ENERGY
FORUM

INCORPORATING SOCIAL AND ENVIRONMENTAL CONCERNS IN LONG TERM ELECTRICITY GENERATION EXPANSION PLANNING IN SRI LANKA

DRAFT REPORT – FOR PUBLIC COMMENTS

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Table of Contents

List of Tables and Figures

Nomenclature

BOD .... Biological Oxygen Demand
CCY .... Combined Cycle Power Plant
CCHP .... Combined Cooling Heat & Power
CEB .... Ceylon Electricity Board
CG .... Centralised Generation
CHP .... Combined Heat & Power
COD .... Chemical Oxygen Demand
CO_x .... Carbon Monoxide/Dioxide
DE .... Distributed Energy
DSM .... Demand Side Management
GDP .... Gross Domestic Product
GEMIS .... Global Emission Model for Integrated Systems
GIS .... Geographic Information Software
GWh .... Giga watt hours
IAEA .... International Atomic Energy Agency
LNG .... Liquid Nitrogen Gas
LTGEP .... Long Term Generation Expansion Plan
MCA .... Multi Criteria Analysis
MW .... Mega watt
NO_x .... Nitrogen Oxide/Dioxide
NORAD .... Royal Norwegian Embassy
NRE .... Non-conventional Renewable Energy
NREL .... National Renewable Energy Laboratory
OTEC .... Ocean Thermal Energy Conversion
O&M .... Operation & Maintenance
PUCSL .... Public Utility Commission of Sri Lanka
SO_x .... Sulphur Oxides
SPM .... Suspended Particulate Matter
SYSIM .... System Simulation Model
T&D .... Transmission & Distribution
WADE .... World Alliance for Decentralised Energy
WASP .... Wien Automatic System Planning Package

1 Executive Summary

1.1 Current Electricity Situation in Sri Lanka

A recent newly drafted government energy policy is currently under consideration by the cabinet of ministers for implementation. However there was no officially accepted electricity generation policy for Sri Lanka up to now. Only a draft document was available that was formulated by the Ministry of Power and Energy in the mid 1990s.

Ceylon Electricity Board

In the absence of a government accepted energy policy, the government owned Ceylon Electricity Board (CEB) has been formulating the annual Long Term Generation Expansion Plans (LTGEP) since the late 1980s. Though the CEB is supposed to function as a commercial entity it took steps to formulate an optimum generation expansion plan for power generation in Sri Lanka that was the most economical option. The Transmission and Generation planning Branch of the CEB used the Wien Automatic System Planning Package (WASP 4), as developed by the International Atomic Energy Authority, for the development of the plan.

However, during the last 15 years, not a single long-term power plant option as recommended by the CEB has been constructed. All plants which were established during this period were either short term measures or were not recommended by the CEBs Long Term Generation Expansion Plan. Even the Upper Kotmale hydro power plant which is currently under implementation was not recommended by the LTGEP of the CEB.

1.3 Reason for Study

This study is therefore in direct response to the current situation. The Energy Forum felt the reason these plans were not implemented was that they were formulated without taking account of key stakeholder opinions. As the plan was formulated in a non participatory fashion, there were no policy directives from the government. As a result important stakeholder parties used their influence to generate resistances that obstructed the plans being implemented.

1.4 Aims and Process of Study

The aim of this study was to address the policy level issues in the power generation sector of Sri Lanka. It was decided to run the WASP4+ model, though it is only a planning tool, as a major component of the study as a way of initiating a constructive dialog between the planners and the marginalized stakeholders. Starting with the CEB base-case the WASP4+ model ran scenarios for accommodating the stakeholders concerns. This adhered to recommendations of the 1st and 2nd stakeholder meetings.

To complement the results of the WASP run it was decided to conduct two parallel studies for rectifying some of the weaknesses associated with the WASP model. The World Alliance for Decentralized Energy (WADE) developed a computer model that was used for analyzing the impact of the distributed energy concept. As certain stakeholder groups were concerned about the unnecessary priority given to the financial aspect of the generation, a separate study was conducted to analyze individual stakeholder concerns. The criteria used were financial, social, national and environmental.

1.5 Results and Outcomes

The study results make for very interesting reading and are an eye opener for policy makers. The results show that the WASP4+ model is not an appropriate tool for power sector planning in Sri Lanka. This is because it is unable to accommodate energy conservation, energy technologies that cannot be dispatched and distributed power plants. Furthermore it was observed that the WASP model is not capable of accommodating newly promoted concepts of fuel diversification and energy mix.

The results show that hydro power- Sri Lanka's main indigenous power source is not recommended for establishment by the WASP model. Even the currently promoted Upper Kotmale power plant is not among the recommended list of the WASP model. This is clearly not in line with the reality of Sri Lanka. The CEB on one hand claim that the hydro power generated is very much cheaper than the thermal power plants. It is likely that if the WASP model was used in the 1940's, 50's and 70's the Laxapane and Mahaweli complexes would not have been built. In these cases the problem is not with the WASP model but with the input data itself. The CEB recommended base-case uses a discount rate of 10% and neglects long term future fuel price increases causing falls in recommendations. Using wrong input data favors technologies with high running costs and this misleads the decision makers.

The CEB generation planning branch, despite intense pressure from energy academics has never attempted to test the performance of Dendro power. The WASP results alone clearly show that Dendro power is the preferred option when compared to imported coal power. The results of the WADE model and the Multi Criteria Analysis further endorses Dendro power. The WADE model results show that the distributed energy has a number of advantages over central power, such as: fewer transmission and distribution losses, reduced required installed capacity, and reduced fuel consumption for industrial heat applications. The Multi Criteria Analysis revealed that the key concern of all stakeholder groups is the national interests and the reliability of an uninterrupted power supply as opposed to financial concerns as were initially perceived. Further the LNG option is not currently recommended due to high capital and running costs. High capital costs makes LNG uncompetitive with oil power and high running costs makes LNG uncompetitive with coal power. If LNG terminals, which are costly when constructed solely for power generation, are integrated into a system that combines transport with power generation the capital costs can be greatly reduced. This therefore requires continual developments, and it is expected that growing international concern for the environment will make LNG more competitive further emphasizing the need for development. This is especially important given the recent rapid fluctuations in fuel prices.

The WASP model is considered as an economic model and hence uses the economic costs for analysis. Accordingly the results do not reflect financial costs involved with the candidate options. This study however, includes a financial analysis with respect to selected technological options on a level playing field. The results of this analysis clearly show that the generally accepted figures for coal and other cheaper options are in fact not as economical as they appear.

The study as a whole shows that the long term electricity generation planning should not be done by commercial entities such as the CEB, but should be done by entities with high national interests and who are responsible for the general public. An example of such an entity is the Public Utility Commission of Sri Lanka. The most promising short term technological option identified in this study is Dendro power and hence there is a need to develop a multi-sectoral national level approach towards developing the sector.

2 Background

2.1 Introduction

The overall objective of the study was to look critically at the energy planning process of Sri Lanka by paying special attention to the electricity sector to fill vital gaps that would make positive changes possible and provide solutions to the current crisis situation. This was done by strengthening the information base required to procure realistic policies and through an inclusive exercise with participation of all energy stakeholder parties.

The study was a civil society contribution to find solutions to the current energy crisis in Sri Lanka and ways to move forward from the current deadlock. The study was designed to evolve with constant interaction of selected stakeholder party representatives, including politicians, Ceylon Electricity Board officials, industrialists, environmentalists, Energy sector academics and researchers, the Public Utility Commission of Sri Lanka, the Ministry of Power and Energy, the Ministry of Science and Technology, the Energy Conservation Fund, the Central Environmental Authority, end users of energy and citizens of Sri Lanka. The study investigated possible mechanisms for incorporating social and environmental concerns in electricity generation planning.

2.2 Electricity Demand Forecast

The demand growth of a country is dependent on a number of factors. The general assumption is that the electricity demand growth is directly linked with the Gross Domestic Product (GDP) growth rate.

However it is evident that government policies towards rural electrification, industrial development and demand, and management will have significant impacts on the actual demand of the nation.

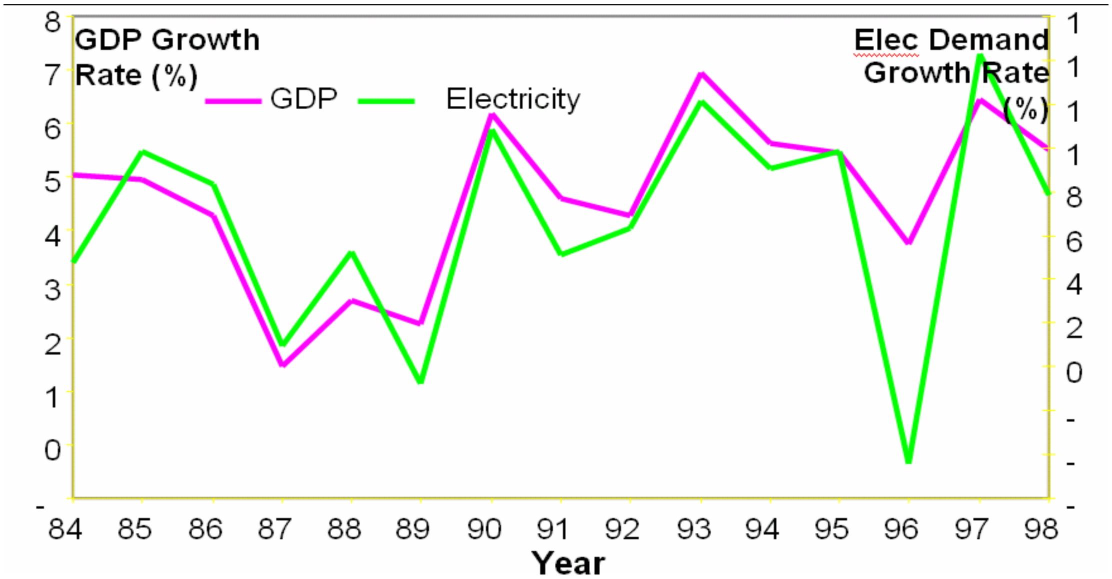


Figure 2.2.1 – Electricity Demand Forecast graph

The 2006 report of the CEB generation planning branch has estimated the electricity demand of the country in the year 2020 as 5900 MW.

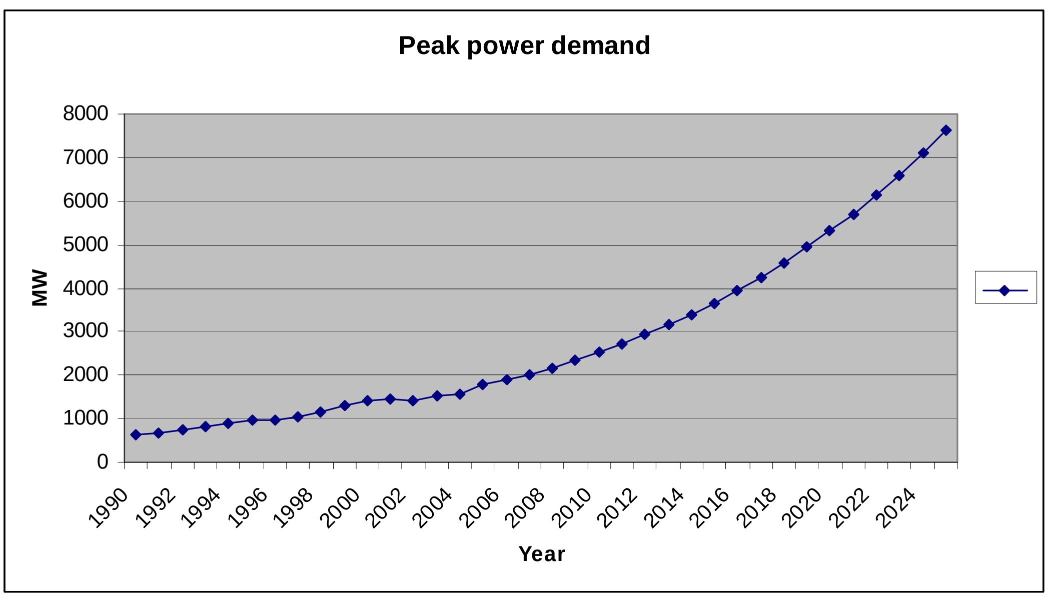


Figure 2.2.2 – Peak Power Demand graph

These figures seem to be a reasonable estimate with respect to the demand growth in the recent past.

The CEB demand forecasts made 15 years ago are as follows:

1991 prediction for 2006 - Peak demand

- Base case - 1810 MW
- High - 2060 MW
- Low - 1675 MW

The actual demands in 2005 & 2006 - Peak Demand

2005 - 1768 MW
2006 (estimated) - 1884 MW

This proves that the CEB estimation is very close to the reality. Accordingly the demand forecast of the CEB in 2006 report has been used for this study. However the system must be able to accommodate a higher growth rate and a drop of demand. Since the GDP growth and power supply are interdependent, predicting a higher growth rate may be advantageous to the nation.

2.3 Existing Power Plants

Plant Name	Units X Capacity	Capacity (Mw)	Annual Avg. Energy (GWh)	Year of Commissioning	Contract period
Existing Hydro Power Plants					
Laxapana Complex					
Canyon	2x30	60	160	Unit Mar 1983 Unit 2 may 1989	
Wimalasurendra	2x25	50	112	Jan-65	
Old Laxapana	3x833+ 2x12.5	50	286	Dec 1950 Dec 1958	
New Laxapana	2x50	100	552	Unit 1 Feb 1974 Unit 2 Mar 1974	
Polpitiya	2x37.5	75	453	Apr-69	
Laxapana		**335**	**1563**		
Mahaweli Complex					
Victoria	3x70	210	865	Unit jan 1985 Unit 2 Oct 1984 Unit 3 feb 1986	
Kotmale	3x67	201	498	Unit 1 Apr 1985 Unit 2 & 3 Feb 1988	
Randenigala	2x61	122	454	Jul-86	
Ukuwela	2x19	38	154	Unit 1 July 1976 Unit 2 Aug 1976	
Bowatenna	1x40	40	48	Jun-81	
Rantambe	2x24x.5	49	239	Jan-90	

Plant Name	Units X Capacity	Capacity (Mw)	Annual Avg. Energy (GWh)	Year of Commissioning	Contract period
Mahaweli		**660**	**2258**		
Samanalawewa	2x60	120	344	Oct-92	
Kukule	2x35	70	300	Jul-03	
Small Hydro		20			
Existing Hydro Total		**1205**	**4465**		
Wind Plant		3			
Existing Wind Total		**3**			
Kelanitissa Power Station					
Gas turbine (Old)	4x17	68	417	Dec. 81Mar.82 Apr.82	
Gas turbine (new)	1x115	115	707	Aug-97	
Combined Cycle	1x165	165	1290	Aug-02	
Kelanitissa Total		**348**	**2414**		
Supugaskanda Power Station					
Diesel	4x18	72	472	May 84 May 84 Sep 84 Oct 84	
Diesel (Ext.)	8x9	72	504	4 Units Sept 97	
Sapugaskanda Total		**144**	**976**	4 Units Oct 99	
Chunnakam	1x8	8		Mar-99	
Small Thermal Total	8	8			
Existing CEB Thermal Total	**528**	**500**	**3390**		
Mini Hydro		**82.2**			
Lakdhanavi		22.5	156	1997	15
Asia Power Ltd		49	330	1998	20
Colombo Power (pvt)Ltd		60	420	Mid 2000	15
ACE Power Horana		20	167	Mar-02	10
ACE Power Matara		20	167	Dec-02	10
AES Kelanitissa (P		163	1314	GT March 2003 St-October 2003	20
Helandanavi (Pvt.)Ltd		100	698	Oct-04	10
ACE.Power Embilipitiya Ltd		100	697	Mar-05	10
Existing IPP Thermal Total		**534.5**	**3949**		
Committed					
Kerawalapitiya CCY		300		GT-Sept.2008 ST-August 2009	20
Upper Kotmale	2x75	150	409	Mar-11	
Committed		**450**			

In order to reach a plant capacity of 5900 MW by the year 2020, 4385 MW of New Plants are needed.

The CEB generation plan -2006 base-case has recommended the following power plants to be added:

Upper Kotmale	-150MW
Oil	-945MW
Coal (West Coast)	-1200MW
Coal (Southern Coast)	-1200MW
Coal (East Coast)	-900MW
TOTAL	**-4385MW**

Capital Investment estimated for the above plants is 4.783 billion US$.

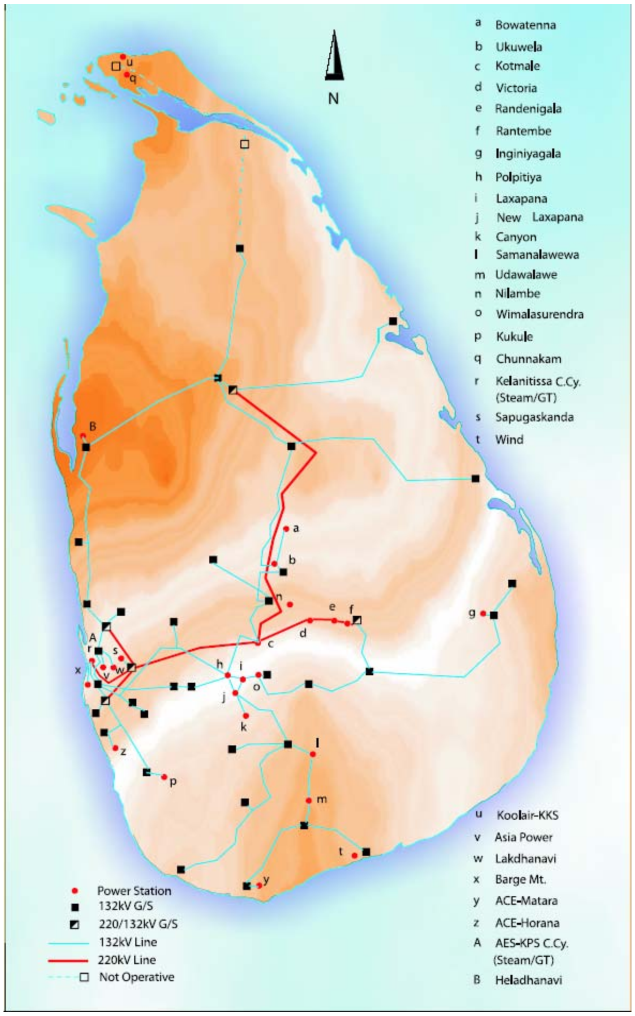


Figure 2.3.1 – Power Station Map

2.4 National Energy Policies and Strategies of Sri Lanka

'Mahinda Chinthanaya' (pages 54-55)

"Our energy sector has been put into a state of confusion due to political and other influences. My main targets will be to free our poor and country's economy from the burden of the increasing fuel prices in the world market and raise the energy supply to meet the demand in the country.
High priority will be given to the energy security of the nation and conservation of energy.

Thermal, including coal power plants, and Hydro electric power plants will be speedily erected, in accordance with the generation plans of the Ceylon Electricity Board, giving due consideration to the social issues of the people and environmental impacts, etc.

I shall take steps to complete the four Hydro electric schemes of Moragolla, Uma-Oya, Ginganga and Broadlands within the next six years.

I shall commence fuel wood production as a rural industry focusing on the country's Dry Zone."

The Government of Sri Lanka is currently in the process of establishing a policy framework for the energy sector in Sri Lanka. This policy has a special emphasis towards Non-conventional Renewable Energy sources (NRE). Accordingly the government will endeavour to reach a level of **10%** of grid electricity using NRE. The target year to reach this level of NRE penetration is **2015**.

Year	**As a Share of the Total**			
	Hydroelectric	**Oil**	**Coal**	**Minimum from NRE**
1995	94%	6%	0%	
2000	45%	54%	0%	1%
2005	36%	61%	0%	3%
2010	42%	31%	20%	7%
2015	28%	8%	54%	10%

Table 2.4.1 – Power Plant share of total power for the last 20 years

This is clearly different to the recommended CEB base case and highlights the need to concentrate on environmental friendly indigenous renewable energy resources.

2.5 Power Generation Potential in Sri Lanka

2.5.1 Potential

The availability of oil resources in the Sri Lanka territory is a matter of major concern. A 2D survey done together with the technical assistance of NORAD has come up with encouraging results, but unfortunately this does not take account of the cost of oil as an indigenous source due to uncertainties with the supply.

Sri Lanka as an island in the Indian Ocean has the right to a vast exclusive economic zone in the Indian Ocean. The wave energy, off-shore wind power and the Ocean Thermal Energy Conversion (OTEC) potential is very high in the Sri Lankan territory. However due to a lack of technical knowledge, these technologies have not been selected as candidate options for power generation.

