixed operating costs of the plant in Section 4.1).

The total owner's cost after Financial Close is S$63.98 million for one unit or S$127.95 million for two units.

3.8 OWNERS COST PRIOR TO FINANCIAL CLOSE

At the time of Financial Close, when the investment decision is being made, the costs accrued up to that time against the project are "sunk" and are sometimes not included in a new entrant cost estimate.

Nevertheless, the industry needs to fund the process of developing projects to bring a plant from initial conception up to financial closure. If these are to be added, the costs can be highly variable. The allowances should include both in-house and external costs to the owner / developer from concept onwards including all studies, approvals, negotiations, preparation of specifications, finance arranging, legal, due diligence processes with financiers etc. These would typically be over a 3 to 5 years period leading up to financial close. An example of typical allowances based on percentages of the EPC cost is shown in *Table 3.8*.

Table 3.8 Owner's cost Pre-Financial Close

No	Item	% of initial plant cost and connection cost	2021 - 2022 (S$m)
1	Permits, licenses, fees	2%	11.63
2	Legal and financial advice and costs	2%	11.63
3	Owner's engineering and in-house costs	2%	11.63
	Total Owner's cost pre-Financial Close (1 unit)		**34.89**[15]

[15] The calculation would not tally due to rounding

Permits, licenses and fees primarily consist of gaining the environmental and planning consents for the plant.

Legal and financial advice is required for establishing the project vehicle, documenting agreements, preparing financial models and information memoranda for equity and debt sourcing, management approvals and due diligence processes.

Owner's engineering and in-house costs prior to financial closure include the costs of conceptual and preliminary designs and studies (such as optimisation studies), specifying the plant, tendering and negotiating the EPC plant contract, negotiating connection agreements, attending on the feasibility assessment and due diligence processes, management reporting and business case preparation, etc.

Project development on a project financed basis sometimes incurs extra transaction costs, such as swaptions for foreign exchange cover or for forward interest rate cover. These are highly project specific and not always necessary. No extra allowance is included.

Table 3.9 Current review Owner's post and pre Financial Close costs compared with previous reviews

No	Item	Units	2017-18	2019-20	2021-22
1	Owner's cost after Financial Close	S$ m	58.80	62.45	63.97
2	Owner's cost pre Financial Close	S$ m	32.07	34.06	34.89
	Total Owner's cost (1 unit)	**S$ m**	**90.87**	**96.51**	**98.86**[16]

[16] The calculation would not tally due to rounding

4 OPERATING COST

4.1 FIXED ANNUAL RUNNING COST

The fixed operation and maintenance cost of the power plant is discussed in this section using a bottom-up approach following the same methodology as adopted in the previous reviews.

As with the previous review, the gas turbine and steam turbine Long Term Service Agreement (LTSA) costs are treated as variable costs rather than fixed costs as the LTSAs are a function of the generation hours and part load factors. Typically, an LTSA only covers the main gas turbine and steam turbine components. The remaining balance of the plant including heat recovery steam generators (HRSGs), cooling system and electrical plant is maintained separately by the owner outside of the LTSA. The cost of this maintenance is typically considered to be a fixed cost and is included in this section. An assessment of the fixed annual cost of operating the power station is shown in *Table 4.1*.

Table 4.1 Fixed annual operating cost for (2 units)

No	Item	Units	2021-22
1	O&M Manning	[S$m]	6.381
2	Head office services	[S$m]	3.829
3	Fixed maintenance and other operations[17]	[S$m]	19.285
4	Additional cyber security maintenance	[S$m]	0.283
5	Starts impact on turbine maintenance	[S$m]	1.181
6	Distillate usage impact on turbine maintenance	[S$m]	0.088
7	EMA licence fee (fixed)	[S$m]	0.064
8	Working capital	[S$m]	4.369
9	Emergency fuel usage	[S$m]	0.848
10	Property tax	[S$m]	2.779
11	Insurance	[S$m]	5.357
	Total fixed operation and maintenance cost	**[S$m]**	**44.464**[16]

The total fixed annual running cost is S$44.464 million and since services and facilities are shared equally, the cost per unit is S$22.232 million.

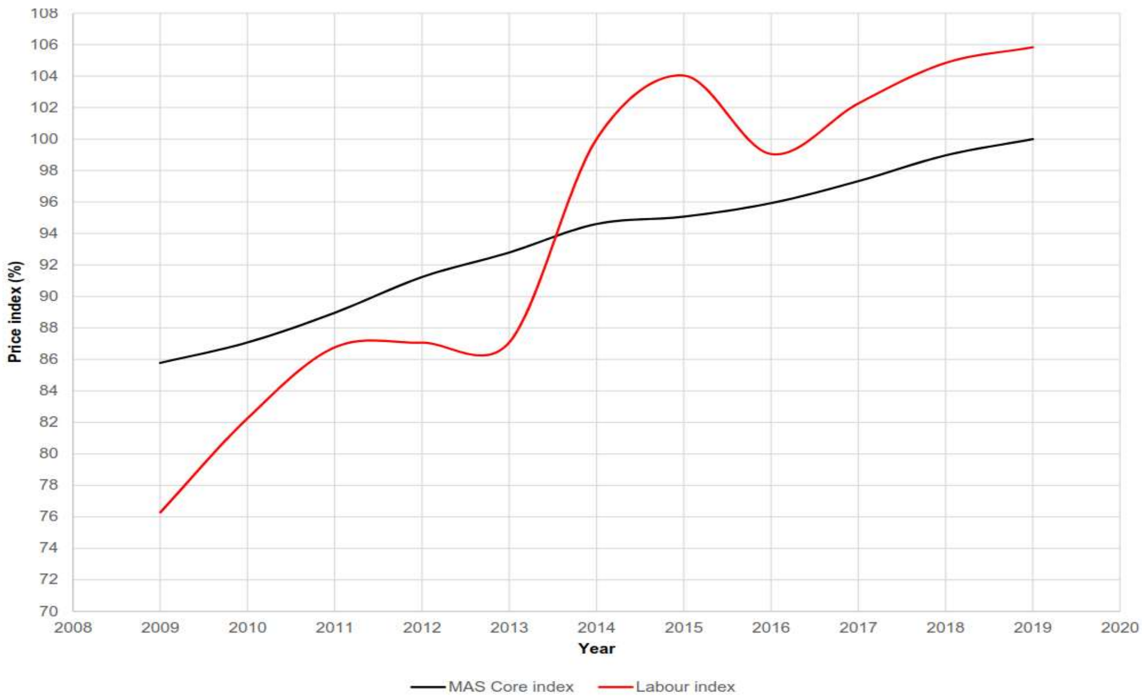
4.1.1 O&M MANNING AND HEAD OFFICE SERVICE COST

The operation and maintenance manning costs have been estimated based on 45 personnel covering the two units at S$141,823/person/year. The unit rate considers the cost allowed in 2021-2022 review indexed using a factor produced from average remuneration changes in a "chemicals" manufacturing environment in Singapore (in the absence of a power generation industry index being available) and MAS core inflation index. The multiplication factor considered for unit costs escalation is 105.65% as compared from previous study. The indices used are shown in *Figure 4-1*.

