DETAILED DESCRIPTION OF PROJECT COMPONENTS

1. Project 1 of the Green Power Development and Energy Efficiency Improvement Investment Program (the multi-tranche financing facility [MFF]) will include the following physical components:

(i) Construction of 30 megawatt (MW), run-of-river hydropower plant at Moragolla in the Central Province;

(ii) Transmission infrastructure capacity enhancement including construction of four new grid substations and associated facilities at Kerewalapitiya (220/33 kilovolt [kV]), Kappalturai (220/132/33 kV), Kalutara and Kesbewa (both 132/33 kV) and augmentation of Katunayake and old Anuradhapura 132/33 kV grid substation in Western, Eastern and North Central provinces;

(iii) Medium voltage (MV) network efficiency improvement through construction of 33 kV lines and gantries around Vavunativu and Madampe in Eastern and North Western provinces; and

(iv) Demand-side management (DSM) pilot projects in Colombo.

2. These components, their rationale and benefits are described below in detail.

A. Moragolla Hydropower Plant

3. The Moragolla hydropower plant is one of the several hydropower projects identified for development in the 10-year development plan of the government of Sri Lanka.[1] The plant with a reservoir for daily peak operation will be located on the Mahaweli river close to Ulapane village in Kandy district of the Central Province about 130 kilometers (km) to the north east of Colombo. The dam is of a concrete gravity type with a height of 35 meters (m) and a length of about 236 m at the crest level. The powerhouse is located on the opposite bank of Kotmale power station across the Mahaweli river. The size of the powerhouse is 46 m in length, 26 m wide and 39 m height. The optimum scale is determined so that the benefit accrued from power generation above the cost incurred for construction can be maximal. The benefit is the avoided cost of a thermal plant. Dependable power (90% probability) and annual energy output for the best case scenario is provided Table 1.

Table 1: Moragolla Hydropower Plant Parameters

Particulars	Unit	Parameters
Maximum plant discharge	m^3/s	25
Installed capacity	MW	30
Dependable power	MW	15
Plant discharge for dependable power	m^3/s	23.5
Nos. of unit in operation for dependable power generation	Nos.	1
Average peak power	MW	24
Annual energy	GWh	97.7

GWh = gigawatt-hour, MW = megawatt, m^3/s = cubic meter per second.
Source: Ceylon Electricity Board and Asian Development Bank estimates.

[1] Government of Sri Lanka. 2010. *Mahinda Chintana: Vision for the Future.* Colombo.

4. The estimated costs as per the draft detailed design report (February 2014) are summarized in Table 2. The base cost of the civil works, electro-mechanical facilities and project management will be funded through the MFF.

Table 2: Moragolla Hydropower Plant's Base Cost Estimates

Description	Base Cost ($ million)		
	Foreign Cost	**Local Cost**	**Total Cost**
Main civil works	21.53	37.48	**59.01**
Electro-mechanical facilities	39.58	4.89	**44.47**
Project management, design and supervision	7.24	3.14	**10.38**
Total	**68.35**	**45.51**	**113.86**

B. Transmission Infrastructure Capacity Enhancement

1. Kerewalapitiya 220 kV Grid Substation

5. Kerewalapitiya grid substation (GSS) will include 2x45 megavolt-ampere (MVA), 220/33 kV transformers, 2x33 kV gas insulated switchgear (GIS) transformer bays, 12x33 kV GIS feeder bays and 33 kV GIS single bus bar arrangement including bus section. The objective of this subproject is to improve the reliability of the transmission system and cater the growing demand.

6. Kerewalapitiya power plant (capacity 300 MW), which is about 10 km north of Colombo city, presently serves Kotugoda GSS through a 220 kV line. Kerewalapitiya does not have a grid substation. The entire output of the power plant is fed to Kotugoda GSS. As per the current load forecast, Kotugoda GSS will be 105.4% loaded under outage of 60 MVA transformer by year 2018. Since Kotugoda grid substation is located in a highly industrialized area of the country it should be able to cater the demand under outage of one unit. The energy demand at present in Wattala, Handala and Kerewalapitiya areas is 81 gigawatt-hour (GWh) and the estimated load growth is 7%. These areas are mainly fed by Kotugoda GSS. Considering the load demand and 33 kV distribution systems in these areas, the forecast loading of Kotugoda GSS without introducing Kerewalapitiya GSS is given in Table 3 and with Kerewalapitiya GSS is given in Table 4. The proposed grid substation will also improve the voltage profile of 33 kV distribution systems and therefore improves the quality of supply in and around Wattala, Handala and Kerewalapitiya areas. This new GSS is proposed to connect to the existing 220 kV bus bar of the Kerewalapitiya combined cycle power plant.

Table 3: Loading without the proposed grid substation at Kerewalapitiya

Grid Substation	Forecast Loading (MVA)										
	Present	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Kotugoda	183	89.7	108.4	116.5	122.2	117.9	129.6	138.2	141.3	148.5	155.8

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

Table 4: Loading with the proposed grid substation at Kerewalapitiya

Grid Substation	Capacity (MVA)		Forecast Loading / (MVA)									
	Current	New	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Kotugoda	183		89.7	108.4	116.5	122.2	106.2	117.2	125.6	129	116.2	123.4
Kerawalapi-tiya		2x45					11.8	12.4	12.6	12.3	32.3	32.4

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

2. Kappalturai 132/33 kV Grid Substation

7. Construction of a new Kappalturai GSS will include installation of 2x60 MVA, 132/33 kV transformers, construction of 4x132 kV single bus bar transmission line bays, 2x132 kV single bus bar transformer bays, 1x132 kV single bus bar arrangement with bus section, 2x33 kV GIS transformer bays, 16x33 kV GIS feeder bays, 1x33 kV GIS single bus bar including bus section. The scope also includes construction of double in and out connection to Kappalturai GSS from New Anuradhapura-Trincomalee 132 kV Zebra, double circuit, 1 km transmission line. Transformers of Kappalturai GSS will be initially operated at 132/33 kV and later upgraded to 220/33 kV operation. The objective of this subproject is to cater for the growing demand of electricity in Trincomalee area by providing quality and reliable power supply and relieve the loading on the existing Trincomalee GSS.

