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Quantitative analysis of potential energy sources

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ABSTRACT

The energy sector is considered to be one of the most important building blocks in the development of our economy as well as a significant index for the growth of humans as a whole. For developing nations like India, there is an increased need for reliable and efficient sources of energy as they are building blocks to a more developed emergent future. In this uncertain time in the global market with reliance on one another for energy, it is vital that we grow and evolve energy so as to be resourceful, productive, cost-efficient and self-sufficient. Energy has many sources-solar, thermal, hydro, wind etc. Each and every source of energy is accompanied by its own constraints. These sources of energy need to be analysed both quantitatively as well as qualitatively so as to choose the most optimal source of energy. These forms of energy can be harnessed effectively to produce energy. The research paper aims at forecasting future energy requirements of different states and the best possible source that meets their transport and cost requirements. Operations research has thus been used to analyse these sources of energy and derive conclusions from available data.

Keywords— *Operations research, Energy, Renewable energy, Transportation problem*

1. INTRODUCTION

According to the International Energy Agency (IEA), the world electricity demand is supposed to increase by 70% in 2040, indicating a substantial increase in the demand for energy. This energy demand is majorly satisfied by the cheapest source that is fossil fuels. (acciona)

There is a dire need to reduce this dependency, which has majorly remained constant even after the increasing use of renewable energy over the years. This is mainly due to the dependence of developing the nation's dependence on fossil fuels due to their cheap costs. This is where the need to shift towards renewable energy comes in.

Renewable energies are clean sources of energy that are replenished through natural resources hence making them inexhaustible. They differ from fossil fuels essentially due to their easy availability and zero emission of greenhouse gases.

The decrease in the production costs of renewable energy has made them more widely utilized in countries worldwide making the growth in clean energy unstoppable as declared by the 2015 IEA results.

However, these have been an upward trend in the use of renewable energy in developed countries such as Iceland who derive around 90% of their energy through non-renewable sources.

Types of renewable energy include:

- Wind Energy
- Solar Energy
- Hydraulic or Hydroelectric energy
- Biomass and Biogas

- Geothermal Energy
- Tidal Energy
- Wave Energy
- Bioethanol
- Biodiesel

2. ADVANTAGES

2.1 Helps in the reduction of pollution: They do not emit greenhouse gases in energy generation processes, making them the cleanest, most viable solution to prevent environmental degradation. (conserve-energy-future-renewable-energy)

2.2 Inexhaustible. Compared to conventional energy sources such as coal, gas, oil and nuclear - reserves of which are finite - clean energies are just as available as the sun from which they originate and adapt to natural cycles, hence their name "renewables". This makes them an essential element in a sustainable energy system that allows development today without risking that of future generations. (energysage)

2.3 Reducing energy dependence: The indigenous nature of clean sources gives local economies an advantage and brings meaning to the term "energy independence". Dependence on fossil fuel imports results in subordination to the economic and political short-term goals of the supplier country, which can compromise the security of energy supply. Everywhere in the world, there is a renewable resource – whether that be the wind, sun, water or organic material – available for producing energy sustainably. (ittana.org)

2.4 Increasingly competitive. The main renewable technologies – such as wind and solar photovoltaic – are drastically reducing their costs, such that they are fully competitive with conventional sources in a growing number of locations. Economies of scale and innovation are already resulting in renewable energies becoming the most sustainable solution, not only environmentally but also economically, for powering the world. (acciona)

2.5 Benefiting from a favourable political horizon. Decisions adopted at COP21 have shone the spotlight firmly on renewable energies. The international community has understood its obligation to firm up the transition towards a low-carbon economy in order to guarantee a sustainable future for the planet. The international consensus in favour of the "de-carbonization" of the economy constitutes a very favourable framework for the promotion of clean energy technologies. (acciona)

India's billion strong population and its 80% high dependence on fossil fuel for energy make it a source of concern for the environment and the country enslaved to other oil producing nations. However, India as a country is also trying to move towards more renewable sources of energy with its corresponding increase in the use of renewable energy making it an optimum example due to its abundant wind, solar and tidal energy. The growth in usage of solar energy, as well as biofuels, shows a shift from using fossil fuels to a conscious attempt to use more environments friendly, biodegradable, economical and easily available.