The personnel include shift operators/technicians and shift supervision as well as day shift management, a share of trading / dispatch costs if this is undertaken at the station (versus head office), engineering, chemistry / environmental, trades supervision, trades and trades assistants, stores control, security, administrative and cleaning support. The cost per person is intended to cover direct and indirect costs.

[17] Calculated as 3% of the plant capital cost per year excluding the cost attributable to the gas turbine and steam turbine (which are included in the variable operating maintenance costs in Section 4.2). These costs need to cover non-turbine maintenance, all other fixed costs including fixed charges of utilities and connections, service contracts, community service obligations, cyber security measures etc.

Figure 4-1: Labour cost[18] and MAS core inflation indices



Head office costs would be highly variable and depend on the structure of the business and the other activities the business engages in. Only head office support directly associated with power generation should be included as part of head office costs. The allowance for head office costs is a nominal allowance (60% of manning cost allowance) for services that might be provided by head-office that are relevant to the generation services of the plant. These would include (for example):

- Support services for generation such as trading etc.,
- Corporate management and governance
- Human Resources and management of group policies (such as workplace safety and health, training etc.)
- Accounting and legal costs at head office; and
- Corporate Social Responsibility costs

4.1.2 STARTS IMPACT ON TURBINE MAINTENANCE COST

The starts impact on turbine maintenance costs accounts for the fact that some gas turbine OEMs account for additional Equivalent Operating hours (EOH) factor or factored fire hours (FFH) for starts and this impacts on the costs under the LTSA.

Based on EOH unit cost of US$2.50/CCGT-MWh at nominal ISO full load and allowing for correction from ISO conditions to reference site conditions, the equivalent cost is S$1,080.84/GT-EOH. The EOH factor is also adjusted by the part-load factor since the EOH measurement is based on operating hours rather than MWh. The LTSA is based on the gas and steam turbine only rather than maintenance of the whole plant.

The starts factor only impacts on the gas turbine component. However, based on 55 starts / unit and 10 EOH / start, the cost is S$590,718 per unit or S$1,181,436 for two units.

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[18] Labour cost index is produced using "Remuneration Per Worker of Manufacturing by Industry Cluster, Annual" available on SingStats. Source: Economic Development Board.

4.1.3 DISTILLATE USAGE IMPACT ON TURBINE MAINTENANCE

Gas turbines installed in the Singapore are required to have dual fuel firing capabilities. The distillate usage has an impact of 1.5 EOH or FFH consumption. Based on the factor of 1.5 when operating on distillate, the additional EOH/FFH consumption over natural gas fuel operation is 0.5 EOH/hour. This equates to an impact on annual fixed running cost of S$44,035 per unit or S$88,071 for two units.

Calculation of the working capital cost and the emergency fuel usage cost below requires an estimate of the costs of distillate and natural gas. For the purposes of this report, the weighted average gas price of S$7.87/GJ and gasoil (10ppm) price of S$10.36/GJ are applied. The gasoil (10ppm) cost is based on the average daily rates from March to May 2020 at US$37.86/bbl and a handling and delivery cost allowance of US$6.32/bbl has been added to give the delivered gas-oil (10ppm) cost of US$44.18/bbl.

4.1.4 EMA LICENCE (FIXED) FEES[19]

The annual generating licence fee for the power plant is S$64,017.59 for two units or S$32,008.80 per unit as advised by EMA.

4.1.5 WORKING CAPITAL COSTS

The working capital costs are the annual costs of the financial facilities needed to fund working capital. This comprises two components:

- ***Emergency fuel inventory:*** As per EMA policy on the fuel reserves for generating companies to maintain fuel reserves to cover at least 60 days of its normal operation of 2 units. Of the 60 days, at least 30 days must be on site and the balance may be stored by a fuel vendor within Singapore provided that it can be securely delivered to the power station when required. Note that the required-on site storage tank capacity remains at not less than 60 days. The methodology applied to calculate the working capital cost for holding the fuel reserves remains unchanged. An effective working capital cost of 30+30/2 days is allowed as the offsite storage charge by the supplier would be between zero and the full cost but a midrange estimate of 50% have been used.

  At the distillate or gasoil (10ppm) cost of S$10.36/GJ and a pre-tax nominal WACC of 9.06%, the working capital cost for the emergency fuel inventory is S$3.898 million for two units or S$1.949 million per unit.

- ***Working capital against the cash cycle*** (timing of receipts from sales versus payments to suppliers) based on a net timing difference of 30 days and excluding fuel costs (based on the short settlement period in the market of 20 days from the time of generation). For two units the working capital requirement on this basis is S$63.131 million and the working capital cost (using a pre-tax nominal WACC of 9.06%) is S$0.470 million for two units per year or S$0.235 million per unit.

The total working capital costs considered for this review is S$4.369 million for two units or S$2.184 million for one unit.

4.1.6 EMERGENCY FUEL USAGE

The emergency fuel usage is an estimated amount of emergency fuel used for testing, tank turnover, maintenance works, etc. As applied in the last review, this is computed based on 1% of equivalent annual fuel usage and the difference in cost of distillate and natural gas (S$10.36/GJ vs S$7.87/GJ). The emergency fuel usage cost for two units is S$0.848 million and correspondingly, S$0.424 million for one unit.

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[19] EMA licence fees are pro-rated based to calendar year 2020, based on EMA's determination for licence fees

4.1.7 *PROPERTY TAX*

Property tax has been estimated based on 10% per year of an assumed Annual Value of 6% of the land, preparation, buildings/structures cost (collectively the total capital value) and the cost of repairs, maintenance and insurance. Reference is also made to IRAS tax guide on the treatment of fixed machinery in the computation for property tax[20]. The value of certain fixed plant and machinery items must be included within the property valuation when calculating property taxes. However, an appended list of exemptions exempts most of the principal plant items of a combined cycle power plant including turbines, generators, boilers, transformers, switchgear etc. To allow for the extra value of the portion of the plant that is included, 10% of the cost of the plant is included in the property tax valuation calculation (except where already included). The total capital value included in the calculation of property tax is S$309.843 million for the power plant. The cost of repairs, maintenance and insurance are added to 6% of the total capital value for the computation of the Annual Value. Applying a property tax rate of 10% to the Annual Value, the annual payable property tax is S$2.779 million for two units or S$1.390 million per unit.

