Czech University of Life Sciences Prague

Faculty of Economics and Management

Diploma Thesis

The Impact of Renewable Energies on a Developing Country's Economy – Case Study India

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Aravindan Babu, BE (mechanical)

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Economics and Management

Thesis title

The impact of renewable energies on the developing country's economies – Case Study INDIA

Objectives of thesis

1. To analyze and evaluate how the implementation of renewable resources impacts the economy of a developing country (India).

2. To compare the financial aspects of renewable energies with that of fossil fuel-based energy production methods, by a case study formulating the Economic balance sheet of selected hydroelectric power plant

Methodology

The well-being of the economy of a country is tide related to stable income resources. The power sector plays a vital role as an income resource, also as an operating factor for other income resources. Recently, renewable energy is substituted for petrol-based power. Winds power, waterfall power, etc. are employed to provide the required power for industries and homes as well. However, establishing this technique in developing countries is not yet completed because of the initial expenses that should be paid in advance. Therefore, decision-makers in developing countries are divided into two groups. The first group prefers to spend money on setting up renewable resources, while the second group believes that using non-renewable energy would save money for other projects that give better income than the power sector. Many factors are considered by the decision-makers to reach final regulations. Quantities of those factors along with each factor's weight have to be investigated. The results of different case studies have to be reported and compared using a real-life, recent dataset.

An econometric one equation model:

GDP = f(Government spending, exports, imports)

$Y1t= \gamma1X1t+ \gamma2X2t+ \gamma3X3t+ \gamma4X4t+ u1t$

Declaration of Variables:

a) Endogenous variable

Y1t – GDP of India (in billions USD)

b) Exogenous variables

X1t – Unit vector (no unit)

X2t – Government spending on renewable energy (in billions USD)

X3t – Exports (in billions USD)

X4t – Imports (in billions USD)

u1t – Error term (no unit)

γ – parameter, added to the model (constant term)

The second part would be a case study, involving the computation of Economic balance sheet for a hydro-electric powerplant.

The proposed extent of the thesis

60-70

Keywords

Economy, Renewable energy, Power, Development, Safety

Recommended information sources

Eren, Baris Memduh, Nigar Taspinar, and Korhan K. Gokmenoglu. "The impact of financial development and economic growth on renewable energy consumption: Empirical analysis of India." Science of the Total Environment 663 (2019): 189-197.

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Declaration:

I hereby declare that I have solely worked on my Master thesis - The Impact of Renewable Energies on a Developing Country's Economy – case Study India and have used only the sources cited at the end of the thesis. I declare that this thesis does not break any copyrights.

Prague, 29.11.2022 ________________________

Bc. Aravindan Babu

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The Impact of Renewable Energies on a Developing Country's Economy – Case Study India

Abstract:

This thesis involves the analysis of GDP of India, being driven by the generation of renewable energies. A regression analysis is done by keeping the GDP on India, a dependent function and Exports, Imports, and Investments on renewable energy production as independent variables. This model uses the data obtained from IRENA, and Indian Budget.gov, for a period of twenty years from 2001 – 2020. Elasticity of the variables has been calculated, in order to tack the future trends in the economy. Also, another case study involving the economic balance sheet has been done for a Small Hydro Power plant. Various technical assets, operating costs, interests on bank loans, and cash flow calculations are done, to get the idea of how feasible it is to invest a huge sum of money initially on renewable energy generation.

Key words – Economy, Renewable energy, Power, Resource, Safety, Investments, Spending

Dopad obnovitelných zdrojů energie na ekonomiku rozvojové země - případová studie Indie

Abstrakt:

Tato práce se zabývá analýzou HDP Indie, který je poháněn výrobou energie z obnovitelných zdrojů. Regresní analýza je provedena tak, že jako závislá funkce je uveden HDP Indie a jako nezávislé proměnné jsou uvedeny vývoz, dovoz a investice do výroby energie z obnovitelných zdrojů. Tento model využívá údaje získané z IRENA a indického webu Budget.gov pro období dvaceti let od roku 2001 do roku 2020. Byla vypočtena elasticita proměnných, aby bylo možné řešit budoucí trendy v ekonomice. Také další případová studie zahrnující ekonomickou rozvahu byla provedena pro malou vodní elektrárnu. Byly provedeny výpočty různých technických aktiv, provozních nákladů, úroků z bankovních úvěrů a peněžních toků, aby bylo možné získat představu o tom, jak reálné je zpočátku investovat obrovskou částku peněz do výroby energie z obnovitelných zdrojů.

Klíčová slova - ekonomika, obnovitelná energie, energie, zdroj, bezpečnost, investice, výdaje.

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List of Abbreviations

GDP – Gross Domestic Product

GHG – Green House Gases

MNRE – Ministry of New and Renewable Energy

IRENA – International Renewable Energy Agency

PV – Photo Valtic

RPO – Renewable Purchase Obligation

ISTS – Interstate Transmission System

SHP – Small Hydro Plants

MW – Megawatt

KW – Kilowatt

NGO – Non-Governmental Organization

MTPH – Metric Tonne per hour

GAAP – Generally Accepted Accounting Principles

AD – Aggregate Demand

OLS – Ordinary Least Squares

AC – Alternating Current

DC – Direct current

EBIT – Earnings before Interests and Taxes

IEA – International Energy Agency

List of Formulae

$Y_{1t} = \gamma_1 X_{1t} + \gamma_2 X_{2t} + \gamma_3 X_{3t} + \gamma_4 X_{4t} + u_{1t}$ – Econometric model

$P = m \times g \times H_{net} \times \eta$ – Capacity

$Exn = \frac{\partial y}{\partial xn} * \frac{xn}{\hat{y}}$ - Coefficient of Elasticity

1. INTRODUCTION

Energy is the prime key for the existence of the modern advancements and favouring mankind in various automations and in every possible aspect. The renewable energies have tremendous potential or capabilities to meet the increasing energy needs of the world. The problem with the conventional energy production methods is that they are dangerous to the environment and to human health. Furthermore, they tend to be cyclical in nature, due to the effects of oligopoly in production and distribution. These traditional fossil fuel-based energy sources are facing increasing pressure on a host of environmental fronts, with perhaps the most serious challenge confronting the future use of coal being the Kyoto Protocol greenhouse gas (GHG) reduction targets.

Fossil fuels account for over 80% of the total energy consumed worldwide each year. Fossil fuels are essential to our existence because they are both energy-dense and inexpensive to process. But aside from their scarcity, one of the main issues with fossil fuels is that when they are burned, carbon dioxide is released into the atmosphere. Global warming is primarily caused by an increase in the amount of heat-trapping carbon dioxide in the atmosphere.

Even though the renewable energy sector in India has been growing significantly over the last two decades, it still has a long way to go before it can fully realize its full potential. According to the latest data, the installed capacity of grid-connected wind power systems has increased by 96%, small hydro by 26%, biomass by 234%, and solar photovoltaic by 200%.

For decentralized systems, such as solar home lighting, the growth has been more than 200%. In addition, the growth has been more than 100% for solar water pumps and solar lanterns. This is a remarkable achievement for the renewable energy sector, which mainly involves applications that were only supplied by major electricity companies.

It is now clear that renewable energy systems will be the new regime of energy sources, rather than traditional oil and coal sources, will be the main drivers of future growth in the energy sector. Due to these developments, there is now a market opportunity to both innovate and capitalize on emerging markets to support renewable energy technology, with the help of governmental and public attitude.

1.1 Importance of renewable energies

Renewable energy systems are typically built on a small-scale, decentralized model that naturally lends itself to, rather than conflicts with, many challenges related to capital costs, cogeneration (combined heat and power), electricity distribution, and the environment.

Renewable energy systems based on PV arrays, windmills, biomass, or small hydropower can be mass-produced "energy appliances" that can be produced at a low cost and customized to meet specific energy loads and service conditions as an alternative to custom, onsite construction of centralized power plants.

Instead of having greater, more centralized effects that, in some situations, seriously contribute to ambient air pollution, acid rain, and global climate change, these systems can have significantly reduced and widely dispersed environmental impacts.

Currently, between 15 and 20 percent of the world's total energy demand is met by renewable energy sources. Traditional biomass, primarily fuel wood used for cooking and heating, makes up the majority of the supply, particularly in poor nations in Africa, Asia, and Latin America. The usage of massive hydropower, which accounts for about 20% of the world's electricity supply, also makes a significant contribution. Currently, around 2% of energy comes from new renewable sources. Numerous scenario studies have examined the possible contribution of renewables to the world's energy sources, and they suggest that, with the correct policies, in the second half of the 21st century, their contribution may range from the current figure of roughly 20% to more than 50%.

1.2 Existing Knowledge

The extent of the change in India is astounding. Over the past 20 years, it has experienced some of the highest economic development in the world, pulling millions of people out of poverty. India builds a metropolis the size of London every year, increasing its urban population and necessitating extensive development of new structures, industry, and transportation systems. Up until now, coal and oil have been the foundation for India's economic development and modernization, providing an increasing number of Indians with access to contemporary energy services. For the previous ten years, this has included adding new energy connections for 50 million people annually.

India now ranks third in the world for annual CO_2 emissions due to the significant increase in the country's use of fossil fuels. However, India's CO_2 emissions per person rank it among the lowest in the world, and they are even lower when you take historical emissions per person into account. The same is true for energy use: the typical Indian household uses a tenth as much electricity as the typical American household.

India is the main market with the fastest pace of growth for renewable power, and by 2026, new capacity additions are expected to treble. The nation has ambitious plans to expand the use of modern bioenergy throughout the economy and is one of the world's top producers of the fuel. In the next years, India is anticipated to surpass China and Canada to surpass the United States and Brazil as the third-largest ethanol market globally(MNRE, 2010).

A major economic opportunity is the shift to renewable energy. India is ideally situated to take the lead globally in green hydrogen and renewable batteries. By 2030, India may have a market for low-carbon technology valued up to $80 billion. India needs the support of the international community to move its growth into a low-carbon trajectory. The Indian energy industry will require, on average, $160 billion year between now and 2030 to attain net zero emissions by 2070, according to the IEA. That is three times the level of investment made today. In order to attain net zero, access to low cost long term financing is essential.(Alvaro Lopez-Peña, 2016)

Reducing greenhouse gas emissions is only one aspect of reaching net zero. India's energy transformation must benefit its people, and carefully thought-out policies may reduce the likelihood of compromising on cost, security, or sustainability. The net zero goal and the decarbonization of the challenging sectors will be greatly helped by green hydrogen. India wants to become a major exporter and producer of green hydrogen. India could easily generate a 5 million tonne green hydrogen demand, which would replace grey hydrogen in the fertilizer and refinery industries. This 5 million tonnes will prevent 28 million tonnes of CO_2 from being produced. By 2050, 400 million tonnes of CO_2 will be reduced because to the expansion of the green hydrogen economy.

