Your ref: PUC/LIC/2023/TL/05 My Ref: GP/CE/EXPAN-2023 Date: November 17, 2023

PUBLIC UTILITIES COMMISSION OF SRI LANKA
5449
21 NOV 2023

The Director General
Public Utilities Commission of Sri Lanka
6th Floor, BOC Merchant Tower
No.28, St, Michael's Road,
Colombo 3.

Input Data for Long Term Generation Expansion Plan (LTGEP) 2025-2044

We write in reference to your letter No. PUC/LIC/2023/TL/05 dated 2023-02-10, granting approval for the LTGEP 2023-2042 and requesting to submit input data to be used in next planning cycle to the Commission for verification. Accordingly, please find the requested input data in the above referred letter as Annex 1.

We earnestly request to verify the input data and inform us by 17th December 2023, to proceed with the planning studies in line with the time targets. Please note that any delay in response would hinder the possibility of submitting the LTGEP on the due date of 30th April, 2024.

DDG (IS)
for necessary action and the comments by Dec 15th
21/11/23

Eng. (Dr.) Narendra De Silva
Actg. General Manager
Eng. (Dr.) Narendra De Silva
Actg. General Manager
Ceylon Electricity Board
Authorized officer for Licenses EL/T/09-002

ANNEX 1

Input Data for Long Term Generation Expansion Plan 2025-2044

1) Candidate Thermal Technologies

The cost related details of candidate thermal technologies are tabulated in Table 1. The prices shall be escalated based on economic indicators for local and foreign escalation factors once they available for year 2024.

Table 1: Cost details of candidate thermal technologies

Plant	Pure Unit Cost (USD/kW)	Construct. Period (Years)	Unit cost with IDC @10% (USD/kW)	Fixed O&M cost (USD/kW Month)	Variable O&M cost (USD/ MWh)
15 MW NG IC Engine	1,094	2	1,166	3.01	5.83
15 MW FO IC Engine	1,235	2	1,315	3.01	5.83
50 MW NG IC Engine	864	2	920	3.01	5.83
50 MW FO IC Engine	1,039	2	1,107	3.01	5.83
50 MW Dual IC Engine	1,062	2	1,131	3.01	5.83
100 MW NG IC Engine	806	2	859	3.01	5.83
100 MW FO IC Engine	982	2	1,046	3.01	5.83
100 MW Dual IC Engine	1,005	2	1,070	3.01	5.83
200 MW NG IC Engine	749	2	797	3.01	5.83
200 MW FO IC Engine	924	2	984	3.01	5.83
200 MW Dual IC Engine	947	2	1,009	3.01	5.83
50 MW NG Gas Turbine	649	2	691	0.59	4.62
50 MW NG Gas Turbine (Aero)	776	2	826	1.37	4.82
100 MW NG Gas Turbine	481	2	512	0.59	4.62
100 MW NG Gas Turbine (Aero)	583	2	621	1.37	4.82
200 MW NG Gas Turbine	394	2	420	0.59	4.62
300 MW NG Gas Turbine	329	2	351	0.59	4.62
200 MW NG Combined Cycle	1,380	3	1,567	1.05	2.61
300 MW NG Combined Cycle	1,282	3	1,456	1.05	2.61
400 MW NG Combined Cycle	1,213	3	1,377	1.05	2.61
500 MW NG Combined Cycle	1,166	3	1,323	1.05	2.61
300 MW High Efficient Coal Plant	1,911	4	2,265	3.47	4.62
600 MW Super Critical Coal Plant	2,055	4	2,436	3.47	4.62
600 MW Nuclear Power Plant	4,919	5	5,958	10.34	2.43

Sources: (Gas Turbine World Handbook 2023, OEM data, Feasibility Studies)

The operational characteristics of candidate thermal technologies are tabulated in Table 2.