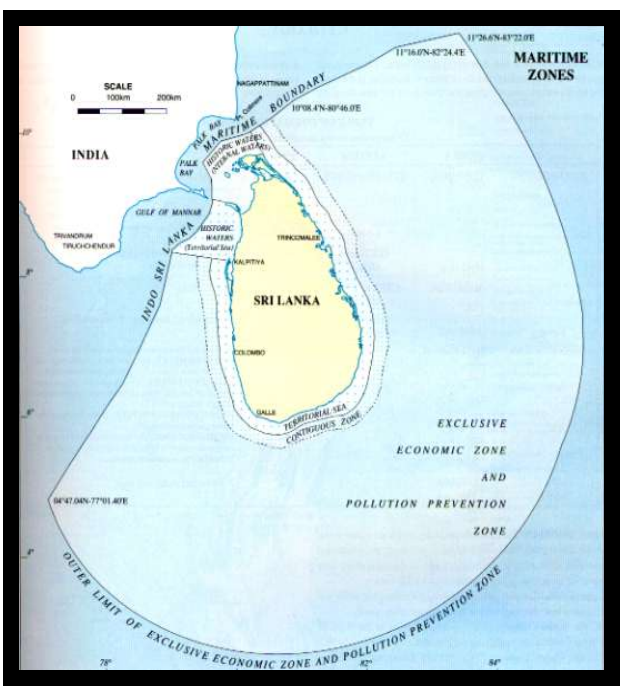
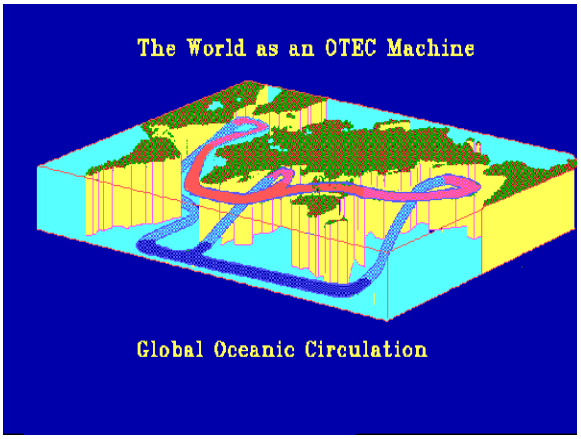


Figure 2.5.1.1 – Potential power generation map



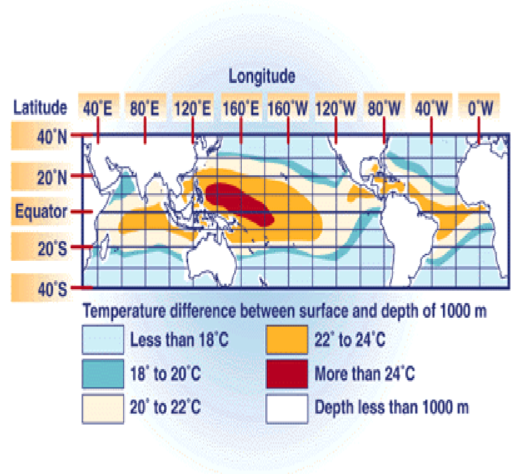


Figure 2.5.1.2 – Global Oceanic Circulation

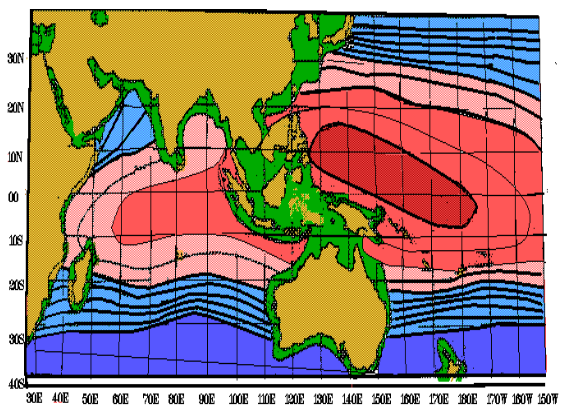
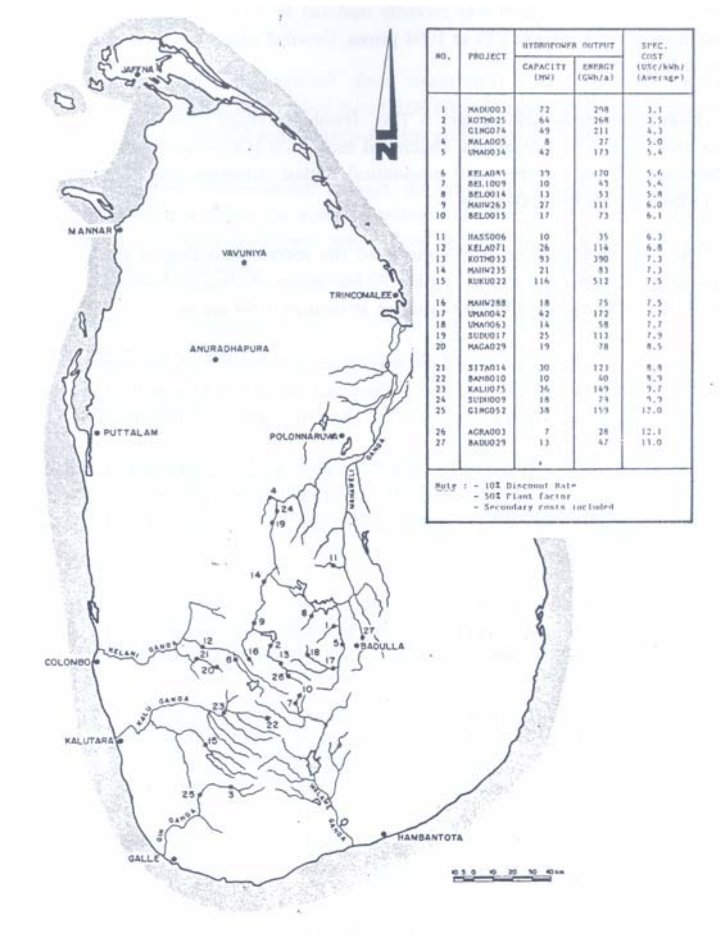


Figure 2.5.1.3 – World Temperature chart

Figure 2.5.1.4 – Asian Oceanic temperatures

2.5.2 Hydro Potential in Sri Lanka

The Sri Lanka electricity generation sector has been dominated by hydroelectricity for many years. The installed capacity and energy supply from hydroelectric stations in Sri Lanka has been increased progressively by commissioning complementary hydropower stations since the first large-scale hydropower station in Laxapana was commissioned in 1950. By 2005 the total installed capacity of hydropower stations summed to approximately 1,205MW. Depending on variable rainfall and system management from year to year, the proportion of electricity generation from hydropower plants has been fluctuating between about 35% and 50% during the last five years. For instance out of the total generation of 8159GWh in 2004, hydro plants supplied only 2,964GWh (37%) while in 1998 hydro plants supplied 3,915GWh (69%) out of a total generation of 5,675GWh.



NO.	PROJECT	HYDROPOWER OUTPUT CAPACITY (MW)	HYDROPOWER OUTPUT ENERGY (GWh/a)	SPEC. COST (USc/kWh) (Average)
1	MADU003	72	298	3.1
2	KOTM025	64	268	3.5
3	GING074	49	211	4.3
4	MALA005	8	27	5.0
5	UMA0034	42	173	5.4
6	KELA085	39	170	5.6
7	BELI009	10	43	5.6
8	BELO014	13	53	5.8
9	MAHW263	27	111	6.0
10	BELO015	17	73	6.1
11	HASS006	10	35	6.3
12	KELA071	26	114	6.8
13	KOTM033	93	390	7.3
14	MAHW235	21	83	7.3
15	KUKU022	116	512	7.5
16	MAHW288	18	75	7.5
17	UMA0042	42	172	7.7
18	UMA0063	14	58	7.7
19	SUDU017	25	113	7.9
20	MAGA029	19	78	8.5
21	SITA014	30	121	8.9
22	BAMB010	10	40	9.3
23	KALU075	36	149	9.7
24	SUDH009	18	73	9.9
25	GING052	38	159	12.0
26	AGRA003	7	28	12.1
27	BADU029	13	47	11.0

Note : - 10% Discount Rate
- 50% Plant factor
- Secondary costs included

The most proven energy technology in Sri Lanka for power generation is Hydro Power. The CEB has already established a number of power plants with a total capacity of 1205 MW. The Independent Power producers have so far established 82.2 MW of power plants. According to the CEB master plan the hydro potential in Sri Lanka is about 2000MW. However due to high capital costs, the CEB has neglected the development of this energy technology. Additional unresolved environmental and social issues also hinder the proposed projects.

Figure 2.5.2.1 – Hydro Power project Outputs

The uncertainty in rainfall during the year has also hampered the development of the hydro dominated electricity industry. During periods of drought hydroelectric plants are unable to provide firm power as they are totally reliant on a sustained level of water. This problem has been seen occurring several times in the recent past, namely 1992, 1996 and 2000/2001. During these years, the entire nation experienced shortages in electricity supply with forced power interruptions spanning up to eight hours per day. There is however an uncertainty regarding the way hydroelectric systems are controlled as there appears to be no direct correlation between the actual rainfall patterns and power plant utilization.

2.5.3 Dendro Power Potential in Sri Lanka

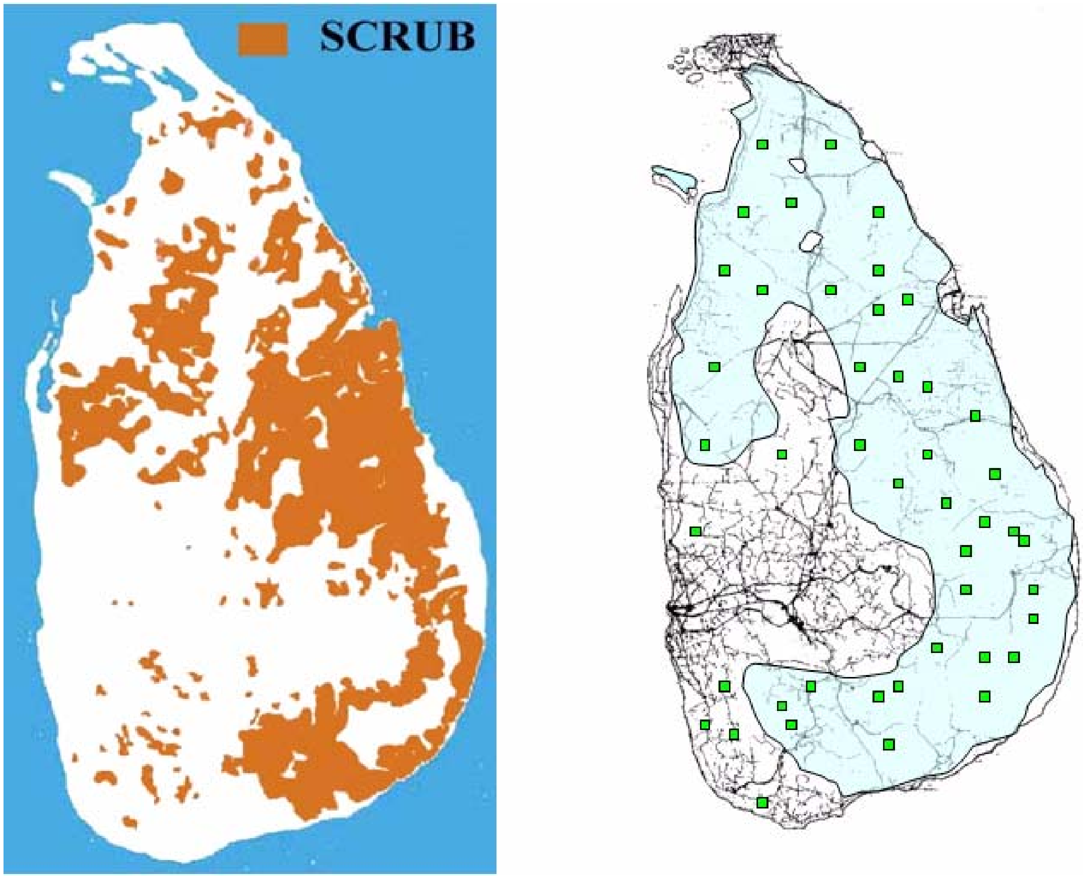


Figure 2.5.3.1 – Dendro Potential in Sri Lanka

It is estimated that 0.5 Million (500,000) hectares of the existing 1.6 million hectares of scrub and haena lands in Sri Lanka could (based on a modest yield of 20 tonnes /ha./yr) provide 10 Million (10,000,000) tonnes of sustainable fuel-wood annually. This could produce 10,000 GWh of domestically sourced electricity annually from about 1,200 MW of small (1 to 10 MW) thermal (wood-fuelled) power stations located throughout the country. Furthermore, the coconut plantations grow nitrogen fixing trees known as Gliricidia as an under crop, and tea plantations grow these trees as shade growth. As these trees are fast growing they are suitable for use as fuel wood and thus it is available in large volumes. The home gardens with 1-2acre plots are ideal for establishing fuel wood plantations as these species can be integrated in agriculture.

2.5.4 Wind Potential in Sri Lanka

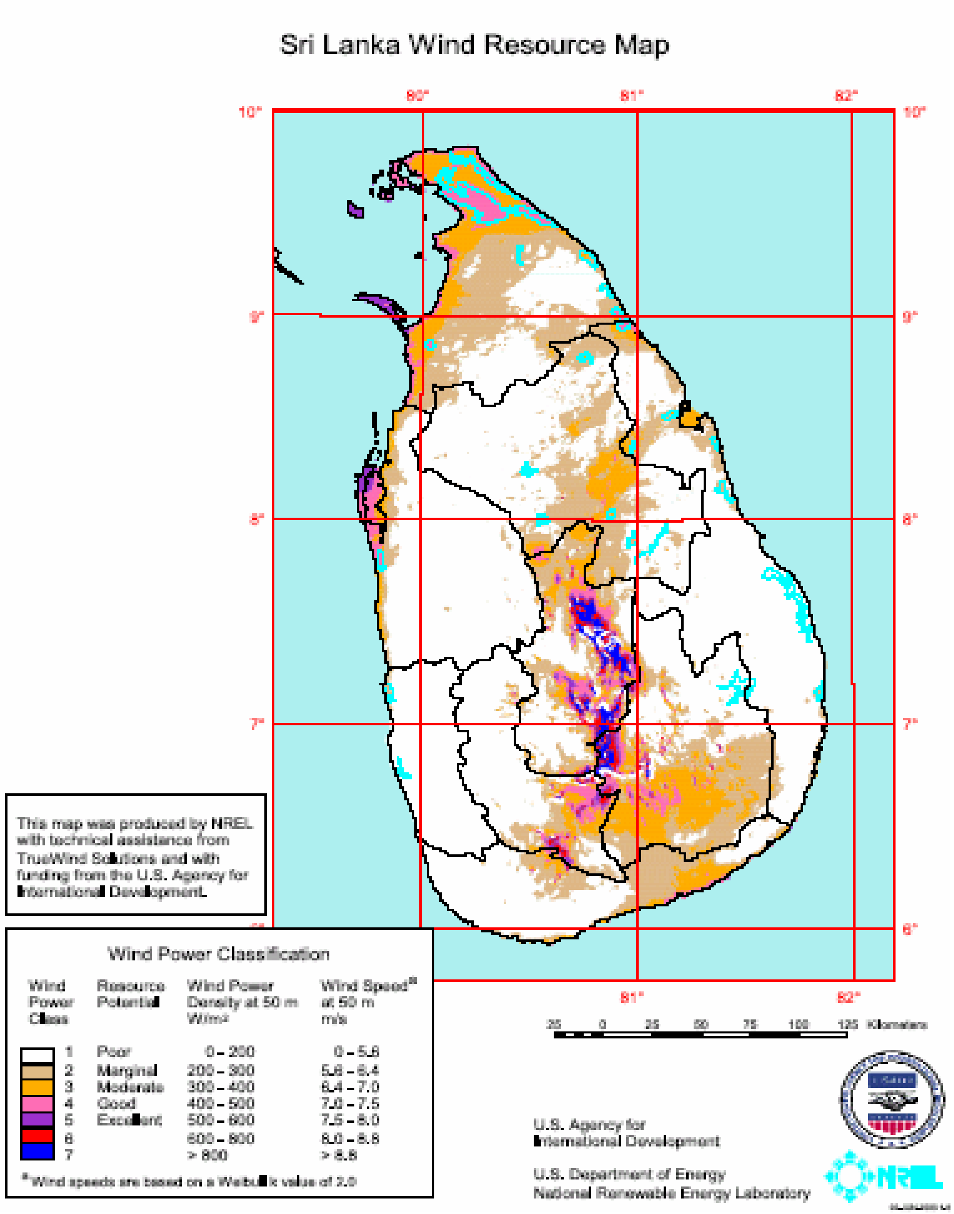


Figure 2.5.4.1 – Sri Lanka Wind Resource Map

The wind maps for Sri Lanka were created at the National Renewable Energy Laboratory (NREL) using a computerized wind mapping system that uses Geographic Information System software (GIS). The maps portray the wind resource with high-resolution grids of wind power density at 50-m above ground. The windy land is 6% of the total land area. The NREL estimated the potential for 20,000 MW of installed capacity using a conservative assumption of 5 MW per km^2. Further the NREL estimates about 700 km^2 with windy lagoons of 24,000 MW. With moderate wind resource potential total windy land area increases to approximately 10,000 km^2 or almost 15% of the total land area. This amount supports more than 50,000 MW of installed capacity. However additional studies are required to accurately assess the wind electric potential, considering factors such as the existing transmission grid and accessibility.

2.6 Description of Study

2.6.1 Study Components

The study methodology included the following three components;

1. A study on incorporating stakeholder concerns in the WASP4+ computer model - Assisted by the PUCSL & Ministry of Science and Technology

2. A study on the impact of replacing central power with distributed energy using the WADE computer model - Assisted by World Alliance for Distributed Energy, UK

3. Multi Criteria Analysis (MCA) for the power generation in Sri Lanka - Assisted by Practical Action Consultancy (UK) and the University of Edinburgh

2.6.2 Selected Candidate options for the Study

- Coal- considered by the CEB as the least cost long-term option for the country for the last 15 years. Hence coal is considered as candidate options in three locations
- Oil
- Hydro (Upper Kotmale, Broadlands, Ginganga, Uma Oya, Moragolla) -
- Dendro
- Wind
- LNG

3 WASP 4+ Computer Model

3.1 Background

Long-term electricity generation expansion planning is to select:

- economically optimum plant additions
- from possible power generation expansion candidates
- in order to meet the forecast electricity demand
- considering the existing and committed power plants, expected reliability level and environmental and social factors.

The Ceylon Electricity Board's (CEB) Long Term Electricity Generation Expansion Plan which is the only long-term generation expansion plan available in Sri Lanka is focused on the objective of meeting the demand for electricity from the grid.

The CEB routinely uses computer-planning models for generation and transmission, and distribution planning. CEB employs software models such as WASP and SYSIM (for hydro) for long term planning.

CEB updates the plan every year, by updating the demand forecast, existing generating plant operating parameters, costs and operating parameters of candidates power plants, and various other related data. The fuel prices are assumed as constant. Once in a few years, CEB updates the hydrology database and updates the hydroelectric capacity and energy availability from the multi-purpose cascade of reservoirs. Periodically the CEB gets the services of independent overseas consultants to review the current practice of CEB generation planning.

The Wien Automatic System Planning Package (WASP 4) used for the generation expansion planning studies is designed to find the economically optimal generation expansion policy for an electric generating system within user-specified constraints. It utilizes probabilistic estimation of system production costs, expected cost of un-served energy and reliability. The optimum generation mix to meet the demand for power and energy in a particular study period is evaluated using dynamic programming techniques for comparing the costs of alternative system expansion policies.

The objective cost function (Bj) which is optimized in the study using the WASP methodology is:

$$B_j = \Sigma\, [I_{jt} - S_{jt}] + F_{jt} + M_{jt} + O_{jt}$$

Where,

I = discounted capital investment costs
S= discounted salvage value of investments

F= discounted fuel costs
M= discounted operation and maintenance costs
O= discounted outage (un-served energy) costs
t= length of study period
j= total number of possible expansion plans

The optimal expansion plan is defined by the minimum [B_j] out of all possible configurations.

The program can consider up to 12 types of thermal plants and two categories of hydro plants as candidates to meet the demand for power and energy. The hydrological information used to describe the energy capabilities of existing and candidate hydro plants have been developed by the reservoir operation simulation model, SYSIM.

The analysis and optimization is based on discounted costs of total system expansion. Both operating costs and investment costs for the candidate plants are considered while only operating costs are considered for the existing plants. A penalty is imposed on the amount of electricity that the system is unable to serve and is added to the total cost. At the end of the planning horizon, a salvage value for plants are also included in the cost function, as a benefit.

Despite the fact that there are limitations and weakness in the WASP computer model as a policy making tool, the Energy Forum study team decided to use the WASP model as a study component as it is easier to initiate a constructive dialog with the CEB on the study outcomes.

3.2. Objective

The main objective of the study was to study the impact of considering renewable power generating technology options which can deliver firm energy as candidate plants in the present generation planning methodology used by the national electricity utility, Ceylon Electricity Board. Also the study aims at capturing other global economic implications, especially on fuel price, which were not adequately captured by the utility.

3.3. Planning Model

In order to compare with the generation expansion studies conducted by the utility, WASP IV, which was developed by International Atomic Energy Agency (IAEA), was used for the study. The limits of some of the key inputs to the WASP IV are shown below.

Parameters	Maximum Allowable
Years of study period	30
Periods per year	12
Load duration curves (one for each period and for each year)	360
Cosine terms in the Fourier representation of the load duration curve of each period	100
Types of plants by "fuel" types of which: 10 types of thermal plants;	12

and 2 composite hydroelectric plants and one pumped storage plants.	
Thermal plants of multiple units. This limit corresponds to the total number of plants in the Fixed system plus those thermal plants considered for system expansion.	88
Types of plants candidates for system expansion, of which: 12 types of thermal plants; 2 hydro electric plant types, each one composed of up to 30 projects, and 1 pump storage plant type with up to 30 composite projects.	15
Environmental pollutants	2
Group limitations	5
Hydrological conditions	5
System configurations in all the study period	5,000

3.4. Input Data

In addition to the four hydro options, Broadlands, Ging Ganga, Uma Oya and Moragolla, the following thermal plant options were considered in the study. The planning period considered was from 2006-2025, and only the output from 2006-2020 is presented.

	Steam-oil	**Steam-oil**	**Coal-WC**	**GT-oil**	**GT-oil**	**GT-oil**		**Comb cy-oil**	**Dendro**	**Dendro**	**LNG**
Capacity (MW)	150	300	300	35	75	105	150	300	100	300	500
Fuel	fuel oil	fuel oil	Coal	diesel	diesel	diesel	diesel	diesel	wood	wood	LNG
Annual Fixed O&M (US$/kW month)	0.782	0.541	0.578	0.524	0.451	0.396	0.397	0.3	0.6	0.6	0.28
Variable O&M (USCents/ kWh)	0.429	0.212	0.226	0.42	0.36	0.315	0.341	0.257	0.2	0.2	0.233
Scheduled Maintenance (days)	40	40	40	30	30	30	30	30	55	55	30
Forced Outage Rate (%)	2.74	2.74	2.74	8	8	8	8	8	10	10	5
Calorific Value(kCal/kg)	10,300	10,300	6,300	10,550	10,550	10,550	10,550	10,550	3,583	3,583	13,205

Min. Operating Level (%)	25	25	25	100	30	30	33.3	33.3	30	30	33.3
Heat Rate at Min Op. level (kCal/kWh)	2873	2,687	2,687	3,062	4,134	4,134	2,614	2,457	5,024	5,024	2,422
Heat rate at Max Oper. Level (kCal/kWh)	2404	2,293	2,293	3,062	2,859	2,859	1,842	1,789	5,024	5,024	1,722
Capital cost inc. IDC (US$/kW)	1,272.5	1,075.6	1,269.9	624.8	510.5	424.9	879.4	716	1,200	1,200	1,345
Construction Period(yr)	4	4	4	1.5	1.5	1.5	3	3	3	3	3
Life(Yr)	30	30	30	20	20	20	30	30	30	30	30

Table 3.4.1 - Thermal Plant Options input data

3.5. Scenarios

As shown in the Table 3.5.1, the scenarios were selected to analyze the probable economic conditions on the long term generation expansion plan. Scenarios 3 to 11 has considered Dendro power plants as candidates (fuel wood price at Rs.3/ kg except for scenario 4, 5 and 7)

Scenario	Description
1	CEB base case with old fuel prices
2	CEB base case with new fuel prices (oil @ $74/ bbl, coal $67/ ton)
3	Include Dendro as a candidate at Rs. 3/ kg (result is same as of case 2)
4	Dendro at Rs 2/ kg
5	Assuming that the economic cost of fuel wood would be Rs. 2.15/ kg (3*0.72)
6	Coal price increase to $80/ ton by year 2020 (linear increase)
7	Include urea benefit as Rs Cents 50/ kWh on Dendro price
8	Upper Kotmale Hydro project included as a candidate plant and at 8% discount Rate
9	LNG fired combined cycle plant as candidate (result is same as of case 2)
10	All options with externalities
11	Discount rate at 4%

Table 3.5.1 - Different Planning Scenarios

The external cost, used in scenario 10, of each energy source is based on the EU values and they have been adopted to reflect the Human Development Index (HDI) value of Sri Lanka (see table below).