4.1.8 *INSURANCE*

Insurance has been estimated based on 0.5% of the capital cost. This is considered to cover property, plant and industrial risks but would not cover business interruption insurance or the cost of hedging against plant outages. For this review, the annual insurance cost is S$5.357 million for two units or S$2.678 million per unit.

4.1.9 *SUMMARY AND COMPARISON WITH PREVIOUS REVIEWS*

The summary of the various fixed running costs is tabulated in *Table 4.2* and a comparison with the previous reviews are also captured in the same table.

Table 4.2 Annual fixed running costs compared with previous reviews (2 units)

No	Item	Units	2017-18	2019-20	2021-22
1	O&M Manning	S$ m	5.39	6.04	6.381
2	Head office services	S$ m	3.23	3.62	3.829
3	Fixed maintenance and other operations	S$ m	17.87	18.74	19.285
4	Additional cyber security maintenance	S$ m	-	0.283	0.283
5	Starts impact on turbine maintenance	S$ m	1.17	1.19	1.181
6	Distillate usage impact on turbine maintenance	S$ m	0.09	0.09	0.088
7	EMA license fee (fixed)[19]	S$ m	0.058	0.062	0.064
8	Working capital	S$ m	4.39	7.71	4.369
9	Emergency fuel usage	S$ m	0.96	1.67	0.848
10	Property tax	S$ m	2.48	2.59	2.779
11	Insurance	S$ m	4.88	5.21	5.357
	Total fixed running cost (2 units)	**S$ m**	**40.52**	**47.21**	**44.464[16]**

4.2 VARIABLE NON-FUEL COST (EXCLUDING CARBON PRICE)

As in the previous review, it is assumed a Long Term Service Agreement (LTSA) would be sought for the first one to two overhaul cycles of the gas turbine and steam turbine (typically 6 to 12 years). These are typically structured on a "per operating hour" or "per MWh" basis and hence are largely variable costs. An assessment of the variable, non-fuel, costs is given in *Table 4.3*.

[20] IRAS e-Tax Guide: Treatment of Fixed Machinery under the Property Tax Act; published 2 September 2014

Table 4.3 Variable non-fuel cost parameters (excluding carbon price)

No	Item	Units	2021-22	Remarks
1	LTSA for Gas turbine	S$/MWh	5.772	Based on EUR2.22 / MWh before correction to site reference conditions and overall part load factor.
2	Steam turbine	S$/MWh	0.000	Included in GT LTSA
3	Balance of plant, chemicals, consumables	S$/MWh	0.550	Escalated by MAS core index
4	Town Water	S$/MWh	0.233	
5	EMC fees	S$/MWh	0.336	Weighted average for EMC budget for FY20/21
6	PSO	S$/MWh	0.251	Weighted average for PSO estimated fees for FY20/21
7	EMA license fee (variable)[19]	S$/MWh	0.199	As advised by EMA
Total *(numbers may not add up due to rounding)*		**S$/MWh**	**7.340**	

The current review values are compared with the previous reviews in *Table 4.4.*

Table 4.4 Variable operating cost allowance comparison

No	Item	Units	2017-18	2019-20	2021-22
1	LTSA for Gas turbine	S$/MWh	6.018	5.472	5.772
2	Steam turbine	S$/MWh	Included	Included	Included
3	Balance of plant, chemicals, consumables	S$/MWh	0.557	0.574	0.550
4	Town Water	S$/MWh	0.178	0.233	0.233
5	EMC fees	S$/MWh	0.246	0.302	0.336
6	PSO	S$/MWh	0.280	0.272	0.251
7	EMA license fee (variable)[19]	S$/MWh	0.179	0.191	0.199
Total *(numbers may not add up due to rounding)*		**S$/MWh**	**7.459**	**7.043**	**7.340**

4.3 CARBON PRICE

The Carbon Pricing Act 2018 came into operation on 1 January 2019. The Carbon Tax Rate is a fixed rate in the third schedule of the Act and is set at SGD 5.0 /tonne CO_2-e. The carbon price covers the six greenhouse gases (GHGs) that Singapore currently reports to the United Nations Framework Convention on Climate Change (UNFCCC) as part of Singapore's national GHG inventory.

The payment of the tax or surrendering of carbon credits must be made by the later of 30 September of the year following the relevant year and 30 days after the service of a notice of assessment. We assume that the purchase of credits to settle the liability would be a tax-deductible expense in the Singapore tax system and hence that the carbon price acts as a regular operating expense in the vesting contract procedures.

For transparency and given that the carbon price in the Act does not escalate, other than as might be provided for by subsequent legislation, we suggest that the carbon price component be shown as a separate component of the LRMC.

EMA has advised that the IPCC factors 2006 Table 2.2 should be applied along with the Global Warming Potentials listed in Schedule 1 of the Carbon Pricing Act. EMA has also advised that distillate be given no weighting as distillate is separately taxed. The parameters for this assessment are shown in *Table 4.5*.

Table 4.5 Carbon emission factor

No	Item	Weighting and sum	CO_2	CH_4	N_2O
1	Natural gas	99%	50.49	0.0189	0.0279
2	Distillate oil	0%			
	Weighted Σ equals	**50.03**	**49.99**	**0.02**	**0.03**

Table 4.6 Calculation of carbon price

No	Item	Units	2021-22
1	Emission factor	kg/GJ [HHV]	50.03
2	Plant net heat rate [HHV basis]	GJ/MWh	7.385
3	Carbon price	S$/tonne $CO_{2\text{-}e}$	5.00
	Green House Gases (GHG) costs	**S$/MWh**	**1.847**

5 OTHER PARAMETERS

5.1 BUILD DURATION

From discussions with EPC contractors, OEMs and a review of recently completed CCGT projects, the current expected build duration for the power plant is at 30 months. However, we considered additional 1.5 months considering the new BCA regulations related constructions industries due CoVID-19 spread control. The total build duration considered in this study is 31.5 months.

5.2 ECONOMIC LIFE

The technical life of this type of plant is considered to be approximately 25 years which is typically applied for CCGT power plants in the region and Singapore. Using the methodology as applied in the previous review (2019-2020) as described in *Appendix B*, the resulting calculated economic life is 78.80 years which is longer than the technical life of the plant. It is recommended that the lower value of the two, namely technical life and calculated economic life, be selected as the economic life of the plant to be used in the review. Thus, an economic life of 25 years is recommended for 2021-2022 review.

5.3 AVERAGE EXPECTED UTILISATION FACTOR

The average expected utilization factor used in this review is 61.77% as advised by EMA. The actual historic capacity factor for the 12 months leading up to the base month and the additional embedded generation expected within the review period were used to compute the average expected utilization factor.

5.4 SUMMARY OF OTHER PARAMETERS

Table 5.1 summarizes the above parameters with a comparison with the values from the previous reviews.