8. The energy demand at present in Trincomalee area is about 190 GWh. Trincomalee town, Nilaweli, Tokyo Cement Company and Prima Company are the places mainly fed by Trincomalee GSS. At present the government is undertaking a large scale integrated development programs for the Trincomalee district. The following are the major projects in the pipeline under the above development program:

- (i) Special economic zone of Kappalturai;
- (ii) Kappalturai industrial estate for small and medium industries;
- (iii) Fisheries sector development projects;
- (iv) Water board projects;
- (v) New town development and existing town improvement projects;
- (vi) Middle income housing complexes;
- (vii) New tourist resorts and areas; and
- (viii) New industrial housing areas.

9. In order for the above development programs to materialize, adequate and reliable power supply is a must. Based on the growing load demand and 33 kV distribution systems in the vicinity, the forecasted loading of Trincomalee GSS for the period of 2013 – 2022 is in Table 5.

Table 5: Load forecast without the proposed new substation at Kappalturai

Grid Substation	Forecast Loading (MVA)										
	Present	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Trincomalee	**63**	59	61	63	65	109	114	118	117	121	124

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

10. At present the capacity of the Trincomalee GSS is 59 MVA. According to the above forecast Trincomalee GSS should be augmented to 94.5 MVA by 2015 and to 126 MVA by 2022. However, it is difficult to augment the existing grid substation due to the limitation of space and several other practical difficulties. In order to meet the growing electricity demand in Nilaweli, Kappalturai areas and the proposed Kappalthurai special economic zone, it is proposed to construct a new GSS at Kappalthurai with 2x60 MVA transformers and sixteen 33 kV feeders in the year 2017. Load forecast with the proposed new substation at Kappalthurai is in Table 6.

Table 6: Load forecast with the proposed new substation at Kappalturai

Grid Substation	Forecast Loading (MVA)										
	Present	**New**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Trincomalee	**63**		59	61	63	65[a]	24	27	28	27	28	30
Kappalthurai		120					85	88	90	90	92	94

Note [a]: Limited to transformer capacity of 63 MVA
MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

11. Proposed grid substation will also improve the voltage profile of the 33 kV distribution systems and therefore improves the quality of supply in and around the Nilaweli and Kappalturai areas. This new grid substation is proposed to connect to the existing New Anuradhapura-Trincomalee 132 kV transmission lines using double in and out connection.

3. Augmentation of Old Anuradhapura 132 kV GSS

12. Augmentation of 132/33 kV Old Anuradhapura GSS will include 3x31.5 MVA 132/33 kV transformers, 3x132 kV single bus transformer bays, 2x132 kV single bus transmission line bays, 132 kV single bus arrangement including bus section, 3x33 kV transformer bays, 12x33 kV feeder bays, 33 kV single bus arrangement including 2x33 kV bus sections. The scope will also include augmentation of 220/132/33 kV New Anuradhapura GSS with two 132 kV double bus transmission line bays and construction of 132 kV Zebra 1 km double circuit transmission line to connect Puttalam-New Anuradhapura transmission line. The objective is to improve the quality and reliability of the electricity supply in Nochchiyagama, Periyankulama, Horowpathana, Medawachchiya and Mihintale areas while catering the growing demand in these areas and ensure the reliability of the power system by replacing old equipment.

13. Old Anuradhapura GSS is situated in the North Central Province of the country. The annual energy demand of the grid substation is 138 GWh and estimated load growth at present is about 5%. Anuradhapura GSS consists of 2x10 MVA transformers commissioned in 1969 and 1975 and a 31.5 MVA transformer commissioned in 1996. Further, the Anuradhapura GSS is fed from New Anuradhapura-Puttalam 132 kV double circuit transmission lines. The existing Anuradhapura GSS feeds Nochchiyagama, Periyankulama, Horowpathana, Medawachchiya and Mihintale areas and some parts of Vavuniya area. No rehabilitation or any augmentation work has been carried out at this grid substation since 1996. It is reported that this 132/33 kV grid substation has many operational problems. Almost all the equipment in the GSS is now 40 years old and spares are not available for most of the equipment. After a complete condition assessment, the Asset Management Branch and the Operation and Maintenance Branch of the

Transmission Division of Ceylon Electricity Board (CEB) have recommended the augmentation of the Anuradhapura GSS in order to provide electricity with a high reliability and better quality.

14. Further, in the planning exercise, it has been planned to transfer Puttalam 132 kV transmission line connection to New Anuradhapura switching station and to rearrange the feeding arrangement of Old Anuradhapaura GSS. Also with the implementation of New Habarana switching station, Habarana-Anuradhapura 132 kV transmission line will not be operated under normal condition. Hence, in the future, Old Anuradhapaura GSS will be fed from New Anuradhapura switching station from a 132 kV double circuit transmission line. Therefore, to transfer the Puttalam 132 kV transmission line it is required to construct two 132 kV transmission line bays at New Anuradhapura switching station and construct 1 km double circuit 132 kV transmission line from Anuradhapura to New Anuradhapura.