Energy Source	**External Cost (US Cents/ kWh)**
Coal	7.6
Oil	6.8
Gas	2.4
Nuclear	0.4
Biomass	1.5
Hydro	0.4
Wind	0.2

Table 3.5.2 - External Costs of Generation

Also in all the cases (scenario no 3 and above) have considered Dendro plants (both 100 MW and 300 MW) as a candidate thermal option.

3.6. Results and Analysis

3.6.1 Capacity Additions

The capacity additions over the planning period, 2006-2020 of each scenario is shown in the table below.

Case	Capacity Additions (MW) 2006-2020							Total (MW)
	Gas turbine	Comb. Cycle-oil	Coal steam	Steam - oil	Dendro	LNG	Hydro	
1	735	0	3,000	0	0	0	0	3,735
2	705	0	3,300	0	0	0	0	4,005
3	705	0	3,300	0	0	0	0	4,005
4	525	0	3,300	0	200	0	0	4,025
5	600	0	3,300	0	100	0	0	4,000
6	1,205	0	1,500	0	1,100	0	261	4,066
7	705	0	3,300	0	0	0	0	4,005
8	625	0	3,600	0	0	0	150	4,375
9	705	0	3,300	0	0	0	0	4,005
10	635	300	3,000	0	0	0	261	4,196
11	315	0	3,600	0	0	0	111	4,026

Table 3.6.1.1 - Capacity Additions for different scenarios

Even with the higher oil price ($74/ bbl), the capacity additions would not change significantly (see figure below) compared to the CEB base case (with old fuel prices). Even in scenario 1, only gas turbines are selected as oil fired thermal capacity additions, which are having very low plant factors (used for supplying electricity at the peak time), and hence even with high oil prices, there would not be a significant impact to the overall cost.

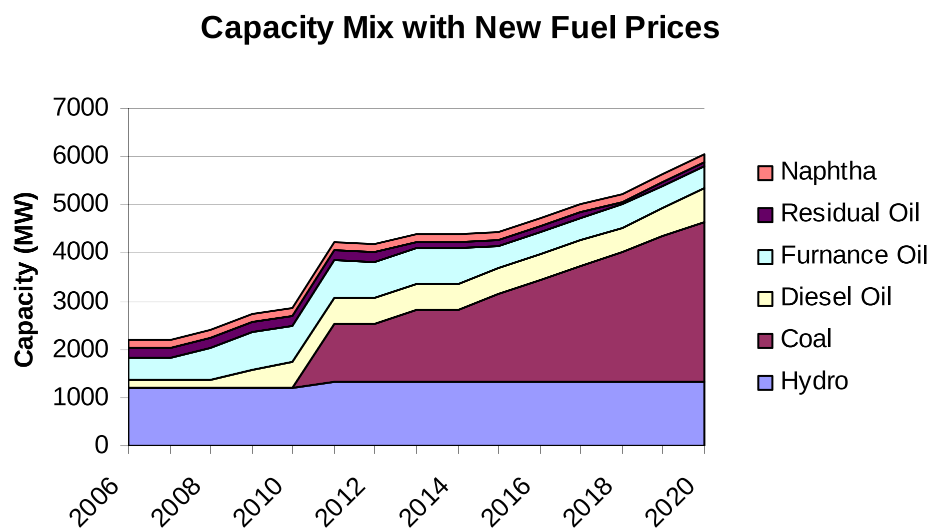


Figure 3.6.1.2 – Capacity Mix with New Fuel Prices graph

At Rs. 2/kg of fuel wood price, the Dendro plants would be selected (200 MW by year 2020) in the generation plan, however the capacity cost estimated ($1,200/ kW) does not cover the plantation establishment cost to the economy. Also the Rs 2/kg is assumed to be the market value for fuel wood; hence it does not fully reflect the actual economic cost of fuel wood.

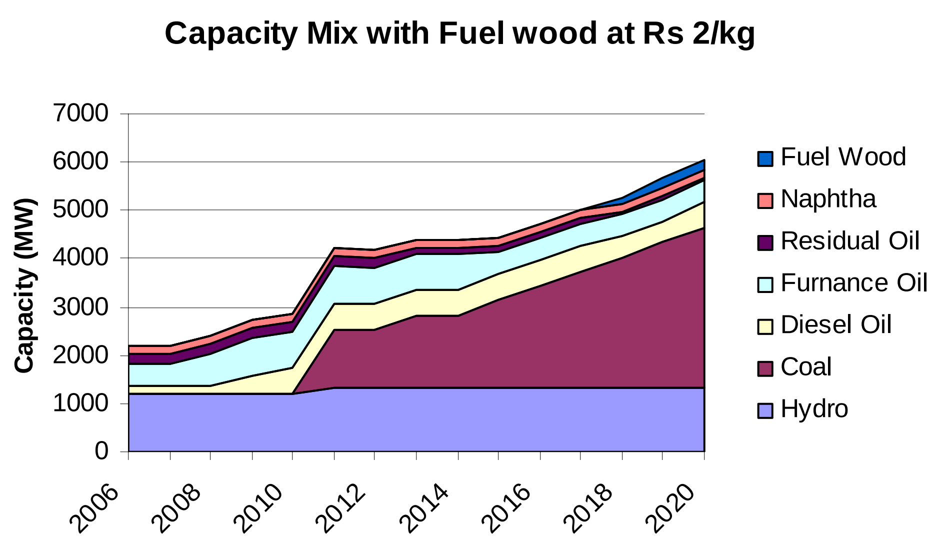


Figure 3.6.1.3 – Capacity Mix with Fuel wood at Rs2/kg graph

The economic cost of fuel wood was estimated using the composite factor used by the Central Bank of Sri Lanka to estimate the economic costs. Hence it was found that there would be 100 MW of Dendro thermal plant additions during the planning period 2006-2020 (see figure below).

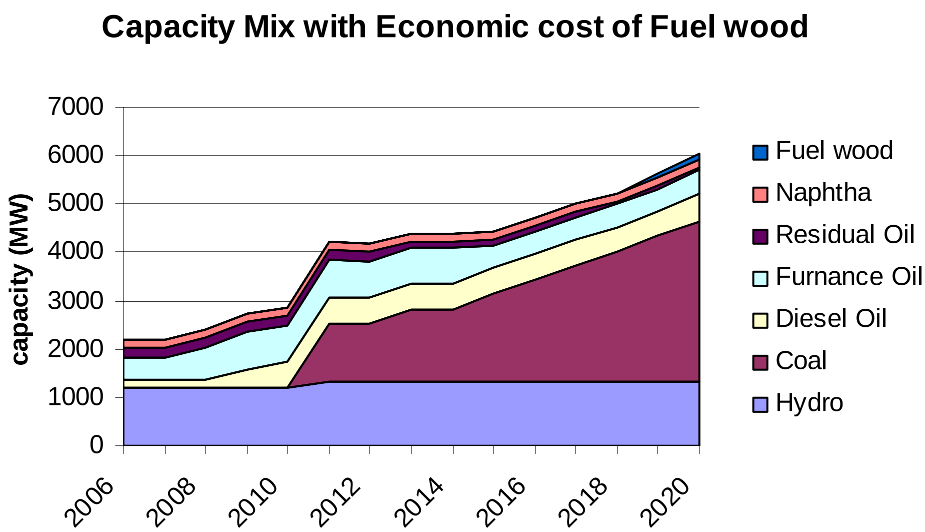


Figure 3.6.1.4 – Capacity Mix with Economic cost of Fuel wood graph

When externalities are considered as a cost, the hydro plant additions would be higher (261 MW by year 2020; all the available options are selected).

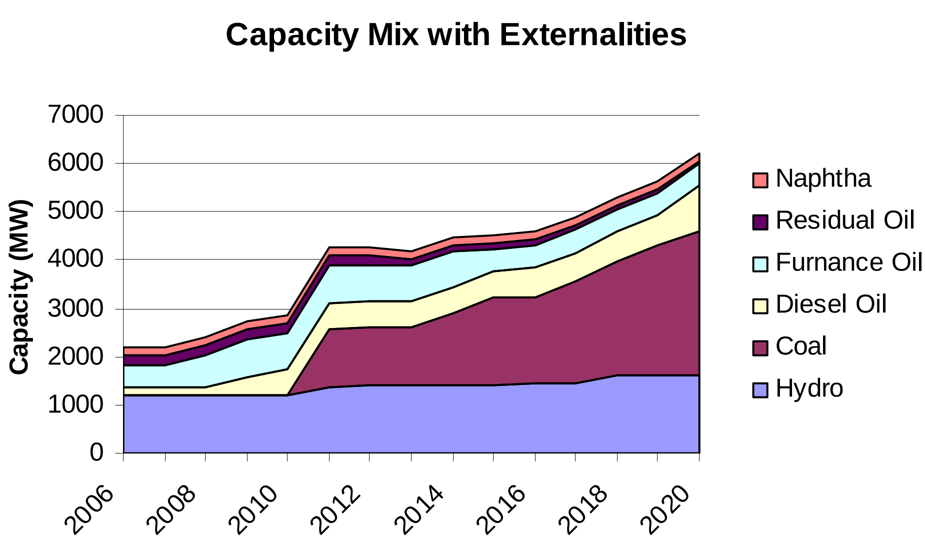


Figure 3.6.1.5 – Capacity Mix with Externalities graph

Also as shown in Table 3.6.1.1, when coal price is increased from $ 67/ ton in year 2006 to $ 80/ ton in year 2020, there would be 1,100 MW of Dendro plant additions (total potential allowed) and 261 MW of hydro plants would be added by replacing the coal fired power plants in the base case (scenario 2).

LNG fired combined cycle plants would not be selected due to its very high capital cost (including terminal construction cost) and fuel cost compared to a coal fired steam power plant.

Although the Upper Kotmale hydro power plant is under construction, it was considered as a candidate plant in Scenario 8. It was found that this project would not have been economical at 10% discount rate, while it becomes economical at 8% discount rate. Also at 4% discount rate (scenario 11) all the candidate hydro plants except Uma Oya are selected. However the hydro plants replace only the oil fired gas turbine plants.

3.6.2 Fuel Cost

As shown in the figure below the expected cost of fuel (scenario 2) would shift from oil to coal and increase at a lower rate compared to the period 2008 to 2011. The sharp drop in fuel cost for 2011 is due to the addition of Upper Kotmale hydro power plant.

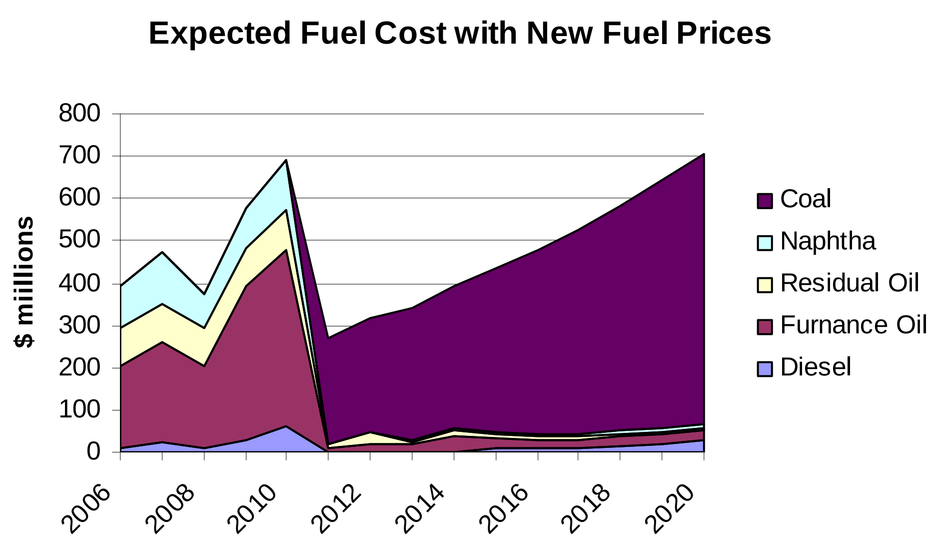


Figure 3.6.2.1 – Expected Fuel Cost with New Fuel Prices graph

When an increase in coal price from $ 67/ ton at present to $ 80/ ton by 2020 is assumed a substantial part of the cost on coal would be replaced by domestic fuel wood (as much as $ 210 million worth of coal in 2020). However it must be noted that the total fuel bill would still increase to $ 900 million (from $ 700 million in scenario 2) in 2020.

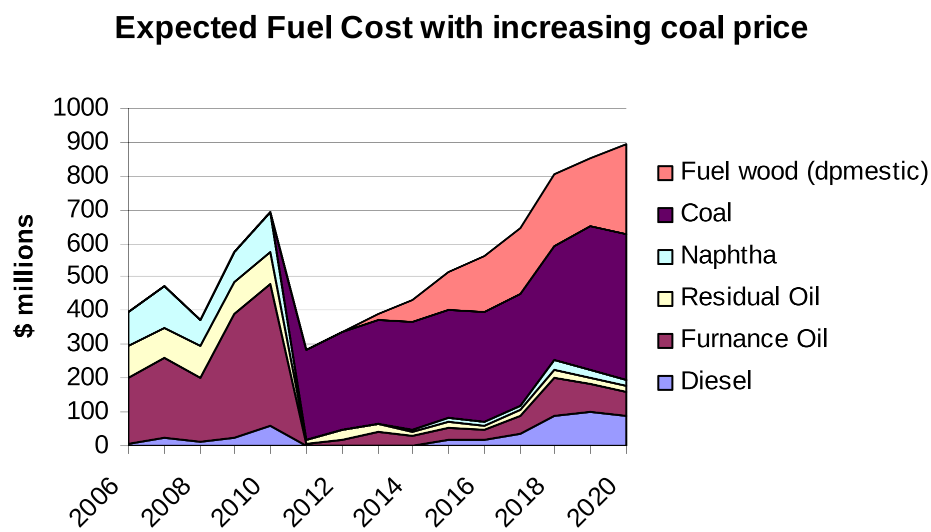


Figure 3.6.2.2 – Expected Fuel Cost with increasing coal price graph

3.6.3 Costs

The total discounted costs over the planning period 2006-2020are shown in the table below;

Scenario	Discounted Total Cost (k$)
1	4,103,581
2	5,150,291
3	5,150,291
4	5,165,584
5	5,157,638
6	6,521,134
7	5,150,291
8	6,008,620
9	5,150,291
10	10,096,390
11	7,700,069

Table 3.6.3.1 – Discounted Total Cost per Scenario

As expected the costs with new fuel prices would be about 25% higher compared to the CEB base case. In the case with Rs 2/ kg for fuel wood, the total discounted cost has increase by about $ 15 million, however the overall total cost of the system by year 2025 would be lower, since the plan was done for the period 2006-2025 and only the period from 2006-2020 is presented (similar to the CEB base case).

The costs for the scenario with escalating coal price is 26.6% higher than the case with new fuel prices, due to lack of cost wise competitive generating options compared to coal fired steam power plants (even with lowered fuel wood prices). As expected, the total discounted cost for the scenario with external cost is very high.

In the case with 4% discount factor, as expected the present value of future cash flow would be higher hence the total cost had increased by about 36%.

3.7. Conclusions

Considering that the main objective of centralized generation planning is to minimize the overall cost to the country, it is important that the planning process takes into account the economic costs of generation instead of financial costs.

Dendro plants would only be economical at a fuel wood price of Rs. 2 per kg. However it is worthwhile to include it in the generation expansion planning studies, with detailed studies on the cost base for all the technologies. In the regard it is also important that the cost of fuel wood for Dendro plants is properly determined and included in the model in terms economic costs.

The capital cost of Dendro plants considered ($ 1,200/ kW) does not include the economic cost of plantation establishment; hence the economic cost of fuel wood production and plantation establishment should be considered for national planning and included in the final fuel wood price.

The WASP IV generation planning model have limitations on the number of options per year, hence it does not allow the analysis of small generating units. Also it cannot incorporate generating options like Wind plants which cannot be centrally dispatched. Hence use of other generation planning models having adequate scope for all types of generating options would be more appropriate for generation planning.

Scenario studies incorporating possible fuel price escalation in the global context would be important. In this process it may be useful to develop correlations between different fuel types so that fuel price increases are applied to all the interdependent fuels when examining such scenarios.

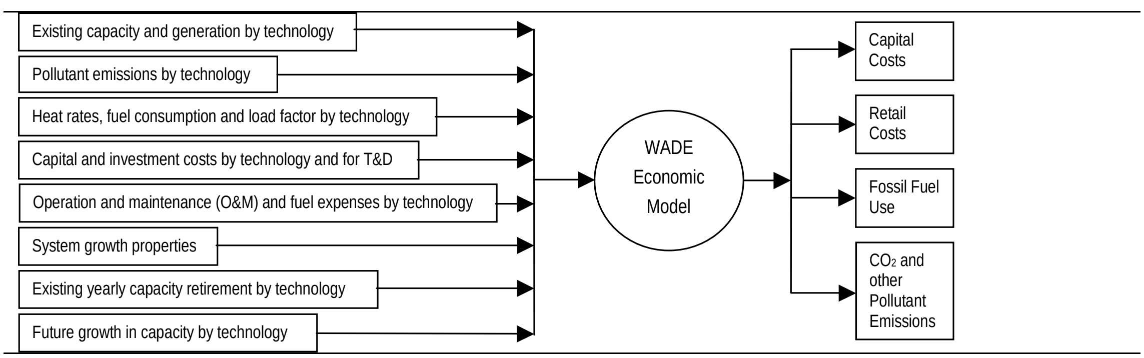
Cost of externalities, though not recommended to be included within the optimization process itself, it can be used to finally examine and compare the impact of different planning outcomes on a common base.

4 Wade Economic Model Application to Sri Lanka

4.1 Aim

WADE was commissioned to apply the WADE model as part of the study to analyse the potential impacts of Distributed Energy (DE) development in Sri Lanka, and provide insights into how DE could be integrated in the CEB's generation planning process.

The purpose of the WADE Economic Model is to calculate the economic and environmental impacts of meeting incremental electricity demand growth with varying mixes of Centralized Generation (CG) and Distributed Energy (DE). With changed input assumptions, the Model can be adapted to any country, region or city in the world. Starting with generating capacity for the current or a recent year, together with estimates of plant retirement rates and demand growth, the model estimates the capacity growth required to meet assumed demand increases, using a specified mix of capacity types over a 20-year period.
The Model's data inputs are detailed and extensive, requiring comprehensive information on a range of factors.



WADE, 2005

Figure 4.1.1 - Data flow of WADE Economic Model

The Model projects new generation and T&D capacity needed to meet incremental demand over 20 years, covering scenarios ranging from 0% DE and 100% CG to 100% DE and 0% CG. The Model also enables users to run any number of scenarios: for example, scenarios that favour certain technologies, involve changes in fuel prices, or aim to meet specific environmental goals. A number of such scenarios were created for the application of the Model to Sri Lanka, as described in this report.

The Model takes into account many real but little-understood features of electricity system operation – such as the significant impact of peak-time network losses on the amount of CG required to meet new demand. For example, with peak T&D losses of 18%, new demand of 1MW could only be met by adding 1.22MW of new CG.

4.2 Process and Timeline

The WADE Economic Model took place from April to August 2006. The process consisted of four stages:

1) Data collection and initial stakeholder meetings – April 2006
2) Data input, Baseline Scenario development and review – May-June 2006
3) Sensitivity analysis and scenario development – July 2006
4) Finalisation of results, evaluation and presentation – August 2006

4.3 Outputs

The WADE Model Application provides results on the capital costs, delivered electricity costs, CO_2 emissions, pollution emissions, fuel use and electricity generation for a Baseline Scenario and a number of sensitivity scenarios. For each scenario the results compare centralized generation with various shares of decentralized generation.

4.4 Introduction

This section describes the scenarios that were developed for the WADE Economic Model application to Sri Lanka. Where possible the input data required by the model were taken directly from the CEB Long Term Generation Expansion Plan 2006-2020 (CEB 2006). Other inputs were based on the available data and projections from various local sources, and on a range of interviews with project developers, CEB officials and other stakeholders in April 2006.

For some of the required data inputs no figures specific to Sri Lanka were available, particularly relating to DE technologies and development. For these the inputs used were based on information from other countries with comparable conditions, drawn from WADE's extensive international network of expertise. In the case various sources gave conflicting information, the inputs were chosen based on the reliability of the various sources, and always in such a way that would not favour DE over CG.

For information about specific inputs or sources, please contact WADE.

4.5 Assumptions and Data for all Scenarios

The following inputs and assumptions were used for all scenarios.

General:

- The analysis covered a 20-year period with 2004 as a base year
- Exchange rate of $0.996422 per 100 LKR

System properties:

- Average T&D losses of 14.1% and peak T&D losses of 18.1%, based on tables 3.2 and 3.3 of CEB 2006
- CG capacity safety margin of 18%, DE capacity safety margin of 5% and T&D capacity safety margin of 5%

Capacity and generation:

- Existing CG capacity, load factors and generation from chapter 2 of CEB 2006
- Existing DE capacity, load factors and generation from chapter 2 CEB 2006 and interviews
- Projected future power plant retirement based on CEB 2006
- Future CG capacity additions from annex 7.2 of CEB 2006, and load factors from annex 7.3 of CEB 2006

Costs and financing:

- Installed capital costs ($/kW) from tables 4.2 and 4.5 CEB 2006 and interviews
- Discount rate of 10% and financing periods from CEB 2006
- Transmission capital costs of $404.72/kW, based on table 7.1 of the CEB Long Term Transmission Development Plan 2005-2014
- Distribution capital costs of $607.08, based on the assumption that transmission represents 20% of total electricity sector investment and distribution 30%[1]
- O&M costs based on table 2.6 of CEB 2006 and interviews
- Current and projected fuel costs based on table 4.4 of CEB 2006 and interviews
- No CO_2 or other pollution emission costs were included

Environmental impacts:

- CO_2 emission factors of fuels from CEB 2006.
- Pollution emission factors for CG technologies from CEB 2006, and from DE technologies from the GEMIS database
- Fuel consumption rates of different technologies based on WADE research

4.6 Baseline Scenario

The Baseline Scenario represents the electricity system in Sri Lanka as it is projected to develop over the next 20 years. For the CG case this is the Base Case Plan of the CEB's generation planning (CEB 2006). The DE case in the Baseline Scenario is based on the on-site power

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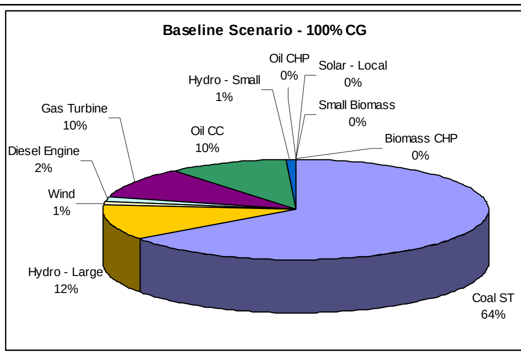
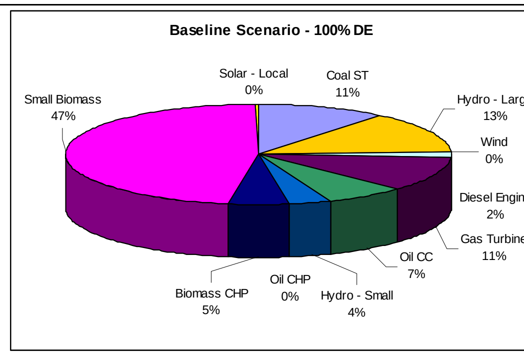
[1] Gemunu Abeysekara, personal communication; this assumption is supported by projections of the IEA (World Energy Outlook 2004), indicating that T&D represents 54% of global energy investment from 2005-2030, with investment in distribution being about 1.5 times investment in transmission.

projects that are planned over the coming years, and the potential for on-site CHP applications on existing industrial sites where biomass or oil is currently being used for heating purposes.