Table 5.1 Other parameters compared with previous reviews

Parameters	2015-2016	2017-2018	2019-2020	2021-2022
Build duration	30 months	30 months	30 months	31.5 months
Economic life	24 years	25 years	25 years	25 years
Average utilization factor	64.40%	58.50%	61.87%	61.77%

6 RESULTS - VESTING CONTRACT PARAMETERS

6.1 INTRODUCTION

The LRMC calculation uses parameters considered in this technical report and parameters from the financial report and those as advised by EMA. For the purposes of comparing the impacts of the changes in technical parameters, a calculation is included in the LRMC, using assumptions for financial parameters where necessary.

6.2 SUMMARY OF TECHNICAL PARAMETERS

Table 6.1 Summary of recommended technical parameters and previous review values

Item	Description	Unit	2019-2020	2021-2022
6	Economic capacity of the most economic technology in operation in Singapore	MW	432.19	419.883
7	Capital cost of the plant identified in item 6	$US/kW	922.84	908.037
8	Land, infrastructure and development cost of the plant identified in item 6	$S million	155.73	159.913
11	HHV Heat Rate of the plant identified in item 6	Btu/kWh	7006.1	6,999.7
12	Build duration of the plant identified in item 6	Months	30	31.5
13	Economic lifetime of the plant identified in item 6	years	25.0	25.0
14	Average expected utilisation factor of the plant identified in item 6, i.e. average generation level as a percentage of capacity	%	61.87%	61.77%
15	Fixed annual running cost of the plant identified in item 6	$S million	23.60	22.232
16	Variable non-fuel cost of the plant identified in item 6	$S/MWh	7.04	7.340

The variances from the previous review are attributable to:

- Reduction in the plant output capacity due to reduction in capacity of all GT models (as per latest GTPro performance) which leads to reducing the unit capital cost of the plant (item 7) due to reduction in EPC cost of large CCGT plants in the region
- An improvement to HHV heat rate at new and clean conditions due to increased efficiency performance across the F class machines.
- Performance and PEACE costs are applied without any market adjustment

6.3 CALCULATED LRMC

For the calculation of the LRMC, parameters produced from the financial report and those as advised by EMA are used. These are tabulated in Table 6.2. Applying the vesting contract formulae and in accordance with the treatment in the previous years of using the nominal WACC, the technical parameters and financial parameters yield the component breakdown of the LRMC as summarized in Table 6.3.

Table 6.2 Assumed financial parameters for LRMC calculation

Item	Parameters	Value for 2021-2022	Source
1	WACC	7.53% WACC post-tax nominal 9.29% WACC pre-tax real	Financial parameters
2	Weighted average gas price	7.87 S$/GJ	EMA

Item	Parameters	Value for 2021-2022	Source
3	Gasoil (10ppm) price	37.86 US$/bbl	EMA; average midpoint of daily Bid / Ask for March to May 2020
4	Exchange rates	USD/SGD → 1.4197 EUR/SGD → 1.5538	Financial parameters; midpoint of daily Bid/Ask for March to May 2020

Table 6.3 Calculated LRMC for 2021-2022

No	Item	Units	2021-2022
1	Capital component	S$/MWh	34.15
2	Fixed operating expenditure	S$/MWh	9.79
3	Variable operating expenditure	S$/MWh	7.34
4	Fuel component	S$/MWh	58.11
5	Carbon tax component	S$/MWh	1.85
	Calculated LRMC	**S$/MWh**	**111.23**[21]

The various parameters from the calculation of 2021-2022 LRMC are compared with that of previous review in *Table 6.4*.

Table 6.4 Calculated LRMC compared with previous reviews

No	Item	Units	2017-18	2019-20	2021-22
1a	WACC post-tax nominal	[%]	6.65%	7.13%	7.53%
1b	WACC pre-tax real	[%]	7.15%	7.05%	9.29%
2	Gas price	[S$/GJ]	9.87	14.79	7.87
3	Exchange rates	[USD/SGD]	1.3643	1.324	1.4197
4	Capital component	[S$/MWh]	31.14	30.94	34.15
5	Fixed O&M component	[S$/MWh]	9.68	10.08	9.79
6	Variable O&M component	[S$/MWh]	7.46	7.04	7.34
7	Fuel component	[S$/MWh]	74.03	109.32	58.11
8	Carbon tax component	[S$/MWh]	-	1.85	1.85
Total LRMC		**[S$/MWh]**	**122.31**	**159.22**	**111.23**

Remarks:

- Reduction in fuel component and fixed O&M component in the current review due to lower gas price as compared with preview review
- Increase in capital component from the previous review due to a slight reduction in plant capacity

[21] The calculation would not tally due to rounding

APPENDIX A

PRESCRIBED PROCEDURE

Source: Extracted from EMA's Procedures for Calculating the Components of the Vesting Contracts, April 2020, Version 2.8

No	Parameters	Description	Method of Determination
1	Determination Date	Date on which the calculations of the LRMC, which is to apply at the Application Date, are deemed to be made.	Determined by EMA
2	Base Month	Cut-off month for data used in determination of the LRMC base parameters. For the following base parameters which tend to be volatile in nature, the data to be used for estimating each of them shall be based on averaging over a three-month period leading up to and including the Base Month: 1. Exchange rate denominated in foreign currencies into Singapore dollars 2. Diesel price to calculate cost of carrying backup fuel 3. Debt premium to calculate cost of debt; and 4. MAS Core Inflation Index	Determined by EMA
3	Application Date	Period for which the LRMC is to apply.	Determined by EMA
4	Current Year	Year in which the Application Date falls.	Determined by EMA
5	Exchange Rate ($US per $Sing)	The exchange rate is that as determined under Section 3.7.	Determined by EMA (in consultation with finance experts)
6	Economic capacity of the most economic technology in operation in Singapore (MW)	The size of the most thermally efficient unit taking into account the requirements of the Singapore system, including the need to provide for contingency reserve to cover the outage of the unit and the fuel quantities available. It is acknowledged that this value may depend on the manufacturer. (For CCGT technology the size of the unit is expected to be around 370MW.)	Determined by EMA (in consultation with the engineering and power systems experts)
7	Capital cost of the plant identified in item 6 ($US/kW)	Capital cost includes the purchase and delivery cost of the plant in a state suitable for installation in Singapore and all associated equipment but <u>excludes</u> switch gears, fuel tanks, transmission and fuel connections, land, buildings and site development included in item 8. Where more than one unit is expected to be installed that will share any equipment, the costs of the shared equipment should be prorated evenly to each of the units.	Determined by EMA (and in consultation with the engineering and power systems experts)
8	Land, infrastructure and development cost of the plant identified in item 6 ($Sing million)	Where more than one unit is expected to be installed that will share any equipment or facilities, the costs of the shared equipment or facilities should be prorated evenly to each of the units. These costs should include all capital, development and installation costs (excluding all costs included in the capital cost of plant	Determined by EMA, (a) In consultation with the engineering and power systems experts in relation to the following values: ▪ Size of site required ▪ Site development

