LIFE CYCLE ASSESSMENT OF RENEWABLE ENERGIES INTEGRATED WITH PROPOSED SYDNEY REVERSE OSMOSIS DESALINATION PLANT

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ABSTRACT

Desalination technologies require high energy consumption. This paper analyses the evolution of environmental impact by means of the Life-Cycle Assessment (LCA) technique, caused by the proposed Sydney desalination plant when integrated with different energy production systems. SimaPro 7.18 software, developed by Dutch PRé Consultants, was used as the LCA analysis tool. Plus the results are benchmarked against traditional black coal powered energy generation for comparison. These hypothetical results clearly show that the wind based power generation is the best method when it comes to environmental impacts, availability and cost.

***Key words*:** LCA, Reverse Osmosis, SimaPro, Desalination, Wind energy, photovoltaic energy

1. INTRODUCTION

One of significant problems in Australia nowadays is the scarcity of fresh water for human consumption [1]. To aid this, Sydney RO plant has been proposed to built with the purpose of serving potable water for its entire seven million people in a sustainable way. Many of Australia's urban water consumers are obliged to follow water restrictions in terms of when they can use water, and for what purposes [2]. This paper deals with environmental impacts and emissions associated with proposed Sydney RO desalination Plant when integrated with different renewable technologies.

Desalination technologies reduce the saline concentration of water to convert it to suitable water to be consumed by humans. Desalination can be sorted into two major groups or processes; thermal and membrane separation [3]. Reverse osmosis (RO) membrane separation is a process based on separation rather than distillation [4].

The main aim is to analyze which renewable energy system is the best suited for power the RO plant. The assessment is conducted giving priority to environmental impacts. Two renewable energy technologies have been chosen by assessing the availability and cost; namely, wind energy and photovoltaic energy. These two technologies were benchmarked against non renewable energy source: Black coal based energy generation.

The scope of this paper is mostly oriented to the comparative Life Cycle Assessment of above mentioned renewable energy technologies which is intern the environmental load associated with proposed Sydney Reverse Osmosis Plant. The assessment technique is the Life Cycle Analysis (LCA), which includes the entire life cycle of each technology, encompassing: extraction and processing raw materials, manufacturing, transportation and distribution, operation and final waste disposal.

The software SimaPro 7.18, developed by Dutch PRe´ Consultants, has been used as the LCA analysis tool and evaluation method Eco-Indicator 99 and greenhouse model have been applied. These results clearly show that the wind based power generation is the best method when it comes to environmental impacts, availability and cost.

2. METHODOLOGY

The analysis done here is a comparative Life Cycle Assessment of two Renewable Energy Technologies to hypothetically integrate with RO Desalination plant. The two candidates are Wind power and solar photovoltaic energy. Further to

that, Black coal based power generation will be used in the analysis to benchmark the renewable energy technologies against it.

The assessment tool we used is SimaPro 7.18 which is well known, internationally accepted and validated software. In order to obtain a complete outlook of the environmental damage of the different renewable technologies and for evaluating their corresponding environmental impacts, we used Eco-Indicator 99 (EI 99) impact assessment method and greenhouse model throughout this analysis and it is highly compatible with ISO 14042 requirements.

3. RESULTS AND DISCUSSION

Summary of desalination plant

The aim of this plant is to supply fresh water for 7 million people Sydney inhabitants (assumed that water consumption is around 0.7-0.8million liters/year/person). The specifications herein are according to the studies of Raluy, *et al* 2005 [3]. The operational time is 8000 h/year and has 25 years of useful life. The desalination plant will use the technology of RO (reverse osmosis) and the membrane will be replaced every 5 years. The energy consumption of a RO plant is 4 kWh/m^3

Wind Energy

The proposed Wind mill for comparison is in Bungendore, Lake George, NSW which has 67 windmills. This farm is deemed to produce enough electricity, at 400,000 MWh/year [5].

The dimensions of the rotor and tower are; 3 blades with a total diameter of 23.8 m, which are made of fiber glass reinforced with epoxyde resin. The tower is 23.8 m high and is made of zinc-coated steel [5]. This includes the operation of the wind power plant with the necessary change of gear oil. Based on the electricity production of the offshore wind park, it also includes the capacity factor, concerning the wind conditions, which has been assumed to be 30%. Gear oil has to be changed every second year. The life time of moving and fixed parts is assumed to be 25 years. The efficiency of the wind power plant is assumed to be 25%.

Construction of moving and fixed parts is modeled based on information from a wind converter manufacturer and from a building enterprise. Moving parts include the materials required for the rotor, the generator, electronics and the power supply line. It also considers that material related transport activities, waste treatment processes of production waste and end of life waste.

For the fixed parts, they include materials required for the foundation, the tower and mounting of converter. However, wind power plants are far away from the desalination plant, it is difficult to assess the average additional effort for the electricity grid infrastructure.

