A general feasibility study on applicability of sea wave energy technology in Sri Lankan context

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ABSTRACT

Sri Lanka is in a need to utilize its untouched renewable energy potential due to the increasing energy demand and unavailability of fossil fuel. Conventional renewable sources are almost utilized and non-conventional energy (NCRE) sources other than wave energy have already been introduced. This paper discusses the practical possibility of developing wave energy in Sri Lanka as well as it focuses on selecting the most appropriate technology out of those available in the world with consideration to technical, economic, social and environmental aspects.

1 INTRODUCTION

Sri Lanka being a developing country has experienced a rapid growth in its electricity consumption over last few decades due to the opening of its economy in 1977. Until late 90s, power generation heavily relied on conventional hydro power sources. After the significant power shortage in 1996, the government started purchasing power from private owned thermal power stations. As a result, the contribution from thermal plants gradually increased and it accounts for more than 50% at the moment [1] as shown in Figure 1-1. It is not a healthy situation for a country like Sri Lanka which does not have any fossil fuel reserves.

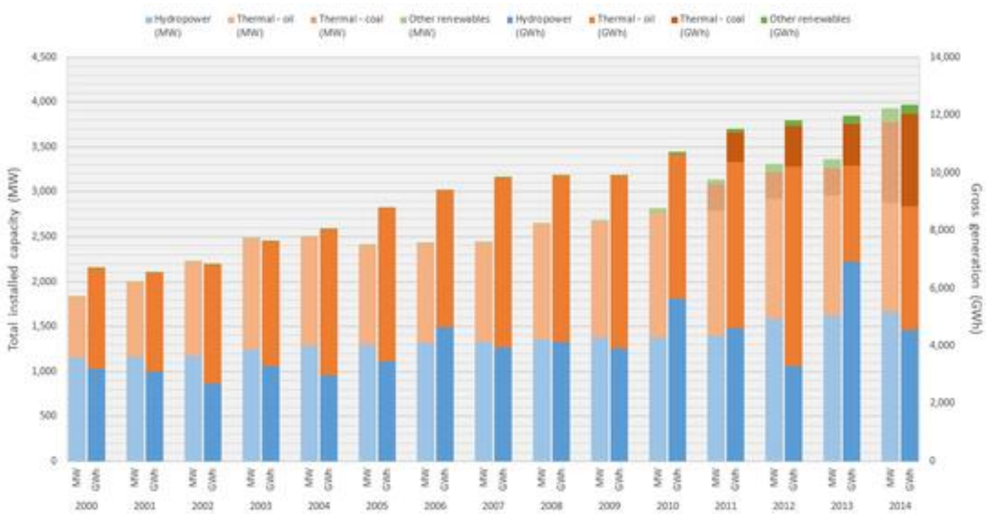

Figure 1-1 Growth of electricity demand in Sri Lanka

On the other hand government opened the electricity market for Non-Conventional Renewable Energy (NCRE) producers. Accordingly, first private owned mini hydro power plant was connected to the national grid in 1997. The two World Bank funded projects ESD[1] and RERED[2] played a key role in the development of renewable energy sector of the country. Mini hydro and wind power industries have significantly established while solar and biomass are still emerging as shown in the Table 1-1.

Sri Lanka Sustainable Energy Authority (SLSEA) was established in 2007 [2] as the official government body for development, promotion and regulation of renewable energy generation. According to the statistics SLSEA, contribution of NCRE sources to the national electricity market was 1217 GWh [3] in year 2014.

Table 1-1 Growth of NCRE generation in Sri Lanka in the last five years [3]

	2,010	**2,011**	**2,012**	**2,013**	**2,014**
Hydro	646	601	565	908	902
Wind	50	89	144	232	270
Biomass	33	32	22	26	41
solar	-	1	2	2	1
Sub Total SPP	728	722	733	1,169	1,215

As far as hydro and wind power technologies are concerned, there is a seasonal variation of generation and therefore it cannot be identified as a sustainable solution for the power crisis of the country. Solar power is a comparatively reliable source but still the generation is limited only to the day time which is not the critical duration of the day in Sri Lankan context. Therefore sea wave power can be promoted as reliable source as it will be available during 24 hours on 365 days of the year with minimum variation.

