HYDROPOWER DEVELOPMENT IN SRI LANKA

by
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Wimalasurendra - "Father of Hydro Electricity in Sri Lanka"

Early in the century the far sighted engineer Wimalasurendra masterminded hydropower development in this country. Having realised the true value of hydropower and with his ingenious foresight master-minded studies for planning hydropower development in Sri Lanka for self sufficiency and rapid industrialization. He is immortalised as the Father of Hydro Electricity in Sri Lanka.

The anniversary of his birth falls on 17th September and it is important that we remember him with gratitude for the great achievements and his contribution to the development of our country.

Devapura Jayasena Wimalasurendra was born on 17th September 1874, the eldest son of famous creative master craftman Mudaliyar Wimalasurendra of Galle. He was educated at Ananda College which was then known as Colombo Buddhist English School. As a student he showed exceptional talents in Science and Mathematics and passed the Senior Cambridge and London Matriculation examinations.

In 1893 he joined the Technical College and pursued engineering studies while serving as an apprentice at the Government Factory. In 1898 he was successful in passing the Institution of Civil Engineers (London) examination held in India and he was the first Sinhalese engineer to be awarded the AMICE.

Engineer Wimalasurendra joined the Public Works Department as an Assistant Civil Engineer and served in Diyatalawa and Norwood. While serving in these stations he would have been able to carryout surveys and field investigations which enabled him later to draw up the master plan for Kelani and Mahaweli hydropower development.

In 1912 Mr. Wimalasurendra proceeded to U.K. and continued his studies in Electrical Engineering at the famous Faraday House in London. After returning he continued his studies on hydropower and in 1918 presented a historic paper before the Engineering Association of Ceylon titled Economics of Power Utilization in Ceylon - where he stated "The river Mahaweli is the greatest asset we possess .... At it's minimum flow without any provision for water storage it is capable of developing over 70,000 EHP at a point which on a direct line is over 12 miles from Peradeniya .....

At a point about one mile below, another about 30,000 EHP could be obtained. At a spot about 8 miles distant from Kandy about 12,000 EHP can be derived. At Ulapane again another 15,000 EHP could be obtained ...... The Kotmale Oya, one of the tributaries of the Mahaweli could be harnessed to give 6000 EHP at Talawakelle alone. Aberdeen falls situated on a source of Kelani river is capable of contributing 10,000 EHP at one spot; The Laxapana falls and Kitulgala rapids can be harnessed to derive over 50,000 EHP and this source is only 42 miles distant from Colombo on a direct line.

"Besides the above there are several other sources distributed throughout the Central Province which could be harnessed to contribute from 3,000 to 1,000 EHP each. Every one of these source could be developed to contribute power on a commercial basis to a main distribution network fed by the above main sources. Power derived from one or more of these sources could be utilised for operating some sections of our railway system electrically especially the hill section, and that most economically ...."

He won corporate Membership of the Institution of Civil Engineers and corporate Membership of the Institution of Electrical Engineers London and it must have been very rare for a Sri Lankan to have achieved these in those early periods. Despite these qualifications he was overlooked by the government of the day and British Engineers with less qualifications and capability were favoured.

He also contributed to the development of the Badulla - Bandarawela railway extension and was responsible for the fascinating loop at Demodara. His advice was also sought for Water Supply and Electricity generation for Kandy, Galle and Nuwara Eliya Municipal Councils. He carried out detailed studies on Laxapana hydroelectric project and the Government accepted it for implementation in 1924.

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However due to the prevailing economic depression, the project was shelved. With the formation of Department of Government Electrical undertakings Mr. Wimalasurendra rose to be appointed as the Chief Engineer. He retired from the Department at the age of 55 years in 1929.

He contested the Ratnapura seat in 1931 in the Legislative Assembly, the first time the country went to the pools under universal franchise. He served the Assembly from 1931 to 1936 and continued to advocate for the rapid industrialisation of this country using Hydropower potential. His foresight could be seen in what he stated in the budget speech in 1935.

"The power output that could be economically developed from the four rivers that flow west and east from the Adam's Peak range has been carefully examined and found to be no less than a million horsepower per year. This output at the lowest valuation is worth more than 2 pounds or 3 pounds per horsepower year. Every unit generated here can be utilised for our purposes - for the manufacture of fertilizers, cement and so on, and for working the transport and the railway system all throughout the country as well as for supplying cheap power and light to even every peasant's cottage throughout the length and breath of the island".

Laxapana hydroelectric project which was approved by the Government in 1924 was shelved due to the economic depression and was finally taken up for implementation in 1939. Unfortunately the contract was suspended due to the Second World war and the work was finally completed in 1950. When the work on this project was coming to completion in 1950 Mr. Wimalasurendra though nearly 75 years of age personally inspected the scheme and expressed his satisfaction as follows:

"Although it was not my good fortune to execute the scheme I had originated, I am happy that I have lived to see it brought to fruition by my countrymen, and that I should have, in the evening of my life, been able to see in reality the dawn which I saw in my mind's eye over a half century ago. Now, if I leave this world, I shall leave fulfilled".

The "Father of Hydro Electricity in Sri Lanka" Mr. Wimalasurendra passed away on 10th August 1953.

Beginning of Hydropower Development

In the early years of development of the plantation industry in Sri Lanka, mechanical energy for processing tea and rubber was sometimes obtained by harnessing locally available hydropower. These small hydropower projects in the plantation sector were dismantled when the grid power was supplied in the sixties. The remains of some of these small power plants are still visible in a number of tea estates, and the dismantled components of these plants have been sold as scrap by scrap metal dealers in Gampola and other up country towns for many years.

In those early projects, a perennial stream was usually harnessed, and where necessary a regulating pond was also constructed. The water was conveyed by means of an open channel to a short penstock and the turbine housed adjacent to the factory. Sometimes, instead of generating electricity, a direct mechanically coupled shaft and belt drive system was used to power the processing equipment such as the tea leaf cutter, blower fan, mechanical sieve, water pumps, etc.