2. OBJECTIVES AND METHODOLOGY

2.1 Objectives

The aim of this thesis is to analyse and obtain a proper insight about the impact on Gross Domestic Product of India, considering the utilization of renewable energy production. The change happens when the country as a whole is ready to accept the fact that the renwable energy productions methods are the future and are ready to invest in those (public, private and government investments/fundings). The objectives of the thesis could be quoted as follows :

1. To analyze and evaluate how the implementation of renewable resources impacts the economy of a developing country – India

2. To compare the financial aspects of a renewable energy production method, by a case study formulating the Economic balance sheet of selected hydroelectric power plant.

Research Hypothesis :

Question 1:

H0: The investments on the renewable energy production methods favours the Gross Domestic Product of India.

H1: The investments on the renewable energy production methods favours the Gross Domestic Product of India.

Question 2:

H0: The expenses involved in production of renewable energy methods is feasible.

H1: The expenses involved in production of renewable energy methods is not feasible.

2.2Methodology

Case study 1 – Impact of Renewable energy production on Gross Domestic Product of India – Econometric One Equation model:

GDP = f(Government spending, exports, imports)

$Y_{1t} = \gamma_1 X_{1t} + \gamma_2 X_{2t} + \gamma_3 X_{3t} + \gamma_4 X_{4t} + u_{1t}$

Declaration of Variables:

a) Endogenous variable

Y1t – GDP of India (in billions EUR)

b) Exogenous variables

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X4t – Imports (in billions EUR)

u1t – Error term (no unit)

γ – parameter, added to the model (constant term)

Case Study 2 – Economic Balance sheet of a small head Hydroelectric Power Plant

(The feasibility of investing in the production of renwable energy)

3. Literature Review

3.1 Wind Energy

Wind energy is a type of solar energy that is produced by the fusion of hydrogen and helium. Through this process, the radiation and heat from the sun are sent out into space. Although only a small portion of this solar radiation is picked up by the Earth, it provides almost all of the country's energy needs.

Wind energy has many advantages over traditional sources of energy. Unlike nuclear power and fossil fuels, which produce radioactive waste, wind power is both environmentally friendly and clean. Wind energy is available in most parts of the world, and it is free and inexhaustible. Wind power can also help decrease the demand for fossil fuels, which are expected to run out in the near future due to the consumption patterns of current consumers. It costs less than solar power.

The movement of air is caused by atmospheric pressure gradients. When the pressure gradient exceeds a certain level, the wind speeds increase, and this increases the amount of energy that can be captured by wind energy-converting equipment. There are various factors that affect the movement of wind. Some of these include uneven solar heat, the Coriolis Effect, and the Earth's local geographical conditions. Understanding the wind characteristics can help improve the design and performance of wind turbines. It can also help develop wind measuring techniques and select wind farm sites(Olimpo, 2011). Wind speeds vary with the seasons, the time of day, and the height above the earth's surface. Few characteristics are considered predominantly, when it comes to design of the blades, stated as follows:

1. Wind speed (Weibull distribution)
2. Wind turbulence – The fluctuation in wind speed in short time scales.
3. Wind gust – Wind blasts with a sudden increase in wind speed in a relatively small interval of time.
4. Wind direction
5. Wind shear – A meteorological phenomenon in which wind increases with the height above the ground

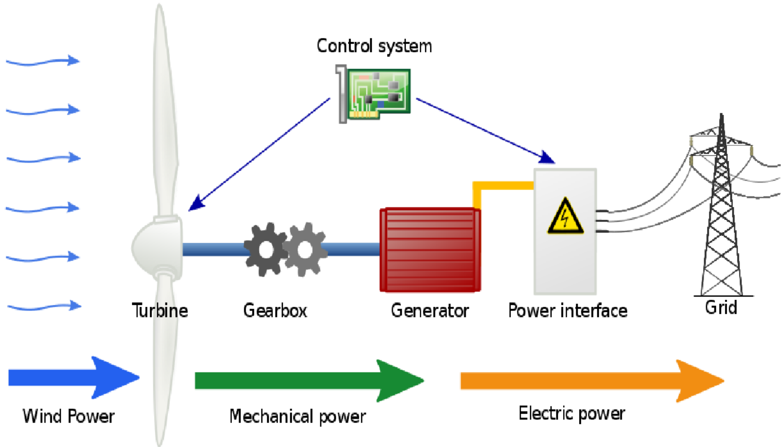


Figure 1: Wind energy production Layout (Source - (Ackermann, 2005))

Despite the advantages of wind power generation, there are still many problems that need to be addressed in order to maximize its potential. These include the long-term environmental effects of wind turbines and the management of their thermal components., and are stated below(Tong, 2010):

1. Environmental impacts – The blades of wind turbines can move at speeds of up to 70 meters per second. This means that flying birds may be killed or hurt if they collide with the blades. A study conducted in US shows thats nearly 40,000 birds a killed every year by the wind turbines/blades. Although the number of birds that are killed annually by wind farms is relatively small compared to the 80 million that are killed by cars, it is important to consider the long-term effects of these activities on the local population and species. To minimize the bird death, some methods have been suggested to scare them away.
2. Wind turbine noise - The noise produced by the blade in an undisturbed inflow (caused by the interaction in the boundary layer with the blade trailing edge), and the inflow turbulence noise which is caused by the interaction of upstream atmospheric turbulence with the blade and depends on the atmospheric conditions.
3. Thermal management of wind turbines – The heat generated by the wind turbine's rotating components, such as the bearings and gearbox, must be dissipated efficiently. This process can prevent the turbine from functioning efficiently. In order to ensure the safety and reliability of the system, the heat generated by the wind turbine must be properly dissipated. Wind turbine cooling includes the following :
   - Wind generator cooling

- Electronic and electric equipment cooling
- Gearbox cooling
- Other components/subsystems cooling

Wind power is characterized by low variable costs and relatively high fixed costs. Several factors such as Investment costs (including wind turbines, foundations, and grid connection), Operation and Maintenance costs (including regular maintenance, repairs, insurance, spare parts, and administration), Wind turbine’s electricity production cost, which highly depends on the wind turbine capacity, wind farm size, and average wind speed at the chosen site.

The country's wind energy sector is led by the indigenous industry. It has shown consistent progress and is expected to grow further with a capacity of around 10,000 MW per year. The country is currently fourth in the world in terms of wind installed capacity with a total of 39.25 gigawatts. Through various incentives, the government is promoting the wind energy sector in the country. These include financial and fiscal support, cess exemption on certain components, and accelerated depreciation benefit. The Generation Based Investment Scheme was also launched for the wind projects that were commissioned before March 31, 2017.

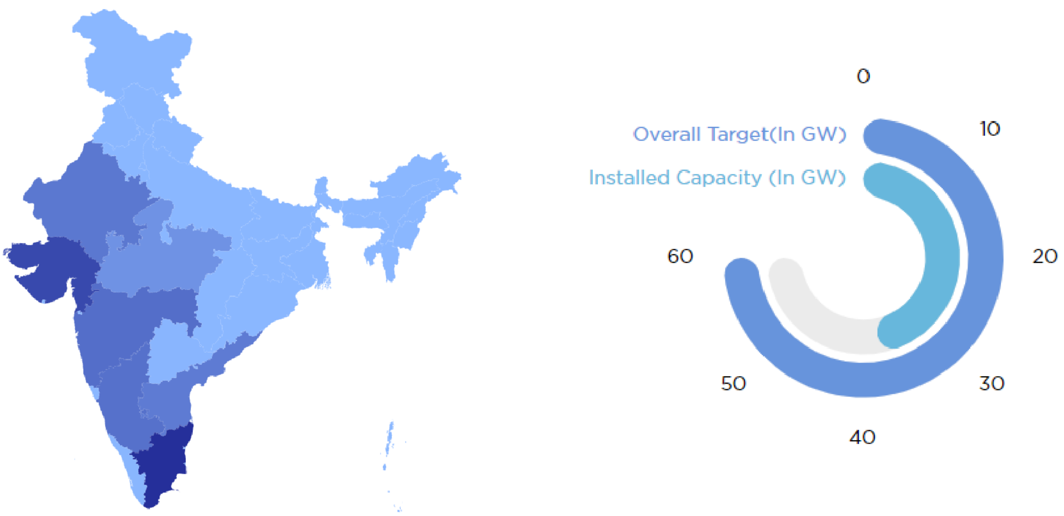


Figure 3.2: Wind energy potential (Installed – regionwise) (Source – (Data - Wind energy potential, 2022))

Year	Generation (GWh)	Investments made (Millions EUR)
2000	1318.91	..
2001	1536.85	..
2002	2205.77	..
2003	2550.56	..
2004	3923.08	..
2005	5561.86	..
2006	6873.69	..
2007	9387.05	..
2008	11835.13	..
2009	14595.04	..
2010	16104.03	0.6770
2011	19528.14	37.8290
2012	23069.18	126.5413
2013	24639.95	139.7961
2014	27235.37	88.9616
2015	31872.87	99.0619
2016	36273.13	64.0913
2017	47669.78	16.9154
2018	55008.66	345.3744
2019	62688.88	86.8933
2020	63522.27	32.5385

Table 3.1: Wind energy generation (Source – IRENA)

3.2 Solar Energy

The energy produced by the sun is referred to as solar energy. It is produced through a thermonuclear process, which involves converting a huge amount of hydrogen to helium. This process creates electromagnetic radiation and heat. The heat from the sun helps to maintain the thermonuclear reaction. The sun's electromagnetic radiation, which includes visible light and ultra-violet radiation, travels out into space in all directions. A small portion of this radiation reaches Earth.

Almost all of the energy that comes from the sun is derived from this radiation. Some of the exceptions are nuclear fusion and geothermal energy. Fossil fuels, on the other hand, are made from solar energy. These animals and plants used to depend on the sun for their life. The energy of the sun comes from its fusion reactions. These processes have been burning for 4.5 billion years. These reactions are expected to continue for around 6.5 billion more years. The total amount of energy that the sun sends out into space is around 3.86 gigawatts. Since the earth is around 6 miles from the sun, it only intercepts about 0.000000045% of this energy.

A photovaltic material, known as a PV-device converts sunlight into electrical energy. One type of cell is usually small enough to produce around a couple of watts of power. These are made of various semiconductor materials and are typically less than four times thick. Cells are then layered between plastic and glass to endure the elements for a long time.