In the CG case most of the new electricity demand is met by coal-fired power stations. Other new generation capacity includes the committed CCY plant at Kerawalapitiya, the Upper Kotmale Hydropower station, and a total of 635 MW gas turbines.

In the DE case the majority of new demand is met by small on-site Dendro plants. A total of 348 MW of Dendro-CHP is also built on existing manufacturing facilities, such as rice mills and tea processing plants. Biomass sources other than Dendro, like rice-husk and Bagasse, play a minor part. The existing potential for mini-hydro plants is also developed.

Figure 4.6.1 illustrates the generation mix for the CG case and the DE case of the Baseline Scenario in 2024.

100% CG Scenario Demand growth: 6.21% Total 2024 electricity demand: 36,582 GWh	100% DE Scenario Demand growth: 6.21% Total 2024 electricity demand: 36,582 GWh
	

WADE, 2006

Figure 4.6.1 - Generation Mixes for the CG and DE cases of the Baseline Scenarios

4.7 Sensitivity Analysis Scenarios

In addition to the Baseline Scenario five variations on the scenarios were run to test the sensitivity of the results to certain parameters, such as generation mix and demand growth. Table 4.7.1 gives an overview of these scenarios.

Scenario	Description
DE Oil Scenario	All Dendro-fired CHP in the baseline replaced by oil CHP.
DE Wind Scenario	All Dendro-fired on-site generation (non-CHP) replaced by small-scale wind power.
Industrial CHP Development Scenario	This scenario models cases, in which various shares (10%, 20% and 50%) of existing on-site industrial heat generation are converted to cogeneration. It assumes that the on-site heat use does not change, and that the electricity generated through CHP displaces grid-electricity. The type of fuel used for CHP is the same as used currently.
Commercial CCHP Development Scenario	This scenario models cases in which various shares (10%, 20% and 50%) of current commercial electricity consumption for cooling are replaced by CCHP. It assumes that the total amount of on-site cooling requirement does not change, and that the electricity generated through CCHP displaces grid-electricity. The CCHP is assumed to be oil-fired.
Industrial CHP and Commercial CCHP Development	This scenario combines the Industrial CHP Development and Commercial CCHP scenarios to evaluate their combined effect.
Demand-Side-Management Scenario	This scenario models a case in which future annual electricity demand growth is reduced by 0.96% through Demand-Side-Management measures.

WADE, 2006

Table 4.7.1 - Sensitivity Scenarios for the WADE Model Application to Sri Lanka

Additional sensitivity analysis was performed for the DE Oil and DE Wind Scenarios. For the DE Oil Scenario a case in which all biomass generation, both CHP and non-CHP, was replaced by oil-fired generation. For the DE Wind Scenario, the sensitivity of the results to the discount rate was explored by lowering the discount rate to 4%.

The Industrial CHP Development and Commercial CCHP Development Scenarios are based on data from the Sri Lanka Energy Balance from the Energy Conservation Fund and WADE research on technologies and applications in comparable circumstances. Table 4.7.2 gives the potentials for industrial CHP development and commercial CCHP development, as well as the figures used in the scenarios.

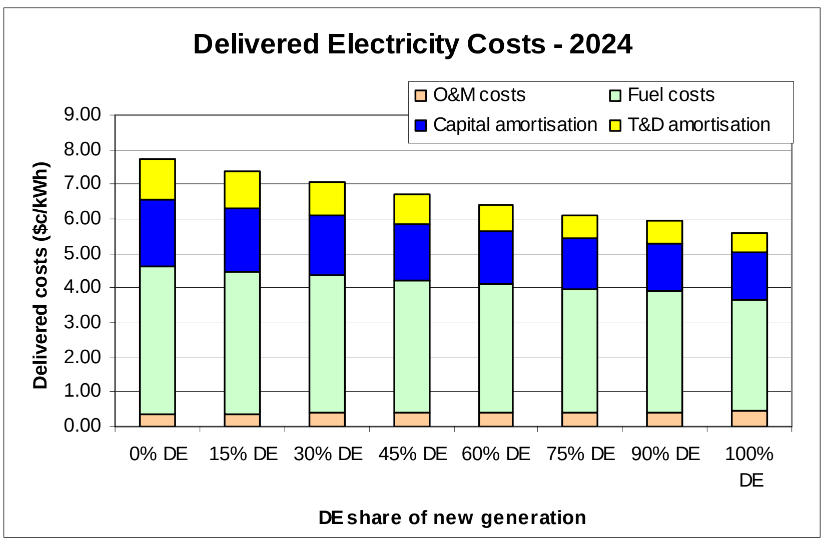
Scenario	Total Potential (GWh/yr)	10% (MW)	20% (MW)	50% (MW)
Industrial CHP	7,403	136.1	272.2	680.6
Commercial CCHP	929	16.3	32.6	81.6

WADE, 2006

Table 4.7.2 - Industrial CHP and Commercial CCHP Potential and Scenarios

4.8 WADE Economic Model Results for Sri Lanka

Main finding: DE can meet future electricity demand in Sri Lanka at lower cost than traditional Centralised Generation.



WADE, 2006

Figure 4.8.1 - Delivered Electricity Costs for the Baseline Scenario for Sri Lanka

The WADE Economic Model results for Sri Lanka indicated that future electricity demand could be met at lower costs with DE than with CG (Figure 4.8.1). In the baseline scenario the capital costs are 42% lower and delivered electricity costs 27% lower if all new generation capacity is distributed rather than centralised (Table 4.8.2).

	100% CG	100% DE	DE Saving	% Reduction
Capital costs (billion $)	8.66	5.02	3.64	42%
Delivered electricity costs ($c/kWh)	7.71	5.60	2.11	27%

WADE, 2006

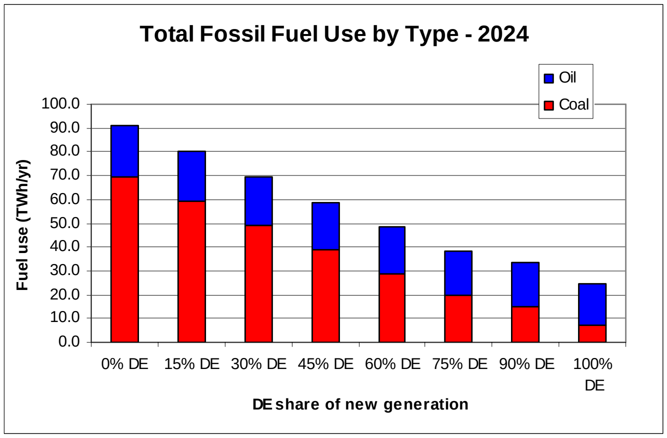
Table 4.8.2 - Potential Capital costs and delivered electricity costs savings through DE

The main reasons for the lower costs of distributed generation are:

- Decentralised generation is more efficient, because it avoids network losses by reducing transmission requirements, and on-site generation allows for the combined generation of heat and power. DE therefore need to generate less electricity to meet the same total demand: in the 100% CG case total generation in 2024 is 42,538 GWh, while DE can meet the same demand by generating only 37,719 GWh. DE therefore requires less new capacity, and uses less fuel, which translates into costs savings.
- On-site power generation also means that less network is needed to deliver electricity to users, so that network investment costs are lower.

Additional finding 1: DE can reduce reliance on fuel imports by taking advantage of the large available biomass resource in Sri Lanka.

The results of the WADE Model scenarios for Sri Lanka also show that with increasing shares of DE the amount of imported coal and oil used for electricity generation decreases (Figure 4.8.3). In the Baseline Scenario total coal use is 225 PJ less in the 100% DE case, a reduction of 90%, and oil use is 17% lower. Even in the DE Oil Scenario oil use still decreases by 4.8 PJ, or 6%.



WADE, 2006

Figure 4.8.3 - Fossil Fuel use by Type for the Baseline Scenario for Sri Lanka

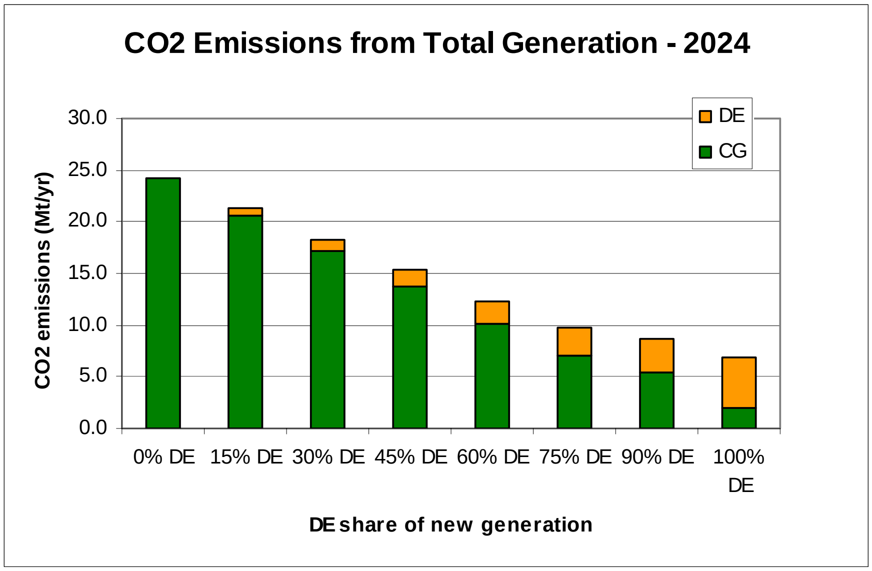
The reasons for the lower fuel is are:

- DE generation is more efficient through using CHP and avoiding T&D losses
- DE cases use more indigenous biomass fuel. In the 100% DE Baseline Scenario the total biomass use is 48.7 TWh/yr, so even with that included the total fuel use decreases by 17.2 TWh/yr compared to the CG case.

These results indicate that DE can help reduce Sri Lanka's reliance on imported coal and oil, and allow the country to take advantage of the large biomass resources.

The significance of the impacts of using imported oil is clearly shown by the further exploration of the DE Oil Scenario. If only biomass co-generation is replaced by oil-fired co-generation (about 10% of all biomass used in the DE baseline) both fuel use and total delivered cost of the DE case will still decrease relative to the CG case. However, if all biomass is replaced by oil CHP, the fuel use of the DE case remains 140 PJ/yr lower, because of the higher efficiency, but oil use is higher, so fuel costs rise too. Consequently the delivered electricity costs for DE in this case are higher too, though only 4%, so easily within the uncertainty of future oil prices. This clearly illustrates that importing foreign fuel has concrete economic disadvantages compared to using indigenous fuel.

Additional finding 2: DE results in lower CO_2 emissions from electricity generation in Sri Lanka than CG.



WADE, 2006

Figure 4.8.4 - CO_2 Emissions from total electricity generation in Sri Lanka

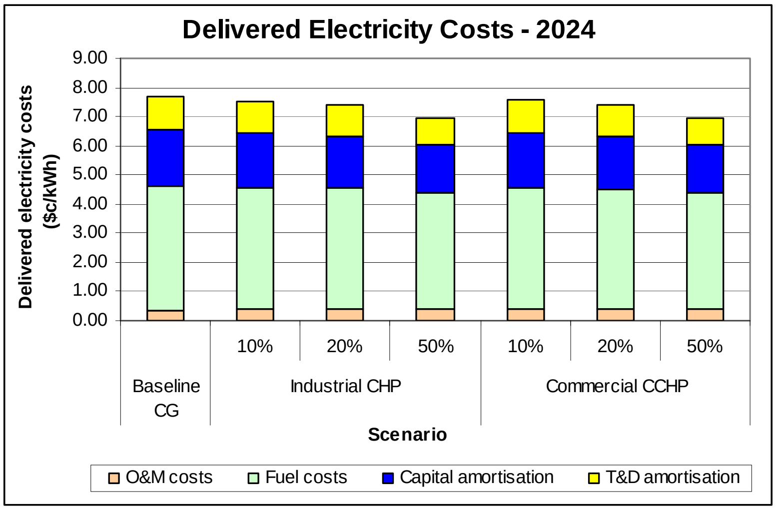
The CO2 emissions from electricity generation in Sri Lanka are substantially lower for all scenarios run for the WADE Model (Figure 4.8.4). In the Baseline Scenario CO2 emissions are reduced by 17.25 Mt/yr from the 100% CG case to the 100% DE case (Table 4.8.5), while even in the DE Oil Scenario CO2 emissions are 69% lower.

	100% CG	100% DE	DE Saving	% Reduction
CO2 emissions from new capacity (Mt/yr)	22.08	4.83	17.25	78%
CO2 emissions from total capacity (Mt/yr)	24.26	7.01	17.25	71%

WADE, 2006

Table 4.8.5 - Potential CO_2 Emissions reductions through DE

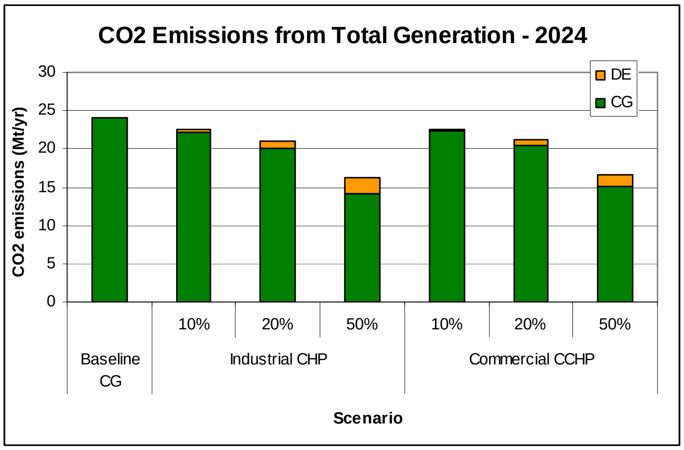
Additional finding 3: The potential for CHP and CCHP applications in Sri Lanka is considerable, and can deliver concrete Cost savings and emissions reductions.



WADE, 2006

Figure 4.8.6 - Delivered electricity costs for the industrial CHP and Commercial CCHP development scenarios

The modeling results indicate that developing the potential for industrial CHP and commercial CCHP in Sri Lanka can reduce both electricity costs and CO2 emissions compared to the centralised Baseline Scenario (Figures 4.8.6 and 4.8.7). The reasons for this are the higher operational efficiency of these technologies, and the lower network losses. Capital costs and fuel use are also lower.



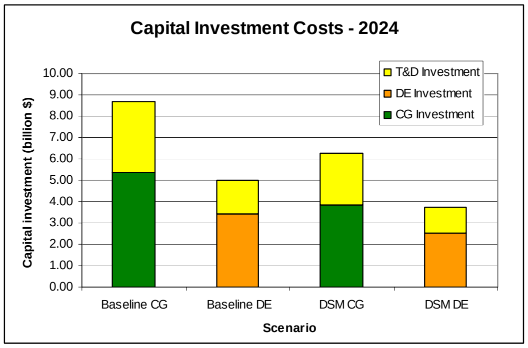
WADE, 2006

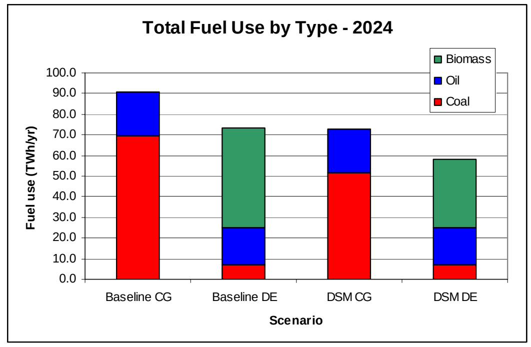
Figure 4.8.7 - CO_2 Emissions for the industrial CHP and Commercial CCHP development scenarios

The graphs indicate that the potential savings are larger for industrial cogeneration development and that commercial CCHP can also make a considerable contribution. Industrial CHP applications are probably more feasible in the short term, because these generators and heat-recovery boiler systems would be installed on industrial sites where heat-only boilers are already present. Commercial CCHP development would require installing on-site generators in commercial centers, where currently cooling demand is met by systems using grid-electricity. In the longer term these applications are very attractive, though, because many of these commercial buildings are in urban areas, where electricity demand is also significant, so that the electricity output can be used close to the point of generation as well.

Additional finding 4: Demand Side Management measures can significantly reduce costs, emissions and fuel use.

The single most important parameter influencing all results of the WADE Economic Model for Sri Lanka is the demand growth. The DSM Scenario shows that reducing the future demand growth by 0.96% through demand-side-management measures can reduce capital investment costs and fuel use significantly (Figure 4.8.9). CO2 emissions are also reduced by 23%.





WADE, 2006

Figure 4.8.9 - Capital costs and Fuel use for the DSM Scenario for Sri Lanka

The graphs in figure 8 also show that the DE case of the Baseline Scenario achieves a fuel-use reduction comparable to a demand reduction of about 1%, while being more cost-effective.

Additional finding 5: The potential for wind generation is considerable, but load factors need to be increased

Capital and delivered electricity costs were lower for all scenarios run, except the DE Wind Scenario. The delivered electricity costs in this scenario were 3.42 $c/kWh higher in the 100% DE case than in the 100% CG case.

The reason for the higher costs in the DE Wind Scenario was the low load factor of existing wind generation in Sri Lanka of 14%, which meant that many new wind turbines had to be replaced to meet demand. The island's potential for wind power is large, so this would be technically possible, but clearly not economically attractive. However, international experience shows that operational load factors for wind farm can be as high as 30%2, at which delivered electricity costs for the 100% DE case come down to 6.43 $c/kWh, a reduction of 17% from the Baseline Scenario.

Further sensitivity analysis of the impacts of discount rates on the results of the DE Wind Scenario showed that at a discount rate of 4% for all generation capacity delivered electricity costs for DE that are only 1.79 $c/kWh higher than for CG. This is quite significant when compared to 3.42 $c/kWh at a discount rate of 10%. This means that at the lower discount rate DE becomes beneficial in terms of delivered costs at a load factor of 19.5%, which should be easily achievable.

4.9 Conclusion

The WADE Economic Model application to Sri Lanka shows that increasing the share of DE can deliver a number of benefits to the country's electricity system:

[22] See DTI, Digest of the UK Energy Statistics, 2006. http://www.dti.gov.uk/energy/statistics/source/

- Capital investment costs and delivered electricity costs can be reduced by 42% and 27% respectively.
- The consumption of imported coal and oil can be lowered by 90% and 17% respectively. DE can therefore reduce the country's reliance on foreign energy source, and facilitate the use of indigenous biomass resources.
- CO_2 emissions from electricity generation can be reduced by as much as 71%.

The WADE modeling outputs also indicated that industrial CHP development is the most effective way to deliver these benefits in the short term, while commercial CCHP development is an attractive long-term option.

Demand growth proved to be the most important factor determining the economic costs and environmental impacts of electricity generation. Generation mix also influenced these, as the DE Wind Scenario shows, but to a less extent.

5 Multi Criteria Analysis

5.1 Introduction

The plans formulated by the CEB since 1990 have not been implemented due to resistances by the civil society groups.

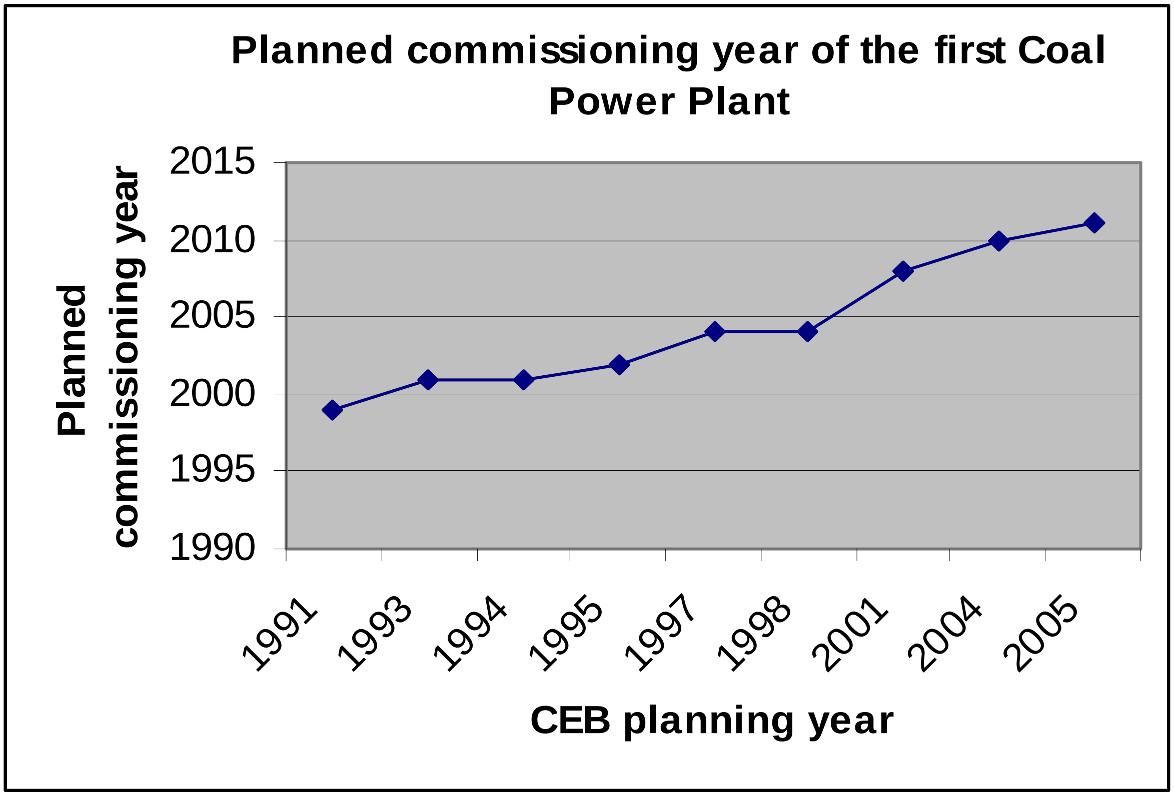


Figure 5.1.1 - Planned Commissioning year of the first coal Power Plant

5.2 CEB Position on Social Environmental Concerns

No participatory methodologies were applied by the relevant authorities to get the inputs from the key stakeholders in formulating the generation expansion plans. In the absence of such an initiative, mass protests resulted in the Government of Sri Lanka postponing the commissioning of the CEB proposed power plants. The resistances were mainly on social and environmental grounds.