Electricity was first supplied to Sri Lanka in 1895 for lighting in the city of Colombo. Gas lighting used previously for street and house lighting was replaced by electricity which was generated from diesel power sets. These sets were introduced in a number of towns in the first few decades of the century.

The first hydropower generator was installed near Nuwara Eliya at the beginning of the century by Mr. Wimalasurendra to provide electricity to this up country resort. The power plant was located at Black pool at the outfall of the Nuwara Eliya lake and the supply was sufficient for the lighting needs of Nuwara Eliya.

Kelani Ganga - Kehelgamu Oya and Maskeli Oya Hydropower Development

The original master plan conceived by Mr. Wimalasurendra was later adopted to develop the power potential in the Kehelgamu Oya and Maskeli Oya. The implementation strategy as planned by him clearly indicated that the first stage was a simple diversion at Norton Bridge in the Kehelgamuwa valley to generate hydropower on a run of the river basis at the Old Laxapana power plant in the Maskeliya valley. Later, this was augmented by construction of a storage reservoir at Castlereigh in the upper reaches of Kehelgamu Oya. Construction of the Mousakelle reservoir in the uppermost reaches of the Maskeli Oya enabled power generation at the New Laxapana power plant. The development of the respective hydropower stations of the cascade were carried out in order to meet the increasing demand. (Fig. 1,2)

It is important to note that the main storage reservoir at Castlereigh with a capacity of 55 MCM and Mousakelle with a capacity of 115 MCM are ideally located at the highest altitudes and are capable of providing efficient regulation of these two tributaries. Any spill waters and the yield from the intermediate catchment gets collected at the next regulating pond and is utilised for power generation.

This configuration of cascade development enables the water to be used most efficiently for power production right along the cascade.

Some day in the future, with the completion of the proposed Broadlands project located below the confluence of the two main tributaries, the stage development of the Kehelgamu Oya and Maskeli Oya power potential between these elevations will be completed. A total of 1100 metres of head between Mousakelle and Castlereigh in the upper reaches, and Broadlands in the lower reaches will have been utilised for hydropower development, and Wimalasurendra's original dreams would have been converted to reality.

Multipurpose Projects

The Gal Oya Project was commissioned in 1949 and a hydropower installation of 10 MW in the Senanayake Samudra was commissioned and connected to the national grid.

The Uda Walawe reservoir project constructed in the late sixties has two power plants with a total capacity of 5.4 MW incorporated in the irrigation sluices. The water releases from these multipurpose projects are governed by the irrigation demand. Due to the fact that the installed capacities are relatively small the operation and maintenance costs are generally high compared with other larger hydropower projects.

Mahaweli Diversion Project

Mahaweli Ganga Hydropower development commenced with the construction of the Polgolla barrage for river diversion and the Ukuwela Power plant operating on a run of the river basis in the seventies. This project was commissioned in 1976 and has an installed capacity of 40 MW. which is firmed up by the upstream storage reservoir at Kotmale built later. The next project in the Mahaweli Diversion was constructed at Bowatenna with an installed capacity of 40 MW and the project was commissioned in 1980.

Accelerated Mahaweli Development Programme

Accelerated Mahaweli Development Programme was launched in 1978 with the intention of completing a substantial part of the program within a short period.

By 1978, hydropower demand had reached a critical stage where CEB had to resort to load-shedding as the installed power capacities were inadequate to generate the energy demand. The earlier plan had included construction of the Samanalawewa project which would have made a substantial contribution towards meeting the demand. That project had not taken off however, on account of lack of agreement on terms and conditions for the loan offered by the Soviet Union for construction of the project. As a result the CEB had no option but to go ahead with an emergency plan to install six 25 MW capacity Gas Turbines at the Kelanitissa Power Station, in Colombo, as a short term measure to meet the increase in demand.

An Accelerated Mahaweli Development Programme implementation strategy envisaged the construction of four major reservoirs, namely, Kotmale, Victoria, Randenigala and Maduru Oya, and the development of Systems A,B,C,D and G. The first three major reservoirs to be constructed on the main stem of the Mahaweli ganga would have a total installed capacity of 550 MW, so that the installed generation capacity in the country would be doubled. These projects were successfully implemented during this period and in addition Rantembe project was also commissioned in 1990 adding on a further 50 MW to the national grid.

The cascade development along the Mahaweli is indicated in Fig 3 and 4 and a total of 565 m of river drop is utilised for power generation. It should be noted that there still remains two more medium scale projects yet to be developed at Ulapane and at Halloluwa within this reach of the main river.

The storage capacities of Victoria and Randenigala reservoirs are fairly substantial and provide good regulation, but at Kotmale the dam height was reduced by 30 m in order to overcome funding shortages. The storage capacity at Kotmale would have been doubled if not for this restriction and it would have been able to provide better regulation and specifically in meeting the irrigation demands at Polgolla diversion.

It should be highlighted that the capacities of these large reservoirs are comparatively small when compared with the average annual river flow and is approximately one third. While these capacities are adequate to regulate seasonal variations between two monsoon periods, these capacities are inadequate to provide carryover storage for longer periods of time.

With the implementation of the multipurpose Mahaweli Projects the energy and power demand was satisfactorily met and we are fortunate to have avoided power cuts up to date. However, the future seems to be uncertain while C.E.B. is falling behind in the implementation of new projects. Fig 5 & 6. Table I indicates a list of all the hydro projects commissioned to date.

Remaining Hydropower Resources

The Hydropower projects developed so far are limited to 1100m head on Kelani, 600m head on Mahaweli and the Samanalawewa which utilises 180m head on Walawe ganges. There are multitude of projects still remaining to be harnessed in the upper reaches and in the tributaries of these three river basins. We are yet to venture for hydropower generation into the other river basins such as Kalu, Nilwala, Gin, Kirindi Oya to name a few.

The Hydropower projects could be broadly categorised into three main groups namely (I) Major and Medium (II) Mini (III) Micro.