The subsequent chapters are focussed on the following points

- Technical feasibility of developing sea wave power in Sri Lanka
- Whether sea wave power is competitive with other NCRE technologies
- Review and comparison of different methods of harnessing sea wave power

2 TECHNICAL FEASIBILITY OF WAVE POWER IN SRI LANKA

So far no single wave power project has been implemented in Sri Lanka but some efforts have been made by foreign and local developers which have not been successful. Only a limited number of researches have been conducted on the technical feasibility of wave power in Sri Lankan context. A pre-feasibility study done by University of Peradeniya in collaboration with Uppsala University, Sweden concludes that a 10MW wave power plant would be electrically feasible for a set of selected sites in the southern coast of Sri Lanka. [4] Still that study has been based on a set of estimated data in the absence of actual data of wave heights.

[1] **E**nergy **S**ervices **D**elivery project
[2] **R**enewable **E**nergy for **R**ural **E**conomic **D**evelopment project

The global Wave Power Resource availability is 3TW [5]. Due to the high cost of harvesting, very few resources have been recovered from the availability. The demand supporting policies such as feed – in tariff leads to improve the researches on the field. Now a days Wave Power generation technologies are more competitive against the other Renewable Energy Generation Technologies due to continuous technological improvements and learning curves. World wide

Wave Resource Availability is shown in Figure 2-1

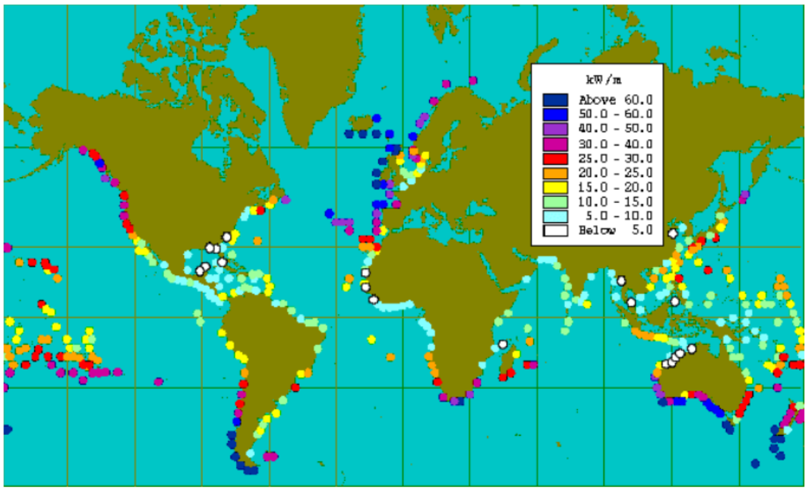

Figure 2-1 Worldwide Wave Resource (Thorpe, 1998) [6] [7]

Source : Roger Beard, "Economic and Social benefit form Wave Energy Conversion Marine Technology"

Sri Lanka is affected by two monsoon periods, northeast and southwest. Waves in the southern coastline are affected by both monsoons. Therefore, south coastline is the most suitable coastal belt for Wave Energy Power Plants. Based on the RERED Final Report in 2005 and CCD_GTZ final report, the annual average wave power availability is 14kW/m. According to Figure 2-1 it is between 15kW/m to 20kW/m. According to