Solar photovoltaic energy

The Solar power plant with a capacity of 50,000 KW which provides the electricity for the desalination plant locates in Buronga, NSW [6]. This plant comprises with the cell type of Polycrystalline-Si to produce electricity. The inventory tables include quartz, silicon, wafer, panel and laminate production, manufacturing of converter and supporting structure owing to 25 years of operation. The efficiency of the solar power plant is assumed to be 25%. Moreover; it also considers transport of materials, energy carriers, semi-finished products, waste treatment processes, end of life waste and air/waterborne process-specific pollutants. Nevertheless, this plant does not include energy storage systems.

Coal-fired power station

For benchmarking the authors have chosen Wallerawang power station which is located near Wallerawang, in the central West of NSW [7] as energy supplier for desalination plant, which has generating capacity of 1,000 MW. 75% of the coal comes from the Angus place colliery. The life span assumed to be 50 years.

The assessment includes the occupation of construction site, industrial area, industrial area vegetation, and their transformations, fuels,

construction material, material transport, end life waste and waste heat emissions.

Impact assessment

LCA assessment has been carried out to assess the environmental significance of two energy sources; Wind Energy and Solar Photovoltaic Energy. Further to that, the results corresponding to two different analyzed scenarios were benchmarked against the Black Coal based power generation in order to estimate the reduction of environmental impacts when switching into Renewable energy technologies.

Impact Category & units	Wind Power	Solar Power	Black coal
CO2 (kg)	0.75	94.7	941
Methane (kg)	8.4×10^{-3}	0.093	1.67
N2O (kg)	4.3×10^{-6}	8.2×10^{-4}	8.3×10^{-3}
Sequestration (kg CO_2 eq)	0	0	0
Other (kg CO_2 eq)	3.2×10^{-3}	0.12	2×10^{-3}

Table:1 Relevant airborne emissions produced by different energy technologies

Table:1 shows the most relevant airborne emissions produced by the analyzed energy technologies per 1 MWh electricity generation. In general, Black Coal power generation technology, the one against which we benchmarking two renewable technologies, is the most polluting to the atmosphere. When we compare the two renewable energy technologies that we suggested, Solar Photovoltaic possesses high magnitude of CO_2 and N_2O emissions than Wind Energy does. CO_2 emissions corresponding to solar photovoltaic is almost 120 times larger than that of Wind energy. Furthermore, the N_2O which emits from solar photovoltaic is 200 times larger than that of wind based energy generation.

Methane has a large potential of acting as a green house gas [8]. Methane emission of solar photovoltaic energy production is 10 times larger than that of wind energy. If we consider black coal based energy generation it has the highest amount of methane emission. It is almost 20 times larger than that of solar photovoltaic based emission.

So we can clearly see that, airborne emissions pertaining to Wind Power generation is negligible with comparison to Solar Photovoltaic power generation. This will conclude that wind based power generation has the least affect to atmosphere especially it has very small impact on the ozone layer depletion.

Table:2 depicts the weighted damage categories. The total points for solar photovoltaic, black coal and for wind energy are 6.3, 39 and 0.08, respectively. Damages corresponding to wind energy are averagely 80 times less than that of photovoltaic energy technology. It is interesting to note that total for black coal based energy generation (39) is more than 6 times larger than that of photo voltaic renewable energy.

Indicator: Weighting (units: Pt)

Damage category	Black coal	Solar photovoltaic	Wind power
Total	39	6.3	0.08
Human Health	15	2.9	0.03
Ecosystem quality	2	0.6	0.01
Resources	22	2.8	0.04

Table 2: Weighted Damage Categories for different energy sources

Solar Photovoltaic energy technology has greater impact on Human Health, Ecosystem Quality and Resources in comparison with Wind power renewable Technology. When it comes to

Human Health, and ecosystem quality Table: 2 depicts that Photovoltaic energy technology has ~100 and ~50 times more affect than Wind technology. Furthermore, photovoltaic technology needs ~70 times more resources than that of Wind technology. The aggregate total points which correspond to wind power are negligible. But still Photovoltaic would be an environmentally friendly solution when compares with Black coal based power generation where it hast the highest figures for all three different damage categories.

4. CONCLUSION

In this work, a hypothetical Life Cycle Assessment (LCA) has been applied for the proposed Sydney RO desalination plant. The environmental loads associated with different energy production systems were evaluated. According to the analysis wind energy is the most excellent energy source resulting in lowest adverse affects to Human health, Eco system quality and resources. However, black coal based energy generation resulted as the highest damaging energy source pertaining to three impact categories mentioned above. On a final note, proposed RO plant in Sydney has a very important margin for minimizing its environmental load and the results presented in this paper indicate that a very interesting and promising field of research is available in order to achieve it.

5. REFERENCES

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