Most of the remaining hydropower projects that fall into the first category have been already identified. The latest study conducted for the CEB in 1989 indicates most of these projects in Table 2. The total available capacity of these projects add up to about 1100 MW and CEB has so far conducted detailed Feasibility Studies only on three projects namely 1. Broadlands 2. Kukule and 3. Upper Kotmale. The remaining projects are yet to be evaluated and there seems to be no urgency or importance shown by the authorities in carrying out detailed studies on these remaining hydro resources. The development of the remaining hydropower resources should be taken as high national priority because of the multitude of other benefits that goes with these developments.

The available Mini Hydro projects are numerous and these could be installed in most of the smaller tributaries, larger irrigation reservoirs, along main canals and in lower reaches of main rivers. These potentials have not been properly identified however the total available would be substantial. Few of the attractive projects have been identified in the studies concluded in 1989 for CEB and Table 3 indicates few of the most economically attractive projects.

The available Micro Hydro projects are more numerous than the above categories and detailed assessment of these potential would be tedious and expensive. However, these projects could make a considerable contributions to the national development in future.

Due to various reasons such as smaller size remote locations, distance from main grid etc. Mini and Micro projects are left for the private sector to develop. In Sri Lanka it is very common to assess the hydropower potential of the Water Falls and these are obviously the most economically attractive sites. It is very important to realise the environmental and scenic importance not only in the immediate future but for generations to come and plan these projects accordingly. If these aspects are not considered at the project identification stage it may lead to unnecessary protests and agitation by various sections of society and frustrate the private developers.

Optimisation of Hydropower Resource

Hydropower schemes are generally characterised by high capital investment and very low operation and maintenance costs. The major expenditure is on the civil engineering works and has to be built to suit the site conditions. The electro-mechanical equipment has to be manufactured to required specifications and are generally imported.

The long life of civil works and the ambient operating conditions give hydropower projects a very long life span and can be kept operating for several generations or centuries. The electro-mechanical components too could be kept in service for long periods with part replacement and refurbishment.

The economic features of hydropower are strengthened by its flexibility of operation, quick response to system demands and energy storage provided in large reservoirs. Water has an inherent value, not only for hydropower but for other uses such as irrigation, water supply, fisheries, recreation and navigation etc and priorities of these uses may change with time.

Generally the development of hydropower enhances the value of water for other purposes. The ready commercialisation of hydropower through market forces should not mask the need to develop water resource on multipurpose basis. The valuation of the multipurposes uses is more difficult and to give a value purely on economic scale in often difficult. Therefore in water resources planning priorities should be established which over ride economic consideration and in which hydropower is allocated its role.

It is extremely important to realise that water is a limited and a scarce resource and with the increase in population and development the demand for water will increase. Thus it is very important that in planning water resource development projects must necessarily consider all these factors with a broader perspective.

The current methodology adopted by CEB for future hydropower projects in based purely on Least Cost Generation Expansion Plan. In this evaluation cost of energy generated by hydro projects is directly compared with cost of generation from alternate sources such as Coal, Diesel or Gas. In this evaluation the additional benefits in using a perpetual and monopoluting source is not given due recognition. The benefits that would continue to accrue after the evaluated time period of 40 or 50 years are considered to be insignificant in the economic analysis.

The appraisal process should ensure that the cost advantage of hydropower extending over 60 years is visualised in comparative project evaluation. This advantage does not appear when using traditional discounting procedures which do little justice to projects which can serve the community in a sustainable way. For real comparison of different energy generations it is imperative that capital expenditures be discounted by using a "real" rate of return and not to undervalue future benefits or skew investments toward short-term or distorted returns to capital.

It should be highlighted that a hydro project after running for 50 years will be worth many timesmore than the original investment and it will continue to produce electricity at a minute fraction of the cost of thermal generation.

As an example New Laxapana hydropower project which was commissioned in 1974 costing 80 Million US dollars could be considered. Instead if an alternative thermal generation plant was commissioned in 1974 after 20 years of running it needs to be replaced today, and the present value (at 10% discount rate) of the replacement cost, and the fuel and maintenance costs, would be about 475 Million US dollars. This would give an indication of the present value of New Laxapana installation when considered for a further limited period of 20 years of generation i.e. upto year 2015. Similarly, the replacement value in 2015 would have to be considered inreality in the case of a thermal installation.

If we assess the replacement cost of the existing Kelani hydropower projects it clearly indicates that this system is worth over 1500 Million US dollars today.

It is also important to realise that low interest loan facilities are available from World Bank. Asian Development Bank etc for the development of hydropower projects while thermal generation projects do not attract such advantages. We have developed all our hydro projects in the past by using such concessionary loan facilities and we could continue to use such concessionary loan facilities to develop our remaining hydropower projects in the future.

The current policy of private sector participation in hydropower development on BOO and BOT basis may not be successful unless Feasibility Reports of these projects are made available. We will be able to attract more investors by saving time and risk if these feasibility studies are carried out in advance. The feasibility reports on major multipurpose projects take as much as two years and it may be difficult to attract private investor and such projects should necessarily be developed by the Government.

Importance of hydropower could be seen from the experience of the developed countries such as North America and Europe where they have harnessed most of their hydro resources. France has exploited over 96% and Switzerland has already exploited 74% of its hydro-potential. Our national strategy should be extract the maximum benefit from this perpetual source as early as possible.

Environmental Impacts

During the recent past Environmental Impacts has been highlighted to a great extent. It is essential to take due recognition and plan Hydro projects so that these impacts are balanced. Hydro projects should be planned with the aim of improving the environment and the living standards of the local population.

These improvements that could be included in the implementation of hydro projects are improved road network, electricity supply, new towns and settlements with improved living conditions catchment protection and soil conservation measures.

These benefits are difficult to quantify in monetary terms but a method of evaluating these benefits more accurately would be of immense benefit in economic evaluation of hydro projects in the future.

