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# A Multi Objective Optimization Approach for Ro-Desalination Plant Using Integrated Energy Sources

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***Abstract:*** ***This paper introduces integrated energy process for a Reverse Osmosis- Desalination plant with available energy sources in Tamilnadu, India. The integrated energy sources are such as combined cycle gas turbines, nuclear energy, integrated gasification combined cycle, pulverized fuel, solar and wind turbines. These energy sources are examined under different scenarios by using multi objective optimization method. It also examines the $CO_2$ isolation process. The results are reviewed with and without $CO_2$ isolation process by LINGO software. This paper concludes that nuclear energy is more competent technology among renewable energy choices.***
***Keywords: RO-Desalination, Integrated energy, Optimization, Lingo.***

## I. INTRODUCTION

As we all know we cannot survive in the world without water. Water in one of the essential need of a human being. There are many aspects related to water because water has become one of the day to day commodities which we are in search for. Now a day we cannot get water for our day today life and not even for drinking purpose, this kind of situation is called water scarcity. Tamilnadu is one of the states in India that is rich in all the type of resources and in the same way the water is also one of the most important resources that are available to all the people to great extent. But in some areas because of many reasons the water is not available. Tamilnadu is staring a one of its worst water crises. The state has suffered a deficit rainfall during the south west monsoon. The water scarcity problem is at the peak in TN. The TN Government is also taking many steps to overcome the problem of the water scarcity, it also spending 976.76 crores in its cities and towns to tackle the severest water shortage in over 140 years.

India's one of the largest desalination plant is minjur reverse osmosis desalination plant at Chennai, Tamilnadu. It produces about 100 million litres of drinking water every day. The sea water is desalinated by making use of Reverse Osmosis technology. Power needed to produce drinking water from sea water for one family for one year is over two times lower than the power used by family's water heater. The absolute minimum amount of energy required by natural osmosis to desalinate average seawater is approximately 1KWh-hour per cubic meter (KWh/$m^3$) of water produced or 3.8KWh-hours per thousand gallons (KWh/Kgal). One of the major expenses for desalination plant is electricity, which is account for half of the total cost spent to make the purified water. To produce one million gallons of purified water approximately 15000 KWh –hours of electricity is needed. Desalination plants around the world consume more than 200 million KWh-hours each day, with energy costs an estimated 55 percent of plant, total operation and maintenance costs. Desalination plant has significant impact on the environment but is one of the fastest way to get drinkable water. Desalination plants emits more greenhouse gases, in order to avoid such things to make the plants environmental friendly by making use of renewable energy resources.

## II. OBJECTIVE OF THE PROBLEM

The objective of the problem is to reduce the electricity production cost and greenhouse gas emission with available energy sources. Here renewable energy plays an important role for desalination while considering greenhouse gas emissions. Renewable energy sources such as solar and wind is abundant in Tamilnadu. But availability of these sources varies from place to place. All the Green House Gas emissions attributed to renewable sources were due to indirect emissions, while for fossil fuel sources, direct $co_2$ emissions accounted for the majority of Green House Gas [ 4] . In world's largest carbon emitter list India being ranked fourth. The more greenhouse gas emissions are released because of large amount of electricity produced in India.

Renewable energies provide substantial benefits for our climate, our health and our economy. Every renewable energy source has different prices and benefits. The cost of renewable energy sources will be drop down even more in coming days[6]. Indian

government planning to reduce emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level. It also intends to produce about 40 per cent of its electricity in 2030 from non-fossil fuel based sources like solar, wind or hydropower [7]