The CEB's long-term generation expansion plan says that Sri Lanka has very stringent ambient air quality standards and standards for particulate matter. Further the report claims that the costs of the control technologies are included in the project costs of the candidate plants of the CEB's Long-Term Electricity Generation Expansion Plan (LTEGEP). However, environmentalists believe that the financial costs do not represent the real social and environmental costs involved with power generation

5.3 JICA Study

The JICA funded 'Master Plan Study on the Development of Power Generation and Transmission System in Sri Lanka' was conducted in 2005 to review the CEB's LTEGEP. The study, which was conducted by the Chubu Electric Power Co. Inc. and Nomura Research Institute, Ltd., included a study component on Environmental and Social Considerations. The Strategic Environmental Assessment in the Master Plan Study analyzed the procedures adopted by the CEB and conducted a study on Impact scoping for the base scenario of the CEB's LTEGEP.

The JICA study has paid attention to impacts under three broad categories: Social Environment, Natural Environment and Pollutions & Public Hazards. Each category was sub divided into a number of sub categories. Evaluation of an impact level had been applied to the possibility of it occurring as opposed to the level after mitigation. Thus evaluation was done by giving a grading for the Possibility of Impact. After grading the concerns a score was assigned to the three broad grades. This was done to show the assumed magnitude of significance in the society of Sri Lanka.

Table 5.3.1 – Concern weights

	Item	Weight given
Social Environment	Involuntary Resettlements	3
	Minority or weak people of society	1
	Inequality and separation in society	2
	Cultural heritage	3
	Local landscape	3
	Economic activities(regional or local)	1
	Water Usage	2
	Contagious or infectious disease	1
	Accidents	1
Natural Environment	Protected area	3
	Geographical & Geological Features Sediment & Hydrology	2 1
	Ecosystems/Wildlife	3
	Global Warming	2
Pollution and Public Hazards	Air Pollution	3
	Water Pollution	3
	Soil Contamination	1
	Wastes	2
	Noise & Vibration	2
	Others	1
	Accidents	2

5.4 Results of JICA Study

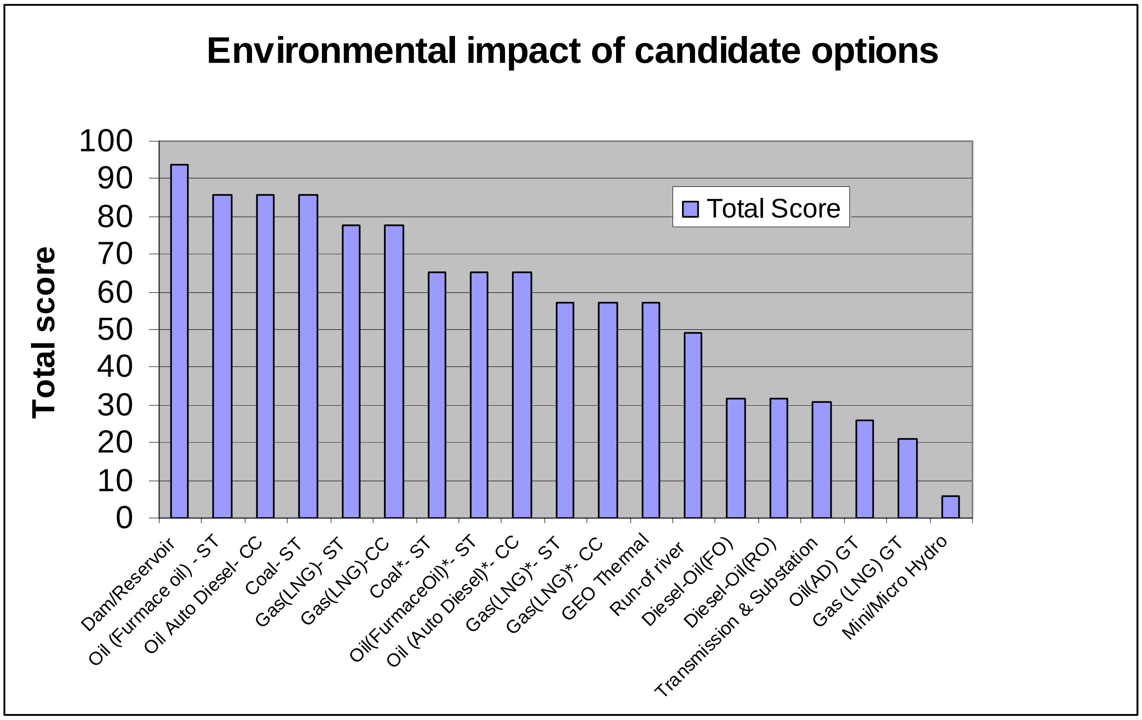


Figure 5.3.2 - Environment Impact of Candidate Options

Applied to thermal power plants with cooling tower system for condenser cooling water

According to the JICA study, the highest environmental impacts are caused by the large hydro power plant.

5.5 Issues relating to JICA Study

1. The Impact level scoping of the Strategic Environmental Assessment in the JICA Master Plan Study was done by a Japanese team of experts and not by local stakeholders. As scoping and scoring are based mainly on concerns an exercise done by a Japanese team of experts is of less value.

2. The basis for scores given to each grade is not clear. Hence there is a greater opportunity of manipulating the final results.

3. The study results show that LNG external costs are higher than that of Coal. This needs further exploration as this maybe different to the globally accepted norms

4. Strategic Environmental Assessment is not inbuilt into the LTEGEP of CEB and hence is of less importance.

5. Despite the concerns raised by various parties the Japanese team has failed to test Dendro power and Wind power. They have however, tried technologies such as Geo Thermal energy in their study.

5.6 Civil society approach on Internalization of Externalities

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group, and this impact is not fully accounted, or compensated for, by the first group. Thus, a power station that generates emissions of SO2, causing damage to building materials or human health, imposes an external cost. This is because the impact on the owners of the buildings or on those who suffer damage to their health is not taken into account by the generator of the electricity when deciding on the activities causing the damage.

The LTEGEP of CEB is of less value for the civil society groups in the current context of power sector decision making and planning. Under the prevailing situation the only tool available for the civil society groups is the Environmental Impact Assessment (EIA). EIA is for enforcing national & regional standards of pollution control for selected power plants. Furthermore, the general public believes the study and the approving procedures are manipulated by the promoters of the selected power plants. The data given in the EIA is often challenged by the affected communities and the civil society organizations. The EIA is currently used in Sri Lanka only as a tool of delaying or canceling power plant construction.

Hence the environmentalists do not consider EIA is an answer for incorporating environmental concerns. These externalities, even if not considered by the planners, have to be borne by some outside parties eventually. If a particular power plant pollutes the surrounding environment then the people living in the area will have to bear any indirect costs involved with the pollution. Any pollution that leads towards long term impacts will be borne by the future generations. To overcome these issues it was proposed to identify the ways and means of internalizing of externalities.

Only a few of the above mentioned environmental impacts were internalized. Prior efforts to quantify burdens and value power sector externalities in Sri Lanka were:

- Resettlement costs of hydro projects (GTZ)
- Opportunity cost of lost production as a result of inundation (GTZ)
- Value of fishery potential in hydro reservoirs (GTZ)
- Quantification of SO2, NOx and ash emissions (GTZ)
- Study conducted by Mohan Munasinghe and Peter Mier

A study conducted by Mohan Minasinghe and Peter Mier conducted in 1994 recommended and suggested the following:

- Valuation of resettlement and lost production cost is reliable
- Valuation of fisheries and irrigation benefits is reliable
- For hydro, valuation of flood control, health and water quality impacts is not significant

- Respiratory diseases are a significant health issue (8% of hospital deaths, 9% of all hospitalization cases)
- Dose-response functions developed in USA were used (Dose-response functions = probability of an individual contracting bronchitis in any one year if exposed to 1ug/m3 of particulates for the entire year)
- Value of a human life is assumed as $400,000 (10% of the estimate of the Pace University Centre for Environment Legal Studies, New York. Here the damage cost method is used and not the control cost method)
- Pace estimate for carbon damage is based on the costs of reforestation to replace an equivalent quantity of carbon. Not the actual damage cost. This figure of $15/ton is considered and used.
- Pace estimates of damages for fossil fuel emissions have been adjusted to reflect the lower values associated with human life ($400,000)
- For hydro projects, the cost of resettlement and opportunity cost of lost production were used.

The following Attributes had been taken into consideration by the Mohan Munasinghe and Peter Mier study:

- SOx, NOx and particulate (for thermal) – health impacts based on human deaths and cost of hospitalization (malaria cases in hydro plants and SOx, NOx and fine particulates in thermal plants)
- CO2 (for thermal and hydro) – based on the cost of reforestation
- Hydro externalities (resettlement and opportunity cost of lost reproduction)
- Employment impacts
- Bio Diversity Index

The results of the Mohan Munasinghe and Peter Mier study:

Percentage external costs of each generation option derived by the study are given below.

Diesel (3.5%S)	- 24.0
Diesel + Nox control (3.5%S)	- 22.3
Coal (Mawella)	- 25.5
Coal +FGD ((Mawella)	- 20.6
Coal (Trinco)	- 29.5
Coal + FGD (Trinco)	- 23.9
Gas turbine Diesel	- 16.0
Combine cycle diesel	- 13.4
Hydro (Broadlands)	- 2.0
Hydro (Kukule)	- 13.9

The percentage increment of costs introduced by the externality additions for each generation option vary within a limited range (13.4 –29.5) – except for the case of Broadlands small hydro. Hence the addition of external costs to already calculated internal costs does not significantly change the conventional least cost plan.

Limitations of the Mohan Munasinghe and Peter Mier study:

It is interesting to compare the results of this study with the figures derived by several externality studies for various fuel types presented in *Environmental Impacts of Electricity Generation*, 25th Annual Symposium Uranium Institute. London, UK; *Environmental Impacts of The Production of Electricity: Comparative Study of Eight Technologies of Electricity Generation*, Spain; and *Environmental Externalities and The Development of Renewable Energy Sources*, Greece. One major highlight is the low external cost values derived for fossil fuels in the Sri Lankan study compared to the studies mentioned above.

Some of the major reasons for the low values for Sri Lanka are given below.
- up-stream externalities are not taken into consideration
- the study uses a 10% discounting rate
- limitations on the number of burdens taken into consideration in the study for Sri Lanka
- `willingness to pay' approach used in valuation tends to provide low values for developing countries
- assumptions made while using data form non-Sri Lankan databases (the study depends heavily on outside data as a result of non-availability within Sri Lanka)

The study uses multi criteria analysis, not as a tool to develop the least cost electricity generation expansion plan, but as a tool for policy analysis to incorporate environmental concerns in generation expansion planning. Here various policy alternatives are compared with the CEB's least financial cost generation plan by considering it as the base case.

The analysis avoids the tricky issue of weighing attributes by using a 'candidate option screening' approach. Each attribute (e.g. pollution represented by emissions) is tested against the financial cost, one at a time, in a two-dimensional plane. The categories of 'quadrant set', 'non-inferior set' and 'knee set' are used to select superior policy options.

By having the conventional least cost plan by the CEB as the base case, the study after the analysis, selects the alternatives of DSM (demand side management using fluorescent lighting), Trincomalee PFBC combine cycle plant and Uma Oya hydro plant as superior policy options. The analysis is also capable of rejecting some of the inferior alternatives (e.g. NO-DSM, Wind in the South Coast, Upper Kotmale and Coal plants low sulfur (0.5%) coal option).

5.7 Aims of the Study

Two stakeholder workshops were conducted under this study to finalize the methodologies for each of the three study components. The Multi Criteria Analysis study component was done in parallel to the other two study components and hence the aim of the study was defined accordingly.

The aim of the MCA analysis was to directly interact with the key stakeholders and list and analyze concerns of different stakeholder groups while selecting the candidate power plant options. The outcome of the MCA study will be used to cross-check the outcomes of the WASP model and explore which of the scenarios of the WADE analysis are in line with the concerns of the each stakeholder groups.

The different WASP scenarios are prioritizing different candidate power plant options for implementation. The MCA study will throw light on selecting the appropriate scenarios and hence the power plant options for implementation. This is done by making the weight given to different concerns visible. The MCA study is not to calculate all the external costs and determine the price of an electricity unit to pass all the costs on to the present day electricity consumer. Hence there is a need to establish an appropriate policy environment for the implementation of the selected scenario to make the selection a reality. Internalizing certain externalities will indirectly benefit the other sectors and hence there is a possibility of sharing costs among the key sectors. Based on the policy decisions a cross-sectoral plan can be established to share the total costs among the key sectors such as agriculture and health that are mostly benefited by the selected Long-Term Electricity Generation Expansion Plan.

5.8 Methodology

The MCA analysis concentrates on two basic factors: the measurable physical impacts & the concerns of different stakeholders.

Measurable physical impacts: As the first step a comprehensive database on candidate power plants was established. The pre-feasibility study reports, feasibility study reports and Environmental Impact Assessment reports were gathered and a database was established. The database includes general information and issues relating to all candidate power plants. Issues are listed against selected technology options. The issues can be environmental, social, technical and economical.

Concerns of different stakeholders: A list of power sector stakeholders was developed and a short-list group was then invited to attend and participate at a workshop. At the workshop stakeholders were divided into three groups. This was done using a question paper consisting of three questions. The three groups met separately and ranked the concerns.

5.9 Key Players

The selected power sector stakeholders were from government institutions, private sector, civil society organizations and the representatives of direct victims of candidate power plants. The direct victims of the candidate power plants were considered as a separate group at the consultative workshop.

The other participants were supposed to belong to three different thinking categories, based on their answers to the three questions:
Group A: the group concentrating on both local and global environmental impacts to ensure the long-term sustainability;
Group B: the group concentrating on national interests with less emphasis on global level environmental impacts; and
Group C: the group considering the economic growth of the country as the crucial factor for the progress of the country.

As it was very difficult to divide the groups a question paper was used for grouping.

	Question	Answer		A	B	C
1	Do you think it is necessary for us to consider the local environmental effects of the candidate power plants, while planning the generation expansion for the next 15 years for Sri Lanka?	Yes (0)	No (0)	0	0	0
2	Do you think it is necessary for us to consider the environmental effects of candidate power plants that happen only at global level, while planning the generation expansion for the next 15 years for Sri Lanka?	Yes (0)	No (1)	0	1	1
3	What do you think the better fuel option for Sri Lanka for next 15 years generation planning?	Dendro (0)	Coal (1)	0	0	1
	Total marks			0	1	2

Marks were given based on the following assumptions:

- Q1 is only to clearly define the Q2 and have no marks.
- Dendro is indigenous and carbon neutral over coal
- Group A - Concerned about both local (0) and global (0) environmental issues and support Dendro (0) as it is Carbon neutral and indigenous- Total 0
- Group B - Keen to safeguard national interests and less concerned about global environmental issues (1) and supports Dendro (0) as it is indigenous- Total 1
- Group C - Concerned about the economic growth of the country and uninterrupted power supply hence less concerned about global environmental issues (0,1) and does not trust Dendro as a viable option (1) - Total 2
- Only other case possible would be 0-0-1 Total -1. Here people are concerned about global environment but has no confidence on Dendro. They were in group 2.

A (0)	Environment concerned group
B(1)	Group with mixed feelings
C (2)	Development concerned group
D	Affected community

5.10 The options Appraised

- Coal (West Coast, Southern Coast, East Coast)
- Oil (gas turbine and combined cycle)
- Hydro (Upper Kotmale, Broadlands, Ginganga, Uma Oya, & Moragolla)
- Dendro
- Wind
- LNG

5.11 Criteria

5.11.1 Criteria for assessing the consequences of each option

The analysis was done to investigate the response of the groups to the following Main Criteria

1. Financial Criterion
2. National Criterion
3. Social Criterion
4. Environmental Criterion

Financial Criterion:

This refers to the financial cost of each option. It is mandatory for all options to adhere to all existing environmental standards. Hence the financial costs include any additional costs involved with meeting the environmental standards specified by the Central Environmental Authority. Financial costs include relevant duties and taxes and also the interests on capital. No discount rate is considered. It is assumed that the consumer tariff is cost reflective. Hence at the end of the day the term 'financial' means a fair indication of the monthly electricity bill of the consumer.

The unit of the financial cost is - Rs. /kWh

National Criterion:

The concerns relating to the country is considered under the National category. The concerns considered under this category include foreign currency savings or usage of each technology, whether the nations dependence for energy on foreign countries further increases or decreases, whether there is a risk involved with ensuring uninterrupted power supply to the nation by selecting any of the candidate options, whether the country gets access to technological know-how that is important to the country by selecting certain options, and whether certain technologies have adverse negative impacts on the cultural heritage and aesthetics. This category is used to discuss the weight given to national concerns of the nation for the next 15 years.

National sub criteria

- Foreign currency Usage - US$/kW
- Impact on Cultural heritage, Aesthetics
- Inability to get technological know-how
- Missing large scale Employment opportunities
- Unreliability of power supply

Social Criterion:

The social criterion refers to the direct impact of the power plant on the communities. This can happen both at the construction stage and the operational stage. The main focus will be on the people living in the power plant area. Benefits to the communities such as infrastructure development are also covered under this criterion.

Social sub Concerns
Community Severance - Loss of employment opportunities, human resettlements
Direct victims of environmental damage
Infrastructure under-development
Vector borne diseases

Environmental Criterion:
All environmental impacts that are not internalized are covered under this criterion. Certain groups do not have faith on the figures given in the feasibility and EIA reports. They wish to consider such concerns separately. Some others consider the national standards are not adequate to safe guard the concerns. Further certain environmental concerns such as CO2 emissions will contribute to impacts irrespective of whether the standards are met. Such concerns can be accommodated under the environmental criterion.

Environmental sub Criteria
Accidents- Related to the plant
Global air pollution - CO_2 (Global warming)
Impact on Environmentally sensitive areas, protected areas, flora, fauna (bio-diversity)
Local air pollution- air temperature, CO, SO_x, NO_x, SPM (ground level and stack)
Sedimentation; Soil erosion; Land degradation
Water quality- Temperature (°C) TSS (mg/l) BOD, COD, marine pollution

5.11.2 Criteria Hierarchy

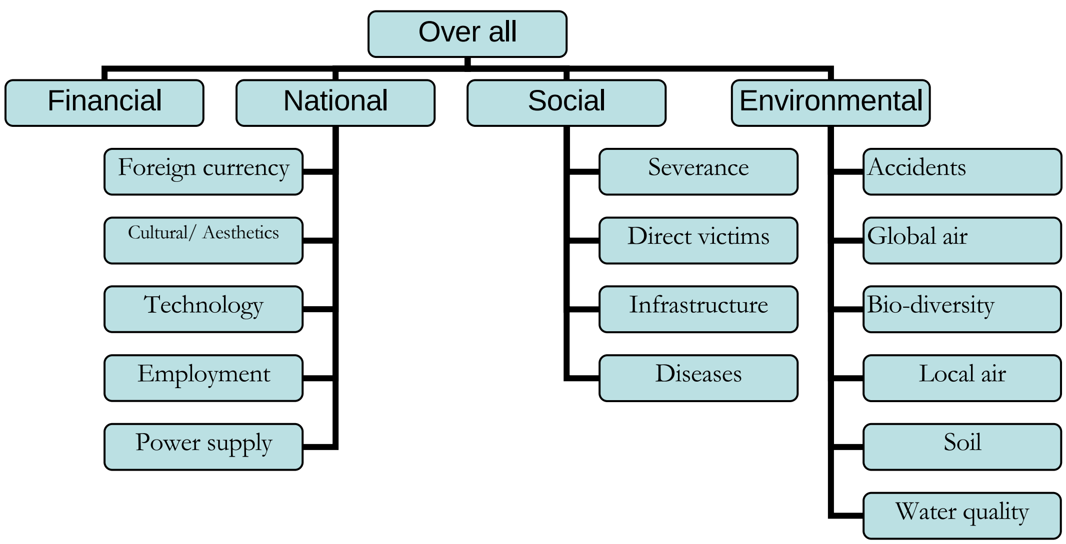


Figure 5.11.2.1 – Overall split of concerns

5.11.3 Scoring

Assessment of the expected performance of each option against the criteria was done by the expert team. They assessed the value associated with the consequences of each option for each criterion.

1 Describe the consequences of the options.
2 Score the options on the criteria.
3 Check the consistency of the scores on each criterion.

Candidate Technological Option	Financial	National					Social				Environmental					
	Unit Financial running cost (UScts/kWh)	Foreign currency Usage USCts/kWh	Cultural heritage & aesthetic value	Technological know-how	Employment opportunities	Unreliability of power supply	Community Severance	Direct victims of environmental damage	Infrastructure under-development	Vector borne diseases	Accidents	Global air	Impact on bio-diversity	Local air pollution	Soil	Water quality
Coal West coast/ Trinco	56.51	17.32	100	100	100	40	100	100	100	0	100	100	50	100	100	100
Auto Diesel Combined cycle	100.00	64.73	80	100	100	50	30	30	100	0	100	39	0	9	20	20
Auto Diesel Gas turbine	94.21	100.00	70	100	100	50	50	50	100	0	100	62	0	15	30	30
Dendro	50.95	2.66	40	40	0	30	0	0	100	0	0	0	0	0	0	0
Wind	69.99	-	50	0	80	50	0	0	100	0	0	0	0	0	0	0
Hydro	93.85	-	60	100	100	100	100	0	100	100	100	0	70	0	10	10
LNG	100.00	16.03	0	100	100	40	0	0	100	0	50	30	0	20	0	0

Table 5.11.3.1 – Option Performance against Criteria

5.11.4 Weighting

This was done as a group exercise whereby each criterion was assigned a weight that reflected their opinion of the importance of that concern.

The steps of the exercise:
1. Select the crucial criterion
2. Give 100 marks to it
3. Now give relative marks to other criteria

This analysis was done to examine the relative importance of the key criteria. The same exercise was done for identifying the relative importance of the sub criteria in each of the key criterion.