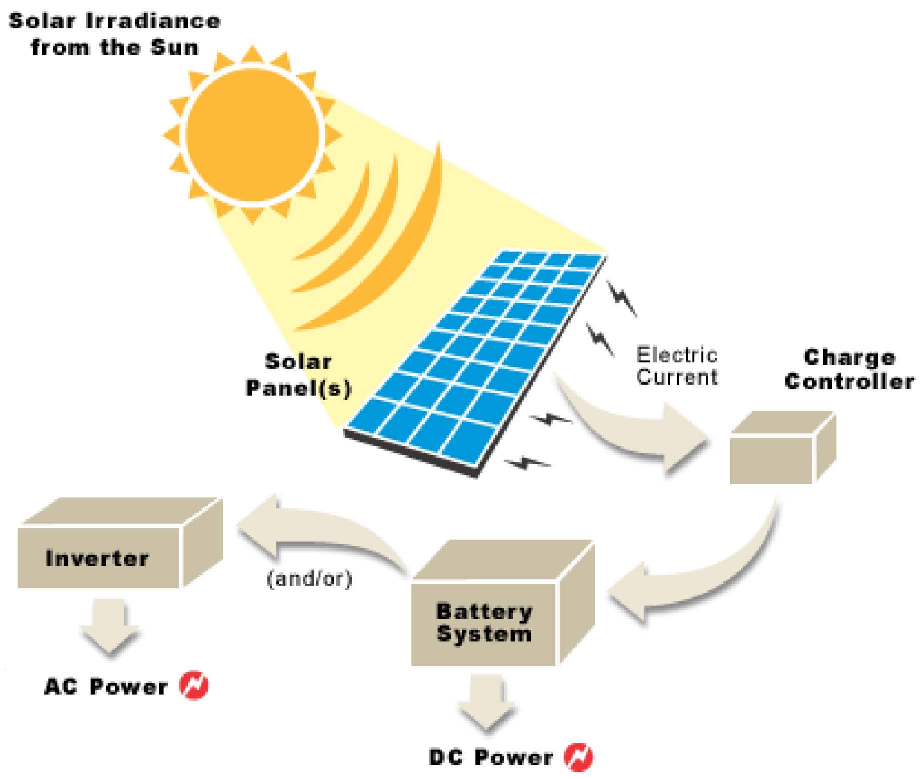


Figure 3.3: Solar Energy Production (Source –(ECOplantEnergy, 2016))

To increase the power output of their cells, these devices are connected together in chains. These are then called modules or panels, and these can be used individually or as part of a larger PV system. This type of modular structure allows PV systems to meet the needs of different electric power users.

A PV system is composed of various components, such as modules and arrays. These include mounting structures that are designed to point the panels toward the sun. The other components convert the electricity produced by the modules into AC power. The rapid advancements in PV technology over the past two decades have led to better efficiency, lower costs, and durability. When a solar cell is strung together, it becomes a module, which then connects to a solar system. A typical residential rooftop system has around 30 modules.

The more advanced a technology is, the lower its cost to increase the installed capacity. This is because the energy production of a solar system depends on the balance between the modules' lifetime and conversion efficiency. The rapid advancements in solar technologies over the past two decades have led to remarkable improvements in various aspects of the field.

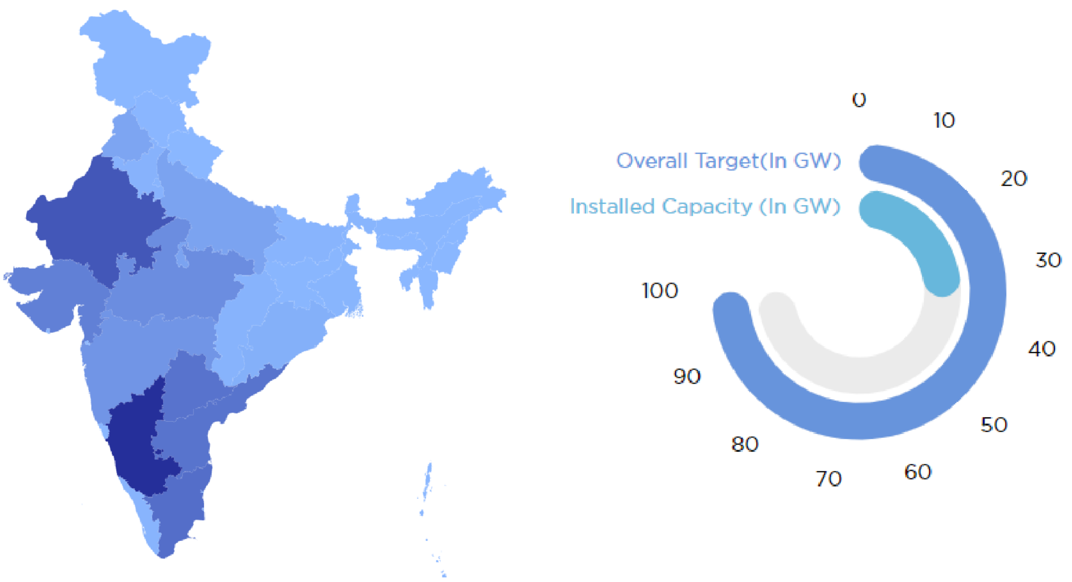


Figure 3.4: Solar energy potential (Installed – regionwise) (Source – (Data - Solar Energy Potential, 2022))

Various policies were undertaken to promote the renewable purchase obligation (RPO). These include the declaration of the trajectory for the RPO, the waiver of ISTS charges, the establishment of a competitive bidding process for the procurement of solar power, the establishment of guidelines for the deployment of solar photovoltaic systems, and the raising of tax free solar bonds. The implementation of these policies has also resulted in the development of smart cities and the establishment of infrastructure for solar projects.

India became the 5th largest solar power producer in the world in terms of installed capacity during the last five years. The country's solar power generation has increased by over 11 times during this period. The country's solar tariff has also become very competitive.

Year	**Solar photovoltaic (GWh)**	**Investments made (Millions EUR)**
2000	1.46	0.0074
2001	7.47	182.6593
2002	9.05	..
2003	10.65	..
2004	10.54	0.0582
2005	15.62	0.0143
2006	12.96	0.0455
2007	34.51	0.3035
2008	37.43	2.8773
2009	46.04	16.3540
2010	65.08	74.2271
2011	305.38	264.1846
2012	969.36	286.1805
2013	1600.14	285.4812
2014	2739.40	203.8583
2015	5619.20	179.7451
2016	9821.90	1462.5516
2017	17768.02	424.9530
2018	30703.50	597.1943
2019	43509.94	296.5866
2020	54305.90	561.9450

Table 3.2: Solar energy generation (Source – IRENA)

3.3 Hydroelectric Power

During the early 20th century, there were several small hydroelectric power plants that were developed in India. Unfortunately, these plants were abandoned. The country has a total installed capacity of 257,787 MW of electricity.

Hydro power generation is mainly based on the principle of impulse momentum. The water potential of a plant is converted into mechanical energy by rotating a turbine, and this energy is then converted into electrical energy by a generator. A diagram of this process is shown below.

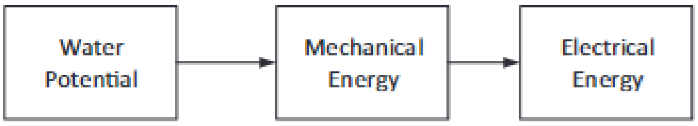


Figure 3.5: Block diagram of hydropower generation(Singh & Singal, 2017).

The various components of a hydro power plant are categorized into two categories: electro-mechanical and civil. These two categories work together to provide various functions and maximize the plant's power generation.

1. The reservoir – Water from a natural water body like a river is stored in the reservoir. This reservoir is built at a level higher than the turbine, to provide the necessary head difference. ($H_1 – H_0$)
2. The Dam – The flow of water stored in the reservoir is obstructed by huge walls of the dam. This prevents the water from flowing and helps us harness the energy present in it. The dam consists of gates present at its bottom, which can be lifted to allow the flow of water through them. By creating a large reservoir, the power plants are bound to rely on the dam.
3. The Penstock – The project's reservoir is connected to the turbine propeller, and the water flows in a downward manner. This happens when the dam's gates are lifted, which causes the water to flow down the penstock. The energy from the water is then converted into kinetic energy.
4. Spillways – A spillway is a type of facility that allows the water to be released from a dam's storage area. It can be used to safely release the excess water that's accumulated

downstream or behind the dam. Almost every dam should have at least one spillway to handle the water that's stored in it. A spillway is made using a cross-sectional tube and a penstock. A connection is made between the spillway's upstream and downstream outlets.

5. Turbine & Generator – The water's kinetic energy causes the blades of the turbine to turn. When the blades rotate, the shaft of the machine turns, which then produces electricity through a generator. Giant magnets rotate past copper coils, producing alternating current (AC) by moving electrons.
6. Power Lines – They are used to distribute power to various stations.

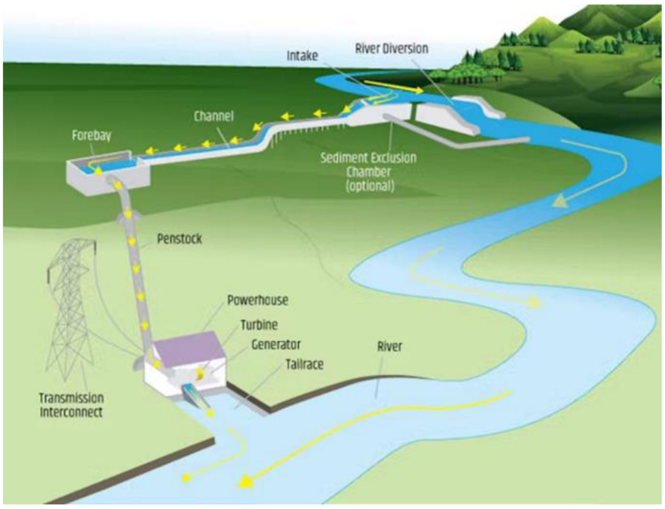


Figure 3.6: Schematic of run of river small hydro power plant (Source – US Department of Energy)

The diagram above shows the operation of a small hydro power plant that operates in a river. In this scheme, the water is diverted from the river through a diversion weir. This component is located across the river, and it continuously flows through the intake. The water is then pumped through a desilting tank to settle the sand particles in the river. The water coming from the desilting tank goes through a cannel to the fore-bay tank, and the water is then transferred to the turbine through a pressure pipe known as penstock. The water coming from the penstock hits the turbine blade and guides it through the guide vanes to rotate the machine.

The shaft and the runner of a hydro power plant's turbine are connected to each other. This ensures that the plant can generate maximum energy. The hydraulic turbine commonly has a efficiency of around 94 to 95%. The operation of a hydro power plant should be reliable, profitable, and efficient. It is also possible to improve the efficiency of a hydro power plant by optimizing its water use and generation. The high costs associated with running a hydroelectric power plant have encouraged the development of new approaches to the operation of such facilities.

A large reservoir can be taken up by a dam, which can flood the alluvial soil in flood plains, mineral deposits, and forests. This can also threaten archeological sites. The power per area ratio is computed to estimate the impact of the project on the environment. Usually, the lower the power per area ratio, the more land area the plant requires. However, this is not always the case.

Prioritizing the improvement, the quality and reliability of SHP projects, the Ministry of Water Resources has taken various steps to promote their development. These include providing financial and physical incentives. Besides this, it has also subsidized small hydro projects. To promote the use of new and efficient water mills, the Ministry has also launched a campaign to encourage the establishment of micro hydel projects that can generate electricity. These projects are being carried out through the cooperation of various organizations, such as cooperative societies, water mills associations, and NGOs.