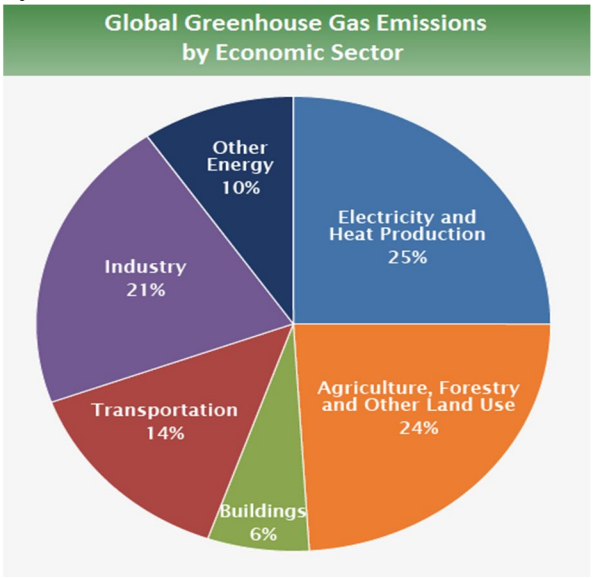


Fig:1 Greenhouse gas emissions by different sectors

The above figure shows the global green house gas emissions by different economic sector. In this chart electricity and heat produces maximum amount of greenhouse gas emissions. The objective of the paper is to find the hybrid energy system such as renewable energy and fossil fuels for a desalination plant. The following explains the different types of renewable and fossil fuel energies.

IGCC: The Integrated Gasification Combined Cycle (IGCC) produces clean power and energy with enhanced efficiency. It utilizes coal gas being produced from a processing unit called coal gasifier. Gasification is the process converting coal into gas to run the gas turbine to generate power and the exhaust gas from the gas turbine enters Heat Recovery Stem Generator (HRSG) to produce steam which in turn runs the steam turbine. In IGCC power plants emission of $Co_2$ was decreased about 1.1Kg/KWh.

Combined Cycle Gas Turbine: The objective of the CCGT plant is to develop overall efficiency by integrating two cycle gas turbine and steam turbine. A CCGT is one such advancement in the field of power generation. The net power output is the summation of both the independent units.

Nuclear Energy: Nuclear energy is an energy which is derived from nucleus of an atom. There are two types of particles such as neutrons and protons present in the atom that are held together form a nuclear energy. Nuclear energy is used to produce electricity by nuclear fusion method.

Pulverized Fuel: A pulverized coal fired boiler is an industrial or utility boiler that generates thermal energy by burning pulverized coal that is blown in to the firebox.

By making use of these energy resources to run the hybrid RO-Desalination plant with and without $CO_2$ isolation. While considering the $co_2$ isolation the cost of electricity production will be increasing. There are five different types of energy scenarios have been considered to run the desalination plant, the scenarios are

All the energy sources are available without considering$CO_2$ isolation.

All the energy sources are available with considering $CO_2$ isolation.

Availability of Renewable Energy sources less than 2/3 of all the energy demand without considering $CO_2$ isolation.

Availability of Renewable Energy sources less than 2/3 of all the energy demand with considering $CO_2$ isolation.

Availability of Renewable Energy sources more than 2/3 of all the energy demand without considering $CO_2$ isolation.

### *A. Optimization Model*

The recommended system and the proposed hybrid energy problem are formulated mathematically by using multi objective optimization method. The objective of the problem is to minimize the electricity production cost and minimize the greenhouse gas emissions with lowest cost. The following shows the optimization problem.

Min Z= Cost+GHGE

Cost=$\sum_{i=1}^{6} cost_i\ e_i$ for every i={1,2,….6}

GHGE=$\sum_{i=1}^{6} g_i\ e_i$ for every i={1,2,….6}

Subject to the constraints

RP=$\sum_{i=1}^{6} e_i$=Capacity$_{ro}$ x $e_{ro}$ for every i={1,2,….6}

$e_i^{min} \leq e_i \leq e_i^{max}$ for every i={1,2,….6}

$e_i^{max} \geq$TP for every i={1,2,….6}

$cost_i=cost_{pi}$ for every i={1,2,….6}

$cost_i=cost_{pi}+cost_{iso}$ for every i={1,2,….6}

$e_{i(RE)} \leq (2/3)RP$ for every i={1,2,….6}

$e_{i(RE)} \geq (2/3)RP$ for every i={1,2,….6}

Here scenario I consists of all energy sources, the total energy requirement can be obtained from all energy sources. Scenario II is equal to scenario I, but there is additional cost for $CO_2$ isolation. Scenario III and IV consists of one condition which is the availability of Renewable energy sources. In scenario III there is no $CO_2$ isolation but in scenario IV there is $CO_2$ isolation. In scenario V the availability of renewable energy sources is more than two thirds of the total required power.