Future Development

The multipurpose use of water has to be recognised in planning water resources especially in view of the fact that it is a limited resource and is needed in all sectors of development. Proper evaluation of its economic contribution and social benefits in other sectors should be carried out on a long term basis. In Sri Lanka the basic short coming in water resource development is that there is no owner for this vital resource. It is seen from the haphazard development in different sectors such as Hydropower, Irrigation, Water supply etc. Except for the Mahaweli Projects developed on multipurpose basis there is lack of coordination among the various users of water. One could clearly see that there is a serious lapse and the need for the establishment of a single authority to own, maintain, coordinate and develop this vital resource is of great importance. The establishment of a Central Water Authority may be the answer to this need and we could learn from the experience gained by our neighbouring countries in this sphere. The development of water resources could be carried out in such a manner that the cost could be recovered from the various end users. Planning could then be done in a more systematic manner so as to maximize the benefits.

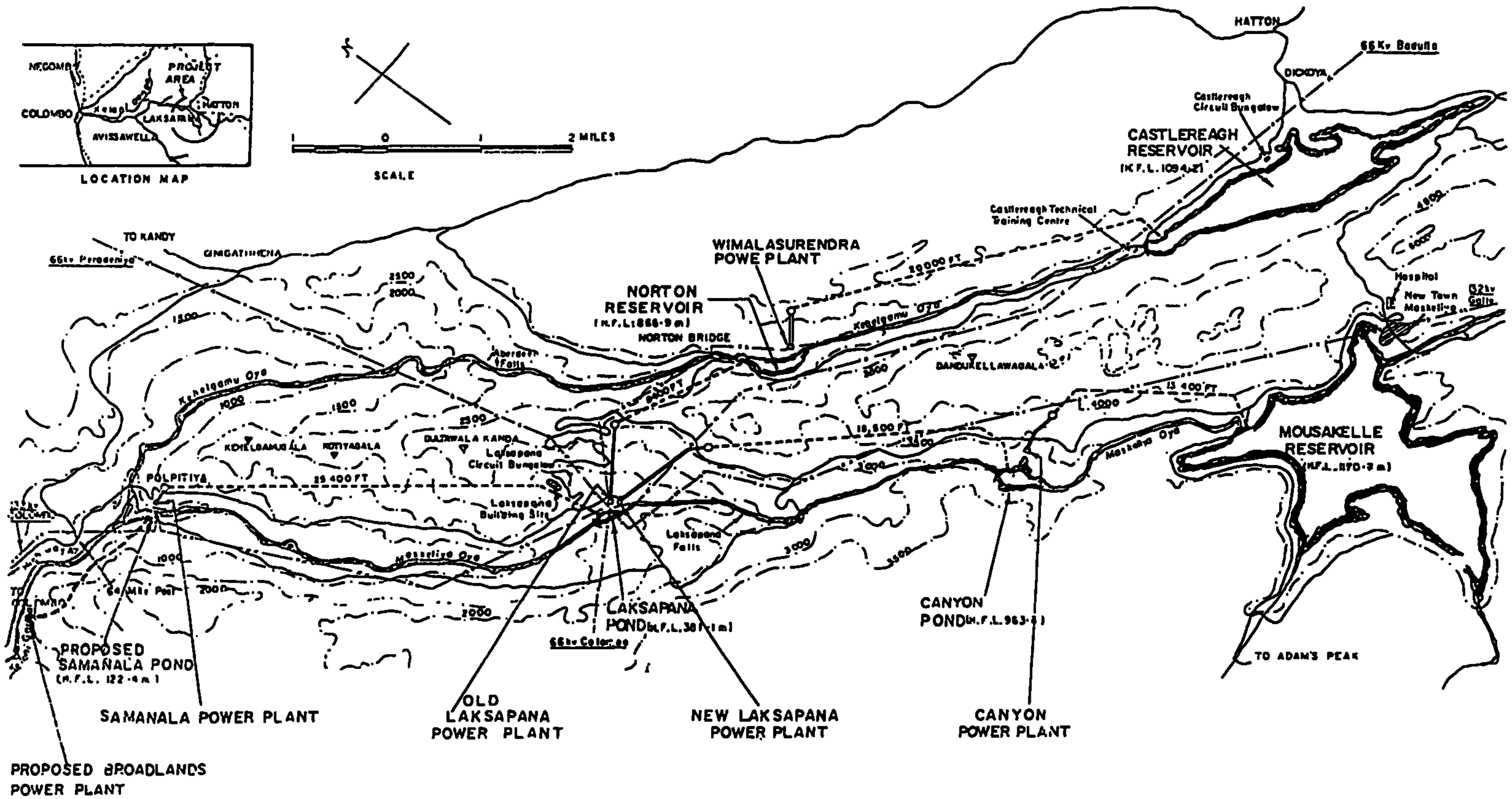

Figure 1 - Kehelgamu Oya & Maskeliya Oya Power Development

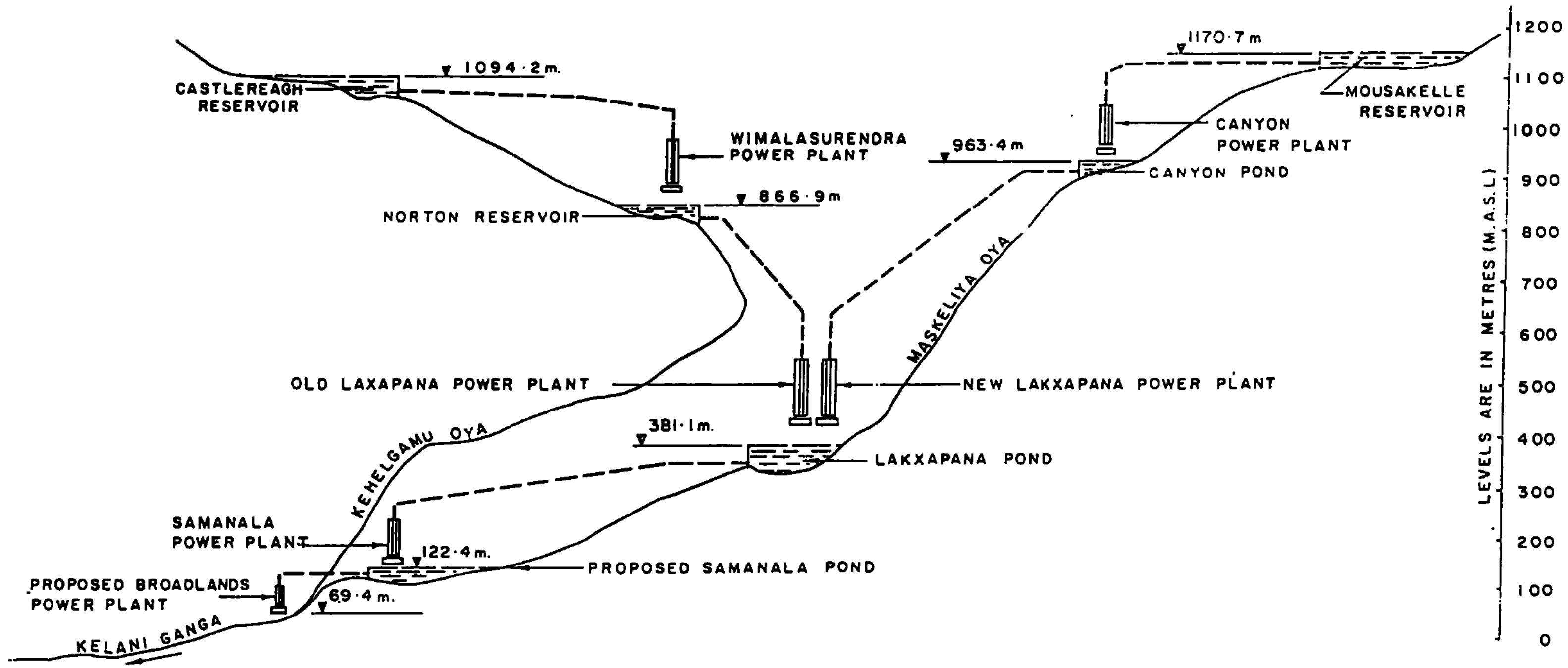

Figure 2 - Schematic Diagram Kelani System

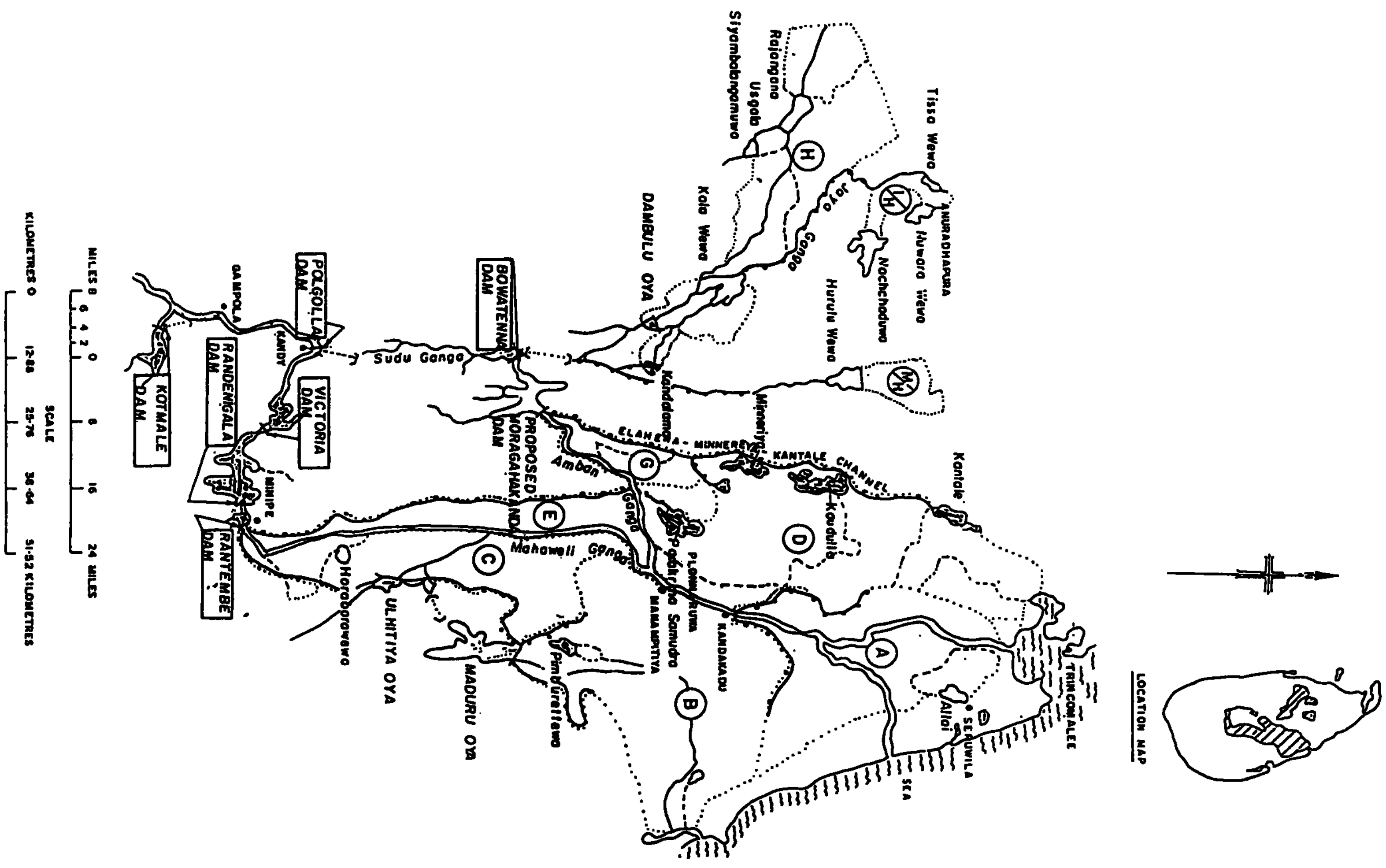

Figure 3 - Mahaweli Hydropower Projects & Development Areas

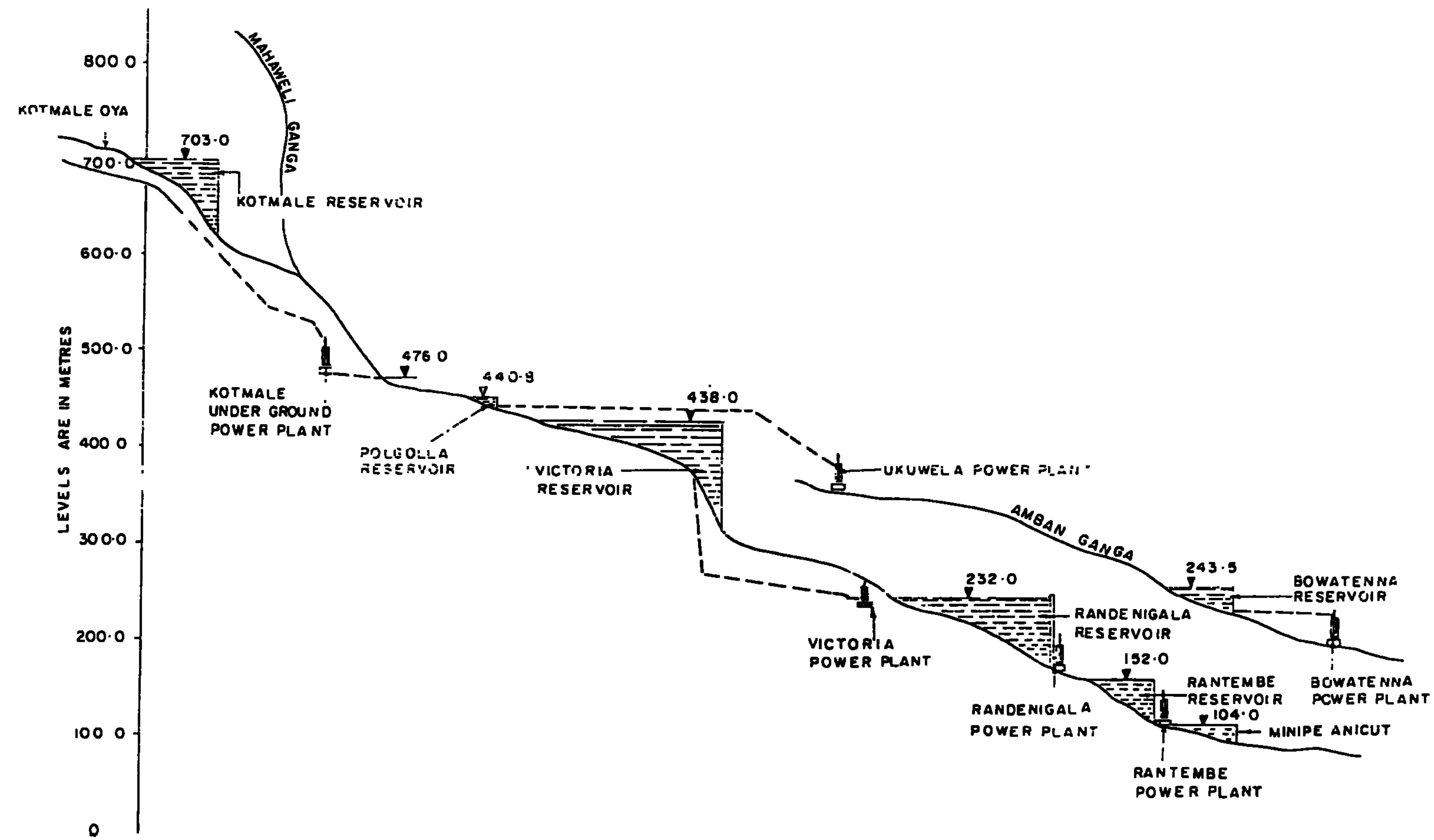

Figure 4 - Schematic Diagram Mahaweli System

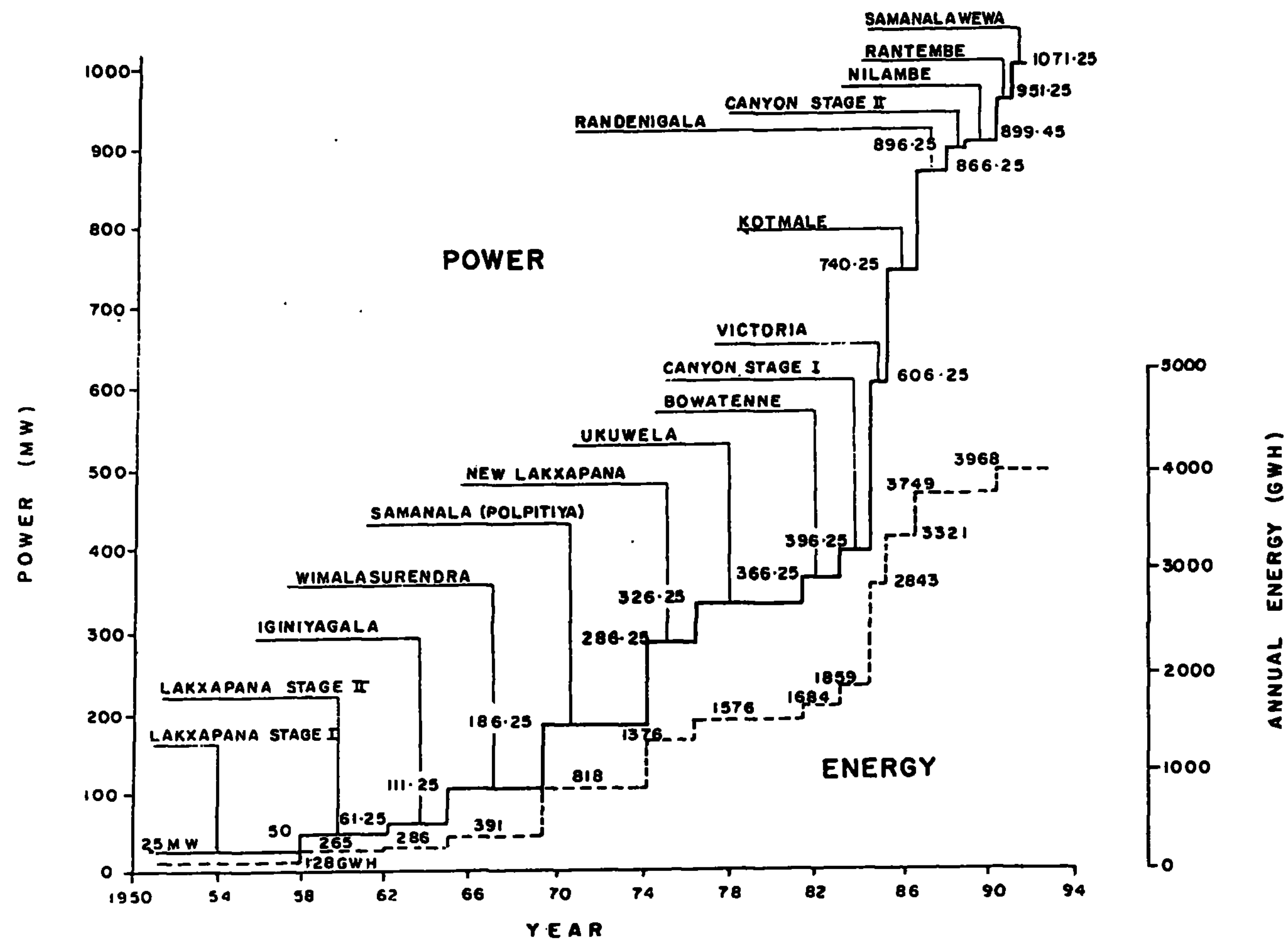

Figure 5 - Power and Energy Chart

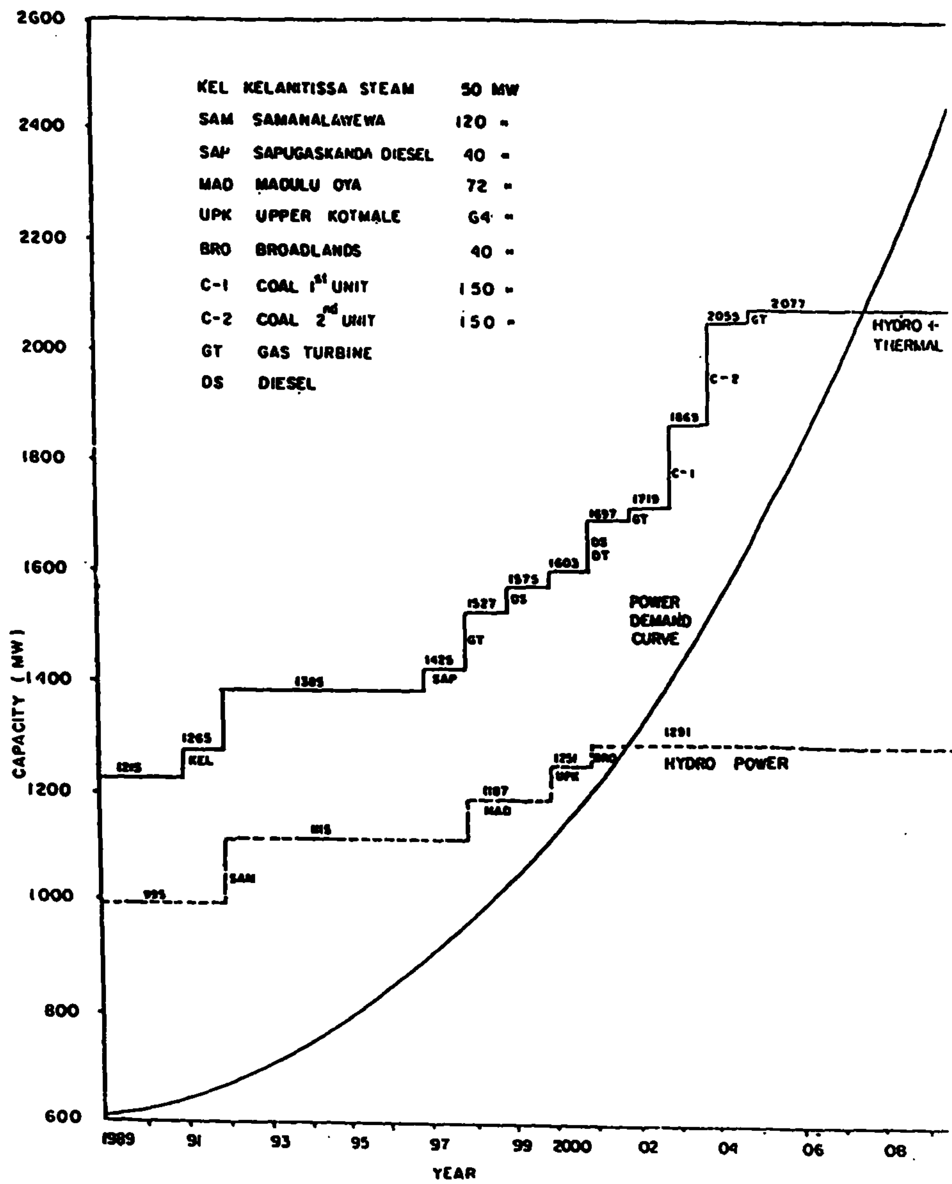

Figure 6 - C.E.B. System Capacity Balance

Table 1 - Commission Hydropower Plants

Name	River System	Installed Capacity (MW)		Average Flow (m^3/s)	Energy Production (Gwh/yr)		Commissioning	Water Use
					Average Historic	Long-Term Expected		
Old Laxapana	Kelani	3 x 8.33 = 25 2 x 12.5 = 25	50	9.1	277	248	Dec 1950 Dec 1953	Power
Inginiyagala	Galoya	2 x 2.475 = 2 x 3.15 =	11	n.a	36	n.a..	Jun 1963	Multipurpose
Wimalasurendra	Kelani	2 x 25 =	50	7.6	126	115	Jan 1965	Power