A (0)	Environment concerned group
B(1)	Group with mixed feelings
C (2)	Development concerned group
D	Affected community

Relative importance of the key criteria

	Score			
	Financial	National	Social	Environment
A (0)	81.00	100.00	80.00	88.00
B(1)	89.00	100.00	88.00	74.00
C (2)	85.00	100.00	50.00	72.00
Mean	85.00	100.00	72.67	78.00
Std	4.00	-	20.03	8.72
	89.00	100.00	92.70	86.72
	81.00	100.00	52.63	69.28
D	60.00	79.00	68.00	100.00
Weight (ABC)	0.25	0.30	0.22	0.23
Weight A	0.23	0.29	0.23	0.25
Weight B	0.25	0.28	0.25	0.21
Weight C	0.28	0.33	0.16	0.23
Weight D	0.20	0.26	0.22	0.33

Table 5.11.4.1 - Relative importance of the sub criteria

National Criterion

	Foreign currency Usage	Impact on Cultural heritage, Aesthetics	Inability to get technological know-how	Missing large scale Employment opportunities	Unreliability of power supply
A (0)	91.00	76.00	64.00	75.00	100.00
B (1)	95.00	52.00	68.00	56.00	100.00
C (2)	76.00	32.00	52.00	38.00	100.00
Mean	87.33	53.33	61.33	56.33	100.00
Std	10.02	22.03	8.33	18.50	-
	97.35	75.36	69.66	74.84	100.00
	77.32	31.30	53.01	37.83	100.00
D	63.00	100.00	51.00	57.00	76.00
Weight A	0.22	0.19	0.16	0.18	0.25
Weight B	0.26	0.14	0.18	0.15	0.27
Weight C	0.26	0.11	0.17	0.13	0.34
Weight (ABC)	0.24	0.15	0.17	0.16	0.28
Weight D	0.18	0.29	0.15	0.16	0.22

Table 5.11.4.2 - Relative Importance of National Criteria

Social Criterion

	Community Severance	Direct victims of environmental damage	Infrastructure under development	Vector borne diseases
A (0)	82.00	100.00	63.00	-
B(1)	100.00	82.00	63.00	60.00
C (2)	40.00	72.00	100.00	15.00
Mean	74.00	84.67	75.33	25.00
Std	30.79	14.19	21.36	31.22
	104.79	98.86	96.70	56.22
	43.21	70.48	53.97	(6.22)
D	70.00	100.00	60.00	64.00
Weight A	0.33	0.41	0.26	-
Weight B	0.33	0.27	0.21	0.20
Weight C	0.18	0.32	0.44	0.07
Weight ABC	0.29	0.33	0.29	0.10
Weight D	0.24	0.34	0.20	0.22

Table 5.11.4.3 - Relative Importance of Social Criteria

Environmental Criterion

	Accidents	Global air pollution	bio-diversity	Local air pollution	Land degradation	Water quality
A (0)	50.00	60.00	93.00	100.00	70.00	83.00
B (1)	70.00	58.00	78.00	82.00	76.00	100.00
C (2)	35.00	30.00	62.00	100.00	64.00	75.00
Mean	51.67	49.33	77.67	94.00	70.00	86.00
Std	17.56	16.77	15.50	10.39	6.00	12.77
	69.23	66.11	93.17	104.39	76.00	98.77
	34.11	32.56	62.16	83.61	64.00	73.23
D	63.00	73.00	100.00	71.00	60.00	62.00
Weight A	0.11	0.13	0.20	0.22	0.15	0.18
Weight B	0.15	0.13	0.17	0.18	0.16	0.22
Weight C	0.10	0.08	0.17	0.27	0.17	0.20
Weight ABC	0.12	0.12	0.18	0.22	0.16	0.20
Weight D	0.15	0.17	0.23	0.17	0.14	0.14

Table 5.11.4.4 - Relative Importance of Environmental Criteria

5.11.5 Combine the Weights and Scores for each option to derive an overall value

1 Calculate overall weighted scores at each level in the hierarchy.

2 Calculate overall weighted scores.

Candidate Technological Option	Financial	National					Social				Environmental						Score (Cost indicator)	All costs Ranking	Score (External Cost indicator)	External cost Ranking
	Unit Financial cost (UScts/kWh)	Foreign currency Usage USCts /kWh	Cultural heritage & aesthetic value	Technological know-how	Employment opportunities	Unreliability of power supply	Community Severance	Direct victims of environmental damage	Infrastructure under-development	Vector borne diseases	Accidents	Global air	Impact on bio-diversity	Local air pollution	Soil	Water quality				
Coal	56.51	17.32	100	100	100	40	100	100	100	0	100	100	50	100	100	100	67.50	7	53.19	7
Auto Diesel Combined cycle	100.00	64.73	80	100	100	50	30	30	100	0	100	39	0	9	20	20	57.48	5	32.86	4
Auto Diesel Gas turbine	94.21	100.00	70	100	100	50	50	50	100	0	100	62	0	15	30	30	62.55	6	38.70	6
Dendro	50.95	2.66	40	40	0	30	0	0	100	0	0	0	0	0	0	0	19.40	1	6.50	1
Wind	69.99	-	50	0	80	50	0	0	100	0	0	0	0	0	0	0	27.84	2	10.12	2
Hydro	93.85	-	60	100	100	100	100	0	100	100	100	0	70	0	10	10	57.30	4	33.54	5
LNG	100.00	16.03	0	100	100	40	0	0	100	0	50	30	0	20	0	0	42.82	3	17.49	3
Main weight	0.25	0.30					0.22				0.23									
Sub weight		0.24	0.15	0.17	0.16	0.28	0.29	0.33			0.12	0.12	0.18	0.22	0.16	0.20				

Table 5.11.5.1 – Combined weights and scores of each option

5.11.6 Results with Sensitivity Analysis

Candidate Technological Option	External least costs					All Factors				
	All	Group A	Group B	Group C	Group D	All	Group A	Group B	Group C	Group D
Dendro	1	1	1	1	1	1	1	1	1	1
Wind	2	2	2	2	2	2	2	2	2	2
LNG	3	3	3	3	3	3	3	3	3	3
Auto Diesel Combined cycle	4	4	4	4	4	5	4	4	5	4
Hydro	5	5	6	5	6	4	5	6	4	6
Auto Diesel Gas turbine	6	6	5	6	5	6	6	5	6	5
Coal	7	7	7	7	7	7	7	7	7	7

Table 5.11.6.1 – Results of Sensitivity Analysis

5.12 Conclusions

Upon Analysis of the relative importance of key criteria it is clear that all stakeholder groups give priority to national interests. The financial and environmental concerns are of second and third importance respectively. This is a clear shift from the generally accepted principle of "least cost".

Under national interests the main priority is the reliability of power supply and the second priority is foreign currency savings.

Under environmental concerns all groups concentrate more on local air, water and land pollution and worry less about global environmental issues and risks relating to accidents. Direct victims of the power projects are given greatest importance under social concerns.

This exercise gives a ranking with respect to different concerns and prioritizes the candidate options. However this study component was not intended to internalize all external costs based on the concerns of the stakeholders and to come up with cost figures.

The outcomes of the separate group exercises were very much similar. To reach a consensus on the appropriate energy mix for Sri Lanka, a separate exercise should be conducted with the representatives of all stakeholder groups. This should analyze the outcomes of three study components.

6 Financial Analysis

6.1 Introduction

Financial analysis was done to assess performance of different energy technologies on a level playing field. The technologies analysed under the study were Coal, Hydro, Dendro, and Wind. The study did not try to accommodate Oil as it is the last option to be considered due high costs involved. The study analysed to limitations of each technology with respect to financial costs involved.

Financial analysis is an essential component in reaching a conclusion in generation planning. It gives an indication relating to the unit cost of power generation. However the final results of the analysis will be based on the assumptions. Reaching a consensus on the assumptions is not an easy task. Hence for this analysis different cost combinations were used. The results of the study should not be considered as exact cost figures but as figures for comparison.

6.2 Predicting the Oil Price Increase

The first graphs give oil price fluctuations in a longer term and the second graph shows the current trend in oil price increase.

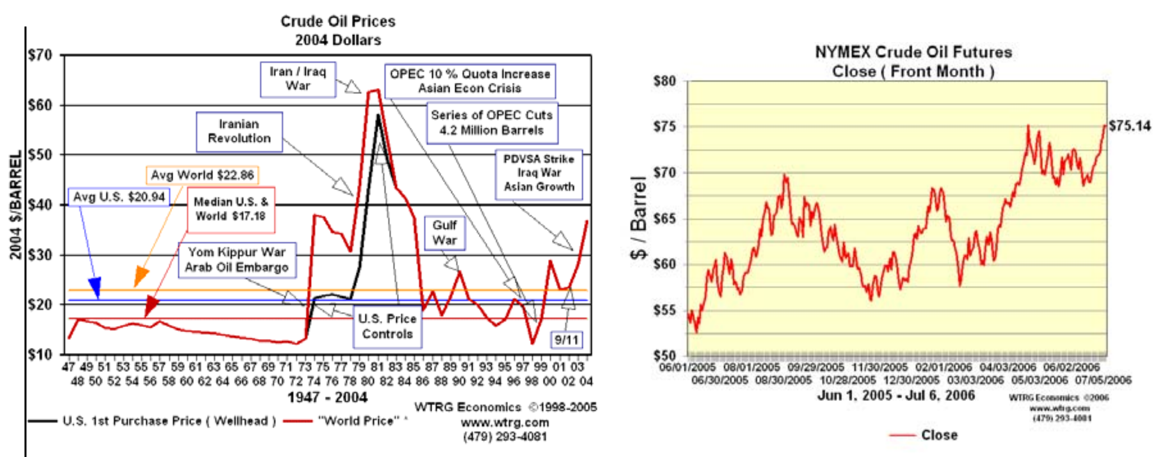
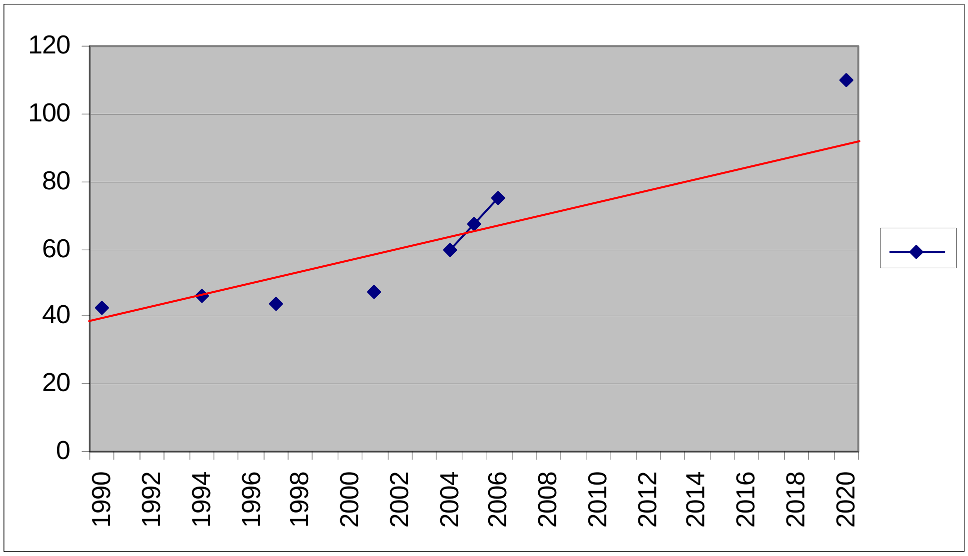


Figure 6.2.1 – Crude oil Prices & Future Crude Oil Prices

6.3 Predicting Coal Price Increase

The coal price increase is dependent on a number of factors and hence is difficult to predict. As a result, the CEB currently does not predict the price increase of coal for their long-term generation planning. Getting a firm estimation for the CIF price of coal is also a difficult task as there are currently no mass-scale coal imports to Sri Lanka. For estimation purposes of this study, the figures used by the CEB for the generation planning in the recent past were analysed. Accordingly the increase rate of coal prices is assumed as 2.67 US$/T/year. As the coal transportation is done using oil the CIF price of coal is linked to the oil price increase.



However from the graph above it is clear that the Japanese CIF coal price has been increasing at a much faster rate of 8.87$/T/year.

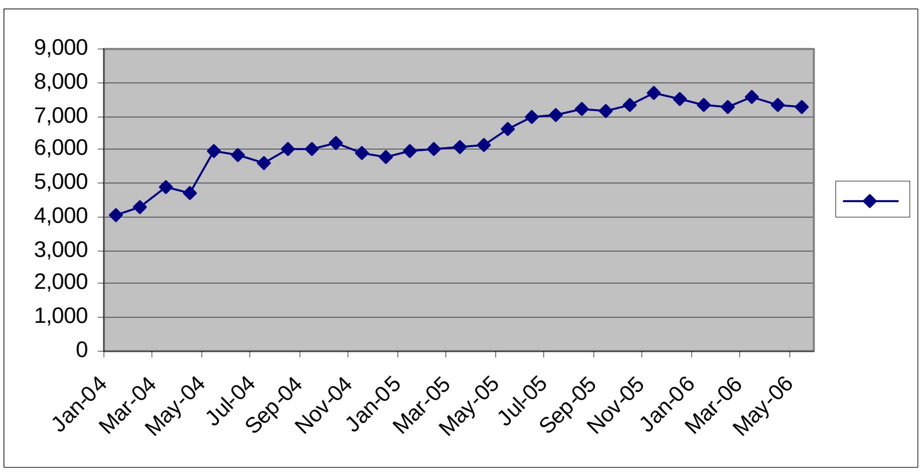


Figure 6.3.1 – Japanese CIF Coal Price increase

6.4 Foreign Currency Exchange rate Increase Prediction

The foreign currency exchange rate prediction is an important factor as it determines the final price of the imported fuel. For this analysis an exchange rate increase of 2.67 Rs./US$/year was assumed.

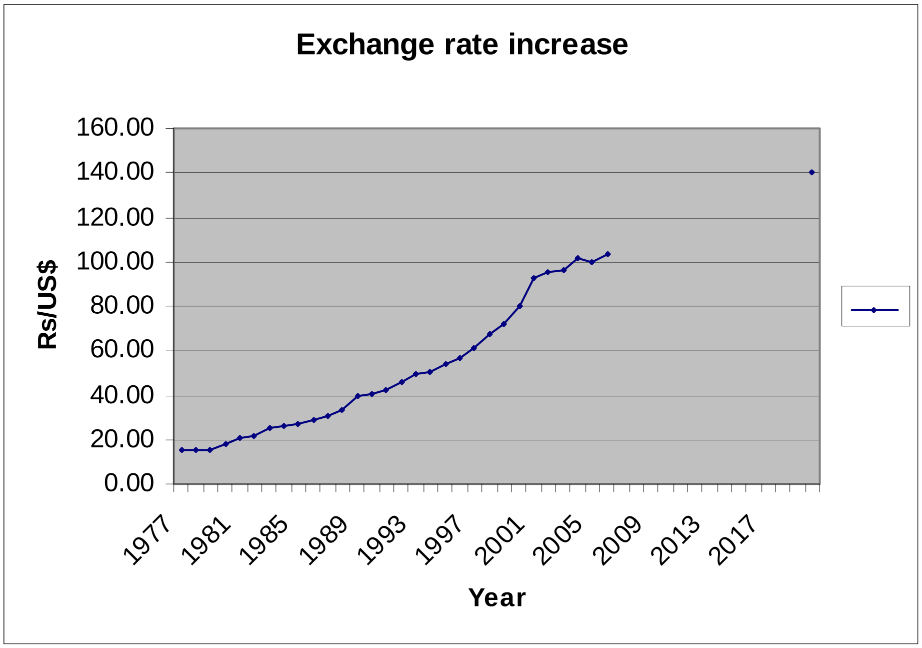


Figure 6.4.1 – Exchange rate increase graph

CDM Benefit for Dendro is taken as 0.65 kg CO_2/kWh and 5US$/T

Input data

Scenario 1: High ROE & high Interest rate

Equity	40%	
Return on Equity	20%	
Debt	60%	
Interest rate	10%	
Loan repayment period	10	years
Discount rate	10%	
Exchange rate	104	

Scenario 2: Low ROE & low Interest rate

Equity	40%	
Return on Equity	4%	
Debt	60%	
Interest rate	2%	
Loan repayment period	10	years
Discount rate	10%	
Exchange rate	104	

Other input data are same as Scenario 1

Scenario 3: Residual value for Hydro - capital cost reduction of 70% (Low ROE & low Interest rate)

Equity	40%			
Return on Equity	4%		UK capital	CEB report 2006 pg 8-1
Debt	60%			
Interest rate	2%			
Loan repayment period	10	years		
Discount rate	10%			
Exchange rate	104			

Technology	Capital (Rs million/ MW)	Life	Construction period	Plant load factor	O&M (% of Capital)	Escalation in O&M	Fuel consumption (kg or l/kWh	Fuel cost (Rs/ kg or l)	Fuel price increase rate Rs/kg/year	Exchange rate increase Rs. /year	Duty on fuel	Benefits Rs/kWh	Depreciation rate
Coal-1	156	30	4	80%	4%	0.00%	0.364	6.97					12.50%
Coal-2	156	30	4	80%	4%	0.00%	0.364	10.30	0.267	2.67	0.29		12.50%
Dendro-1	125	30	3	80%	4%	0.00%	1.40	2.50			-		12.50%
Dendro-2	125	30	3	80%	4%	0.00%	1.40	2.33	-	-	-	0.17	12.50%
Hydro – UK	263	30	4	31%	1%	0.00%	-	-			-		12.50%
Wind	125	15	2	27%	3%	0.00%	-	-			-		12.50%
Diesel GT	45	15	2	80%	4%	0.00%	0.3238	50.53	0.02	-	0.29		12.50%

Technology	Capital (Rs million/ MW)	Lif e	Construction period	Plant load factor	O&M (% of Capital)	Escalation in O&M	Fuel consumption (kg or l/kWh	Fuel cost (Rs/ kg or l)	Fuel price increase rate Rs/kg or l/year	Exchange rate increase Rs. /year	Duty on fuel	Benefits Rs/kWh	Depreciation rate
Coal-1	156	30	4	80%	2%	0.00%	0.364	6.97					12.50%
Coal-2	156	30	4	80%	2%	0.00%	0.364	10.30	0.267	2.67	0.29		12.50%
Dendro-1	125	30	3	80%	3%	0.00%	1.40	2.50			-		12.50%
Dendro-2	125	30	3	80%	3%	0.00%	1.40	2.41	0.05	-	-	0.34	12.50%
Hydro	184	30	4	31%	1%	0.00%	-	-			-		12.50%
Wind	125	15	2	27%	3%	0.00%	-	-			-		12.50%

6.5 Results

Scenario 1: High ROE & high Interest rate

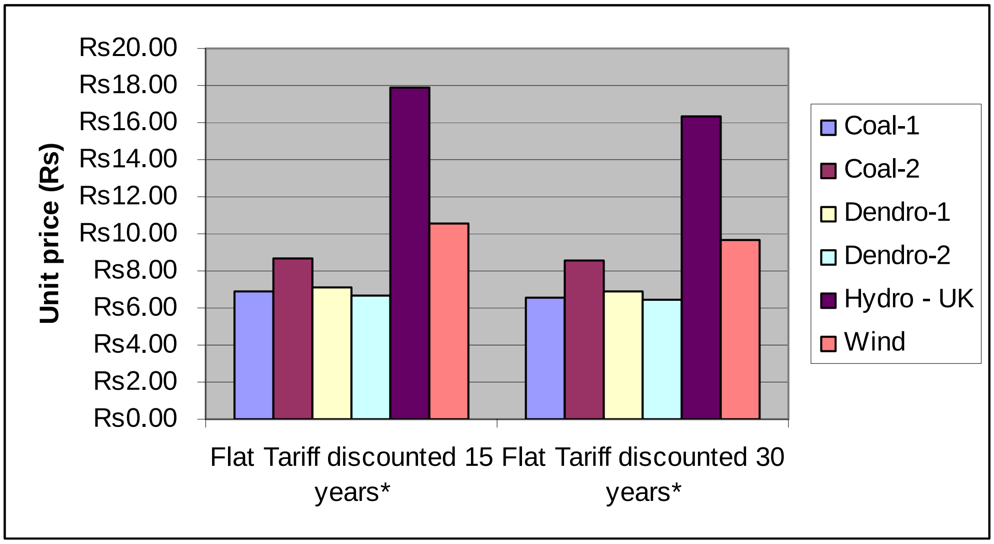


Figure 6.5.1 – High ROE & high Interest rate

Scenario 2: Low ROE & low Interest rate

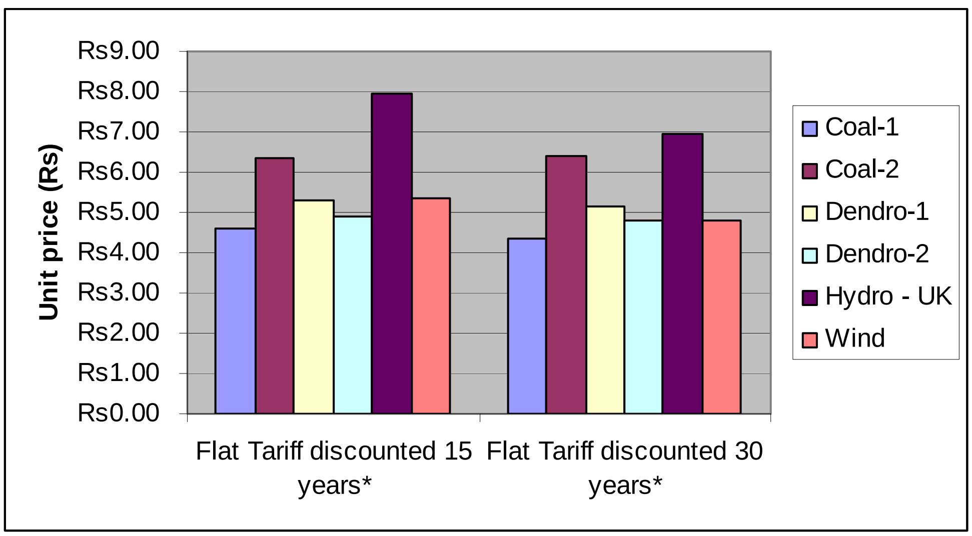


Figure 6.5.2 – Low ROE & Low Interest Rate

Scenario 3: Residual value for Hydro - capital cost reduction of 70% (Low ROE & low Interest rate)

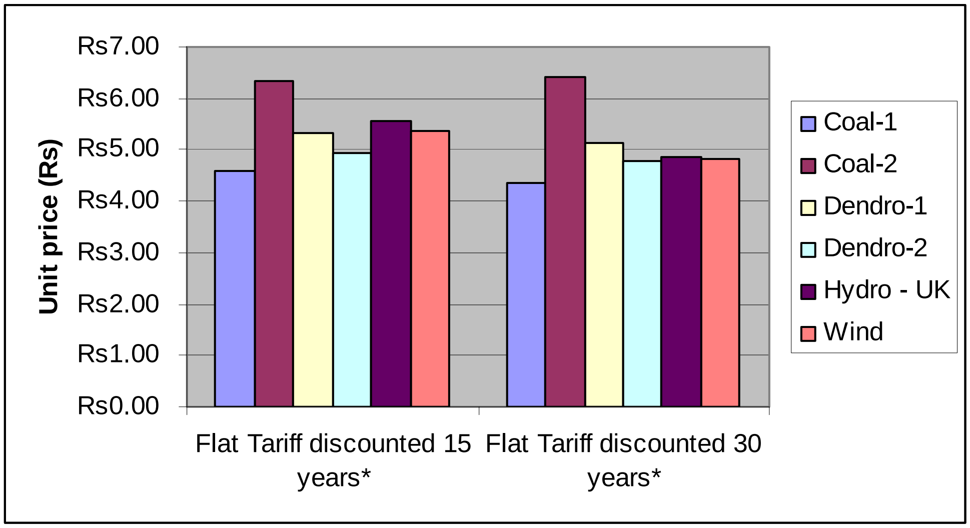


Figure 6.5.3 – Residual Value for Hydro – Low ROE & Low Interest Rate

6.6 Conclusions

1. Coal and Dendro are competitive at high interest and ROE rates under constant coal prices and exchange rates. With the introduction of coal price increases, exchange rate increases and duty on coal import, Dendro power becomes cheaper. However the hydro costs are very high at high interest and ROE rates.