Table 2: Characteristics of candidate thermal technologies

Plant	Max Load (MW)	Min Load (MW)	Heat Rate (kcal/kWh)		Full Load Efficiency (Net, HHV) %	FOR %
			Full	min		
15 MW NG IC Engine	18	2	2,051	2,890	42.0	10.0
15 MW FO IC Engine	20	2	2,086	2,681	41.3	10.0
50 MW NG IC Engine	54	1	1,987	2,647	43.3	10.0
50 MW FO IC Engine	59	1	2,086	2,681	41.3	10.0
50 MW DUAL IC Engine	47	2	2,067	2,746	41.7	10.0
100 MW NG IC Engine	108	1	1,987	2,647	43.3	10.0
100 MW FO IC Engine	108	1	2,086	2,681	41.3	10.0
100 MW DUAL IC Engine	106	2	2,067	2,746	41.7	10.0
200 MW NG IC Engine	205	1	1,987	2,647	43.3	10.0
200 MW FO IC Engine	206	1	2,086	2,681	41.3	10.0
200 MW DUAL IC Engine	200	2	2,067	2,746	41.7	10.0
50 MW NG Gas Turbine	41	16	2,921	3,798	29.5	8.0
50 MW NG Gas Turbine (Aero)	49	25	2,377	3,091	36.2	8.0
100 MW NG Gas Turbine	106	53	2,469	3,312	34.9	8.0
100 MW NG Gas Turbine (Aero)	128	64	2,337	3,134	36.9	8.0
200 MW NG Gas Turbine	192	77	2,489	3,595	34.6	8.0
300 MW NG Gas Turbine	287	66	2,307	3,332	37.3	8.0
200 MW NG Combined Cycle	206	95	1,755	2,457	49.1	8.0
300 MW NG Combined Cycle	289	115	1,751	2,451	49.2	8.0
400 MW NG Combined Cycle	440	176	1,581	2,215	54.5	8.0
500 MW NG Combined Cycle	535	213	1,557	2,180	55.3	8.0
300 MW High Efficient Coal Plant	270	135	2,241	2,547	38.4	3.0
600 MW Super Critical Coal Plant	564	338	2,082	2,246	41.4	3.0
600 MW Nuclear Power Plant	552	497	2,685	2,723	32.1	0.5

Power Plant Capacities are based on Net Capacity and Heat rates are based on HHV
Sources: (Gas Turbine World Handbook 2023, OEM data, Feasibility Studies)

Furthermore, additional plant technologies are being investigated to be considered in line with target of achieving carbon neutrality goal by year 2050. However, these power plant technologies have not yet reached technological maturity for commercial level deployment. Hence, at present sufficient cost and operational details of these technologies, are not available to model them accurately.

Following candidate technologies are being pursued to be introduced in LTGEP 2025-2044 once sufficient data is available.

1. Nuclear SMR
2. Natural gas operated open cycle and combined cycle with CCS
3. Hydrogen operated open cycle and combined cycle
4. Hydrogen operated IC engines
5. Fuel Cell

2) Fuel Prices

The fuel prices are derived based on combination of historical fuel prices and fuel price projections. In previous planning studies world bank fuel price forecast has been used to derive future fuel price projections which had projections ranging from 3-10 years. However, latest publication (World Bank Commodity Price Forecasts, October 2023) has further restricted the forecast for only 2 years. Hence such 2-year forecast is not sufficient to be used alone for planning study ranging for 20 years. The basis of deriving fuel prices and the weights used for each scenario is tabulated in Table 3 and Table 4 respectively.

Table 3: Basis for deriving Prices

Fuel	Basis for deriving Prices
Coal	API 4 index
Natural Gas	13% Brent Crude Oil Index
Oil	CPC Prices and Brent Crude Oil Index

Table 4: Weights Considered for fuel price scenarios

	Actual Data				Forecast Data	
	2020	2021	2022	2023	2024	2025
4 year + Forecast	1	2	3	4	3	2
3 year + Forecast	-	2	2	3	2	1
2 year + Forecast	-	-	1	2	2	1
Forecast Only	-	-	-	-	2	1

The Handling fee for coal is based on handling fee for 2022/2023 season and handling fee for oil-based products are based on CPC prices. The capital cost associated for LNG Infrastructure shall be excluded and only operational cost shall be considered for Handling fee for LNG fuel. (Since the Natural gas quantity requirement varies for different policy scenarios, apportioning a single value for the fuel price is inappropriate). The capital cost for LNG infrastructure shall be considered as an investment cost.

The derived fuel prices under the above projections are tabulated in Table 5. Oil based fuel prices are derived from Brent Crude Oil index and historical price ratios of these products.

Table 5: Derived fuel prices for each scenario

	Coal	Natural Gas	Diesel	Furnace Oil	Naptha
	US$/Mton	US$/MMBtu	US$/bbl	US$/bbl	US$/bbl
4 year + Forecast	168.8	10.8	115.3	117.2	86.2
3 year + Forecast	173.4	11.0	117.3	118.9	88.1
2 year + Forecast	164.8	11.1	120.7	121.1	89.6
Forecast Only	133.0	11.2	112.2	116.7	86.1

It is expected to utilize 4-year historical fuel prices with future projections for preparing LTGEP 2025-2044 studies.