4. Construction of Kesbewa GSS

15. Kesbewa 132/33 kV GSS will include 2x31.5 MVA 132/33 kV transformers, 2x132 kV single bus transformer bays, 2x132 kV single bus transmission line bays, 132 kV single bus arrangement including bus section, 2x33 kV transformer bays, 8x33 kV feeder bays and 1x33 kV single bus arrangement including bus section. The scope of work will also include single in-and-out connection from Pannipitiya - Matugama 132 kV transmission line and reconstruction of Pannipitiya - Panadura 12.3 km 132 kV Zebra transmission line. The objective is to cater the growing demand for electricity in Kesbewa, Piliyandala, Kahathuduwa and Dampe areas by providing quality and reliable power supply, connect the proposed Kesbewa GSS to the national grid in order to supply quality and reliable power, remove bottlenecks in the transmission system and improve the system reliability by replacing old transmission lines.

16. At present the annual energy demand in Kesbewa, Piliyandala, Kahathuduwa and Dampe areas is 106 GWh and the estimated load growth is 5%. These areas are mainly fed by Panadura and Ratmalana GSS. According to the present distribution feeding arrangement around 59% of Kesbewa, Piliyandala, Kahathuduwa and Dampe area loads are fed from Panadura GSS and the remaining loads are fed from Ratmalana GSS. Considering the load demand and the 33 kV distribution systems in these areas, the forecasted loading of nearby substations without introducing Kesbewa GSS is in Table 7.

Table 7: Load forecast without the proposed new substation at Kesbewa

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)									
	Pre-sent	Pro-posed	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ratmalana	94.5		72.4	74.1	74.6	74.2	70.7	63.5	65.0	63.7	64.5	65.5
Panadura	63	94.5	52.7	56.5	76.4	57.2	54.2	68.5	71.4	70.9	72.9	75.2

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

17. Grid substations should be able to cater the demand under outage of one unit, without exceeding 120% loading on the existing units. As per the above load forecast, the loading of Ratmalana GSS presently exceeds 115% under outage of one transformer. Also the loading of Panadura GSS will exceed 89% under outage of one transformer in 2014, even after the commissioning of its third transformer. In order to meet the growing electricity demand in Kesbewa, Piliyandala, Kahathuduwa and Dampe areas and thereby to relieve loading of

Ratmalana and Panadura GSS, it is proposed to construct a new grid substation at Kesbewa with two 31.5 MVA transformers and eight 33 kV feeders in 2018. Load forecast with the proposed new substation at Kesbewa is in Table 8.

Table 8: Load forecast with the proposed new substation at Kesbewa

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)									
	Pre-sent	Propo-sed	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ratmalana	94.5		72.4	74.1	74.6	74.2	70.7	48.8	49.7	47.6	47.8	47.9
Panadura	63	94.5	52.7	56.5	76.4	57.2	54.2	58.3	60.7	59.7	61.3	63.0
Kesbewa		63						24.9	26.0	27.2	28.3	29.9

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

18. The proposed GSS will also improve the voltage profile of 33 kV distribution system, reduce distribution losses and the quality of supply in and around Kesbewa, Piliyandala, Kahathuduwa and Dampe areas. This new GSS is proposed to connect to the national power system by constructing a 1 km double circuit, Zebra, 132 kV transmission line as a single in-and-out connection to Pannipitiya - Matugama 132 kV transmission line. The existing two circuits of 132 kV transmission lines from Pannipitiya GSS to Matugama GSS are Goat conductors with the rating of 115 MVA. As per the present transmission network configuration, these transmission lines transmit power to the load centers in Western, South and Southern provinces through Panadura, Horana and Mathugama GSS. Further, a new grid substation at Kalutara will be connected to the same transmission line by 2017. Since this transmission line is passing through Kesbewa area and there is no path to construct new transmission lines from existing Pannipitiya switching station, the only option to connect Kesbewa grid substation to the national grid is connecting as a single in-and-out connection to the existing line. According to the system studies, under outage of one circuit of this transmission line the other circuit will be overloaded in 2017 when Kesbewa grid substation connected. Therefore, this line should be reconstructed with a high capacity conductor. Hence it is proposed to reconstruct Pannipitiya - Matugama (up to Panadura T point) 12.3 km, 132 kV transmission line with Zebra conductor.

5. Construction of Kalutara GSS

19. Kalutara GSS will include 2x31.5 MVA 132/33 kV transformers, 2x132 kV single bus bar transformer bay, 2x132 kV single bus bar transmission line bays, 1x132 kV single bus bar including bus section, 2x33 kV transformer bays, 8x33 kV feeder bays, 1x33 kV single bus bar including bus section. The scope of work also includes construction of 132 kV, single in-and-out connection from Pannipitiya-Matugama 132 kV, double circuit, 6 km, Zebra transmission line to connect Kalutara GSS. The objective is to reduce losses, improve reliability of the system and cater the growing demand.

20. By considering the present 33 kV distribution systems, Kalutara area is mainly fed by Panadura and Matugama GSS. Long 33 kV lines cause higher distribution losses. The forecasted loading of Panadura grid substation without introducing Kalutara GSS is given in Table 9.

Table 9: Load forecast without the proposed new substation at Kalutara

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)									
	Pre-sent	Propo-sed	2013	2014	2015	2016	2017	2018	201 9	2020	2021	2022
Panadura	63	31.5	53	56	76	78	77	82	86	87	90	94

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

21. Grid substations should be able to cater the demand under outage of one unit, without exceeding 120% loading on the existing units. In order to meet the growing electricity demand while minimizing distribution losses and relieve loading of Panadura GSS, it is proposed to construct a new grid substation at Kalutara with two 31.5 MVA transformers and eight 33 kV feeders. Load forecast with the proposed new substation at Kalutara is given in Table 10.