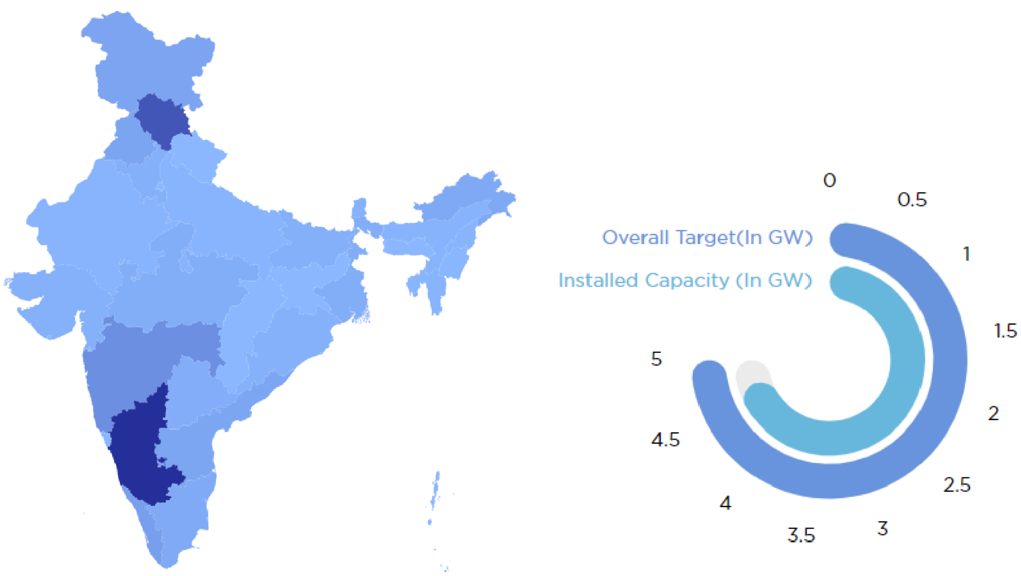


Figure 3.7: Hydro power potential (Installed – regionwise) (Source – (Data - Hydroelectric Potential, 2022))

Year	Hydropower (GWh)	Small hydropower (GWh)	Investments made (Millions EUR)
2000	74638.72	73485.37	1.747
2001	74447.11	73293.76	..
2002	71459.83	70306.48	9.5239
2003	67069.00	65915.65	10.6326
2004	77868.12	76057.77	399.2088
2005	89990.10	87011.70	19.2766
2006	108312.41	105041.96	160.46
2007	119382.69	114798.24	464.2988
2008	122337.66	117388.26	290.3123
2009	113684.25	108734.85	..
2010	112125.40	107176.00	184.1544
2011	124673.11	119723.71	784.2728
2012	133093.99	128144.59	324.0622
2013	125953.39	121003.99	0.9646
2014	140814.21	135864.81	..
2015	135511.82	130562.42	..
2016	130160.70	125211.30	6.6901
2017	131351.16	126401.76	23.5991
2018	136642.33	131692.93	322.3396
2019	149543.97	144594.57	41.6
2020	164678.21	159728.81	225.1241

Table 3.3: Hydroelectric energy generation (Source – IRENA)

3.4 Bio-Mass Energy

Biofuels are liquid fuels that are produced from biomass. Some of these include ethanol, biodiesel, and methanol. They are commonly used in transportation, such as for cars and trucks. Due to their nature, they compete with diesel and gasoline. Biofuels are produced from renewable sources, which makes them eco-friendlier than fossil fuels. In addition, they tend to have a lower environmental impact than petroleum products. Supporters of biofuels claim that converting biomass into fuel can create economic activity that benefits local farmers and communities. These include higher commodity prices, rural employment, and income growth. Various types of mechanical, chemical, biological, thermal, and thermal technologies are capable of converting solid waste into useful chemicals and green fuels, such as hydrogen, natural gas, and ethanol.

In general, biomass refers to any organic matter that can be produced on a recurring or renewable basis. This includes various types of crops and trees, as well as wood and animal wastes, plant residues, and municipal wastes. Through photosynthesis, which is a process that involves the interaction of sunlight, air, and water, biomass can be transformed into carbohydrates. This process usually results in the conversion of less than a percent of the available energy. The chemical bonds of biomass are then utilized to store the solar energy. The energy that is stored in these chemical bonds is then converted into a product known as carbon dioxide and water. This process is carried out cyclically, and the availability of CO2 allows for the production of new biomass.

When it comes to the use of biomass in the fight against global warming, one of the most overlooked factors is the time lag between the release of carbon dioxide from burning fossil fuels and its uptake as biomass. This can take many years. In order to mitigate this time delay, it is important to recognize and implement strategies to minimize its impact. The developing world is faced with the same dilemma as it consumes a huge amount of biomass for fuel, but it doesn't have a replacement planting program. Numerous crops have been proposed for commercial production. Some of these include oilseeds, woody plants, grasses, sugar cane, and starch. There has been a renewed interest in the utilization of biomass as an energy source. Few reasons are quoted as follows:

1. Various technological developments have led to the development of new ways to reduce the cost of biomass and improve its conversion efficiency. For instance, when

it comes to producing electricity, the cost of electricity is currently competitive with fossil fuels. New innovations in the field of gasification are also expected to allow the production of hydrogen and methanol from energy crops.

2. The second stimulus is the agricultural sector, which is currently producing surpluses in both the US and Western Europe. Due to the situation, a policy has been established that allows land to be set aside to reduce the surpluses. Other problems such as the depopulation of rural areas and the payment of subsidies to keep the land fallow are also contributing factors to the increasing demand for alternative non-food crops. This sector can potentially yield an endless supply of energy crops.
3. The threat of climate change has become a major factor that has prompted the development of renewable energy sources. Although biomass is produced through sustainable means, it still emits around the same amount of carbon as it does during plant growth. This means that the use of biomass does not contribute to the accumulation of greenhouse gases in the atmosphere.

Depending on the process, biomass can be either a renewable resource or a by-product of human activities, such as the organic wastes. The potential of biomass energy from agricultural and forest residue is estimated to be around 30 to 60 per year, which is equivalent to around 400 per year of energy demand. If biomass is to contribute to the global energy supply, then it will require the cultivation of dedicated crops, which can be done using marginal and fallow lands. These are not suitable for food crops. Biofuel technology can be classified into a number of generations of technological development as summarized:

Conventional biofuels are mainly manufactured from food crops such as starch, sugar, and vegetable oil. Currently, most of these are being produced in commercial quantities. Existing technologies are used to produce conventional biofuels, which are typically produced through fermentation, anaerobic digestion, and transesterification. These technologies are still being developed to meet the economic viability of their production(Lackner, 2016). Examples of bioethanol include biodiesel and bio hydrogen. The technologies used to produce conventional biofuels have been commercialized and are suitable for household or local deployment.

Advanced biofuels are those that are produced from non-food sources such as lignocellulose wastes and non-food crops. The manufacturing process involves fermentation and enzymatic digestion. Some of the major types of renewable fuels that are currently being considered for commercialization include bio-hydrogen, hydro-treated vegetable oil, and biomass-generated esters. Due to the various challenges associated with the production of conventional biofuels, such as the lack of feedstock, the development of advanced biofuels from inedible sources has become an encouraging trend.

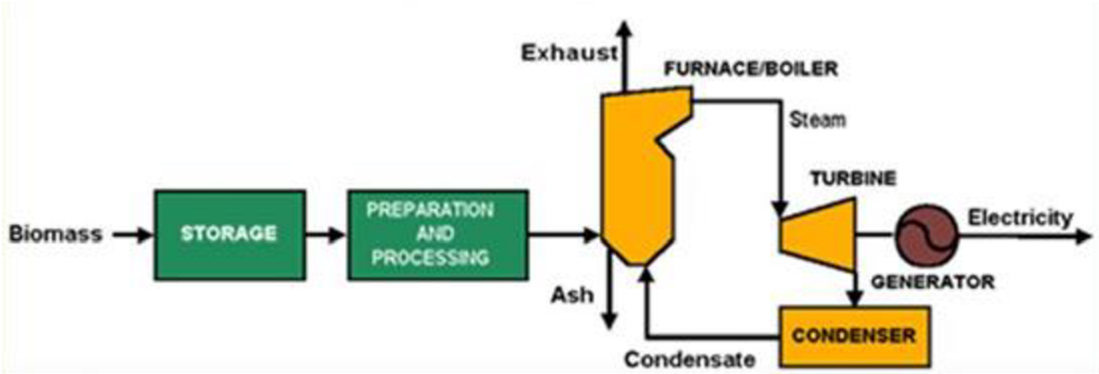


Figure 3.8: Energy generation from Bio-mass (Source (U.S. Department of Energy, 2016))

A study conducted by MNRE revealed that the country's biomass supply is expected to be at around 750 million metric tons annually. It estimated that the surplus availability of biomass could be around 230 million metric tons per year, which translates to a potential of 28 gigawatts. The study also noted that the country's 550 sugar mills could generate around 14 gigawatts of additional power through the use of bagasse cogeneration. This would be done through the adoption of optimal cogeneration technology.

The Ministry of Power has been implementing various initiatives related to the development of biomass power plants and bagasse cogeneration facilities in the country since the early Nineties. Over 800 biomass power plants and non-bagasse cogeneration projects have been installed with a capacity of over 10,205.61 MW. The states that have taken lead in the implementation of these projects include Karnataka, Tamil Nadu, Maharashtra, and Uttar Pradesh.

Project Type	Capital Subsidy
Briquette / Pellet Manufacturing plants	9,000 EUR per MTPH (metric ton/hour) manufacturing capacity (maximum CFA of 45,000 EUR per plant)
Biomass (Non-bagasse) cogeneration projects	8,000 EUR per MW (on Installed Capacity) (maximum CFA of 85,000 EUR per project)

Table 3.4: Central Financial Assistance (Source – mnre.gov)

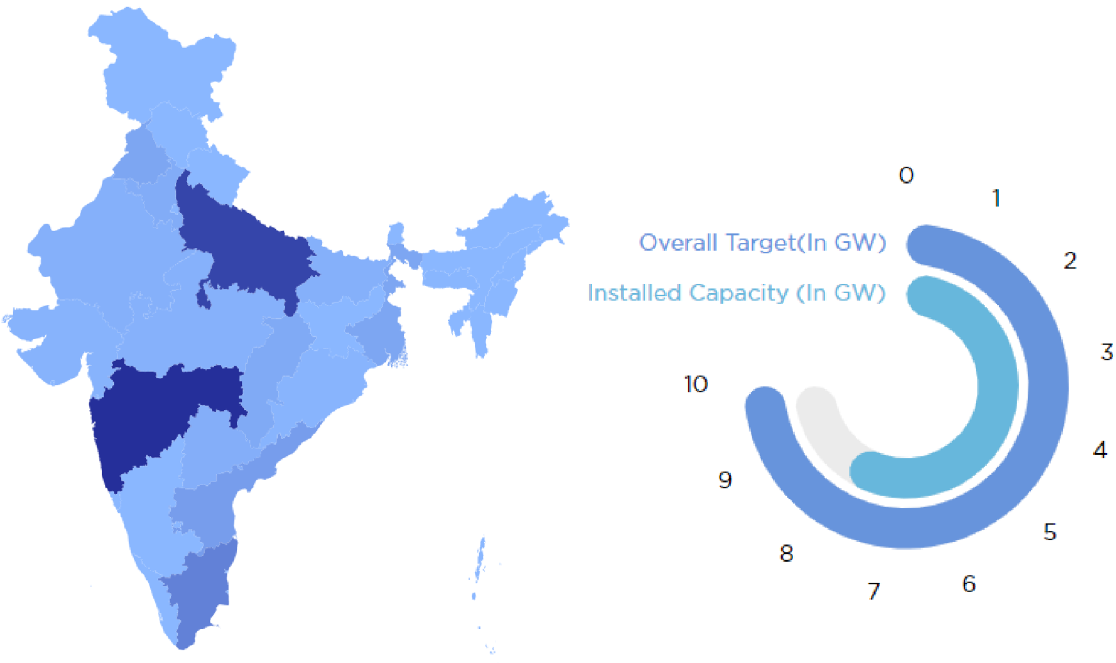


Figure 3.9: Bio-Energy Production Potential of India - 2020(Installed – regionwise) (Source (Data - Bio Energy Potential, 2022))

Year	Solid biofuels (GWh)	Renewable municipal waste (GWh)	Biogas (GWh)	Investments made (Millions EUR)
2000	2775.07	..	..	0.2995
2001	2951.15	..	..	..
2002	3483.26	..	..	5.5404
2003	4132.28	..	..	0.0004
2004	5144.17	..	..	0.0967
2005	6198.16	36.93	..	..
2006	7369.99	40.97	..	0.0455
2007	9326.8	59.94	0.44	..
2008	10384.47	81.26	1.35	0.7976
2009	11342.71	88.58	1.35	29.5974
2010	17090.06	112.84	1.35	7.9174
2011	17766.82	148.03	6.04	..