Udawalawe	Walawe	3 x 2 =	6	n.a	10	n.a.	Apr 1969	Multipurpose
Polpitiya	Kelani	2 x 37.5 =	75	9.1	385	463	Apr 1969	Power
New Laxapana	Kelani	2 x 50 =	100	16.2	456	581	Unit 1 Feb 1974 Unit 2 Mar 1974	Power
Ukuwela	Mahaweli	2 x 19 =	38	34.1	168	174	Unit 1 Jul 1976 Unit 2 Aug 1976	Multipurpose
Bowatenna	Mahaweli	1 x 40 =	40	48.2	39 (1987)	55	Jun 1981	Multipurpose
Canyon	Kelani	2 x 30 =	60	12.7	135	181	Unit 1 Mar 1983 Unit 2 1988	Power
Victoria	Mahaweli	3 x 70 =	210	57.3	626 (1985-87)	817	Unit 1 Jan 1985 Unit 2 Feb 1988 Unit 3 Feb 1986	Multipurpose
Kotmale	Mahaweli	3 x 67 =	201	30.8	--	499	Unit 1 Apr 1985 Unit 2 Oct 1984 Unit 3 Feb 1988	Multipurpose
Randenigala	Mahaweli	2 x 61 =	122	75.3	199 (1987)	435	Jul1986	Multipurpose
Nilambe	Mahaweli	2 x 1.6 =	3	--	--	15	Jul 1988	Multipurpose
Rantembe	Mahaweli	2 x 24.5 =	49	91.1	--	228	Jan 1991	Power
Samanalawewa	Walawe	2 x 60.0 =	120	17.3	--	421	Jan 1992	Power
			1115			4213		

Table 2 - List of Candidate Hydroschemes

Project Code	Average Flow (m3/s)	Rated Head (m)	Inst. Capacity (MW)	Annual Energy (Gwh)	Generation Cost (UScents/kwh) Average	Weighted	Rresettlement (Persons)	Inundated Area (ha) Forest	Agric	Employment Effect (M-Years)