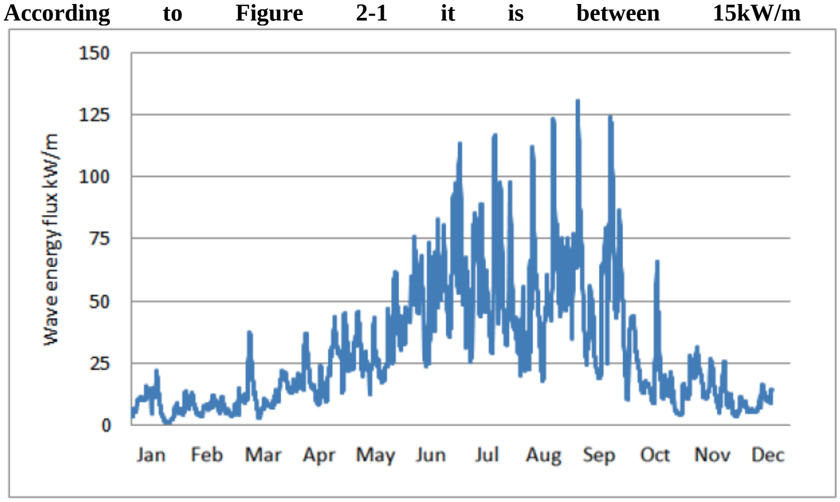

Figure 2-2 estimation of annual average wave power availability in Galle area is around 15 kW/m.

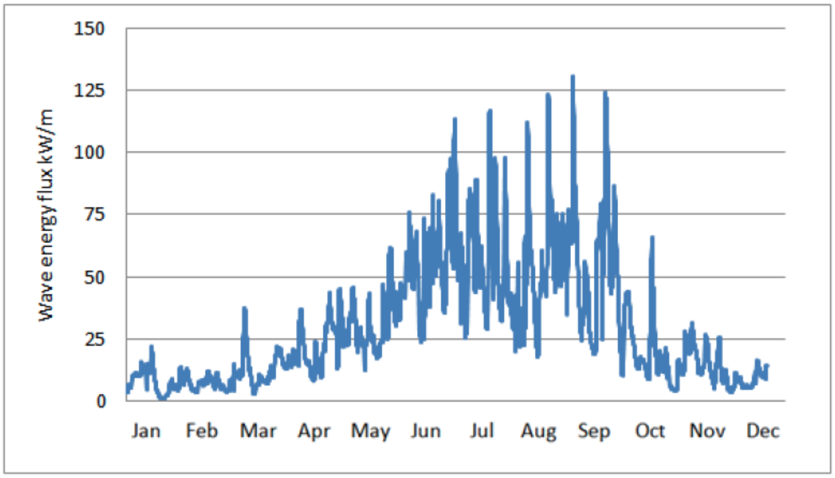

Figure 2-2 Seasonal Wave Energy Flux – Estimated in Galle [8]

3 WAVE POWER AND OTHER NCRE SOURCES

It is vital important to analyses and figure out economic feasibility of each NCRE source used in Sri Lanka with comparison to sea wave energy source. It was investigated that capital expenditure, fixed O&M cost, and variable O&M cost of each NCRE source as follows for 1 MW commercial power plant. The Mini hydro, Wind (on shore), Solar (Photovoltaic), and sea wave (ECO Power – Invention) have been selected as NCRE sources for analysis exercise.

3.1 Data used for the analysis

Construction, installation, commissioning, operation, and maintain of capacity of 1 MW commercial type plant is considered as a pilot power plant only for analysis purpose. Performance information of commercial plants was abstracted from a study done by the U.S. Department of Energy [9] whereas sea wave plant detail was provided by Eco power, Israel based on their experimental plant performance.

Table 3-1 Capital expenditure, fixed O&M cost, and variable O&M cost of each NCRE source [9]

NCRE Source	Average Capital Cost per 1 MW plant (USD)	Capital cost (USD/Kw)	Fixed O&M Cost (USD/kw-yr)	Variable O&M Cost (USD/Mwh)
Mini - Hydro	1,659,259.26	1,659.26	37.80	4.47
Wind (On shore)	2,213,000.00	2,213.00	39.55	No cost
Solar (Photovoltaic)	3,873,000.00	3,873.00	24.69	No cost
Sea Wave (ECO POWER - Invention)	1,200,000.00	1,200.00	28.54	No cost

The bio mass source has not been considered as a NCRE source in above analysis due to the fact that bio mass plant concept itself comprises with more conservative environmental protection aspect which demands high cost of capital among others whereas performances are significantly differ from type of inputs such as solid wood, liquid biofuels, and biogas.