2012	24162.69	185.68	9.72	1.4216
2013	28903.58	237.05	13.07	0.0483
2014	33619.82	274.77	15.77	0.0356
2015	29193.94	320.12	22.13	11.7508
2016	18547.68	290.4	23.73	0.6073
2017	17033.14	301.25	28.82	12.7626
2018	19259.83	416.9	31.45	0.1165
2019	21895.22	579.17	31.89	..
2020	21955.47	931.62	31.89	..

Table 3.5: Biomass energy generation (Source – IRENA)

3.5 Power Sub-Stations

The construction of new facilities and the expansion of existing ones are some of the common projects undertaken by electric utilities. Unfortunately, many of the employees who are involved in these projects are not familiar with the various steps involved in completing the project. Substations are of four types.

The first type of project that involves the construction of a facility is a generator switchyard. This type of facility is usually designed and constructed by the designers of a power plant. It is a large installation that requires a lot of planning and finance. Although the construction of power plant switchyards is not discussed here, modifications and expansion of these facilities follow the same processes as those for system stations.

Another type of facility that is commonly utilized is a customer substation. This type of facility is designed and constructed to provide a steady supply of electricity to a specific business customer. Its technical requirements are different from those of a utility. This discussion will not focus on the construction of this type of facility.

A third type of facility is a system station, which is designed to transfer bulk power across the electricity network. These large facilities are usually located in regions where there is a lot of transmission lines. They provide the electrical power for these lines. Substations are important components of the electric system, and they play a vital role in maintaining the reliability of the electricity network. They are typically expensive to maintain and construct. This chapter will mainly focus on the construction and operation of these facilities.

The fourth type of facility that is commonly utilized is a distribution station. This is the most common type of facility that is involved in the electricity distribution system. It is located close to the load centers and is typically situated near neighborhoods. Because of the number of these types of facilities, this chapter will cover their construction and operation. Depending on the type of equipment used, the substations could be:

- Outdoor type with air-insulated equipment
- Indoor type with air-insulated equipment
- Outdoor type with gas-insulated equipment
- Indoor type with gas-insulated equipment
- Mixed technology substations
- Mobile substations

Step-Up and Step-Down Transformers:

A transformer is a type of device that is used to transfer electric power from one part of a circuit to another. When the power moves through a transformer, its voltage level is adjusted to meet the specific needs of the secondary or output end. A step-up transformer has a higher output voltage level, while a step-down transformer has a lower one.

A step-up transformer increases the output voltage to the load, while a step-down transformer reduces the input voltage. High-level power transmission is required in order to operate efficiently, but consumers have to use the power at a lower voltage to avoid safety issues. In some countries, such as India, step-up transformers are very useful as the power generation level is 11 volts. These devices are used to increase the voltage for transmission.

A step-down transformer converts high-V power to a low-V level, which is ideal for devices that are connected to the power systems of various kinds of households and businesses. Some features of power circuits, such as 230V to 110V, require as little as 16 volts. This is why step-down devices are needed to reduce the power level. Although separate circuits within electrical systems commonly share the same frequency, the voltage needs of different devices can vary. This is why smaller step-up or step-down devices are commonly used in household appliances. They can either be three-phase or single-phase. These two types of devices serve different purposes. They can be designed in various configurations depending on the needs of their users.

3.6 Power Transmission Grids

The non-coincidence of the consumption centers and production facilities makes it necessary for the transportation of the generated energy. This process can be carried out through power transmission lines. Even though the two functions of a power transmission line are overlapping, they can still be used in different ways. For instance, a power transmission line connects a production facility to a consumption point. In this case, the power flows in the same direction but its value changes according to the energy consumption of the consuming facility. Interconnection lines are used to connect two production facilities. Since the power flowing through these lines is in the opposite direction, it usually goes through transmission power lines that are much longer. When it comes to transferring energy, low intensity and high voltage are usually used to minimize the losses in the wire. This is because the resistance of the wires varies depending on their length. The energy losses caused by heating are usually high.

One of the main areas of research in the field of power transmission lines is the structure of power transmission lines. There are three main types of structures that can be used: open or radial, closed, or meshed. The first type is commonly used in low-power systems and is the most cost-effective. The cost of the second type is higher compared to the radial, but its security and installation are better. The third type, on the other hand, is more complex and expensive. This type of structure is ideal when there are high numbers of receivers and the supply security is high(Seventh plan, 2018).

It is generally assumed that power transmission lines are ideal conductors if the distances between the points of consumption and the power generation are short. However, this is not the case, as the points are far from the consumption. There are four physical phenomena that can be considered when it comes to designing power transmission lines. These include the conductive, inductive, and resistive effects.

The voltage fall and the heating of the wire are caused by the resistance of the wire. The thickness and material of the wire are the factors that influence the effects of the electric field. The inductive effect is commonly considered when the reactance of the wire is comparable to that of the reactive resistance. The rising voltage level of the conductor can reduce the resistance of the wires. This phenomenon is known as the inductive effect, which is the main limiting factor in the power transfer process. The capacitive effect is caused by the interaction between the floor and the conductors.

The conductive effect is considered when lines are over 80 kilometers long. This phenomenon can be caused by the insulation, as well as the environment around the cable. In the design of a power transmission line, the energy yield is proportional to the costs involved in the project. The efficiency and loss factor of different types of power transmission lines must be considered in order to determine their optimal design. In first approximation, the losses are exclusively Joule losses.

3.7 Environmental Impacts of Renewable Energy production

The various factors that affect the lifecycle of electricity generation can vary widely depending on the type of technology, the size of the fuel, and the location of the resources used. This makes the impact of electricity generation on the environment and human health unique. This section covers the different lifecycle impacts of different types of electricity generation facilities in the Pacific Northwest. They are identified in the region's new resource planning analysis and the legal and regulatory frameworks in place to address them.

Hydroelectric power plants:

Hydroelectric development generally has a variety of environmental impacts. These include the quality of the water, the effects of erosion and sediment, and the disturbance of the land. When comparing hydroelectric projects, the environmental effects of each project are site-specific. For instance, projects that involve the construction of dams or other water control structures can have less environmental impact than those that require new construction.

The operation and construction of hydroelectric dams can affect the quality of water in a river system. These projects can also cause various thermal changes that can affect the flow of water. In addition, they can slow the movement of water in the river system, which can lead to stratification and oxygen depletion. The spill flows from a dam can increase the dissolved gas levels in the river. Although these are not always harmful, they can have detrimental effects on the aquatic environment and can kill or injure fish. In addition, the water quality can affect the appearance of the project site.

Soil erosion and sediment problems can occur during construction or after a project has already been removed or retired(Botelho et al., 2017). Changes in the flow and sediment load can affect the natural equilibrium of the water's sediment. They can also contribute to the formation of a pond's water turbidity. The increased flow and sediment load can result in deposits near the dam and a decrease in the sediment downstream. This can affect the growth of organisms that rely on the nutrients in the water for their nourishment. As the water level fluctuates, erosion can occur, and a lack of vegetation can lead to the perpetual carving of the earth around the water source.

Solar Electricity Generation:

The rapid growth of solar energy in the India has been attributed to various factors. One of these is the declining prices of solar panels. Also, the country's growing concerns about carbon emissions have led to the development of more concentrated solar facilities and utility-scale projects. Flat-panel solar PV systems are commonly used to convert sunlight into electricity. A distributed solar facility is a small-scale installation that's situated near a customer's consumption area. This type of system is often referred to as a rooftop solar facility.

A utility-scale solar PV installation is a large-scale facility that's designed to produce electricity for sale at the wholesale market. These types of facilities are typically located in remote areas. Concentrating solar facilities use mirrors to concentrate the sun's heat. The production of solar PV panels involves the use of toxic chemicals, the acquisition of raw materials, and the consumption of electricity. These activities pose various environmental risks. Besides silicon, which is the most common component of a solar panel, the process also involves the use of other rare or precious metals such as silver, indium, and tellurium.

Developers of solar photovoltaic facilities typically require around 8 acres of land per megawatt-hour of power generation, while wind turbines require 85 acres per megawatt-hour. Wind turbines are not precluded from other uses, such as grazing and agriculture, while solar facilities are permitted only at densities that cannot be used for other purposes.

Biomass Energy generation:

Due to the diverse technologies and fuels used in biomass-based electricity generation, the potential impacts of this type of energy on the environment are complex. Some of the most common concerns include the effects of biomass combustion on air and water quality. Biomass feedstocks can include various types of waste, such as municipal solid waste, wood processing residue, and agricultural byproducts. They can be categorized into three main types: primary, secondary, and tertiary. The primary feedstock includes crops grown for the production of energy.

On the other hand, the latter includes food waste, pulping liquor, and manure(L.G. Roberts, 2014). The production of primary feedstock, which includes the use of land and water for agriculture, is considered to be the most significant contributor to the environmental impact of this type of energy. It can cause the destruction of habitats and agricultural runoff. In addition, the use of pesticides can also have human health impacts(Giwa et al., 2017).