MADU003	15.2	285	72	298	3.1	4.5	0	36	24	6110
KOTMO25	20.4	189	64	268	3.5	5.4	0	0	40	5260
GING074	16.4	172	49	211	4.3	5.5	1560	114	56	5540
NALA005	2.8	172	8	27	5.0	5.5	0	0	0	1390
UMAO034	16.8	117	35	143	5.1	6.7	0	170	0	4980
UMAO034	10.3	245	42	173	5.4	8.1	0	25	5	6350
KELA085	36.2	64	39	170	5.6	7.9	0	0	0	6070
BELI009	2.2	274	10	43	5.6	8.2	0	0	0	1670
BELO014	3.2	251	13	53	5.8	8.4	0	0	0	2130
MAHW263	26.1	62	27	111	6.0	9.5	0	0	70	4180
BELI015	0.9	1106	17	73	6.1	6.6	0	0	0	3280
HASS006	1.8	320	10	35	6.3	11.0	50	30	0	1370
UMAO021	12.1	156	31	129	6.6	10.1	0	18	22	5000
KELA071	49.2	32	26	114	6.8	9.6	5200	500	203	4010
NALA004	2.8	94	5	18	7.1	7.9	0	0	0	760
KOTMO033	15.7	340	93	390	7.3	8.8	1700	0	230	14180
MAHW235	67.0	18	21	83	7.3	11.9	0	62	18	3570
KUKUO22	29.6	225	116	512	7.5	7.5	9100	700	4260	15100
MAHW288	3.2	339	18	75	7.5	11.9	0	0	20	3300
UMAO042	8.6	281	42	172	7.7	9.1	1300	3	110	7750
UMAO063	1.4	588	14	58	7.7	9.6	0	0	0	2210
SUDUO17	39.4	34	25	113	7.9	11.8	2600	1	579	4530
MAGA029	15.7	72	19	78	8.5	15.6	0	0	70	4470
SITAO14	27.4	60	30	123	8.8	12.3	3600	0	630	5000
BAMBO10	6.6	82	10	40	8.9	12.3	180	30	40	2570