Table 10: Load forecast with the proposed new substation at Kalutara

Grid Substation	Capacity (MVA)		Forecast Loading (MVA)									
	Pre-sent	Propo-sed	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Panadura	63	31.5	53	56	76	57	54	58	61	60	61	63
Kalutara		63				21	22	24	26	27	29	31

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

22. The proposed grid substation will improve the voltage profile of 33 kV distribution systems, reduce distribution losses and the quality of supply in and around Kalutara areas. This new grid substation is proposed to connect to the existing Pannipitiya-Matugama 132 kV transmission line using single in-and-out connection.

6. Augmentation of Katunayaka GSS

23. Augmentation of Katunayake GSS will include installation of 31.5 MVA transformer, construction of 1x132 kV single bus bar transformer bay, 1x33 kV transformer bay, 4x33 kV feeder bays and 1x33 kV bus section bay. The objective is to enhance the capacity of the Katunayake GSS in order to meet the growing demand of the nearby industrial area and to improve the reliability and quality of power supply to consumers in Katunayake industrial area and future prospective consumers to this grid substation.

24. The energy demand at present in Negombo, Katunayake Industrial Zone, airport areas is about 20 GWh with 61% Load factor. The estimated load growth is 7%. These areas are mainly fed by Katunayake GSS. The future major projects being planned around Katunayake area are Airport and Aviation Expansion Project (15 MVA) and a hotel complex at Katunayake zone (5 MVA). Considering the future load demand and growth of the existing demand, the forecasted loading of Katunayake GSS is given in Table 11.

Table 11: Load forecast at Katunayaka GSS

Grid Substation	Forecast Loading (MVA)										
	Pre-sent	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Katunayake	**63**	45.3	50.5	53.8	55.9	62.9	67.3	71.2	72.4	75.2	78.1

MVA = megavolt-ampere.
Source: Ceylon Electricity Board estimate.

25. The CEB's System Control Center monthly review report for 2013 indicates 22.6 MVA loading of each transformer unit at Katunayake GSS. This is about 72% loading of the total transformer capacity. In the absence of the single unit out of two transformers, the other transformer will be loaded up to 144%, which will gives rise to technical failures and hence economic losses. Therefore, the addition of the third transformer with 31.5 MVA capacity is indispensable under these circumstances.

C. Medium voltage network efficiency improvement

1. 33 kV Distribution line from Madampe GSS to Bowatte and Gantry at Bowatte

26. This subproject will include construction of a 20 km, 33 kV Lynx double circuit tower line from Madampe GSS to a single bus bar (SBB) gantry at Bowatte and SBB gantry at Bowatte.

27. This subproject will connect the existing MV system in Bowatte area in the North Western Province to existing Madampe GSS. Load growth in the province is forecasted at an average 7% over the ten-year planning period. Electrification ratio (2012) for the province is 82% and energy losses in the MV system are 1.7%. Construction of this express line provides power injection at Bowatte to improve reliability and line end voltages, reduce the MV losses and increase line capacities, while improving the system operation flexibility. The proposed 33 kV switching gantry at Bowatte is to connect the above backbone line from Madampe GSS to the existing MV system in the area and improve the operational flexibility of the MV system. MV tail end line voltage before and after implementation of this proposal is 90.2% and 96.4%, respectively. The estimated annual energy savings are 2,035 megawatt-hours (MWh). About 29,120 consumers will benefit from this subproject.

2. 33 kV Distribution Line from Vavunativu GSS to Urani and Gantry at Urani

28. This subproject will include construction of a 6 km, 33 kV Lynx double circuit tower line from Vavunativu GSS to gantry at Urani and double bus bar (DBB) gantry at Urani.

29. This subproject will connect the existing MV system in Urani area in the Eastern Province to Vavunativu GSS that is scheduled for commissioning in 2014. Load growth in the province is forecasted at an average 9% over the ten-year planning period. Electrification ratio (2012) for the province is 79.8% and energy loss in the MV system is 4.21%. Construction of this express line provides a power injection at Urani to improve reliability and line end voltages, reduce the MV losses and increase line capacities, while improving the system operation flexibility. The proposed 33 kV switching gantry at Urani is to connect the above backbone line from Vavunativu GSS to the existing MV system in the area and improve the operational

flexibility of the MV system. MV tail end line voltage before and after implementation of this proposal is 90.5% and 97.6%, respectively. The estimated annual energy savings are 1,618 MWh. About 35,410 consumers will benefit from this subproject.

3. 33 kV Distribution Line from Vavunativu GSS to Kaluwanchikudy and DBB gantry at Kaluwanchikudy

30. This subproject will include construction of a 27 km, 33 kV Lynx double circuit tower line from Vavunativu GSS to gantry at Kaluwanchikudy and DBB gantry at Kaluwanchikudy.

31. This subproject will connect the existing MV system in Kaluwanchikudy area in the Eastern Province to Vavunativu GSS that is scheduled for commissioning in 2014. Load growth in the province is forecasted at an average 9% over the ten-year planning period. Electrification ratio (2012) for the province is 79.8% and energy loss in the MV system is 4.21%. Construction of this express line provides a power injection at Kaluwanchikudy to improve reliability and line end voltages, reduce the MV losses and increase line capacities, while improving the system operation flexibility. The proposed 33 kV switching gantry at Kaluwanchikudy is to connect the above backbone line from Vavunativu GSS to the existing MV system in the area and improve the operational flexibility of the MV system. MV tail end line voltage before and after implementation of this proposal is 87.9% and 96.1%, respectively. The estimated annual energy savings are 1,332 MWh. About 36,730 consumers will benefit from this subproject.

4. 33 kV Distribution Line from Vavunativu GSS to Karadiyanaru and Gantry at Karadiyanaru

32. This subproject will include construction of a 13 km, 33 kV Lynx double circuit tower line from Vavunativu GSS to gantry at Karadiyanaru and DBB gantry at Karadiyanaru.