2. Coal power is cheaper in the case of low interest and ROE rates. Further the gap between hydro power and other technologies reduces considerably.

3. Considering the life time of the hydro plant the residual value for hydro can be applied as a capital cost reduction. This reduction is assumed as 70%. Under low ROE & low interest rate conditions hydro power becomes cheaper than the coal.

4. Wind power remains competitive under a plant factor of 27%.

7 Overall Conclusions

The CEB, in the absence of an entity engaged with power sector planning, and despite being considered as a commercial entity, during the last 15 years has been generous enough to develop a long-term electricity generation expansion plan purely for economic considerations as opposed to their own financial gains, and not for financial interests and were updating it annually.

It is with this study that Energy Forum took the unprecedented steps to initiate a constructive dialog between the CEB and Environmentalists, whom up till this point had directly conflicting views. This has ended the deadlock situation and will enable a general consensus on the Long Term Generation Expansion Plan to be achieved in the future.

The conclusions of the study are as follows:

1. WASP is not a sophisticated model for accommodating demand side management and non dispatchable energy technologies.

2. The CEB's WASP study is only limited to oil, coal and four hydro power plant options. The CEB's base case results can be easily predicted for the following obvious reasons:

- Hydro power is not picked for the base case by the WASP model as the CEB uses a 10% discount rate while neglecting future fuel price increases. This causes falls in recommendations and favours technology options with high running costs and gives misleading results. Hence the large hydro potential that exists in Sri Lanka which is yet to tapped has not received due recognition under the CEB plan.

- Oil is picked by the WASP analysis for the base case during the first few years due to its short construction period when compared to coal power construction. Furthermore oil plays a role at low plant factor requirements for satisfying peak demand.

- Coal is picked by the WASP analysis for the base case as the long-term option as coal is cheaper than oil.

3. Dendro option, though not considered by the CEB for optimization, has the capability of replacing both oil and coal due to the following reasons

- The construction period is shorter than coal power.
- The fuel cost is very much lower than both oil and coal if the following factors are taken in to account:
- exchange rate increase
- increasing oil and coal prices
- being an indigenous resource

- multiple benefits of Gliricidia, the species which is recognised as the energy plantation crop
- having low external costs when compared with oil & coal
- the advantages of establishing Dendro power plants in a distributed setup

The limiting factor of Dendro power is the potential for establishing energy plantations in one of the following ways:
- as a dedicated energy plantation
- as a multi crop in home gardens for hedges, buttress, soil conservation, nitrogen fixing source, shade, wind barrier, to maintain the ground water level and etc.
- as an under growth in the coconut plantations
- as the shade for tea plantations
- as a multi crop of reforestation

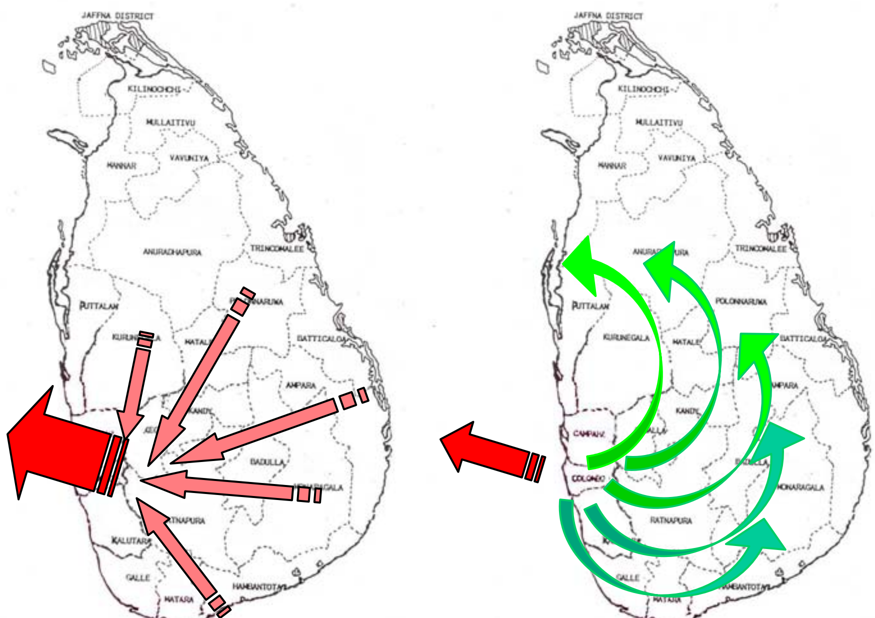
4. Decentralised generation is more efficient, because it avoids network losses by reducing transmission requirements, and on-site generation allows for the combined generation of heat and power. DE therefore needs to generate less electricity to meet the same total demand, for example; in the 100% CG case the total generation in 2024 is 42,538 GWh, while DE can meet the same demand by generating only 37,719 GWh. DE therefore requires less new capacity, and uses less fuel, which translates into cost savings. Lower transmission requirements also mean that a smaller network is needed to deliver electricity to users, so network investment costs are lower.

5. Industrial (Combined Heat and Power) CHP applications are feasible in the short term, because these generators and heat-recovery boiler systems could be installed on industrial sites where heat-only boilers are already present. Combined Cooling, Heating and Power (CCHP) development would require installing on-site generators in commercial centers, where currently cooling demand is met by systems using grid-electricity. In the longer term these applications are very attractive. However, because many of these commercial buildings are in urban areas, where electricity demand is large anyway, the electricity output is usually used close to the point of generation.

6. The CEB plan is mainly based on the least cost principle. However the MCA study revealed that people are more worried about the national interests rather than the cost. Further the CEB has not paid due attention to the external costs involved with power generation. This has become the main reason for not being able to sell the long-term generation expansion plan to the general public and the decision makers.

7. If proper attention is paid to external costs involved with power generation then the other technological options such as LNG, Wind, Wave and OTEC could have being considered as a part of the energy mix.

8. This study is only an eye opener for the concerned parties to discuss the issues relating to the long-term electricity generation expansion planning in Sri Lanka. Predicting the fossil fuel price increases is the crucial factor that determines the proper energy mix. The outcomes of this study show that most of the energy technologies covered under this study have a role to play in a proper energy mix and these are areas that can be explored further.



Cost of Energy
Draining the Economy

Value of Energy
Catalysing the Economy !!

Annex A – Generation Expansion Plans

Generation expansion plans: **Scenario No. 1**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 2 × 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		300 MW Coal Steam 105 MW Gas Turbine		1.108
2020		300 MW Coal Steam		1.676

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 2**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 2 × 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		2 × 300 MW Coal Steam 75 MW Gas Turbine		1.236
2020		300 MW Coal Steam		1.698

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 3**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 2 × 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		2 × 300 MW Coal Steam 75 MW Gas Turbine		1.236
2020		300 MW Coal Steam		1.698

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 4**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		2 × 105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	1.857
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.035
2012		300 MW Coal Steam	20 MW ACE Power Matara	0.000
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.001
2014		300 MW Coal Steam		0.027
2015		2 × 100 MW Dendro Thermal	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	0.358
2016		300 MW Coal Steam		0.534
2017		300 MW Coal Steam		0.818
2018		300 MW Coal Steam 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	0.972
2019		300 MW Coal Steam		0.866
2020		300 MW Coal Steam		0.860

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 5**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam 100 MW Dendro Thermal	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.055
2014		300 MW Coal Steam		0.169
2015		300 MW Coal Steam 105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.162
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 75 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.368
2019		300 MW Coal Steam 105 MW Gas Turbine		1.119
2020		300 MW Coal Steam		1.726

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 6**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		2 × 105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	1.857
2011	*150 MW Upper Kothmale*	2 × 300 MW Coal Steam		0.000
2012		300 MW Coal Steam	20 MW ACE Power Matara	0.000
2013		100 MW Dendro Thermal 2 × 105 MW Gas Turbine	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.015
2014		300 MW Coal Steam		0.023
2015		100 MW Dendro Thermal 2 × 105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	0.507
2016	35 MW Broadlends	300 MW Dendro Thermal		0.574
2017	27 MW Moragolla 49 MW Gin Ganga	105 MW Gas Turbine 75 MW Gas Turbine		0.827
2018		300 MW Dendro Thermal 2 × 35 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	0.926
2019		300 MW Dendro Thermal 105 MW Gas Turbine		0.821
2020	150 MW Uma Oya	300 MW Coal Steam		0.769

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 7**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 2 × 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		2 × 300 MW Coal Steam 75 MW Gas Turbine		1.236
2020		300 MW Coal Steam		1.698

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 8**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	150 MW Upper Kothmale	3 × 300 Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		2 × 300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 105 Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		2 × 300 MW Coal Steam 105 MW Gas Turbine		1.108
2020		300 MW Coal Steam		1.676

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 9**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.268
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.046
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.075
2014		300 MW Coal Steam		0.061
2015		105 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.021
2016		300 MW Coal Steam		1.057
2017		300 MW Coal Steam		1.211
2018		300 MW Coal Steam 2 × 105 MW Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.244
2019		2 × 300 MW Coal Steam 75 MW Gas Turbine		1.236
2020		300 MW Coal Steam		1.698

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 10**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	1.857
2011	*150 MW Upper Kothmale*	3 × 300 Coal Steam		0
2012			20 MW ACE Power Matara	0
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.014
2014		300 MW Coal Steam		0.012
2015		105 MW Gas Turbine 75 MW Gas Turbine	60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	0.082
2016	35 MW Broadlends	300 MW Coal Steam		0.343
2017	27 MW Moragolla 49 MW Gin Ganga	300 MW Coal Steam		0.424
2018		300 MW Coal Steam 35 Gas Turbine	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	0.319
2019		300 MW Coal Steam 300 MW Combined Cycle (Oil) 105 MW Gas Turbine		0.429
2020	150 MW Uma Oya	300 MW Coal Steam		0.172

Note: Committed Plats are in Italics

Generation expansion plans: **Scenario No. 11**

Year	Hydro Additions	Thermal Additions	Thermal Retirements	LOLP, %
2006				1.422
2007				3.942
2008		*200 MW GT part of Kerawalapitiya CCY Plant*		2.516
2009		*100 MW ST Part of Kerawalapitiya CCY Plant* 2 × 105 MW Gas Turbines		1.419
2010		105 MW Gas Turbine	4 × 17 MW Gas Turbines at Kelanitissa	3.572
2011	*150 MW Upper Kothmale*	3 × 300 MW Coal Steam		0.003
2012			20 MW ACE Power Matara	0.049
2013		300 MW Coal Steam	4 × 18 MW Supugaskanda Diesel Plant 20 MW ACE Power Horana 22.5 MW Lakdhanavi Plant	0.085
2014		300 MW Coal Steam		0.073
2015			60 MW Colombo Power Plant 100 MW Heladhanavi Diesel Power Plants at Puttlam 100 MW ACE Power Diesel Power Plant at Embilipitiya	1.042
2016	35 MW Broadlends	300 MW Coal Steam		1.059
2017	27 MW Moragolla 49 MW Gin Ganga	300 MW Coal Steam		1.231
2018		300 MW Coal Steam	51 MW Asia Power Plant 115 MW Gas Turbine 7 at KPS	1.296
2019		2 × 300 MW Coal Steam		1.101
2020		2 × 300 MW Coal Steam		1.536

Note: Committed Plats are in Italics

Annex B – WADE

WADE is a non-profit research and advocacy organisation that was established in June 2002 to accelerate the worldwide deployment of decentralised energy (DE) systems. WADE is now backed by national cogeneration and DE organisations, and DE companies and providers, as well as a number of national governments. In total, WADE's direct and indirect membership support includes over 200 organisations and corporations around the world.

DE technologies encompass the following types of energy generation system that produce heat and electricity at, or close to, the point of consumption, including:
high-efficiency cogeneration/combined heat and power
on-site renewable energy systems
energy recycling systems, including the use of waste gases, waste heat and pressure drops to generate electricity on-site.

WADE classifies such systems as DE regardless of project size, fuel or technology, or of whether the system is on-grid or off-grid.

WADE believes that the wider use of DE holds the key to bringing about the cost-effective modernisation and development of the world's electricity systems. With inefficient central power systems holding a 93% share of the world's electricity generation and with the DE share at only 7%, WADE's mission is to bring about the doubling of this share to 14% by 2012. A more cost-effective, sustainable and robust electricity system will emerge as the share of DE increases.

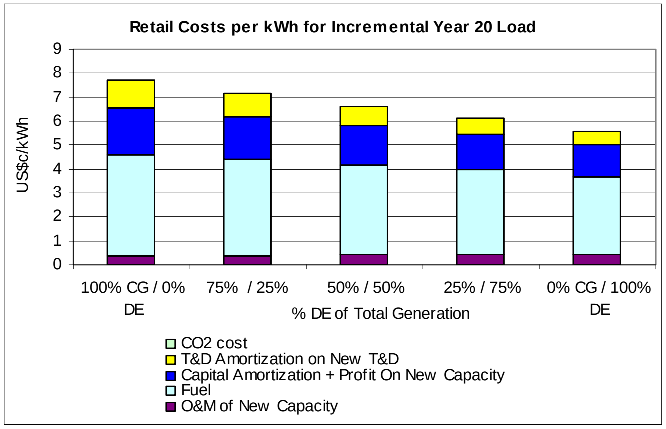
Further information about WADE is available at www.localpower.org or by contacting:

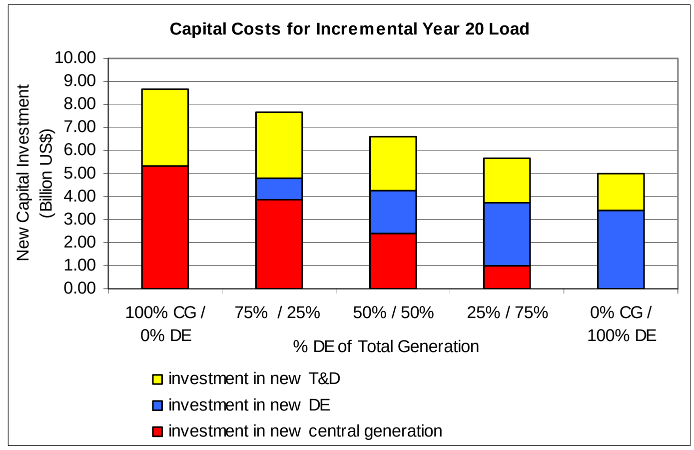
World Alliance for Decentralised Energy, 15 Great Stuart Street, Edinburgh, EH3 7TP Scotland, UK

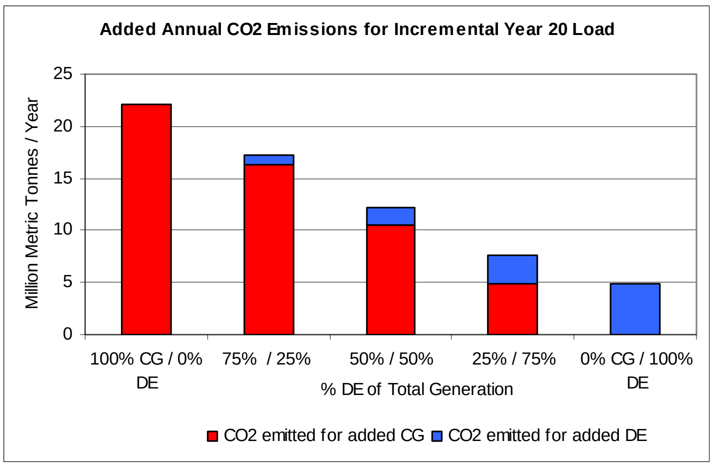
tel +44 131 625 3333; fax +44 131 625 3334; info@localpower.org

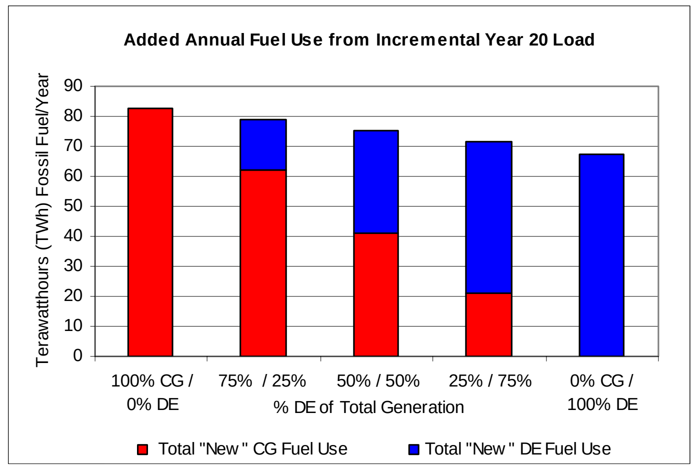
To date, in addition to Sri Lanka, the WADE Economic Model has been run for:
Brazil, European Union (funded by the EU DG-FER programme), Ireland (funded by the Irish Government), Thailand (funded by the EU COGEN-3 programme), USA, China (funded by the UK Foreign and Commonwealth Office), United Kingdom (funded by Greenpeace UK), Germany, The City of Calgary (NewERA, funded by the Canadian Federal Government), Ontario (NewERA, funded by the Canadian Federal Government)

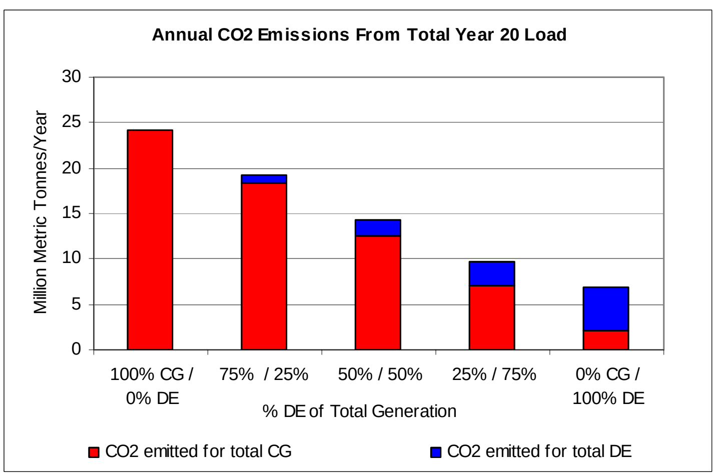
WADE base case

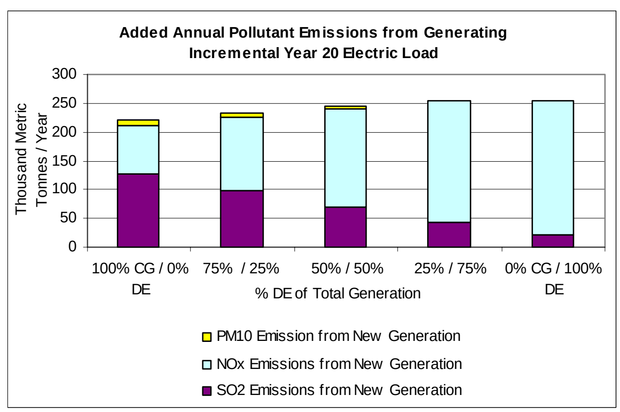

Retail Costs per kWh for Incremental Year 20 Load
US$c/kWh
9
8
7
6
5
4
3
2
1
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
CO2 cost
T&D Amortization on New T&D
Capital Amortization + Profit On New Capacity
Fuel
O&M of New Capacity

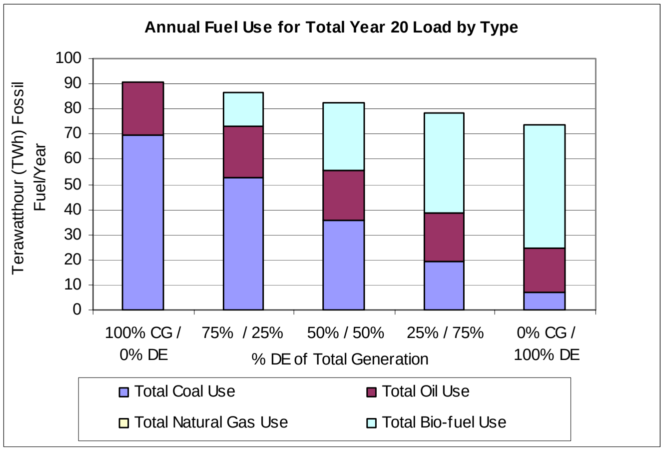

Capital Costs for Incremental Year 20 Load
New Capital Investment (Billion US$)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
investment in new T&D
investment in new DE
investment in new central generation


Added Annual CO2 Emissions for Incremental Year 20 Load
Million Metric Tonnes / Year
25
20
15
10
5
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
CO2 emitted for added CG
CO2 emitted for added DE

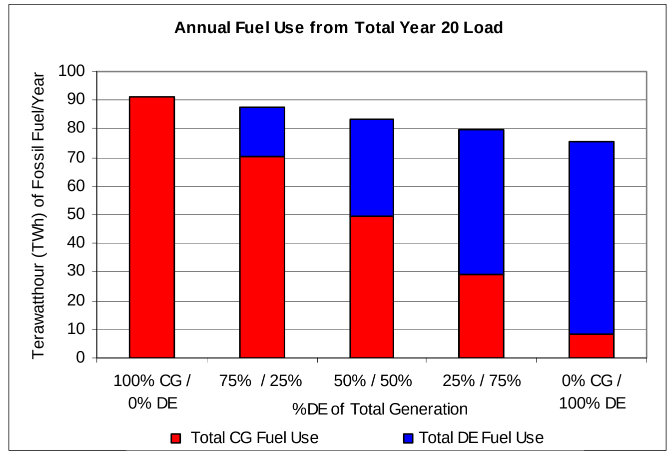

Added Annual Fuel Use from Incremental Year 20 Load
Terawatthours (TWh) Fossil Fuel/Year
90
80
70
60
50
40
30
20
10
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
Total "New" CG Fuel Use
Total "New" DE Fuel Use


Annual CO2 Emissions From Total Year 20 Load
Million Metric Tonnes/Year
30
25
20
15
10
5
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
CO2 emitted for total CG
CO2 emitted for total DE