3. INDUSTRY OVERVIEW

The energy sector for production of electricity was initially started as utilities formed to meet electric needs of specific cities in which the economics of serving densely populated areas allowed construction of power plants as well as evolution, growth, and research into different sources of energy. Over time, these utilities became larger and served territories specified by state regulatory agencies. These utilities built the infrastructure—power plants, high-voltage transmission, and low-voltage distribution lines—to serve their larger regulated service territories

Studying, analysing and research on the energy sector is vital as it helps to develop new technology that is more productive, resourceful, environment-friendly and cost-effective. Thus decisions regarding optimization of resources so as to do "to do things best under the given circumstances" are made by operations research.

The energy sector is vital to the growth of the economy in general and manufacturing sector in particular. These sectors are almost fully dependant on power/energy. Thus the optimization of these resources is key to the growth of the country as a whole.

Energy growth is directly linked to well-being and prosperity across the globe. Meeting the growing demand for energy in a safe and environmentally responsible manner is a key challenge.

4. LITERATURE REVIEW

The main analysis in given research paper is to study MISO's energy market and applications of OR in the said sector. Their aim is to create economic incentives to minimize total production cost of operating power plants. They can do this by minimizing the total production cost of operating power plants through the cost-optimized scheduling of their energy output.

Optimization algorithms can be used to fulfill the cost optimization purpose. The production cost parameters that aid in optimizing the cost of energy are raw material cost, start-up cost, load cost, variable cost and transport cost.

OR has played a critical role, it has made a huge impact in the initial deployment of the energy market. Anticipated demand, available power plant capacity, and system conditions change throughout the day, MISO also operates a real-time market in which it uses technology to precisely analyse moment-to-moment conditions of the system. Based on this information, operators balance generation and demand to keep the system reliable and economically efficient. This structured analysis of quantitative data in a

systematic manner has helped MISO balance energy generation by plants and energy consumption by users. (Carlson, Chen, & Hong, 2012)

Each source of energy has its own advantages and disadvantages. Coal, oil, and petroleum are currently used to meet the high demand for energy. These sources of energy are not only harmful but are also depleting and will not be available for an infinite period of time. This is why there is a need to switch to renewable energy. India is blessed with abundant resources which makes it easier to depend and slowly shift to renewable energy.

India's wind energy capacity is the 5th largest worldwide. States such as Gujrat, Kerela, Tamil Nadu, and Karnataka have a high potential to generate wind energy. India can also use waste such as cow dung and agricultural waste to produce biogas which would help to generate electricity. India has a huge potential to use tide energy as it is surrounded by oceans on its 3 sides. It is estimated that India's power consumption requirement will increase significantly and thus make use of renewable energy to meet this demand. (Shaji, 2014)

Solar energy is a modern, renewable and abundantly available source of energy. The large dependence on non-renewable resources has led to a large demand-supply gap. According to "Distributed Solar Energy System." one of the ways to solve the supply-demand gap of solar energy is by decentralizing solar energy. The government of India is promoting solar energy by making several policies which encourage people to install various solar panels in their houses, farms, buildings, factories and other places. Solar energy is clean and pollution-free energy which can reduce the dependency of thermal energy. (Ramchandra & Hedge)

The demand and prices of fossil fuels are expected to rise with increasing population and hence the dependence on natural reserves. The irreversible damage to the environment and depletion of the natural reserves have emphasized the need to switch to renewable energy. The International Agency (IEA) forecasts positive developments in renewable energy as they are the main alternatives and reasons behind cutting down the use of fossil fuels.