### *B. Problem formulation*

In order to meet our water demands, to implement the Ro-Desalination plant with capacity of 100 mega litre per day. The RO-Desalination plant is considered with five scenarios with and without $co_2$ isolation. The electricity production cost of the energy sources varies while applying $co_2$ isolation. The following table shows the electricity generation cost and their emissions**.**

Table-I Cost of electricity generation without considering $co_2$ emissions.

| Type of Energy | Solar | Wind turbines | Nuclear | Pulverized fuel | IGCC | CCGT |
|---|---|---|---|---|---|---|
| Generation cost/Kwh | 10 | 5 | 4 | 3 | 3 | 3.5 |
| Emissions /Kwh | 0 | 0 | 0 | 250 | 200 | 110 |

Table-II Cost of electricity generation with considering $co_2$ emissions.

| Type of Energy | Solar | Wind turbines | Nuclear | Pulverized fuel | IGCC | CCGT |
|---|---|---|---|---|---|---|
| Generation cost/Kwh | 10 | 5 | 4 | 6 | 5 | 5.5 |
| Emissions /Kwh | 0 | 0 | 0 | 40 | 37 | 17 |

### *C. Results and Discussions*

To solve a small scale RO-Desalination plant of 100,000m$^3$ /day, the five scenarios are solved with and without considering $CO_2$ isolation by making use of LIN**G**O software. The following steps are used to solve the problem.

*1)* In step 1, to minimize the electricity production cost with maximum possible GHGE.

*2)* In step 2, to minimize the GHGE with maximum electricity production cost.

*3)* In step 3, to minimize the electricity production cost for different values of GHGE obtained in step 1 and 2.

*4)* In step 4, the results are represented in graphs.

*a)* *Scenario I:* In scenario I all the renewable energy sources are available without any restrictions. There is no $CO_2$ isolation in this scenario. The result of the optimization is, the minimum electricity production cost is Rs.7,50,000 and minimum greenhouse emission is zero. The minimum cost can be obtained from 100% of the power requirement from the IGCC and the minimum GHGE can be obtained from 100% power requirement from the nuclear energy. The results are showed in table 3 and are presented in figure1

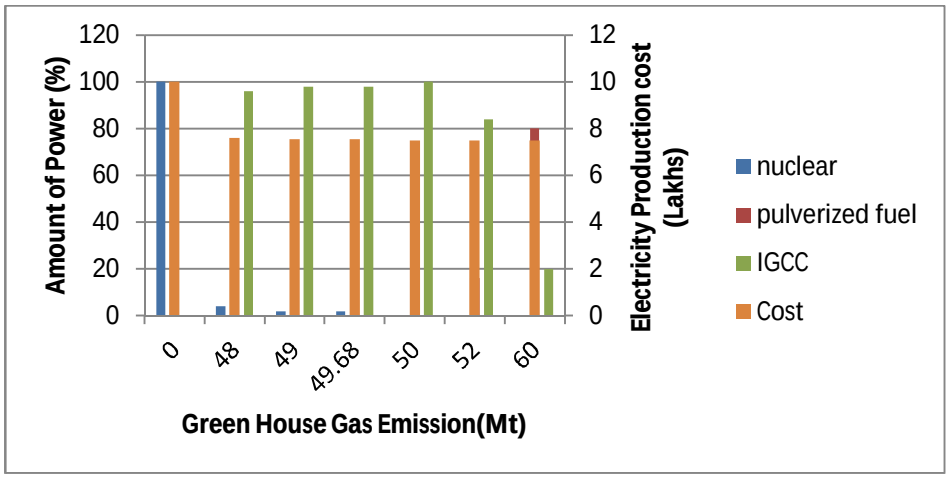


Fig:2 Graph for Scenario I

Table-III Results of the Scenario I

| GHGE | Cost(Lakhs) | Nuclear | Pulverized fuel | IGCC |
|---|---|---|---|---|
| 0 | 10 | 100 | 0 | 0 |
| 48 | 7.60 | 4 | 0 | 96 |
| 49 | 7.55 | 2 | 0 | 98 |
| 49.68 | 7.55 | 1.99 | 0 | 98 |
| 50 | 7.50 | 0 | 0 | 100 |
| 52 | 7.50 | 0 | 16 | 84 |
| 60 | 7.50 | 0 | 80 | 19.99 |