Historical fuel prices for year have been captured only up to October 2023, and adjustments shall be made once data is available for last two months of 2023.

Furthermore, additional fuel types are being investigated to be considered in line with target of achieving carbon neutrality goal by year 2050. However, in the absence of proper historical and future price projections nominal fuel prices shall be considered for fuels as mentioned in Table 6.

Table 6: Other fuels prices

Fuel	US$/kg	Basis and Source
Nuclear	1832	Historical prices
Hydrogen (imported)	5	IEA, Global Hydrogen Review 2023

The effect of utilizing hydrogen from curtailments of local renewable energy sources shall be studied at production cost modelling stage.

3) Candidate ORE Technologies

The cost related details of candidate ORE technologies are tabulated in Table 7. The prices shall be escalated based on economic indicators for local and foreign escalation factors once they available for year 2024.

Table 7: Details of candidate ORE technologies

ORE Technology	Pure Capital Cost (USD/kW)	Capital Cost with IDC (USD/kW)	Fixed O&M Cost (% of the capital cost)	Construction years
Solar (Large Scale)	777	828	1.5%	1.5
Solar (Distributed)	899	938	0.9%	1
Floating solar	1139	1213	1.5%	1.5
Onshore Wind	1274	1386	3.2%	2
Offshore Wind (Fixed Bottom)	3461	4285	2.9%	5
Offshore Wind (Floating)	4796	5936	2.9%	5
Biomass	1632	1738	4.0%	1.5
Mini hydro	1684	1794	2.5%	1.5

Sources: (IRENA Renewable Power Generation Costs 2022, CSIRO GenCost 2022-23, Latest Tender and Market Prices)

4) The Capacity Contribution from Renewable Sources

The determination of planning reserves as a single figure was to ensure sufficient capacity availability to meet the peak demand and is valid for traditional hydro thermal oriented power systems. However, as Sri Lanka is progressing more towards integrating a higher share from weather dependent VRE sources, calculation of reserve margin restricted to a single period is not sufficient.

Hence resource adequacy checks shall be deployed to ensure sufficient availability of firm capacity for critical periods. The periods of interest are day peak and night peak of dry, high wind and wet seasons. The capacity contribution from renewable energy sources and storage sources are based on their firm capacity availability during critical periods.

Summary of firm capacity contributions to be used for renewable energy and storage sources for LTGEP 2025-2044 are shown in Table 8.

Table 8: Summary of firm capacity contributions from ORE and Storage

Technology	Dry		High Wind		Wet	
	Day Peak	Night Peak	Day Peak	Night Peak	Day Peak	Night Peak
Solar	0.54	0.00	0.50	0.00	0.37	0.00
Wind	0.01	0.06	0.16	0.35	0.01	0.08
Mini Hydro	0.08	0.08	0.26	0.26	0.38	0.38
Biomass	0.10	0.10	0.10	0.10	0.10	0.10
Battery Energy Storage*	0.8	0.8	1.00	1.00	0.8	0.6
Pumped Hydro Storage*	0.8	0.8	1.00	1.00	0.8	0.6

It is to be noted that the firm capacity is derived based on historical renewable energy profiles for a single location with at least 85 % percentile assured available capacity for the critical period of interest. The effect of geographical scattering shall be captured with production cost modelling with stochastic generation of renewable energy profiles.

Furthermore, all storage devices are expected to have capability to store energy from the grid, rather than from a single generating source. This contributes to obtaining higher firm capacity. The actual firm capacity shall vary year by year based on the characteristic of generation sources available each year and is to be captured through production cost modelling study. The above figures are only used as a preliminary resource adequacy check for deriving reserve margin.

5) Externalities

Estimating externality costs of specific power generating technologies and fuel options is a challenging task due to the difficulty in isolating the contribution of power industry from the impacts from all other industries. Furthermore, electricity accounts only about 14% share of the total energy usage in the country. Literature suggest that monetizing the externalities is highly subjective and could vary within a wide range depending on the income level of the country, population density around the power plants etc. Therefore, a country specific study needs to be conducted to evaluate the externality cost applicable to Sri Lanka. Furthermore, externality cost should be estimated for both thermal and renewable power generation on a same basis to be comparable.