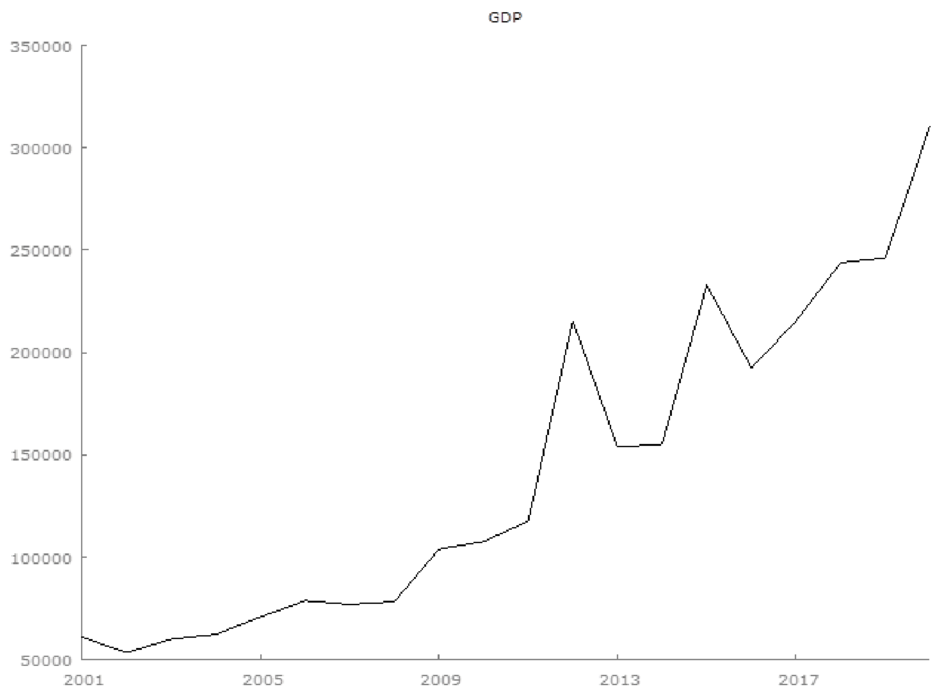
Although the Clean Water Act can regulate the effects of agricultural runoff, it does not apply to the nonpoint source of this water pollution. This means that the impacts of this type of energy are not covered by the law. Biomass' environmental impacts can vary depending on the type of fuel and the technology used. Since India is primarily a user of wood waste, its primary concern is the impact of this type of energy on water, air quality, and the environment.

4. Analytical Part

4.1 Indicators of developing country

Economic growth refers to the process of boosting an economy's economic welfare. Economic development can implicate a stronger economy that enables for a broader range of social services that contribute to a nation's welfare. An undeveloped economy, for example, will be based primarily on agriculture and will provide very minimal social services like health care and education. Economic development entails higher real incomes, extended life expectancy, lower poverty, and greater provision of basic prerequisites. The following indicatiors were considered for the model, to support the research(Tejvan Pettinger, 2020).

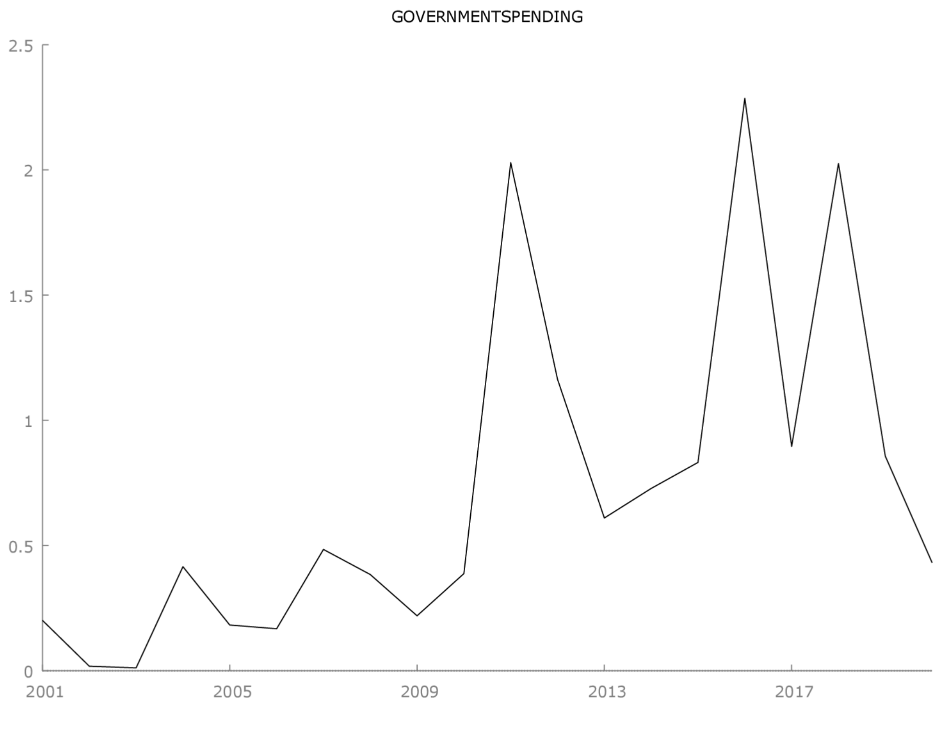
GDP - Gross Domestic Product (GDP) is often regarded as a barometer of economic progress, the effectiveness of economic policies, and, in many cases, a broad measure of a country's social welfare. While national accountants have long argued that GDP is a measure of economic activity and not a measure of wellbeing, there is a long history of scholarly controversy on the linkage between GDP, or rather social income, and welfare(Paul Schreyer, 2016).



Graph 4.1: Trend of India's GDP Growth 2001-2020 (Source – Trading economics)

Investments on Energy Production - Consumption is often the greatest component of GDP. Prior to Economic Reforms, consumption accounted for around 52% of GDP, but, following reforms, it has surged to more than 62%. Many participants were asked to rate their country's economic performance purely in terms of consumption, which is separated into three types of products: durable, non-durable, and services. Consumption occurs through institutions, industry, and consumers. Individual consumption grows, which leads to an increase in aggregate demand.

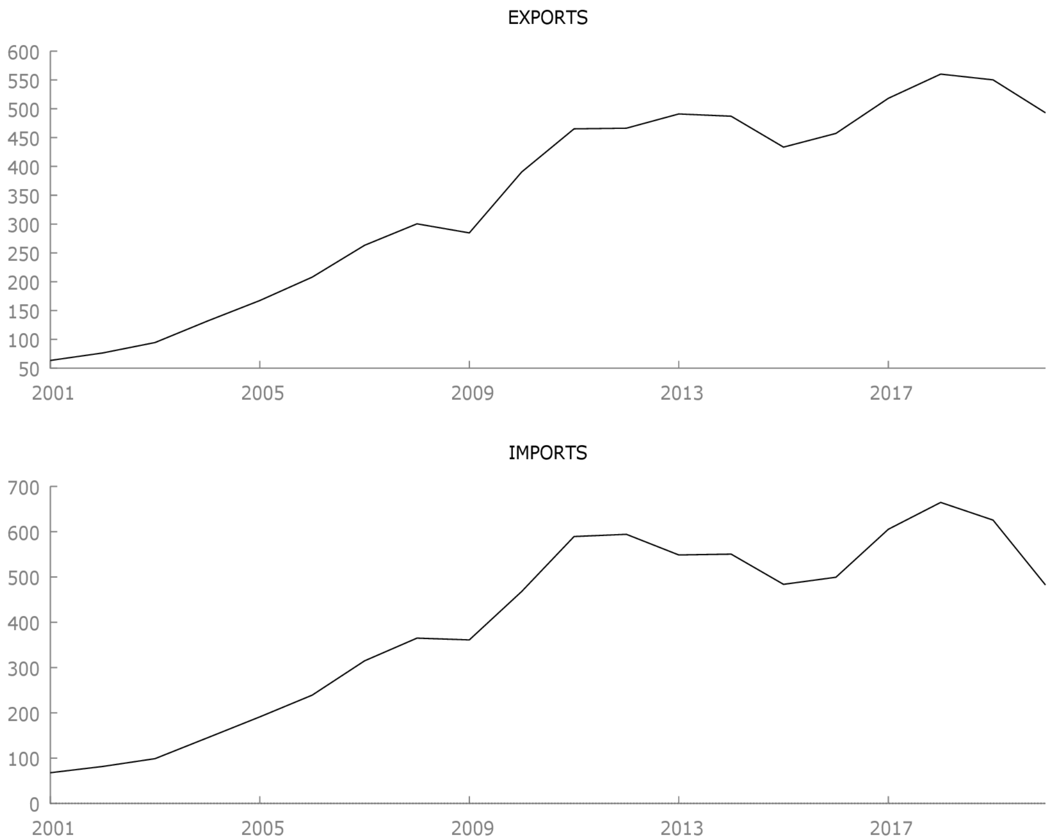
Accelerated demand causes a rise in output, which returns to the consumer in the form of wages and profit. In a basic closed economy, the household spends its earnings. Consumption (C), or expenditure on consumer products, is the single component of aggregate Demand (AD). Nevertheless, in today's free economy, foreign trade and government expenditure both contributes to aggregate demand(Ambala: G. K. Web Services, 2011).



Graph 4.2: Investments on Energy Production (Source – IndianBudget.gov)

Exports and Imports – The history of exporting and importing goods dates back to the Roman Empire. During the 13th and 14th centuries, the Silk Road became a major trade route between Asia and Europe. During this time, caravans carrying goods from India and China made their way through the desert to Alexandria and Constantinople. Throughout history, the process of exporting and importing goods has been carried out by intermediaries, due to the varying languages and distances involved. During the 1400s, the spice trade was very popular due to Europeans' lack of refrigeration.

Because of their ability to disguise the flavor of meat, spices were commonly used as medicines in Europe. The spice trade was very popular due to the region's demand. However, getting the spices from their native lands was not easy, as they were often grown in jungle areas. The overland journey to these lands was very long and involved many intermediaries. Each middleman charged a fee, which eventually increased the price of the spice by a factor of 1,000 percent. The exportation of goods and services is considered to be the sale of products or services made or sourced in a foreign country. On the other hand, the importation of goods and services is a different type of trade. This process involves buying products and services from other countries and bringing them back to the home country.



Graph 4.3: Imports and Exports in India (2001-2020) (Source - Trading economics)

4.2 Data Set for the study

The data has been obtained from IRENA, Trading Economics, and Indian Budget.gov for a period of twenty years from 2001 till 2020. The energy production has been neglected taking into consideration that the public and private investments have been accounted in the model.

Year	GDP	GOVERNMENT SPENDING	EXPORTS	IMPORTS
2001	61029.28	0.2008656	63.3984	67.8288
2002	53410.24	0.0178464	76.388	81.64
2003	59951.84	0.011128	94.4736	98.8728
2004	62337.6	0.4154072	131.716	144.8824
2005	70803.2	0.1823536	167.2736	191.0896
2006	78807.04	0.1674296	207.9688	239.1584
2007	76960	0.4842552	263.2032	314.912
2008	78345.28	0.3841344	300.456	364.9672
2009	103896	0.219076	284.7	361.0672
2010	107744	0.3877328	390.364	467.9688
2011	117594.9	2.0289568	465.2752	589.3368
2012	215488	1.1638744	466.336	594.1624
2013	153920	0.6098664	491.0672	548.6624
2014	155382.2	0.727792	487.084	550.4096
2015	233111.8	0.831688	433.4616	483.704
2016	192400	2.2860968	457.2256	499.3768
2017	215488	0.895908	518.1904	605.3008
2018	243963.2	2.0251816	560.1856	664.5704
2019	246272	0.8570016	550.1808	625.6432
2020	310800	0.43145	493.116	482.45

Table 4.1: Data Set (billions EUR, (Data - India Exports, 2022; Data - India GDP, 2022; Data - India Imports, 2022; Data - Indian Public investments on renewable energies, 2022))

4.3 Economic and Econometric model

One-equation model describes the relationship between one endogenous variable which is the Gross domestic product and other exogenous variables such as the investments on renewable energy production, exports, and imports. The model is expected to prove that the spending on the renewable energy production and product should positively influence the GDP of India.