b) *Scenario II:* In this scenario all the energy sources are available in scenario I but with considering $CO_2$ isolation. Here all the energy sources are available and the produced $CO_2$ is treated via $CO_2$ isolation. The result of the scenario is nuclear power will be the optimum one. It will produce zero green house emission with minimum cost of rupees 10, 00,000. When $CO_2$ isolation is applied to this scenario, nuclear energy system is more competitive to other energy system.

c) *Scenario III:* In this scenario, we have considered the renewable energy sources with restrictions according to their availability. India is abundant in renewable energy sources like solar, wind and some areas are very low in renewable energy sources. The restriction is availability of renewable energy sources is less than two third of the total power supply. In this scenario nuclear and IGCC contributes to full fill the energy needs of the Desalination plant. The following figure shows the power supply of the energy sources with restriction of the renewable energy sources.

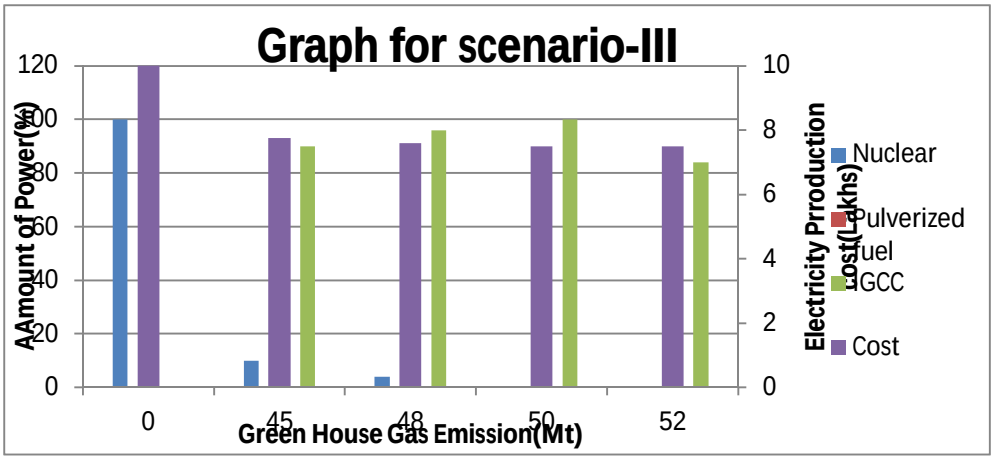


Fig:3 Graph for the scenario III

Table-IV Results of the scenario III

| GHGE | Cost | Nuclear | Pulverized fuel | IGCC |
|---|---|---|---|---|
| 0 | 10 | 100 | 0 | 0 |
| 45 | 7.75 | 10 | 0 | 90 |
| 48 | 7.6 | 4 | 0 | 96 |
| 50 | 7.5 | 0 | 0 | 100 |
| 52 | 7.5 | 0 | 16 | 84 |

*d)* *Scenario IV:* Scenario IV is identical to scenario III but with applying $CO_2$ isolation. The isolation cost of $CO_2$ is added to electricity production cost. The maximum electricity production cost is 10,00,000 and nuclear energy is the optimum energy of the desalination plant.

*e)* *Scenario V:* In this scenario supply of renewable energy source is comparatively high and also considering $CO_2$ isolation. Here the optimum energy sources are solar, wind, nuclear and IGCC. Compare to other energy sources solar energy contributes high. Solar and nuclear energy emits very low amount of greenhouse gases. Compare to other scenarios the cost of electricity production is very high. Here nuclear and IGCC are best competitors of solar and wind energy.