33. This subproject will connect the existing MV system in Karadiyanaru area in the Eastern Province to Vavunativu GSS that is scheduled for commissioning in 2014. Load growth in the province is forecasted at an average 9% over the ten-year planning period. Electrification ratio (2012) for the province is 79.8% and energy loss in the MV system is 4.21%. Construction of this express line provides a power injection at Karadiyanaru to improve reliability and line end voltages, reduce the MV losses and increase line capacities, while improving the system operation flexibility. The proposed 33 kV switching gantry at Karadiyanaru is to connect the above backbone line from Vavunativu GSS to the existing MV system in the area, and improve the operational flexibility of the MV system. MV tail end line voltage before and after implementation of this proposal is 93.7% and 97.2%, respectively. The estimated annual energy savings are 286 MWh. About 22,000 consumers will benefit from this subproject.

5. 33 kV Distribution Line from Vavunativu GSS to Thalankuda and Gantry at Thalankuda

34. This subproject will include construction of a 21 km, 33 kV Lynx double circuit tower line from Vavunativu GSS to gantry at Thalankuda and DBB gantry at Thalankuda.

35. This subproject will connect the existing MV system in Thalankuda area in the Eastern Province to Vavunativu GSS that is scheduled for commissioning in 2014. Load growth in the province is forecasted at an average 9% over the ten-year planning period. Electrification ratio (2012) for the province is 79.8% and energy loss in the MV system is 4.21%. Construction of this express line provides a power injection at Thalankuda to improve reliability and line end

voltages, reduce the MV losses and increase line capacities, while improving the system operation flexibility. The proposed 33 kV switching gantry at Thalankuda is to connect the above backbone line from Vavunativu GSS to the existing MV system in the area and improve the operational flexibility of the MV system. MV tail end line voltage before and after implementation of this proposal is 83.5% and 96.9%, respectively. The estimated annual energy savings are 1,835 MWh. About 31,176 consumers will benefit from this subproject.

6. 33 kV Distribution Line from Wellampitiya to Ambathale Gantry

36. This subproject will connect Wellampitiya to Ambathale gantry by converting the existing 33 kV single circuit Raccoon line to a Lynx double circuit pole line.

37. The converted distribution line will improve reliability, operational flexibility, and increase load carrying capacity to meet demand growth in the area including that of major water pumping station at Ambathale. Load growth in Colombo district of the Western Province is forecasted at an average 7% over the ten-year planning period. Electrification ratio (2012) in Colombo district is 99% and the energy loss in the MV system is 5%. After implementing the proposal receiving end voltage at Amabathale will improve by 1.8% (0.6 kV). The estimated annual energy saving is 1.1 GWh. About 2,037 consumers and a major water pumping station of 9 MVA capacity will benefit from this subproject.

D. DSM pilot projects in Colombo

38. Project 1 will include pilot DSM interventions through use of smart metering technologies, smart building technologies, and cold thermal storage resulting to energy savings. In the case of replication, the DSM interventions are also relevant for renewable energy integration as DSM, especially demand response and interruptible loads, can be useful in maintaining demand and supply balance with high level of intermittent renewables.

1. Application of smart-grid and smart-metering techniques for DSM integration

39. The smart metering technology provides a way of measuring site-specific information, allowing introduction of different prices for consumption based on the time of day and the season and managing energy consumption by customers themselves. Smart meters may include measurements of surge voltages and harmonic distortion, allowing diagnosis of power quality problems. Potential benefits of smart metering include (a) an exact billing, (b) introduction of time-of-use tariffs, (c) remote reporting, and (d) a tool to help consumers better manage their energy use through getting up-to-date information on electricity consumption and in doing so help to manage their energy use and reduce their energy bills and carbon emissions. The existing trials in some countries showed that electricity consumption may be on average reduced by approximately 3-5%. The proposed pilot will use the smart metering technology through installation of customer smart meters along selected feeders to raise awareness on possibility of and create incentives for energy savings.

40. Smart grid/smart metering solutions will be implemented by CEB and Lanka Electricity Company Limited (LECO) that is CEB’s subsidiary company in their respective areas for load management for retail/domestic consumers. It is expected that each utility will identity one transformer (typically 250 - 300 consumers) for the metering and measurements. Suitable meters that can record the power consumption of customers connected to each substation will

be installed at the substation. Further, the following devices will be installed in each customer premises within the selected area:

(i) Smart meters that can record power consumption in minute intervals. These meters will be connected together with existing meters so that the new meters will only be involved in the trial.

(ii) Three piggyback plug sockets that can monitor the turn-on and turn-off status and that can control the operation of non-essential loads such as electric irons, washing machines, water pumps, air conditioner etc. and loads with thermal storage such as refrigerators and hot water tanks.

41. The smart metering system will be used for (a) load estimation, (b) voluntary demand reduction, and (c) direct load control.

42. Load estimation: The smart meter readings that will be transferred to a concentrator once a day together with information received from piggyback plugs is used for load modelling. In parallel to this digital recording of the power consumption, the basic data such as the number of adults and children in the house and appliances in the house will be gathered through a questionnaire. This will be useful to develop the signature of different appliances and different house stocks. This data collection will help to obtain load patterns of different houses, thus enabling the estimation of load pattern of a larger area. The load signatures together with some heuristic and statistical methods can then be developed to predict the load pattern in a regime where time-varying prices and direct load control are in operation.