No	Parameters	Description	Method of Determination
		included in item 7 and financing costs during the build period). These costs should include the following specific items: ▪ Acquisition costs of sufficient land to accommodate the plant defined above in item 6 (alternatively land may be included as annual rental cost under Fixed Annual Running Costs) ▪ Site development ▪ Buildings and facilities ▪ Connections to gas pipelines ▪ Switchgear and connections to transmission ▪ Emergency fuel facilities ▪ Project management and consultancy	▪ Buildings and facilities ▪ Connections to pipelines ▪ Switchgear connections to transmission ▪ Emergency fuel facilities ▪ Project management and consultancy; and (b) In consultation with the real estate experts in relation to land value.
9a	HSFO 180 CST Oil Price (US$/MT)	The HSFO 180 CST Oil Price is that as determined in Section 3.7.1	Determined by EMA.
9b	Brent Index Price (US$/bbl)	The Brent Index is that as determined in Section 3.7.2.	Determined by EMA.
10a	Gas Price ($Sing/GJ)	The current most economic generating technology in Singapore uses natural gas. This is calculated using the weighted average price of gas used for commercial power generation, determined by EMA in accordance with Section 3.7.	Determined by EMA.
10b	LNG Price ($Sing/GJ)	This is the Singapore regasified LNG price as determined by the Authority. The LNG Price is used in place of 10a for the LNG Vesting Quantities under the LNG Vesting Scheme. The LNG Price includes: ▪ the LNG hydrocarbon charge ▪ any fees or charges imposed by the Authority on the imported gas ▪ the LNG terminal tariff ▪ the average gas pipeline transportation tariff applicable to regasified LNG users ▪ the LNG Aggregator's margin ▪ the cost of Lost and Unaccounted For Gas (LUFG)	Determined by EMA.
11	HHV Heat Rate of the plant identified in item 6 (Btu/kWh)	The high heat value heat rate of the plant specified under item 6 that is expected to actually be achieved, taking into account any improvement or degradation in efficiency from installation in Singapore and other reasonable factors.	Determined by EMA (in consultation with the engineering and power systems experts)
12	Build duration of the plant identified in item 6 (years)	The time from the commencement of the major cost of development and installation being incurred up to the time of plant commissioning. This parameter is used to calculate the financing cost over the duration of the building period and assumes that the development costs are incurred evenly across this period. The build	Determined by EMA (in consultation with the engineering and power systems experts)

No	Parameters	Description	Method of Determination
		duration should be specified to reflect this use and meaning as opposed to the actual time from the commencement of site development to the time of plant commissioning.	
13	Economic lifetime of the plant identified in item 6 (years)	The expected time from commissioning to decommissioning of the plant. This number is used to amortise the capital cost of the plant, and of installation and development.	Determined by EMA (in consultation with the engineering and power systems experts)
14	Average expected utilisation factor of the plant identified in item 6, i.e. average generation level as a percentage of capacity (%)	The utilisation factor is the expected annual proportion of plant capacity that will be used for supplying energy for sale. It should exclude station usage, expected maintenance and forced outages and the expected time spent providing reserve capacity. The determination of the factor should assume that the plant is efficiently base-loaded.	Determined by EMA (in consultation with the engineering and power systems experts)
15	Fixed annual running cost of the plant identified in item 6 ($Sing)	These costs are the fixed operating and overhead costs that are incurred in having the plant available for supplying energy and reserves but which are not dependent on the quantity of energy supplied. It is acknowledged that some costs are not easily classified as fixed or variable. The costs expected to be included in this parameter are: ▪ Operating labour cost - it is expected that the plant will be running for three shifts per day and seven days per week so all operating labour cost is likely to be a fixed annual cost ▪ Direct overhaul and maintenance cost, with any semi-variable costs treated as annual fixed costs ▪ Generating license ▪ Insurance ▪ Property tax ▪ Costs of emergency fuel ▪ Other charges ▪ Other overhead costs	(a) Determined by EMA, in consultation with engineering and power systems experts in relation to the following values: ▪ Operating labour ▪ Direct overhaul and maintenance cost ▪ Costs of emergency fuel ▪ Other overhead costs; and (b) Determined solely by EMA ▪ Generating license ▪ Insurance ▪ Property tax ▪ Other charges
16	Variable non-fuel cost of the plant identified in item 6 ($Sing/MWh)	Any costs, other than fuel costs, that vary with the level of energy output for a base-load plant and are not covered by item 15.	Determined by EMA (in consultation with the engineering and power systems experts)
17	Proportion of debt to assets	The proportion of debt to total assets. It is an estimate of the industry standard ratio for private sector generators in an economic environment similar to Singapore.	Determined by EMA (in consultation with the finance experts)
18	Risk free Rate (%)	The risk-free rate in Singapore shall be determined as the average of the daily closing yield on a default-free bond issued by the local government	Determined by EMA (in consultation with the finance experts)

No	Parameters	Description	Method of Determination
19	Cost of Debt (%)	Risk-free rate plus a premium as determined by the Authority	Determined by EMA (in consultation with the finance experts)
20	Market Risk Premium (%)	The market risk premium represents the additional return over investing in risk-free securities that an investor will demand for investing in electricity generators in Singapore, as determined by the Authority.	Determined by EMA (in consultation with the finance experts)
21	Beta	Parameter for scaling the market risk premium for calculating the cost of equity as determined by the Authority. Beta is a measure of the expected volatility of the returns on a project relative to the returns on the market, that is, the systematic risk of the project	Determined by EMA (in consultation with the finance experts)
22	Tax rate (%)	Corporate tax rate applicable to generating companies in Singapore at the Base Month.	Determined by EMA.
23	Cost of equity (%)	The return of equity is calculated as item 18 + (item 20)(item 21).	Calculated by EMA (in consultation with the finance experts)
24a	Carbon price (SGD/tonne CO_2-e)	Carbon price for the emissions of greenhouse gas	Determined by EMA in accordance with the Carbon Pricing Act
24b	Carbon emission factor (tonnes CO_2-e/GJ)	Carbon emissions factor for the fuels used by the plant	Determined by EMA in accordance with the International Panel on Climate Change ("IPCC") 2006

APPENDIX B

ECONOMIC LIFE

The economic life calculation methodology in this review is unchanged from the last review. The computation to determine the improvement in heat rate and reduction in capex of “F/H” class CCGTs from the base year of 1994 remains unchanged and it is updated to 2020 parameters for “F/H” class CCGTs,

- From 1994 to 2020,
  - improvement in net heat rate = -0.0060 GJ/MWh/year
  - real rate of specific capex reduction = 0.865%/year

The resulting number of years using this approach is 78.80 years which is longer than the technical life of the plant. Thus, the economic life of the new entrant plant is the lesser of this value and the technical life of the plant, which would be approximately 30 years (based on WSP industry experience). This calculated economic life is sensitive to the gas price which has varied over previous reviews. For consistency with the previous reviews a life of 25 years is recommended in the analysis.