GDP = f(Government spending, exports, imports)

Declaration of Variables:

a) Endogenous variable

Y1t – GDP of India (in billions EUR)

b) Exogenous variables

X1t – Unit vector (no unit)

X2t – Government spending on renewable energy (in billions EUR)

X3t – Exports (in billions EUR)

X4t – Imports (in billions EUR)

u1t – Error term (no unit)

γ – parameter, added to the model (constant term)

$Y_{1t}= \gamma_1X_{1t}+ \gamma_2X_{2t}+ \gamma_3X_{3t}+ \gamma_4X_{4t}+ u_{1t}$

Correlation matrix:

A correlation matrix is used to check if there is a high correlation between variables, which can lead to multi collinearity. Multicollinearity is briefly described as the high dependency between the explanatory variables and the value of the correlation coefficients are higher than 0.8, whether it be positive or negative. From the correlation matrix above (fig.1), it is clear that the value of correlation coefficient is not higher than 0.8 (5% critical value = 0.4438), hence there is no multicollinearity in this model.

GDP	GOVERNMENT SPENDING	EXPORTS	IMPORTS	
1.0000	0.5163	0.8478	0.7895	GDP
	1.0000	0.6712	0.6972	GOVERNMENT SPENDING
		1.0000	0.9884	EXPORTS
			1.0000	IMPORTS

Table 4.2: Correlation Matrix (5% critical value = 0.4438 for n = 20) Source: gretl

4.4 Estimation of Parameters:

	1	0.200866	63.3984	67.8288		61029.28
	1	0.017846	76.388	81.64		53410.24
	1	0.011128	94.4736	98.8728		59951.84
	1	0.415407	131.716	144.8824		62337.6
	1	0.182354	167.2736	191.0896		70803.2
	1	0.16743	207.9688	239.1584		78807.04
	1	0.484255	263.2032	314.912		76960
	1	0.384134	300.456	364.9672		78345.28
	1	0.219076	284.7	361.0672		103896
X=	1	0.387733	390.364	467.9688	Y=	107744
	1	2.028957	465.2752	589.3368		117594.9
	1	1.163874	466.336	594.1624		215488
	1	0.609866	491.0672	548.6624		153920
	1	0.727792	487.084	550.4096		155382.2
	1	0.831688	433.4616	483.704		233111.8
	1	2.286097	457.2256	499.3768		192400
	1	0.895908	518.1904	605.3008		215488
	1	2.025182	560.1856	664.5704		243963.2
	1	0.857002	550.1808	625.6432		246272
	1	0.43145	493.116	482.45		310800

Table 4.3: Matrix X and Vector Y

Unit root test - A trend analysis is a process utilized to determine the appropriate form of the trend that can be shown in the data. It involves determining the optimal amount of time to exhibit the trend. A unit root test is also used to test the validity of the trend. On performing the unit root test, it has been observed that the data is stationary according to the KPSS Test. The Interpolated p-value comes to be 0.04, which is greater than 0.01 and fulfils the conditions to prove that the data is stationary.

Ordinary Least Square (OLS) method is use to determine the coefficients in the econometric model and the values of the coefficients are obtained from the Gretl software. For this, matrix X and vector Y needs to be defined in this way. On performing the Ordinary Least Squares estimation on your data set, the estimated model can be written as:

$$Y_{1t} = 7684.3 + 4280.05\, X_{2t} + 1317.74\, X_{3t} - 858.218 X_{4t} + u_{1t}$$

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
constant	7684.30	19139.6	0.4015	0.6934	
GOVERNMENT SPENDING	4280.05	17529.4	0.2442	0.8102	
EXPORTS	1371.74	327.636	4.187	0.0007	***
IMPORTS	−858.218	290.405	−2.955	0.0093	***

Mean dependent variable	141885.2	S.D. dependent variable	79397.02
Sum squared residue	2.14e+10	S.E. of regression	36571.03
R-squared	0.821338	Adjusted R-squared	0.787839
F(3, 16)	24.51818	P-value(F)	3.18e-06
Log-likelihood	−236.2876	Akaike criterion	480.5751
Schwarz criterion	484.5581	Hannan-Quinn	481.3526
rho	−0.204185	Durbin-Watson	2.282518

Table 4.4: OLS Model, 2001-2020 (Dependent variable: GDP) Source: gretl

When the Government spending is increased by 1 billion EUR, the GDP increases by 4280.05 billion EUR per year. Similarly, if the exports are increased by 1 billion EUR, the

GDP again increases by 1317.74 billion EUR per year. But on the contrary, if the imports are increased by 1 billion EUR, there is a decrease of 858.218 billion EUR per year, which is logically right. (Money is sent to import/buy goods). As mentioned earlier under the econometric model section, the OLS estimation has proved that the public and private investments on the production of renewable energies have positively influenced GDP.

4.5 Statistical verification of the model

Statistical verification of the model is done by calculating R-square and adjusted R-square of the model, followed by calculating the statistical significance of the parameters and Durbin-Watson test. R-squared and adjusted R-squared are calculated in this manner: computing theoretical values of dependent variable according to the model, computing the residuals, differences from the average, their squaring and the sum – which leads to the result of $S_u{}^2$ and $S_y{}^2$, which then gives the final result.

R-Squared is the measure of goodness of fit. It describes how well is the variation of dependent variable explained by the variation of independent variables. The closer to value is to 1, the better the values actually fit. As shown in the table below from the OLS estimation, R-squared value is 0.821338, for which can be said that there is a strong goodness of fit for this data set. Adjusted R-squared value is 0.787839 and their value is usually lower than that of R-Squared.

Also, considering Durbin-Watson test, the value 2.282518 is more or less equal to two, explaining the fact that there is no autocorrelation in our model. The value being above 2 explains the slight existence of negative correlation. But indeed, the both the R^2 value proves the goodness of fit in the data.

R-squared	0.821338
Adjusted R-squared	0.787839
Durbin-Watson	2.282518

Table 4.5: R^2 and Durbin-Watson results

H_O: γi is not statistically significance

H_A: γi is statistically significance

- The level of significance was chosen for the project is α = 0.01
- The number of observations is 20 and the model has 4 parameters
- The degree of freedom = 20 – 4 = 16
- Based on level of significance α = 0.01; T-table value = 0.496072

Parameters	γ1	γ2	γ3	γ4
T-ratio	0.4015	0.2442	4.187	|−2.955|
Critical T-value	0.496072	0.496072	0.496072	0.496072
T-value Comparison	0.4<0.496	0.2442<0.496	4.187>0.496	2.955>0.496
Hypothesis	Accept H_O	Accept H_O	Accept H_A	Accept H_A

Table 4.6: Statistical verification of parameters

4.6 Model Application and Scenario Simulation

a) Coefficients of elasticity calculation**:**

The elasticity coefficient is a number that indicates the percentage change that will occur in one variable (y) when another variable changes one percent. It is defined as the ratio: (%change in y) / (%change in x)

$$Y_{1t} = 7684.3 + 4280.05\ X_{2t} + 1317.74\ X_{3t} - 858.218 X_{4t} + u_{1t}$$

Theoretical value ŷ for 2020 = 65506.75

$$Ex2 = \frac{\partial y}{\partial x2} * \frac{x2}{\hat{y}} \quad = (4280.05)\ (0.43145)/65506.75 = 0.028\%$$

$$Ex3 = \frac{\partial y}{\partial x3} * \frac{x3}{\hat{y}} \quad = (1317.74)\ (493.116)/65506.75 = 9.919\%$$

$$Ex4 = \frac{\partial y}{\partial x4} * \frac{x4}{\hat{y}} \quad = (-858.218)\ (482.45)/65506.75 = -6.323\%$$

b) Scenarios simulation:

Imagine if there is an increase in the amount of investments by 25% comparing the last year, then its effect on the GDP should result in an increased value.

X_2 rises by 25% at 2021

$E_{X2} = 0.028$

$\Delta y_1 = E_{X2} * \Delta_{x2} = 0.028*25 = 0.7\%$

Hence, the GDP increases by 0.7% and will be $Y_{2021} = 312975.6$ Billion EUR.

5. Economic Balance Sheet – Cost Analysis

5.1 Small Hydro Power Plant

The different types of hydroelectric plants are categorized into run of river and reservoir-based. The run of river scheme is beneficial as it does not involve the rehabilitation of the people and provides minimal environmental impact. On the other hand, the capacity of a hydroelectric plant is considered to be small or large. In different countries, the term small hydro is used to refer to plants that produce less than 25 megawatt. Large hydro is defined as those that produce over 25 megawatt.

As an energy source, small hydroelectric power plants are regarded as harmless and renewable. These features have led to a new trend in the development of renewable energy generation. One of the most effective ways to meet the increasing energy needs of countries such as India is through small hydropower. This type of renewable energy is very clean and can be used in a variety of ways. Compared to fossil fuels, it is also very sustainable as it does not contribute to the environment's degradation(Sachdev et al., 2015).

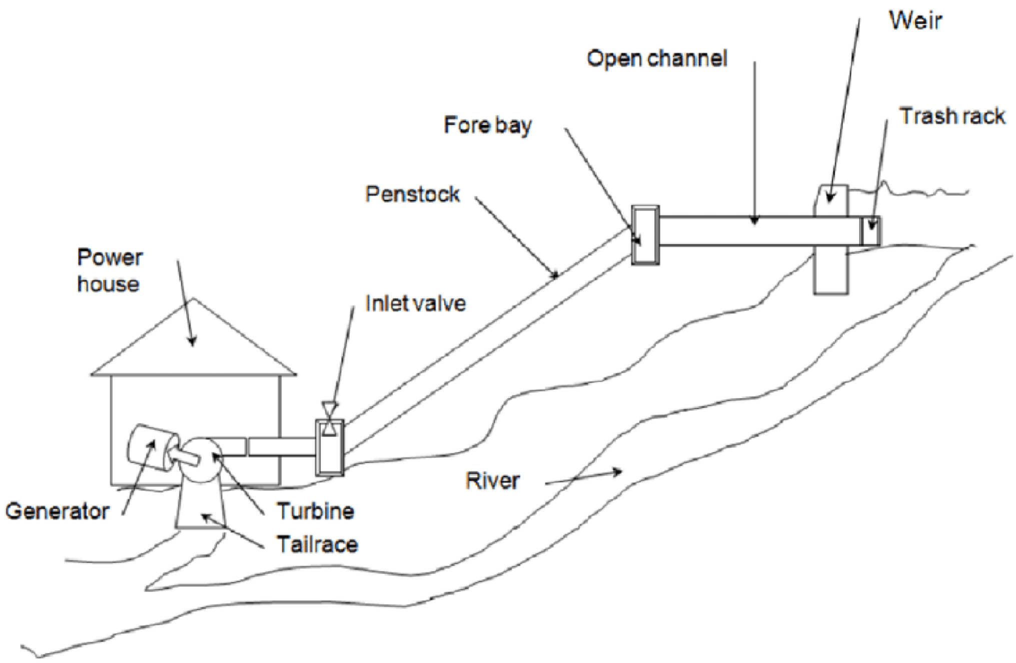


Figure 5.1: Working layout of Small Hydro Plant (Source – Energy.gov(Energy.Gov, 2022))

Apart from the traditional hydroelectric power plants with massive structures including the reservoir, 2 feet diametric penstocks, spillways and a power plant, the small hydro plants are pretty simple and effective. The main concept includes the utilization of the kinetic energy of the run off excess rain water from hill stations or in general, from a region or a location with higher elevation. The Fore bay is the key element, which potentially directs or holds the run-off excess rain/flood water, to send to the powerhouse via Penstock.