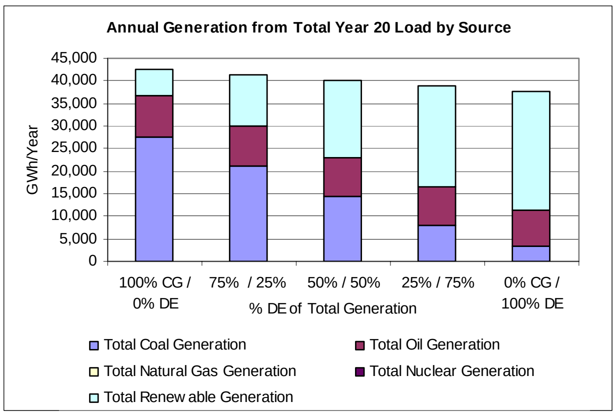

Added Annual Pollutant Emissions from Generating Incremental Year 20 Electric Load
Thousand Metric Tonnes / Year
300
250
200
150
100
50
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
PM10 Emission from New Generation
NOx Emissions from New Generation
SO2 Emissions from New Generation



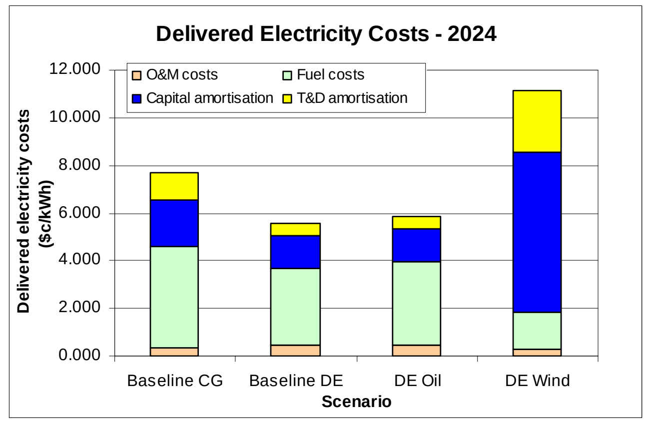
Annual Fuel Use for Total Year 20 Load by Type
Terawatthour (TWh) Fossil Fuel/Year
100
90
80
70
60
50
40
30
20
10
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
Total Coal Use
Total Oil Use
Total Natural Gas Use
Total Bio-fuel Use



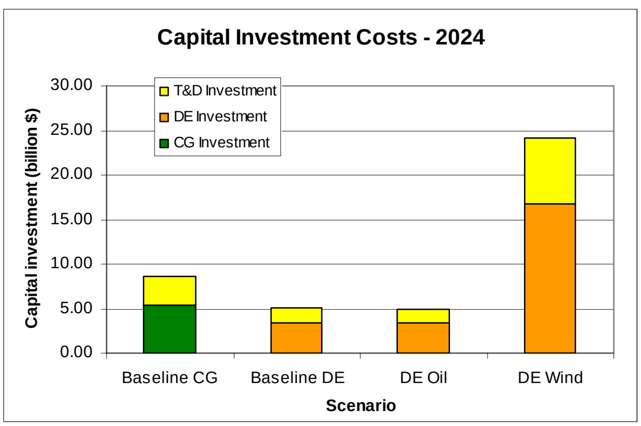
Annual Fuel Use from Total Year 20 Load
Terawatthour (TWh) of Fossil Fuel/Year
100
90
80
70
60
50
40
30
20
10
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
%DE of Total Generation
Total CG Fuel Use
Total DE Fuel Use



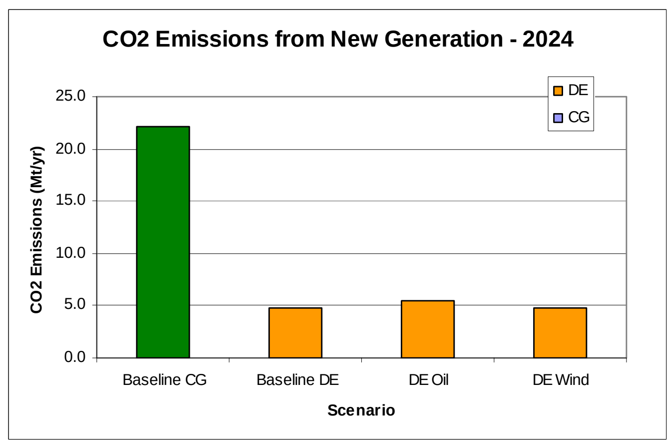
Annual Generation from Total Year 20 Load by Source
GWh/Year
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
Total Coal Generation
Total Oil Generation
Total Natural Gas Generation
Total Nuclear Generation
Total Renew able Generation



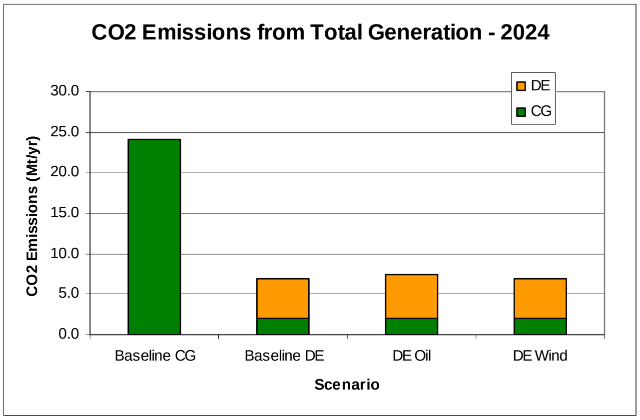
Delivered Electricity Costs - 2024
Delivered electricity costs ($c/kWh)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
O&M costs
Fuel costs
Capital amortisation
T&D amortisation
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario

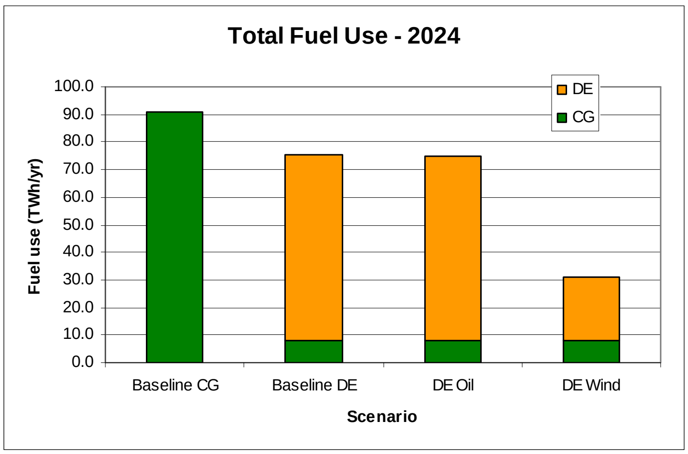


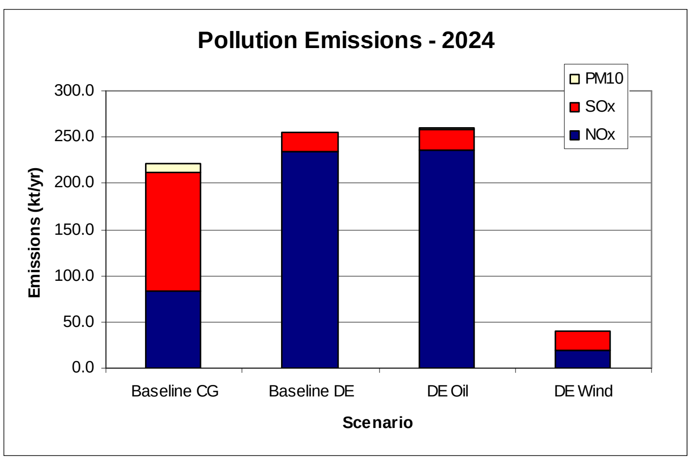
Capital Investment Costs - 2024
Capital investment (billion $)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
T&D Investment
DE Investment
CG Investment
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario

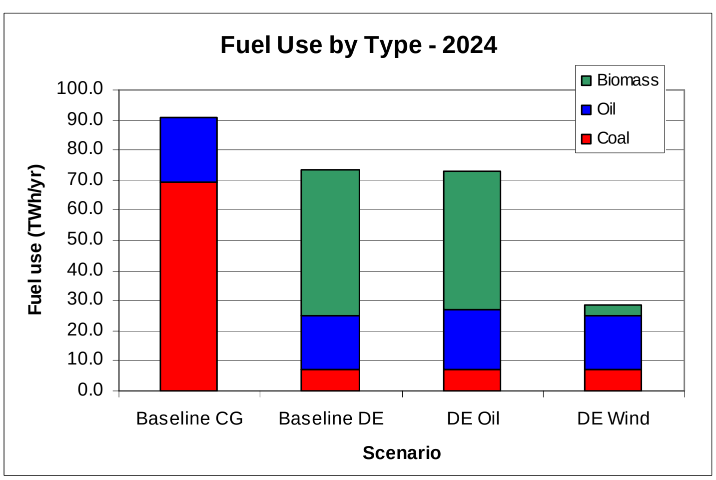


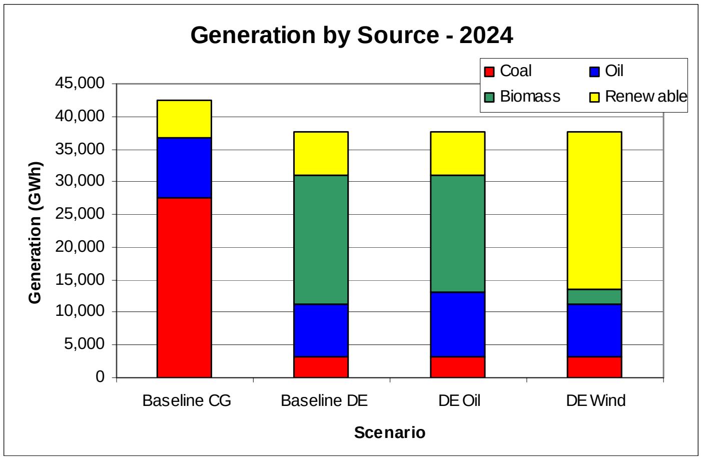
CO2 Emissions from New Generation - 2024
CO2 Emissions (Mt/yr)
25.0
20.0
15.0
10.0
5.0
0.0
DE
CG
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario

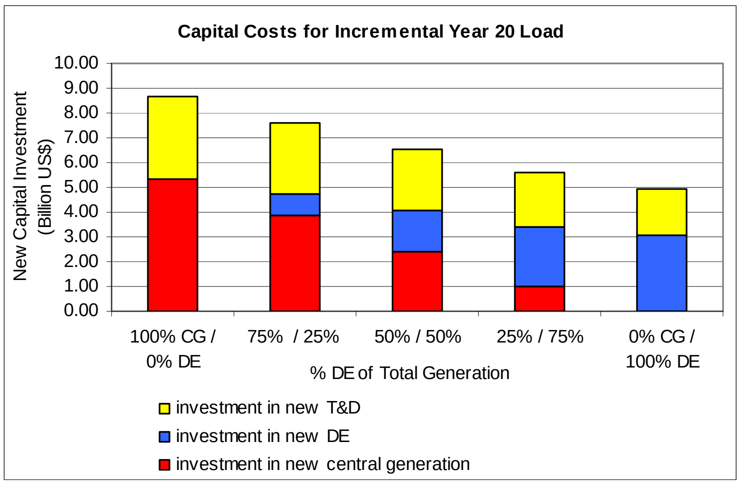

CO2 Emissions from Total Generation - 2024
CO2 Emissions (Mt/yr)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
DE
CG
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario

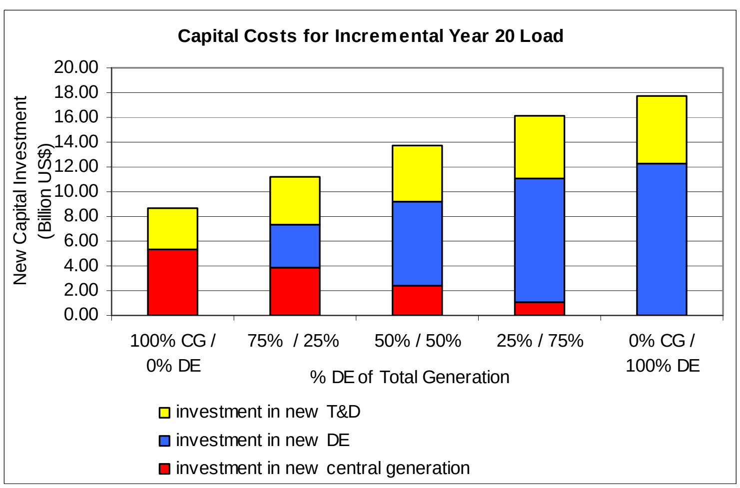

Total Fuel Use - 2024
Fuel use (TWh/yr)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
DE
CG
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario

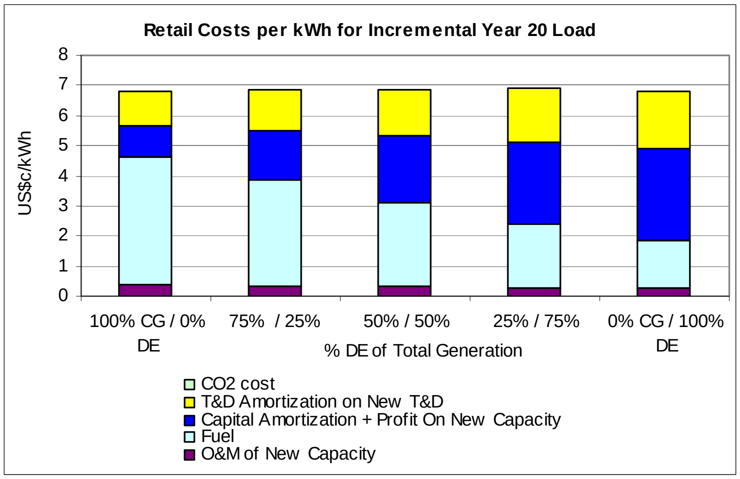

Pollution Emissions - 2024
Emissions (kt/yr)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
PM10
SOx
NOx
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario


Fuel Use by Type - 2024
Fuel use (TWh/yr)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Biomass
Oil
Coal
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario


Generation by Source - 2024
Coal
Oil
Biomass
Renew able
Generation (GWh)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Baseline CG
Baseline DE
DE Oil
DE Wind
Scenario


Capital Costs for Incremental Year 20 Load
New Capital Investment (Billion US$)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
investment in new T&D
investment in new DE
investment in new central generation


Capital Costs for Incremental Year 20 Load
New Capital Investment (Billion US$)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
investment in new T&D
investment in new DE
investment in new central generation


Retail Costs per kWh for Incremental Year 20 Load
US$c/kWh
8
7
6
5
4
3
2
1
0
100% CG / 0% DE
75% / 25%
50% / 50%
25% / 75%
0% CG / 100% DE
% DE of Total Generation
CO2 cost
T&D Amortization on New T&D
Capital Amortization + Profit On New Capacity
Fuel
O&M of New Capacity

Annex C - What are the National Benefits of Developing Indigenous Resources for Energy Generation?

Presentation made by Mr. P. G. Joseph at the 2nd Stakeholder meeting on 25th April 2006.

Degree of Indigenousness
Indigenous: belonging naturally to a (place or) country.
"Indigenousness": the quality of being indigenous.

Degree of Indigenousness of an Energy Option: To what extent does that option deploys indigenous inputs for the generation of Energy?

- Final Price of Energy to Consumer US$ or SLRs

- Issues Linked to Indigenous Energy Resources Development

    - Foreign Exchange Depletion
    - Local (Rural) Economic Growth/ Poverty Alleviation/ Employment
    - Energy Security (local/ national)
    - Advantage of being Small and Decentralized
    - Wealth Distribution
    - Urban Migration
    - Land Degradation
    - Local Environmental Degradation (-ve)

In the past, Focus had been on Increasing $ Supply – Inadequate
Reduce $ Demand ! – Import Substitution if viable
'Export or Perish': 'Import & Perish ?'
Export Development Board: Import Substitution Board?

- Local Value Additions
- Mini Hydro: Dam, Penstock construction, local development of other components.
- Wind: Concrete Tower? Integrated lifting mechanism? Locally fabricated Small Wind Generators?
- Wave: Modular Breakwater devices? Wells Propellers?
- Cost of "Not Served Energy"

- "…For the sake of our economic and national security, we must reduce our dependence on foreign sources of energy – including on the natural gas that is a source of electricity for many American homes and the crude oil that supplies gasoline for our cars……" -G.W.B.
- United Nations Development Programme
- United Nations Department of Economic and Social Affairs
- World Energy Council

    - **World Energy Assessment overview 2004 Update**

    - **Energy Security**

- *Energy security is a term that applies to the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices, without unacceptable or irreversible impact on the environment.*
- "……One important measure is to avoid excessive dependence on fossil fuel imports. This involves diversifying supply – both geographically and among various primary energy sources – as well as increasing end-use efficiency and encouraging greater reliance on local, including renewable, resources……."

- Being Small & Decentralized

- Smaller Chunks of Capacities are added to the System (5/10 MW not 300/500 MW)
- Lower Initial Capital required
- Shorter Gestation Period
- Lower Capital Cost of Transmission
- Lower Transmission Losses
- District-wise Energy Security
- Opportunity for Co/Tri Generation

- Wealth Distribution
- National Economic Growth alone is not desirable.
- More attention should be paid to impart Growth to the poorer segment.
- "Trickling Down" effect is too little, too slow.

- How to value Indigenousness?

Issue	10% NRE in 2015	Self-Sufficiency in 2015
Foreign Exchange Parity Rate	US$= SLR 204 Doubling of prices of most consumer items	US$ = SLR 102 No added inflation
Local Econ. Growth/ Poverty Alleviation/ Employment	• 50% in Poverty • Samurdthy Doubled • Subsidy to "industries"	• No Poverty • Samurdthy Closed • No Subsidy
Energy Security	?% Probability of 58% Electricity Not Served	Energy Security Assured
Small & Decentralized	Will be dealt separately	
Distribution of Wealth	Rich richer, poor poorer	Rich and poor richer

Annex D – Attendance Sheets for 1st, and 2nd stakeholder meetings, and the MCA workshop

Attendance Sheet -01

Discussion on incorporating social and environmental concerns in long-term electricity generation expansion planning

Minutes of the Discussion 01- held on 16th November 2005
At the Trans Asia Hotel Colombo

Present

1.	Mr. Damitha Kumarasinghe	- Public Utility Commission of Sri Lanka
2.	Mr. Shavi Fernando	- Ceylon Electricity Board
3.	Mr. P. G. Joseph	- Ministry of Science and Technology
4.	Mr. K.G.S. Jayawardana	- Central Environmental Authority
5.	Mr. Harsha Wickramasinghe	- Energy Conservation Fund
6.	Mr. Mahinsasa Narayana	- NERD Centre
7.	Prof. H. Sriyananda	- Open University of Sri Lanka
8.	Prof. Arjuna de Zoysa	- Open University of Sri Lanka
9.	Ms. Nilanthi Bandara	- Central Environmental Authority
10.	Dr. Nishantha Nanayakkara	- Small Power Producers Association
11.	Miss. Rekha Karunaratne	- Small Power Producers Association
12.	Mr. Parakrama Jayasinghe	- Bio Energy Association of Sri Lanka
13.	Mr. Jagath Gunewardana	- Environmentalist
14.	Mr. Suranjan Kodithuwakku	- Green Movement of Sri Lanka
15.	Mr. Dileepa Witharana	- Practical Actions (Former ITDG)
16.	Mr. Jayantha Gunasekara	- Practical Actions (Former ITDG)
17.	Mr. Asoka Abeygunawardana	- Energy Forum
18.	Mr. Bandula Chandrasekera	- Energy Forum
19.	Miss. Wathsala Herath	- Energy Forum

Excused

20.	Dr. Ray Wijewardana	- BEASL
21.	Prof. Priyantha Wijethunge	- PUCSL
22.	Mr. Gamunu Abeysekara	- DGM, CEB
23.	Dr. Herath Samarakoon	- Chief Engineers, CEB
24.	Mr. P. Weerahandy	- Ministry of Power Energy
25.	Mr. Lalith Gunaratne	- Energy Forum

Absent

26.	Mr. Michael Warnakulasooriya	- ECF

27. Dr. Lalith Wickramanayake - Environmental Foundation Limited
28. Mr. Upali Darnagama - USAID
29. Ms. Dharshini de Silva - UNDP

Attendance Sheet -02

The Second Stakeholder meeting on " Incorporating Social and Environment concerns in Long-Term Electricity generation expansion planning

Held on 24th April 2006 at Queens Court- Hotel Trans Asia

Present

1. Mr. Harsha Wickramasinghe - Energy Conservation Fund
2. Mr. P. G. Joseph - Ministry of Science and Technology
3. Mr. Mahinsasa Narayana - NERD Centre
4. Prof. Arjuna de Zoysa - Open University of Sri Lanka
5. Mr. K.G.S. Jayawardana - Central Environmental Authority
6. Mr. Parakrama Jayasinghe - Bio Energy Association of Sri Lanka
7. Dr. Ray Wijewardana -BEASL
8. Mr. Dileepa Witharana - Practical Actions (Former ITDG)
9. Mr. Ranjan Karunaratne - Green Movement of Sri Lanka
10. Mr. Achala Navaratne - Environmental Foundation Ltd
11. Mr. Asoka Abeygunawardana - Energy Forum
12. Mr. Bandula Chandrasekera - Energy Forum
13. Miss. Wathsala Herath - Energy Forum
14. Mr. Cyril Gunathilaka - Energy Forum
15. Mr. Chinthaka Jayaratne - Energy Forum
16. Mr. Sytze Dijkstra -WADE
17. Mr. Lalith Gunaratne - Energy Forum
18. Dr. Cynthia Caron - Energy Forum

Attendance Sheet 03

MCA consultative workshop on electricity generation expansion planning in Sri Lanka on 25th July 2006 at Taj Samudra Hotel

Group A

1. Mr. Ruwan Weerasooriya	Ministry of Environment
2. Mr. A. U. Walpola	Hydro Power Int' l (Pvt) Ltd
3. Mr. Lalith Gunaratne	Energy Forum
4. Mr. K.G.S. Jayawardena	Central Environmental Authority
5. Ms. Rekha Karunaratne	Small Power Producers Association
6. Dr. Sumith Wanniarachchi	Green Party
7. Mr. Suranjan Kodituwakku	Green Movement of Sri Lanka
8. Mr. Parakrama Jayasinghe	Bio Energy,Association of Sri Lanka
9. Mr. S. A. D. Kingsley	Forest Department
10. Mr. Andrew Cornwall	Challenges Worldwide
11. Mr. Thushan Kapurusinghe	UNDP

Group B

1. Dr. Cynthia Caron	Energy Forum
2. Mr. Mahinsasa Narayana	NERD Centre
3. Dr. Vishaka Hedellage	Practical Action
4. Prof. Priyantha Wijethunge	Public Utility Commission of Sri Lanka
5. Mr. Kanchana Siriwardana	Public Utility Commission of Sri Lanka
6. Mr. Damitha Kumarasinghe	Public Utility Commission of Sri Lanka
7. Mr. Harsha Wickramasinghe	Energy Conservation Fund
8. Mr. Prasad Gunesekara	CEB
9. Ms. Dinali Jayasinghe	UNDP
10. Mr. M. M. R. Padmasiri	ECF

Group C

1.Mr. Sampath Abeyguneseraka	Green
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7. Mr. Nalaka Jayashinge	Broad-lands- The Rafters Retreat
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