APPENDIX C

THERMODYNAMIC ANALYSIS

The thermodynamic analysis of the CCGT plant was performed using GTPro / GTMaster / PEACE (Version 29.0 with updates until 1 May 2020). The output graphics from the simulations are provided:

- Figure C.1: Ansaldo Energia / GT 26
- Figure C.2: General Electric / 9F.05
- Figure C.3: MHPS / 701 F4
- Figure C.4: Siemens / SGT5-4000F

Figure C-1: Heat and Mass Balance Diagram for Ansaldo Energia GT26

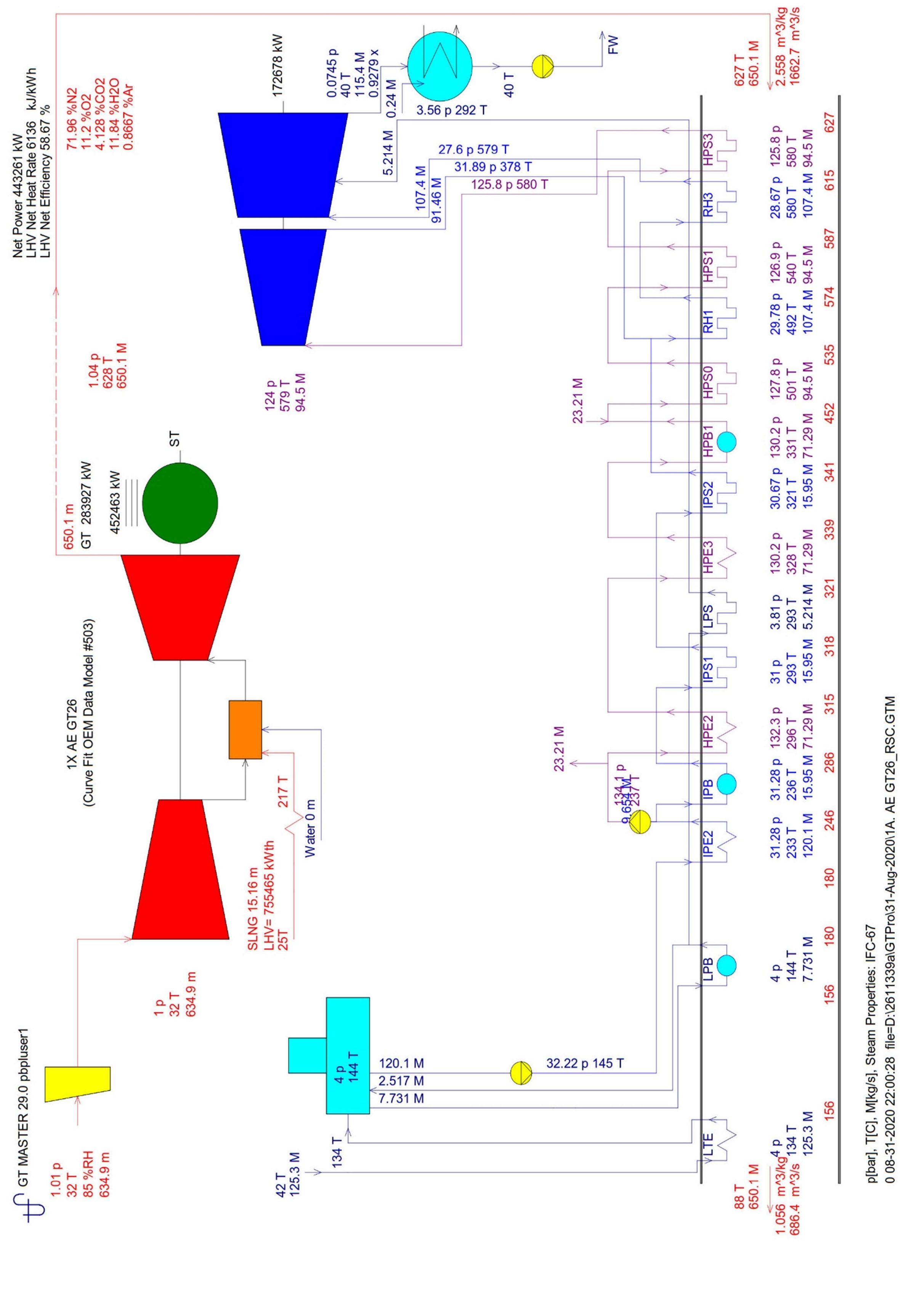


Figure C-2: Heat and Mass Balance Diagram for General Electric 9F.05

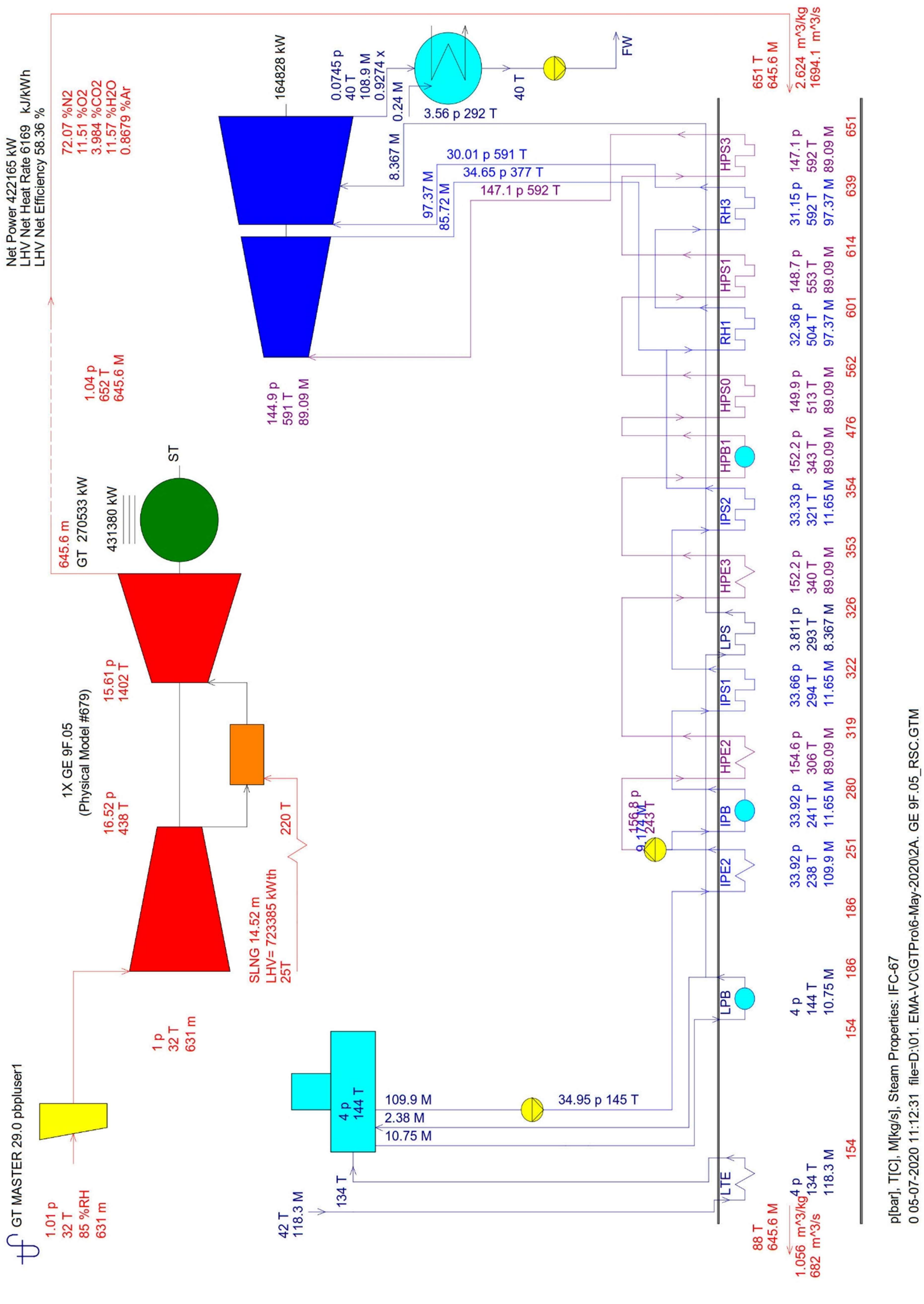


Figure C-3: Heat and Mass Balance Diagram for Mitsubhisi Hitachi Power System 701 F4

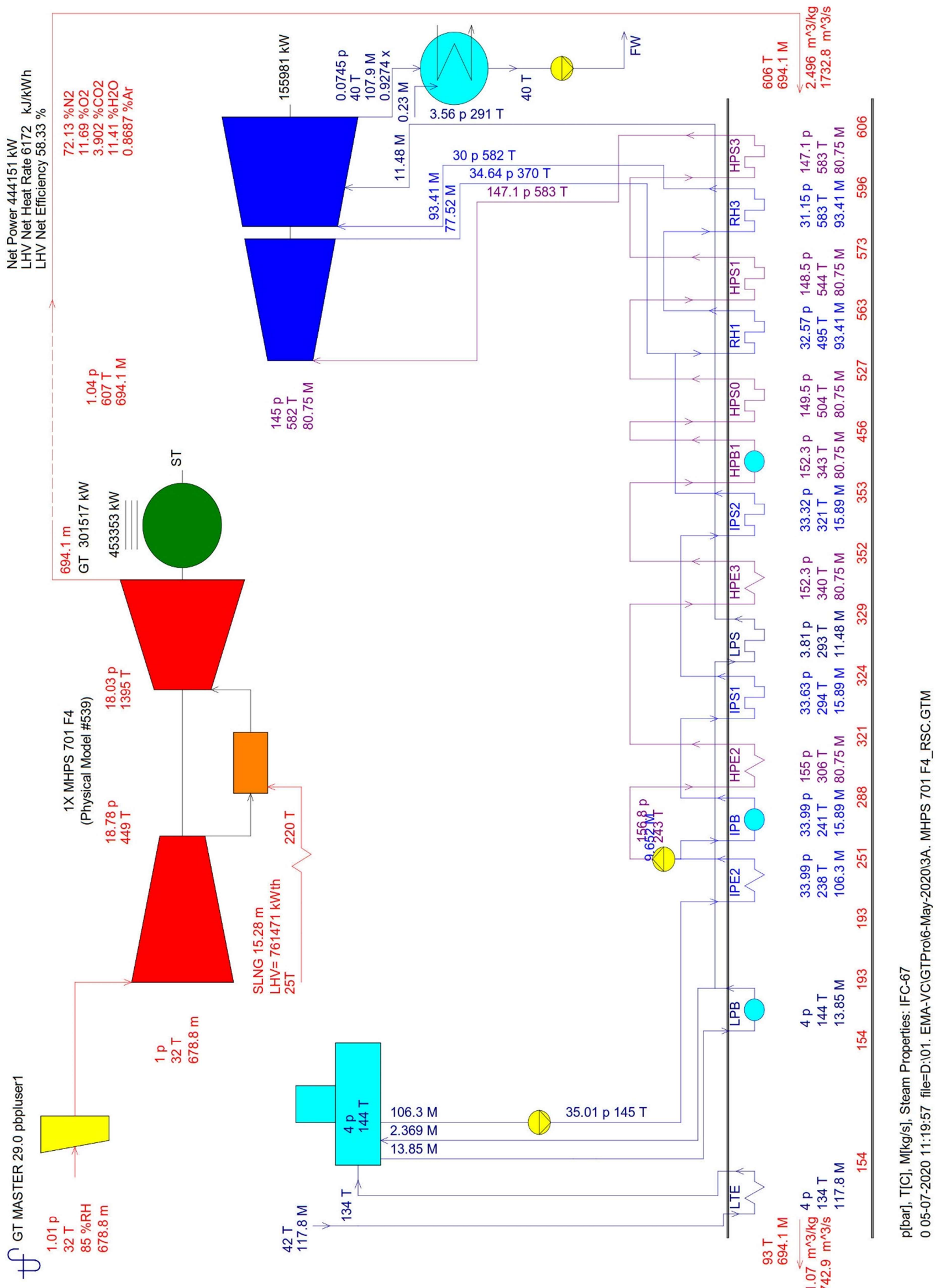
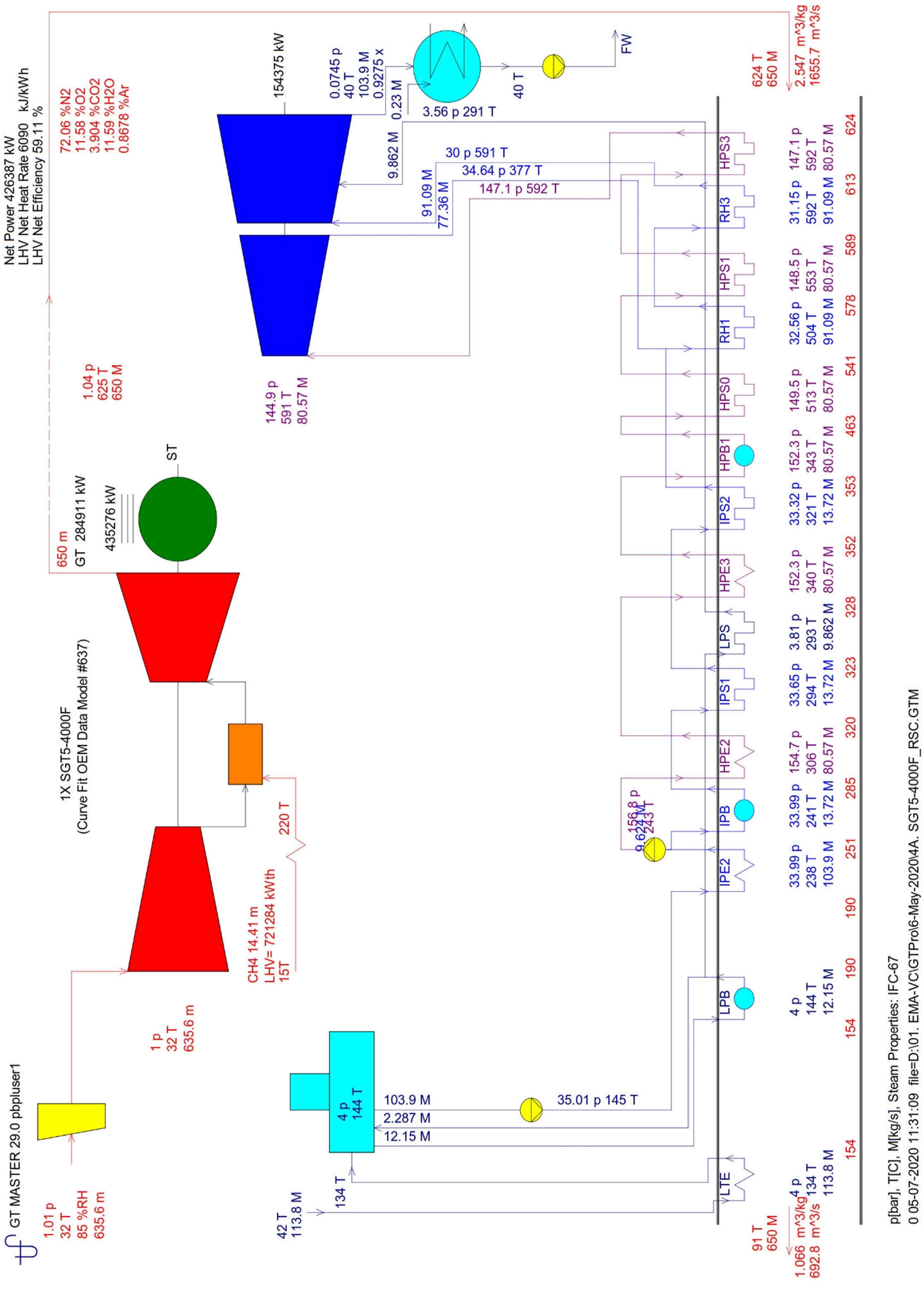