Power generation using renewable energy sources should be increased in order to decrease the unit cost of energy and to make them compatible with a competitive alternative to the conventional sources. (Abolhosseini, Heshmati, & Altmann, 2014)

5. SIGNIFICANCE

Tidal energy is one of the oldest forms of energy generation that derives its energy from earth-moon system by creating tides. It converts the natural rise and fall of these tides into electricity. It can only be installed along coastlines, which experience two high tides and low tides on a daily basis. It can be produced from several technologies the main ones being tidal barrages, tidal fences, and tidal turbines. Tidal energy is a kind of renewable energy with large potential. It is an easy to install renewable source of energy with no direct greenhouse gas emissions and a low environmental impact. The ocean's tidal patterns are well scheduled, making tidal energy a highly predictable energy source that is not subject to the impact of weather conditions and is most suitable for electrical grid management, as compared to other renewables that are more variable. (Kabeya)

Wind energy is the way by which wind power is used to generate electricity. A wind turbine is used to convert the wind's kinetic energy into mechanical power. The main advantages of wind energy are that it is renewable and sustainable. Wind can be used indefinitely to generate power, unlike fossil fuels that have a limited availability. It is a clean and eco-friendly source of energy and does not require burning fossil fuels for generating energy. It will reduce the dependency on coal, gas, and oil which is used to generate electricity. Once the turbine is placed it has a low maintenance and running cost with huge potential.

Geothermal energy is that energy that has been generated and stored in the Earth. The original formation of the planet and radioactive decay of materials results in the generation of this energy. Geothermal energy is environmentally friendly as it produces no such emissions as it does not require the burning of coal or crude oil for power generation.

Geothermal reserves are naturally replenished and thus it is a renewable energy and can be used for a never-ending time frame. With the use of this energy about 80% of another conventional energy usage can be cut down. It has higher efficiency and thus will require less electricity as compared to the conventional systems for the purpose of heating and cooling. After installation, no extra activities like mining or transportation is needed. (National geographic)

Solar energy is the generation of energy by converting sunlight into electricity. Solar panels trap the sun's light and convert it into power. It is a true and an important source of renewable source of energy. It is widely used to generate power. Solar energy can be used as long as there is sunlight and it will be available for many billion years in the future. By using this source for electricity it reduces the total electricity bills and also has a low maintenance cost. India has a huge potential solar energy due to its geographical location. Government is taking initiatives to increase the use of solar energy by making solar power plants in every possible region so that the dependency on fossil fuel reduces. (Toppr)

Nuclear Energy is the 5th largest source of energy production in India. Under this type of electricity generation, electricity is generated with the help of nuclear fission. All the nuclear reactions are taken place under a Nuclear reactor. Nuclear energy produces energy ten million times more than using oil or gas.

India has initiated plans for the further development and growth of nuclear energy as it's an alternate source of energy which causes minimal pollution and by-product. The nuclear waste which is generated after the generated after the production of nuclear energy is well treaded and does not cause much harm to the environment. The Government of India has initiated plans for starting 6 new nuclear plants which will further decrease the dependency of the country on thermal power plants leading to a cleaner and pollution less energy generation process. (World nuclear association)

6. METHODOLOGY

Transportation problem helps solve the distribution between the demand and supply for different markets which causes problems for every organisation.

The Transportation problem is developed to deal with problems of optimal allocation and usage of resources, in this case, the energy produced from different sources by taking in the data regarding the total supply, total demand and the cost of production etc.
A generic transportation problem is like a matrix, where the supply is row-wise and the demand is column-wise and the cost of the resources from different sources is provided.

7. ANALYSIS

Non-renewable resources of energy like coal, crude oil etc. are limited resources that are rapidly depleting. We are not fully sure of their rate of formation, however, their extraction and usage are not always economically viable, easily available or biodegradable. At present 80% of the worlds energy source is fossil fuels. Even in India the main source of energy is non-renewable in nature. Although effective, non-renewable sources are exhaustible, thus increasing the need for developing practical solutions for this depleting resource is of utmost importance.

The only solution to tackle the problems of renewable resources is to turn toward using new modern forms of non-renewable resources. These resources are finite in nature and depletion of these resources as well as their easy availability is not an area of concerned. Energy sources such as biogas, wind, water etc. need to be effectually harnessed to produce the best possible result.