43. Voluntary demand reduction: By providing time-varying price information and energy consumption to customers, they are expected to voluntarily switch off appliances to reduce their electricity bill. Such reduction is possible as human behavior is driven by a desire for the maximization of materialistic objectives such as profit for producers and utility for consumers. The aim is to test and understand the elasticity of domestic electricity consumption in response to price signals. It is proposed to install smart meters and In-Home Displays to consumers in the selected areas. Artificial price information will be transmitted a day ahead with different tariffs for the off-peak and peak periods. The energy consumption and price information will be displayed in the In-Home Display. The effectiveness of this pilot scheme will be evaluated by taking load profiles of each piloted house for a period of time and analyzing the correlation of it to the price signal sent.

44. Direct load control: Direct load control (DLC) schemes that remotely shut down or change the thermostat settings of customers' electrical equipment (e.g., air conditioner, water heater) are already in operation. This DSM measure is very useful under a regime where penetration of renewable generation is high. With the variation of renewable energy it may be difficult to maintain the second-by-second balance between the generation and demand unless a large reserve is maintained. Under such circumstances, direct load control is an attractive and economical option. Further direct load control could be used during a period where network assets are over-loaded thus reducing the losses in distribution networks. Load curtailment or interruption through DLC is also possible on smart appliances such as heating, ventilation and air conditioning, lights, and washing machines. For example, a washing machine will have its start delayed to a time with low electricity price. The user settings are respected: the cycle must end before a user set end time.

2. Retrofitting existing buildings with smart concepts, instrumentation and systems

45. It is practically impossible to envisage all aspects of energy consumption of the building at a design stage. The buildings are designed keeping in mind all possible usage scenarios. Many of the buildings face significant changes in its usage pattern and hence in its energy consumption pattern over its lifetime. The conventional control systems available and varying usage patterns of buildings give rise to various sources of energy waste. Some of the sources of energy wastage are as follows:

(i) Heating, ventilation and air conditioning (HVAC) equipment carrying out simultaneous heating and cooling the given space because of fault in sensor or other fault;
(ii) HVAC and lighting systems running at full capacity when buildings are not significantly occupied;
(iii) Lack of visibility and attention to energy waste on part of occupants and building engineers; and
(iv) Default configuration of all systems and equipment which may be at sub-optimal set points.

46. Advanced buildings use number of sensors, controls and other devices, which are part of Building Management Systems (BMS) or alternatively called as Building Automation Systems (BAS). These control panels and BMS provide ease of access to various access points to observe and manage the building equipment. Smart building solution provides an additional analytical tools and single data repository for number of buildings. The smart building systems are equipped with powerful tools to analyze data regarding energy consumption pattern of buildings. These tools are also instrumental in proper integration with utility grid. Utility grids manage supply and demand of energy at local and regional levels. Another important feature of the smart buildings is integration of renewable energy and storage technologies to minimize grid power. At the other end of the spectrum is the adoption of net-zero buildings.

47. For the purpose of the pilot project, the following two commercial buildings in Colombo have been identified and assessed for the purpose of implementing the smart buildings concept. These are (a) Bank of Ceylon building, and (b) Hotel Cinnamon Lakeside. A detailed questionnaire was circulated to obtain feedback about the current status of energy efficiency evaluated based on the inputs. The DSM interventions have been proposed based on the preliminary analysis undertaken. This would, however, need validation through a detailed energy audit and establishing the baseline before actually implementing the proposed DSM measures. Once implemented and the "smart building" is operational, post implementation monitoring would be conducted for a period of three years. During the post implementation period, the building will be open for visitors and researchers to view the facilities/systems and to conduct studies/further research.

48. Energy management becomes instrumental in saving energy wastes with the help of smart building systems coupled with smart grids. The smart building systems can help to optimize building base load, power consumption pattern of major equipment such as HVAC and lightings. Analytical tools can help in tuning the set points and schedules for such equipment. Wherever possible, wasteful equipment can be isolated and the peak demand can be managed because of much better understanding of energy use. When looked from a macro perspective, such systems at regional level can provide a lot better understanding of building energy portfolio. Such information would eventually equip utilities to manage peak loads much more

efficiently. Isolation of equipment and systems which could be run in off peak loads would help fill the gap in demand and hence will help operating power generation facilities at optimum levels. The pilot project will result in flattening of the load curve for CEB and a large scale replication of the model could result in significant reduction in the overall energy demand as well as shaving of peak load. The pre-feasibility study for one of the proposed pilot projects in a five star hotel in Colombo shows that the Energy Performance Index (EPI) is below 250 kilowatt-hour per square meter (kWh/m2) per year, which is comparable with similar properties in South Asia. The EPI based on the annual energy used per room per year is also below 24,110 kWh/room per year. It could be concluded that hotel's energy performance is among the better energy performing hotels. However, there is still scope to improve the energy performance by introducing advanced energy conservation measures. A high level analysis of the energy reduction possibilities by introducing the energy conservation measures like (a) hot water regeneration heat pump, (b) chilled water pumping system optimization, (c) optimization on Air Handling Units (AHUs) through Variable Frequency Drives (VFDs), and (d) lighting optimization shows that it would be possible to reduce the overall annual energy bill by at least 10%. Table 12 shows the energy savings that can be achieved through retrofitting the following energy conservation measures.

Table 12: Energy Conservation Measures suggested for Five Star Hotel

S. No.	Energy Conservation Measures	Equipment Impacted	Energy Saved	
			kWh	FO (liters)
1	Hot water generation through heat pump	FO Boiler	(160,000)	135,000
2	Chilled water pumping system optimization	Chilled water pumps 2 Nos.	98,000	--
3	Opimization on AHUs through VFDs	20 no. AHUs	110,000	--
4	Lighting optimization	35 W halogen, 11 W CFL, 28 W TL, 50 W incandescent bulbs	363,000	--
	Total		**411,000**	**135,000**

AHU = air handling units, CFL = compact fluorescent lamp, FO = fuel oil, kWh = kilowatt-hour, TL = tube light, VFD = variable frequency drive, W = watt.
Source: Ceylon Electricity Board and Asian Development Bank estimates.