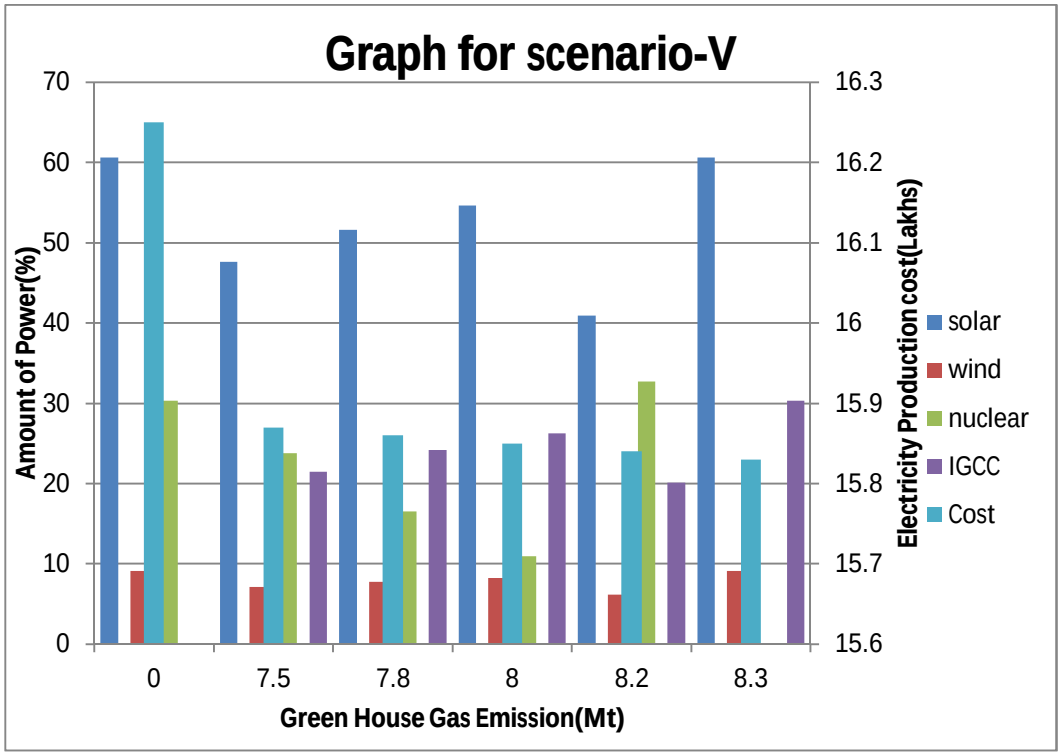


Fig:4 Graph for the Scenario V

Table-V Result of the scenario V

| GHGE | Cost | solar | wind | Nuclear | IGCC |
|---|---|---|---|---|---|
| 0 | 16.25 | 60.61 | 9.09 | 30.30 | 0 |
| 7.5 | 15.87 | 47.62 | 7.14 | 23.81 | 21.43 |
| 7.8 | 15.86 | 51.60 | 7.74 | 16.51 | 24.15 |
| 8.0 | 15.85 | 54.65 | 8.2 | 10.92 | 26.23 |
| 8.2 | 15.84 | 40.96 | 6.14 | 32.74 | 20.15 |
| 8.3 | 15.83 | 60.61 | 9.09 | 0 | 30.3 |

## III. CONCLUSION

A small scale RO- Desalination plant with hybrid power system is suggested with and without considering $CO_2$ isolation. Here various scenarios are considered based on the available energy resources in India. Each scenario possesses different solution for the desalination plant. Nuclear energy is the highest contribution among the various energy sources. Pulverized fuel is also one of the powerful energy sources while applying $CO_2$ isolation but the electricity production cost is very high compared to non $CO_2$ isolation. While considering renewable energy sources with $Co_2$ isolation, solar PV compete effectively with fossil fuel as well as which emits minimum amount of greenhouse gases but the electricity production cost is very high compared to other scenarios. There are different types of compositions are provided for different values of GHGE. The decision maker can choose whatever suitable for the project.

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