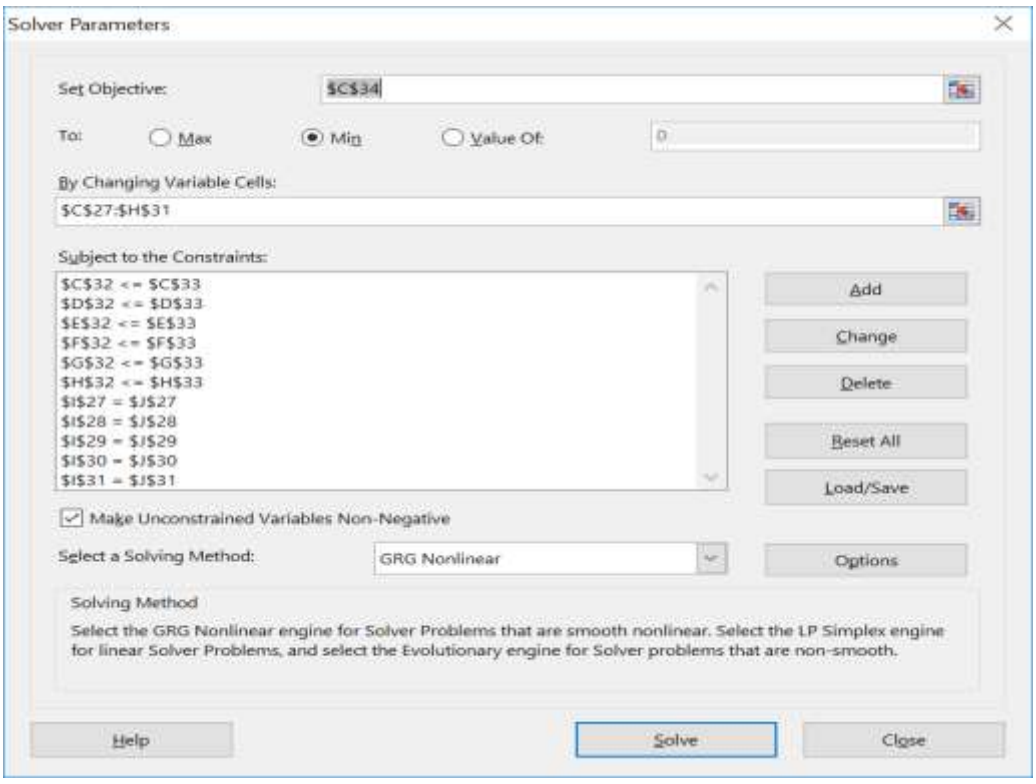
Transportation Problem:

Cost per unit							
	Maharastra	Tamil Nadu	Gujrat	Andra Pradesh	Uttar Pradesh	Supply	Total Supply
Thermal	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	2311.3	439679.3
Solar	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	80174	
Hydro	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	148678	
Wind	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	207856	
Nuclear	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	660	
Demand	58185.4	41316.1	39631.9	33725.3	33381.6		
Total Demand	206240.3						

The Total Demand and Total supply are not equal, thus a dummy column has to be added

Cost per unit							
	Maharastra	Tamil Nadu	Gujrat	Andra Pradesh	Uttar Pradesh	Dummy Row	Supply
Thermal	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	₹ 1,94,000.00	₹ 0.00	2311.3
Solar	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	₹ 1,50,000.00	₹ 0.00	80174
Hydro	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	₹ 1,83,000.00	₹ 0.00	148678
Wind	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	₹ 2,44,000.00	₹ 0.00	207856
Nuclear	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	₹ 3,01,000.00	₹ 0.00	660
Demand	58185.4	41316.1	39631.9	33725.3	33381.6	233439	

Once the dummy column is added we arrive at the solutions by using the solver tool.



By using the <= constraints for the demand and the = constraints for the supply we arrive at the optimal solution.