Moreover, Plant factors are such important key criteria to figure out physical/actual production capacity of each type of plant. With reference to article published by public Utility commission Sri Lanka;2011, plant factors were abstracted as below.

Table 3-2 Average Plant Factors of different NCRE sources [10]

NCRE Source	Average Plant Factor
Mini - Hydro	35%
Wind (On shore)	37%
Solar (Photovoltaic)	70%
Sea Wave (ECO POWER - Invention)	40%

The Public utilities commission of Sri Lanka (PUCSL) announces flat tariff for purchasing electricity to the national grid under standardized power purchased agreement.

Table 3-3 Feed in tariff declared by PUCSL for different NCRE sources [10]

NCRE Source	PUC Flat Tariff - Rate in SPPA (Rs/Kwh)
Mini - Hydro	17.15
Wind (On shore)	21.22
Solar (Photovoltaic)	25.09
Sea Wave (ECO POWER - Invention)	25.09

3.2 Outcome of Economic analysis

The analysis of payback period for each source is done as per actual performance data abstracted by above information. It is assumed that whole process of construction, installation, commissioning, and start its operation will be taken 1 year time and second year onwards it starts its operation and maintenance works. The payback period is measured starting from day when starts its operation.

Table 3-4 Payback period analysis outcome for NCRE sources

NCRE Source	Average Capital Cost per 1 MW plant (USD)	Units produce per year (Mwh)	Pay Back Period
Mini - Hydro	1,659,259.26	3,066	6 Y 5 M
Wind (On shore)	2,213,000.00	3,243	5 Y 10 M
Solar (Photovoltaic)	3,873,000.00	6,093	3 Y 11 M
Sea Wave (ECO POWER - Invention)	1,200,000.00	3,504	2 Y 2 M

The highest payback period is recorded by mini hydro (On shore) source which is 6 years and 5 months whereas lowest is shown in sea wave (Eco Power – Invention) which is 2 years and 2 months.

In addition, Break even analysis is shown really interesting fact the sea wave (Eco Power – Invention) required minimum number of units which is 7,628 Mwh to meet breakeven point. Further, low capital cost and 40% of plant factor of sea wave (Eco Power – Invention) has significant contribution to end up with healthy breakeven point.

Table 3-5 Break even analysis outcome for NCRE sources

NCRE Source	Average Capital Cost per 1 MW plant (USD)	Units produce per year (Mwh)	Break Even Point (Units Mwh)
Mini - Hydro	1,659,259.26	3,066	19,574
Wind (On shore)	2,213,000.00	3,243	18,812
Solar (Photovoltaic)	3,873,000.00	6,093	24,032
Sea Wave (ECO POWER - Invention)	1,200,000.00	3,504	7,628

Moreover, Net Present Value (NPV) analysis is shown highest NPV in Solar (Photovoltaic) which is 3,361,323 USD for 15 years' time at flat interest rate of 10% for whole 15 years period of time. However, sea wave (Eco Power – Invention) is held second highest NPV which is valued 2,860,701 USD under same above criteria.

Table 3-6 Break even analysis outcome for NCRE sources

NCRE Source	Average Capital Cost per 1 MW plant (USD)	Units produce per year (Mwh)	NPV @10% (USD)
Mini - Hydro	1,659,259.26	3,066	255,311
Wind (On shore)	2,213,000.00	3,243	597,662
Solar (Photovoltaic)	3,873,000.00	6,093	3,361,328
Sea Wave (ECO POWER - Invention)	1,200,000.00	3,504	2,860,701

4 DIFFERENT TECHNOLOGIES OF HARNESSING WAVE POWER

While a wide range of wave energy technologies have been invented all over the world, only a handful of them have been practically implemented. In the recent past, most of the countries have not been interested in implementing wave power plants, though they have enough resources due to the high levelled cost but learning curves and technological development has brought down costs making it competitive against other renewable energy technologies [14].