49. The pilot project has the potential for replication across various segments of the industry and can be successfully employed in commercial and industrial establishments based on the learnings derived during the pilot phase.

3. Implementing Cold Thermal Storage in Commercial and Industrial Facilities

50. The feasibility of using thermal storage may be considered for reducing the peak demand and energy reduction. This, however, will require a detailed study to arrive at an optimal thermal storage capacity, which is a function of refrigeration load demand and electricity tariff. An ideal site for thermal storage plant with regards to techno-commercial feasibility will essentially have the following profile:

(i) Availability of a stand by chiller at site for a 24x7 running facility to cater to cooling load when Thermal Energy Storage (TES) chiller is in charging mode.

(ii) The ability of the existing chiller to operate in dual mode to be able to operate at negative temperature. This option is needed to optimize on costs, instead of putting a new chiller at site to run with TES.

(iii) Considerable tariff difference in the peak and non-peak hours.

51. The subproject involves implementing a cold thermal storage solution in commercial and industrial facilities. The subproject will be implemented in identified commercial and industrial installations where there is a significant air conditioning load. The objective of the pilot and replication subproject will be to achieve demand-side management through shaving the peak demand and valley filling during off peak periods. This will be achieved by storing the chilled water or ice during the off peak periods and using the same for air conditioning during peak periods thereby reducing the demand.

52. Four facilities from commercial and industrial installations will be selected for these utility-driven DSM subprojects. All facilities will have a significant air conditioning requirement and systems in place, and chilled water/ice requirements during day time and evening peak time. Ideally, the four facilities will be (i) a commercial/office building, (ii) a tourist/business hotel, (iii) an industrial facility, and (iv) a food/beverage industry. The electricity supplier (a Distribution licensee) or a nominated agency will conduct studies/audits to identify the potential for savings, and then design the storage projects at each facility, including a feasibility assessment. Thereafter, the four pilot subprojects will be implemented with financial assistance/cost-sharing with the electricity supplier. Post implementation monitoring will be conducted for a period of two years after commissioning the chilled water storage facilities. The experience, successes and any failures/points of caution, including the ex-post evaluation will be published and leveraged during the replication phase.

53. A chilled water supply or ice is required in the following systems: (a) centrally air conditioned commercial buildings and manufacturing industries, (b) storage and manufacture of milk, beverages and food items. Most of the chilled water and ice usage requirements are during the day time through the evening, and the systems generally have a lower requirement in the night. Therefore, chillers and other similar equipment generally idle during the off-peak period of the country's load profile. The project concept is to produce chilled water or ice (as the case may be, depending on the facility requirements) during the off-peak period, and use during the day and evening peak periods. The advantages to the customer will be (a) saving in energy and demand charges, through time of use (TOU) tariffs as well as improved efficiency of chiller operation at full load, (b) avoided investments on new chiller capacity. There will be requirements to invest on chilled water or ice storage facilities. There will be heat gains when chilled water/ice is stored, which have to be discounted from the savings. The electricity supplier will save on day-time and peak-time demand from this group of customers, resulting in financial savings as well as economic savings.

54. Table 13 summarizes the base cost of the components of Project 1.

Table 13: List of Generation, Transmission, Medium Voltage/Distribution and DSM Subprojects to be financed under Project 1 (Tranche 1) of MFF

No.	Subproject Name	Base Cost (US$ Million)	Scope Outline
A	**Hydropower Development**	**103.48**	
A1	Construction of Moragolla Hydropower Plant	103.48	30 MW run-of-river hydropower plant
B	**Transmission Infrastructure**	**52.88**	
B1	Construction of Kerewalapitiya GSS	8.24	220/33 kV GSS (2x45 MVA TF, 2x33 kV GIS TF bay, 12x33 kV GIS feeder bays and 33 kV GIS SB arrangement including bus section)
B2	Construction of Kappalturai GSS	12.48	220 (132)/33 kV GSS (of 2x60 MVA SB TF bays, 4x220 kV SB TL bays, 1x220 kV bus section bay including SB arrangement, 2x33 kV TF bays, 16x33 kV feeder bays and 1x33 kV bus section bay including 33 kV SB arrangement)
B3	Augmentation of Old Anuradhapura GSS	10.34	Reconstruction of 3x31.5 MVA 132/33 kV TF GSS
B4	Construction of Kalutara GSS	8.78	2x31.5 MVA 132/33 kV TF, 2x132 kV SB TF bays, 2x132 kV SB TL bays, 132 kV SB arrangement including bus section, 2x33 kV TF bays, 8x33 kV feeder bays and 1x33 kV SB arrangement including bus section; construction of single in and out connection from Panadura – Matugama 132 kV TL, Zebra, DC (6 km)
B5	Construction of Kesbewa GSS	10.52	Construction of 132/33 kV GSS (2x31.5 MVA 132/33 kV TF, 2x132 kV SB TF bays, 2x132 kV SB TL bays, 132 kV SB arrangement including bus section, 2x33 kV TF bays, 8x33 kV feeder bays and 1x33 kV SB arrangement including bus section); construction of Pannipitiya-Kesbewa 132 kV Zebra, DC TL (9 km)
B6	Augmentation of Katunayake GSS	2.52	Augmentation of 2x31.5 MVA to 3x31.5 MVA, 1x132 kV SB TF bay, 1x 33 kV TF bay, 4x33 kV feeder bays and 1x33 kV bus section bay
C	**MV/Distribution Network**	**8.19**	
C1	Madampe GSS to Bowate DL and Gantry at Bowate	2.41	33 kV Lynx DC tower line (20 km) and SBB Gantry at Bowatte
C2	Vavunativu GSS to Thalankuda DL and Thalankuda Gantry	1.67	33 kV DC Lynx tower line (21 km) and a DBB Gantry at Thalankuda
C3	Vavunativu GSS to Kaluwanchikudy DL and Kaluwanchikudy Gantry	2.13	33 kV DC Lynx tower line (27 km) and a DBB Gantry at Kaluwanchikudy
C4	Vavunativu GSS to Urani DL and Urani Gantry	0.54	33 kV DC Lynx tower line (6 km) and DBB at Urani
C5	Vavunativu GSS to Karadiyanaru DL and Karadiyanaru Gantry	1.06	33 kV DC Lynx tower line (13 km) and DBB at Karadiyanaru
C6	Wellampitiya to Ambathatale Gantry DL	0.38	Lynx DC steel pole(5.3 km) line