In the event, a country specific study is not available, the report "Environmental Externalities from Electric Power Generation, The Case of RCREEE Member States, September 2013" is proposed to be used as a source for externality cost for conducting sensitivity analysis in LTGEP 2025-2044. The report has summarized the range of externalities estimation from previous studies for most of the fuel options and renewables.

6) Base Demand Forecast 2025-2049

Demand forecast 2025-2049 was derived as a combination of medium term and long-term econometric forecast. As for the medium-term forecast, time series model in monthly time step has been used to evaluate the variations in demand due to end user tariff increase, weather conditions, trends in installation of off-grid solutions, battery storage by customers and any other seasonal factors. When analyzing the effect of end user tariff revisions, it is observed that there are short term trends such as domestic customers moving to lower tariff blocks and moderate reduction in consumption over the months when the seasonality is removed. Such variations are captured through the medium-term forecast.

Econometric modelling approach was used for the long-term forecast which captures the historic demand growth rates. Discussions were held with officials of Central Bank of Sri Lanka (CBSL) and Department of Census and Statistics to obtain information on the economic contraction of the country. Furthermore, information on major development projects and electrification projects were also obtained from relevant Ministries.

During the discussions with CBSL, it was stated that CBSL Annual Report considers the expected level of growth in the country assuming an optimistic scenario. Hence, for the base demand forecast much lower GDP growth rate was considered with the consensus of the officials of CBSL considering the economic contraction of the country. It is expected that prediction accuracy would improve due to considering a more realistic GDP growth rate. Table 9 compares CBSL GDP growth projections with the GDP projections by World Bank.

Table 9: GDP Growth Projection (%)

Year	Sri Lanka Development Update The World Bank April 2023	CBSL Annual Report April 2023
2023	-4.3	-2.0
2024	1.2	3.3
2025	2.0	4.0
2026	3.0	4.5
2027	-	5.0

Table10 presents the base demand forecast derived based on the GDP growth rates proposed by World Bank report "Sri Lanka Development Update" in April 2023.

Table 10: Base Demand Forecast 2025-2049

Year	Demand[1]	Net Loss[2]	Net Generation	Day Peak Demand	Night Peak Demand
	GWh	%	GWh	MW	MW
2025	16,319	7.93	17,725	2,727	2,696
2026	17,203	7.76	18,650	2,872	2,824
2027	18,135	7.62	19,630	3,027	2,959
2028	19,118	7.48	20,662	3,190	3,101
2029	20,153	7.34	21,750	3,362	3,250
2030	21,245	7.34	22,927	3,548	3,411
2031	22,264	7.33	24,026	3,722	3,560
2032	23,329	7.33	25,174	3,904	3,714
2033	24,438	7.32	26,369	4,094	3,874
2034	25,602	7.32	27,624	4,294	4,041
2035	26,842	7.31	28,961	4,507	4,219
2036	28,188	7.31	30,411	4,738	4,412
2037	29,619	7.31	31,953	4,985	4,616
2038	31,141	7.30	33,594	5,247	4,833
2039	32,702	7.30	35,275	5,516	5,055
2040	34,338	7.29	37,038	5,798	5,286
2041	36,058	7.29	38,892	6,095	5,528
2042	37,798	7.28	40,767	6,397	5,772
2043	39,582	7.28	42,689	6,706	6,020
2044	41,424	7.27	44,673	7,026	6,275
2045	43,235	7.27	46,624	7,342	6,524
2046	45,062	7.26	48,592	7,660	6,773
2047	46,922	7.26	50,594	7,985	7,025
2048	48,732	7.25	52,544	8,303	7,267
2049	50,592	7.25	54,546	8,630	7,516
5 Year Avg Growth	5.4%		5.2%	5.4%	4.8%
10 Year Avg Growth	5.1%		5.1%	5.2%	4.6%
20 Year Avg Growth	5.1%		5.0%	5.2%	4.6%
25 Year Avg Growth	5.0%		5.0%	5.1%	4.5%

[1] In the process of developing the demand forecast, all embedded generation that is not metered real time at NSCC is evaluated to reflect the actual demand and generation.

[2] Net losses include losses at the Transmission & Distribution levels and excludes Generation (including auxiliary consumption) losses. Loss forecast will vary depending on the renewable thermal generation mix of the future.