Allocation								
	Maharastra	Tamil Nadu	Gujrat	Andra Pradesh	Uttar Pradesh	Dummy Row	Total Allocation	Supply
Thermal	60.13	284.72	284.68	539.82	284.68	857.26	2311.3	2311.3
Solar	759.79	535.21	535.21	535.21	535.21	77273.39	80174	80174
Hydro	57365.47	40496.18	38812.01	6088.10	5916.24	0.00	148678	148678
Wind	0.00	0.00	0.00	26562.18	26645.47	154648.36	207856	207856
Nuclear	0	0	0	0	0	660	660	660
Total Allocation	58185.4	41316.1	39631.9	33725.3	33381.6	233439		
Demand	58185.4	41316.1	39631.9	33725.3	33381.6	233439		
Total cost	₹ 40,90,79,15,341.32							

Schedule	
Total Cost From the Transportation Problem	₹ 40,90,79,15,341.32
Add:	
Thermal Consumption Constraint Cost	₹ 17,14,74,07,800.00
Absolute Total Cost	₹ 58,05,53,23,141.32

We arrive at the total cost of energy of the selected 5 states.

Analysis of the Transportation problem:
The demand for various states is the forecasted demand for the year 2021-2022.

The supply for various sources of generating energy is the summation of the potential of all the 5 states taken together to produce that particular energy source.

Once the total demand and total supply are equal and the cost allocations are made the solver tool is used with an input of 11 constraints which generates the optimum allocation of the power generated with respect to the demand.

Taking into consideration the present situation in India there has been a growing need to make certain changes in the generation of energy. There is a need to switch to renewable energy in order to sustain. India currently depends mainly on fossil fuels like oil and coal to generate power. India's dependency on importing fossil fuels is rising year by year which puts pressure on India's balance of payment. It is estimated that by 2050 India's electricity generation requirement will be around one trillion watts which is more than India's power capacity. This will be a big challenge for the country but at the same time a huge opportunity which the Indian companies can capitalise on and also provide jobs which would in return lead to greater Indian prosperity. This huge demand can be met by using renewable energy like solar, wind, geothermal, tidal and wave energy. The use of renewable energy will help in meeting the demand for energy in the future, reduce dependency on fossil fuels which are scarce in availability and help India be self-sufficient. Remote cities in India do not get electricity throughout the day, use of renewable energy will also help to solve this problem.

The Indian government should consider this as a priority and take initiatives like provide for financial help by providing loans and incentives. This will, in turn, provide the country with a more sustainable and Eco-friendly way to generate power. India can lead the way to a lower carbon and renewable energy path. (Shaji, A Review on India's Renewable Energy Potential, 2014)

As we can see the supply potential for renewable energy sources are extremely high which is a great sign for the country as in time the raw material reserves which are required for thermal power generation is reducing and it also causes an increase in pollution. From the Problem solved above, we can estimate that hydro power could be a major source of energy provider in the future and the dependency on thermal energy would reduce from 80% to about 45%. This is a significant decrease in the % consumption of thermal energy.

The assumption of 30% of the total demand of each state being satisfied by thermal energy is a vital part of the model and its solution as in the next 3-4 years it would be very difficult for India as a nation to totally make its energy generation thermal free thus the consumption of thermal energy would reduce to a minimum of 30% and not more.

8. CONCLUSION

An overall development in technologies worldwide is opening doors to newer sources of power generation. The use of renewable energy provides a clean and more sustainable form to generate electricity. Countries like France, Iceland, and Sweden have made a switch and they now mainly depend on renewable energy. India is slowly moving towards the use of renewable energy to reduce its dependency on fossil fuels. India has a huge potential to generate power by making use of these sources as it has abundant resources. There is no single solution to every energy need and problem, but an optimal mix of the possible renewable energy that will benefit the environment, society, and the world as a whole.

9. LIMITATIONS

- The cost of a unit of electricity was taken as the same for different states but different for various sources of generation of electricity.
- The top 5 states in relation with consumption of electricity give us and insight into how the nation as a whole would move towards renewable and unconventional energy.
- 30% of the Total demand is met by thermal energy as currently, India as a nation used 80% of its total consumption of electricity from the thermal sources
- The demand values of the dummy column are extremely high as they act as the balancing figure which is required because a transportation problem can be solved only when The Total demand = Total supply.
- The Total Supply is considerable higher than the total demand as these states also provide electricity for other states, thus if the demand of other states is not considered then a dummy row is to be added.
- The supply of energy which is the total energy generated by various sources is the potential which the states possess to generate and utilise the particular energy source.
- Demand and Supply which is taken in the transportation problem is subject to change due to various factors like Government policies, population level, change in the level of technology etc.

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