No.	Subproject Name	Base Cost (US$ Million)	Scope Outline
D	**DSM/Energy Efficiency Pilots**	**3.14**	
D1	DSM Pilot for Smart Grid/Metering	0.64	Smart metering intervention
D2	DSM Pilot for Smart Buildings	1.67	Smart building intervention
D3	DSM Pilot for Thermal Energy Storage	0.83	Cold storage intervention
E	**Project Management and Capacity Building Services**	**12.31**	
E1	Project management and supervision	10.38	Project management and supervision of construction of Moragolla hydropower plant
E2	Project management and implementation support	1.20	Implementation supervision and preparation of Project 2 of MFF
E3	Capacity building for power sector development	0.73	Support to CEB in transmission design planning, upgrading design and standards and introduction of new technologies
Total Base Cost for A+B+C+D+E		**180.00**	

CEB = Ceylon Electricity Board, DBB = double bus bar, DC = double circuit, DL = distribution line, DSM = demand side management, GIS = gas insulated switchgear, GSS = grid substation, km = kilometer, kV = kilovolt, MFF = multitranche financing facility, MVA = megavolt-ampere, SBB = single bus bar, TF = transformer, TL = transmission line.
Sources: Ceylon Electricity Board and Asian Development Bank estimates.

E. Tentative Subprojects of Project 2

55. Table 14 provides a tentative list of subprojects that may be included in Project 2 in 2016. These will be prepared and finalized by CEB with support of project management consultants under Project 1 following ADB's due diligence requirements and subsequently submitted in the relevant periodic financing request by the government to ADB for consideration.

Table 14: Tentative List of Transmission, Medium Voltage/Distribution and DSM Subprojects to be financed under Project 2 (Tranche 2) of MFF

No	Project Name	Base Cost (USD Million)	Scope Outline
A	**Transmission Infrastructure**	**150.71**	
1	Construction of Mannar-Nadukuda TL and Nadukuda GSS	26.09	30 km 220 kV Transmission Line and 126 MVA 220/132/33 kV GSS
2	Construction of New Polpitiya-Hambantota (via Embilipitiya) TL and 220 kV Hambantota GSS	76.98	220 kV 150 km Transmission Line and GSS
3	Augmentation of Kotugoda, Biyagama and Kolonnawa GSS	8.42	GSS augmentation
4	Construction of Chemmuni GSS	10.22	132 km 10 km of TL and 63 MVA 132/33 kV GSS
5	Augmentation of Kukule GS	2.50	132 kV 21.5 MVA GSS
6	Vavunia GSS 220kV Development	13.52	132 kV 55 km TL and 500 MVA GSS
7	Construction of Samanalawewa-Embilipiyiya 132 kV TL and Rehabilitation of Embilipitiya GSS	10.48	101 km 132 kV Transmission Line and GSS
8	Augmentation of Madampe GSS	2.50	31.5 MVA 132/33 kV GSS

No	Project Name	Base Cost (USD Million)	Scope Outline
B	**Distribution Network Efficiency Improvement**	**18.43**	
1	33 kV Capacitor Banks	2.50	Total 75 MVAr
2	Maharagama PSS to Nawinna PSS	0.25	3.6 km Lynx SC Steel Pole
3	Kegalle GSS to Kotiyakumbura via Moronthota DC 33 kV Tower Line and Gantry at Choicy & Kotiyakumbara	3.57	25 km Lynx DC Tower
4	Polonnaruwa to Medirigiriya DC Tower Line with Gantry at Medirigiriya	2.65	28 km Lynx DC Tower
5	Kegalle GSS to Polgahawela DC Tower Line with Gantry at Polgahawela	1.89	18 km Lynx DC Tower
6	Suriyawewa GS to Mattala airport SC Tower Line	0.84	8.5 km SC Lynx Tower
7	Panadura GSS to Pallimulla PSS SC pole line	0.12	4.5 km Lynx SC Pole
8	Pannipitiya GSS to Kesbewa SC Pole Line	0.20	7 km Lynx SC Pole
9	Tissa Gantry to Kataragama DC Tower line with Gantry at Kataragama	1.94	14.5 km Lynx DC Tower
10	Express Line from Monorgalla GSS to Wellawaya and Gantry at Wellawaya	4.47	34 km Lynx DC Tower
C	**Energy Efficiency**	**10.86**	
	DSM implementation subprojects	10.86	Smart grid, smart buildings and cold storage based subprojects
	TOTAL (A+B+C)	**180.00**	

CEB = Ceylon Electricity Board, DC = double circuit, DL = distribution line, DSM = demand side management, GSS = grid substation, km = kilometer, kV = kilovolt, MVA = megavolt-ampere, MVAr = megavolt-ampere reactive, SC = single circuit, PSS = primary substation, TL = transmission line.
Sources: Ceylon Electricity Board and Asian Development Bank estimates.