KALU075	30.7	65	36	149	9.7	10.8	5000	45	1650	5670
SUDU009	44.9	20	18	79	9.9	14.8	1000	0	369	4240
MAHW287	3.6	173	10	42	11.1	19.1	0	0	0	3690
GINGO052	37.8	57	38	159	12.0	12.5	950	190	3350	7570
AGRA003	5.1	69	7	28	12.1	14.7	3100	28	292	1800
BADU029	8.8	85	13	47	13.0	24.1	100	7	13	4590
DIYA008	0.5	305	3	11	15.8	17.3	160	60	0	1070
GINGO53	48.5	56	50	210	16.4	17.3	12120	430	4960	11170
MAHA007	2.6	291	13	50	16.5	25.0	0	2	18	2220
BADUO13	10.3	161	28	106	17.6	31.8	0	40	330	5980
HEEN009	7.8	36	5	20	17.7	23.8	260	178	81	2800
MAHA096	10.4	43	8	34	18.4	24.6	2700	0	411	3280
LOGG011	7.4	16	2	8	24.8	37.0	1100	0	170	1730
MAGU043	10.7	55	8	38	36.7	60.7	400	170	1600	7280
HULU015	4	48	4	13	37.9	55.0	640	13	117	2710
NILA059	19.8	40	15	65	38.5	43.3	9800	135	2195	10890
			1094	4569						

Note:

NALA004 and NALA005 mutually exclusive
MAHW287 and MAHW288 mutually exclusive
GINGO52 and GINGO053 mutually exclusive
MADU003 mutually exclusive with UMAO008 and UMAO021
Secondary costs. included, 10% discount rate, 50 year life time
Installed capacities based on a 50% plant factor
Weighted" generation cost considers only 50% of non-guaranteed energy