Figure C-4: Heat and Mass Balance Diagram for Siemens SGT5-4000F



APPENDIX D

POTENTIAL INDEX FOR CAPITAL COST ITEM 7 AND 8 FOR 2022 REVIEW

As mentioned in section 3.8 (a) of this report, the capital cost parameters of item 7 and 8 is applicable for one (1) year period from 1st January 2021 to 31st December 2021. Hence, EMA propose to apply an index factor or factors to derive the capital cost parameters of 7 and 8 will be applicable for year 2022. The capital costs parameters for 7 and 8 for 2022 will be calculated utilizing publically available information (e.g., Tender Price Index, MAS core inflation index and etc.,).

We noted that the capital cost parameters for item 7, the main plant capex, have been uncertain due to volatility in the global market for CCGT plant construction. At the present time the market for large CCGT plants is suppressed due to oversupply of manufacturing capability relative to world demand for such plants. There is no present indication that this situation should change in the period prior to 2022 review which would reassess the costs, in 2022.

We are suggesting that no indexation is applied to the main power plant equipment ("Specialized equipment" and "Other equipment" within the PEACE package, which comprises 45.96% of Item 7. The balance of Item 7 is comprised of typical Singaporean construction activities. These could be escalated using the Tender Price Index.

The elements of Item 7 and the suggested indexation method is shown in *Table D.1*.

Table D.1 Recommended indexation for Item 7 for 2022 review

Item	2021-22 [kSGD]	Weighting	Suggested index
Specialized Equipment	231,088	42.69%	None
Other Equipment	17,666	3.26%	None
Civil	34,879	6.44%	TPI
Mechanical	41,473	7.66%	TPI
Electrical Assembly & Wiring	8,784	1.62%	TPI
Buildings & Structures (shared except turbine hall)	14,009	2.59%	TPI
Engineering & Plant Start-up	29,694	5.48%	TPI
Contractor's Soft & Miscellaneous Costs	96,084	17.75%	TPI
Gas compression system	11,453	2.12%	TPI
Cooling water system	6,799	1.26%	TPI
Fuel unloading jetty and facilities	8,118	1.50%	TPI
Fuel tanks	26,792	4.95%	TPI
Additional security measures and cyber security measures	2,897	0.54%	TPI
Air filters	147	0.03%	TPI
Adjustment for civil/foundations	5,813	1.07%	TPI
Discounted through life capital costs	5,593	1.03%	TPI
Total initial plant cost excl. connection costs	**541,288**[22]	**100.00%**	

For Item 8 is comprised of Land, Connections and owner's costs before and after financial close. Land costs should be escalated using the JTC Property Price Index. The Owner's costs are based on percentages of the other capital costs however the nature of these costs varies (labour, contingencies, spares etc) and should be

[22] The calculation would not tally due to rounding

escalated with a general escalator such as MAS Core Inflation. Most of the connection costs are based on the electricity connections which are a fixed value of $/MW and have not escalated in several reviews. The balance of the connection costs has a general construction nature and could be escalated at the Tender Price Index.

The elements of Item 8 and the suggested indexation method is shown in Table D.2.

Table D.2 Recommended indexation for Item 8 for 2022 review

Item	2021-22 [kSGD]	Weighting	Suggested index
Land	15,190	9.50%	JTC
Electrical connection charges (fixed)	22,604	14.13%	None
Electrical connection charges (other)	15,924	9.96%	TPI
Gas connection charges	7,331	4.58%	TPI
Owner costs	98,864	61.82%	MAS Core
Total	**159,913**	**100.00%**	

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