Many technologies have been developed for harvesting wave energy. The selecting of a suitable device can be categorized according to different criteria such as resource availability, energy conversion efficiency, grid availability etc. However, most important parameters are location and the operating principle. The developed technologies are as described below.

4.1 Oscillating Wave Column (OWC)

The water column is moving up and down when the waves are passing through the OWC. Then the pressurized air is passing through the turbine. The turbine is connected to the suitable generator to generate the electricity. Due to low conversion efficiency, the technology is suitable for high power waves. [11]500kW grid connected plant is in Australia developed by Energetech [12] [13] [14]

4.2 The Pelamis

This device is a long multi-segment floating or semi-submerged cylindrical structure composed of several sections connected by hinged joints. When the waves pass, the segments move with the waves, but are resisted somewhat by hydraulics. The movement of the hydraulics pressurizes oil, which is pumped into hydraulic motors that power electric generators. The technology is suitable for high power waves [12] [13] [14].

4.3 The Wave Dragon

The Wave Dragon overtopping device elevates ocean waves to a reservoir above sea level where water is spell out through a number of low head turbines to generate the electricity. The technology is suitable for high power waves [12] [13] [14]

4.4 The Archimedes Wave Swing (AWS)

The submerged wave power buoy reacts to changes in sub-sea water pressure caused by passing waves and converts the resulting motion to electricity via a direct-drive generator. The system is suitable for deployment in water depths in excess of 25m and can be configured for ratings between 25kW and 250kW by selecting the appropriate scale [12] [13] [14].

4.5 The McCabe Wave Pump

The wave pump has three pontoons which are linearly hinged together and pointed parallel to the wave direction. The center pontoon is fixed relative to the forward and afterword pontoons. The hydraulic pump is connected between center pontoon and afterward pontoon. The pressurized hydraulic fluid is used to drive the motor generator [12] [14] [13]

4.6 The Power Buoy & Aqua Buoy

The device I floating on the surface of the water, held in place by cables connected to the seabed. The rise and fall of the Buoys are driving hydraulic pumps and generate electricity [12] [14] [13]

4.7 Cost Comparison of different technologies

Table 4-1 Cost Comparison of different technologies

Technology	Capital Cost USD/kW	O&M Cost USd/kW
OWC	3131.00	144.73
Pelamis	1860.00	86.67
Wave dragon	3200.00	66.54
AWS device	3595.00	Not Available
McCabe Wave Pump	Not Available	Not Avialable
The PowerBuoy	1500.00	Not Available
The AquaBuoy	3000.00	Not Available
Sea Wave – (Eco power –Invention)	1200.00	28.54

The study has been confirmed that the technology developed by Eco Power is more economical and as well as technically feasible subjected to availability of required type of waves.

5 CONCLUSION

It is concluded that sea wave (Eco Power – Invention) is re-borne with this new invention and it stretches up conventional boundaries of in Non-Conventional Renewable Energy industry. Further sea wave (Eco Power – Invention) has been recorded such healthy economic feasibility by maintaining satisfactory margin compare with other NCRE sources such as Mini-hydro, wind, Solar which are widely available in Sri Lanka.

The main challenge to develop wave energy generation in Sri Lanka is the comparatively low height of the waves which may down size the production rate per unit time. Moreover, Degree to environment impact and obstruction to aesthetic or natural beauty landscape shall be another challenge in Sri Lankan cultural context as feasible wave are generated in southern coast beaches where tourism industry is dominated and highly utilized.

As fact are above, energy crisis is not longer to become national level topic as we all experienced power-cuts during last few weeks in Sri Lanka. Therefore, Sea wave energy shall be used heavily to overcome energy shot fall in the island which has no environment pollution, no operational cost, less capital requirement, less maintenance charges, more importantly available 24x7 all around the island throughout the year.

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