5.2 Turbines and Generators

Hydropower turbines are two types that are commonly used for producing electricity - reaction and impulse. The type of turbine that's chosen for a project depends on the height of the water's standing head, as well as its flow over time. Other factors such as the cost and efficiency of the equipment are also considered to determine the project's success. Here are some of the most commonly used turbines(Energy.Gov, 2021).

1. Reaction Turbines – A propeller machine has a runner that has up to six blades. Water constantly contacts all of them, and the pressure inside the pipe ensures that the runner is balanced. The pitch of the blades can be adjusted or fixed, and various components such as a draft tube, a scroll case, and wicket gates are also included(Abeykoon, 2022). There are several different types of propeller turbines:
    a. Propeller turbines
    b. Bulb turbines
    c. Tube turbines
    d. Straflo
    e. Kaplan turbines
    f. Francis turbines
2. Impulse Turbines – An impulse turbine uses the water's velocity to move the runner, and it can discharge water at atmospheric pressure. When the water hits the runner, it causes a stream of water to flow out the bottom of the turbine's housing. This type of machine is commonly used in low-flow and high-head applications. There are two main types of impulse turbines:
    a. Pelton turbines
    b. Cross-Flow turbines

The goal of the turbine is to transform the mechanical energy from wind, water, or steam into electricity. This process is carried out in a hydroelectric power plant. The combination of the generator and the turbine is called a generating unit, and in this type of plant, the water flows through the penstock and enters the scroll case. The blades of the machine are drawn to the axis to exit through the tube underneath. The rushing water's mechanical energy is then converted into electrical energy by the generator.

Electromagnetic induction is a process utilized in generators to convert mechanical energy into electrical energy. An electric current goes through a magnetic field, which creates a shift in its direction. In AC generators, slip rings are utilized to get current. They can also be converted to DC by using split rings. An AC generator is commonly used in power generation stations instead of a DC generator due to its various advantages. These include its efficiency and wide range of applications.

A 630KW capacity Francis turbine, coupled with an AC Generator is considered for this case study. A short description of the product chosen for the study is provided below(Selected Francis Turbine, 2022):

Net Head: 50m

Design Flow: 1.52m^3/s

Capacity: 630KW

Turbine real machine efficiency: 89%

Rated Efficiency of Generator: 92%

Rated rotating speed: 750 rpm/min

Generator: Brushless Excitation

Blade Material: Stainless Steel

Installation Method: Horizontal

Provided that the head is 50m, with gravity with universal value of 9.8 $m/s^{2,}$ and the maximum flow rate is assumed to be 0.5 m^3/s as the north-eastern part of India records the highest amount of rainfall every year. Hence considering all these values with an efficiency of 70% (head with 80% efficiency)(Ferziger et al., 2021), the production capacity of the plant is given as(RenewablesFirst, 2018),

Capacity formula: $P = m \times g \times H_{net} \times \eta$

P = 0.5*9.81*50*0.70 = 171.5 KW

Hence the capacity of the power plant under the maximum conditions would be 2963.52 MW and the cost of electricity in India per KWh is 0.094 EUR.

One site engineer, who works 5 working days a week, and two operators who works to a maximum of 5 days a week on shift basis 8 hours a day are required for the maximum generation of 2963.5 MW per year. Hence the fixed capital investments in total would be 39,202 EUR.

5.3 Cost Analysis:

Capital Investments:

In order to operate the power plant, the predominant things required ate land for the construction and operation of the power house, the necessary technical assets, water source and labors. The area required for the powerhouse is approximately 1100 sq.ft and the price of the land per sq.ft in India is 11.2 EUR and the construction work would take 10,000 EUR.

Technical Equipments				
Name	Price per piece	Units	Total	Total EUR
Penstock Pipe 500mm Diameter - 6 metres	182	15	2730	2730
Francis Turbine - generator unit 500KW	11200	1	11200	11200
Chemicals for cleaning and sanitation	50	12	600	600
Filtration materials	27	36	972	972
cooling unit	1500	1	1500	1500
Total - technology				17002

Fix capital investments - Constructions				
Name	Price per piece	Units	Total	Total EUR
Buildings including renovations - renovations				22200
Total - constructions				22200

Fix capital investments - total				
Name	Price per piece	Units	Total	Total EUR
Buildings and constructions				22200
Technical Equipements				17002
Project reserve				1960.1
Total fix capital investment cost				39202

Parameter	Unit	Cost
Operators - 2	EUR	4560
Site Engineer - 1	EUR	4680
Personal Costs - 3 workers	EUR	9258
Consumables Cost	EUR	1572
Safety Equipments	EUR	196.01
Insurance	EUR	1960.1
Maintenance Costs	EUR	19.601
Income Tax (GST)	%	18

Table 5.1: Fixed Capital Investments

Depreciation calculation:

In accounting, depreciation expense is a method utilized to determine the cost of a certain asset over its useful life. It is usually the reduction in its value due to wear and tear, as well as other factors. The four main methods of depreciation are explained below.

1. Straight-Line Depreciation Method
2. Double Declining Balance Depreciation Method
3. Units of Production Depreciation Method
4. Sum-of-the-Years-Digits Depreciation Method

The life expectancy of the buildings is considered as 30 years and the operational efficiency of the technical assets are assumed to be 10 years.

Time of the asset depreciation - buildings	30
Depreciation for the first year	1.4
Depreciation on other years	3.4
Investments - buildings	0

Time of the asset depreciation - technology	10
Depreciation for the first year	7.3
Depreciation on other years	10.3
Investments - technology	0

Depreciation of assets		
Depreciation of assets - 1st year	EUR/year	1437.19
Depreciation of assets 2nd -10th year	EUR/year	2344.09
Depreciation of assets 11th -30th year	EUR/year	754.8

Table 5.2: Depreciation calculation

Loan Repayment:

A loan amount of 35,000 EUR is borrowed from the bank for a period of 5 years with an interest rate of 8.5%. According to the lone repayment a year formula,

$$P = \frac{r(P)}{1-(1+r)^\wedge - n}$$

Year	Annuity	Repayment of interest	Repayment of principal	Loan balance
1	8881.80	2975.00	5906.80	29093.20
2	8881.80	2472.92	6408.88	22684.32
3	8881.80	1928.17	6953.63	15730.69
4	8881.80	1337.11	7544.69	8185.99
5	8881.80	695.81	8185.99	0.00

Table 5.3: Loan Repayment

Determination of Operating income, Profits, and Income tax:

As per the maximum efficiency calculation, with a production of 2963.52 MW a year, revenue of 279888 EUR is generated per year(GlobalPetrolPrices, 2022). Now, the Operating costs excluding depreciation and interest payments includes the sum of Direct Operating Costs (Technical Assets Cost, Maintenance Costs - 1%, Personal Costs - 5 workers, Project reserve 2%) and the Indirect Operating Costs (Insurance and Safety equipment). Taxable income is the difference between the revenue generated and the operating costs in total.

Revenue from Power generation	EUR/year	279888
Operating costs excluding depreciation and interest payments		27747.97
Direct Operating Costs	EUR/year	25591.86
Technical Assets Cost		15430
Maintenance Costs - 1%		392.02
Personal Costs - 5 workers		9258
Project reserve 2%		1960.1
Indirect Operating Costs	EUR/year	2156.11
Insurance - 2%		1960.1
Safety Equipments - 0.5%		196.01
Taxable Income	EUR/year	252140

EBIT (Annual Profit before taxes)		
1st year	EUR/year	250702.8
2nd-10th year	EUR/year	249795.9
5th -30th year	EUR/year	251385.2
Income Tax		
1st year	EUR/year	45126.51
2nd-10th year	EUR/year	44963.27
5th -30th year	EUR/year	45249.34

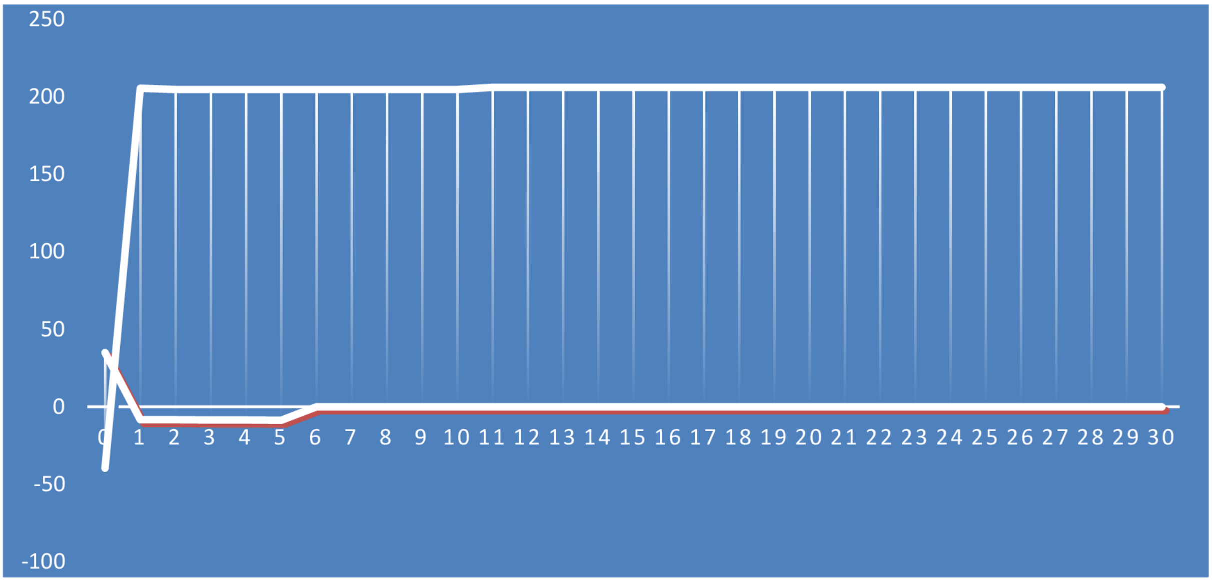
Table 5.4: Operating Costs, EBIT and Taxes

5.4 Cash Flow analysis:

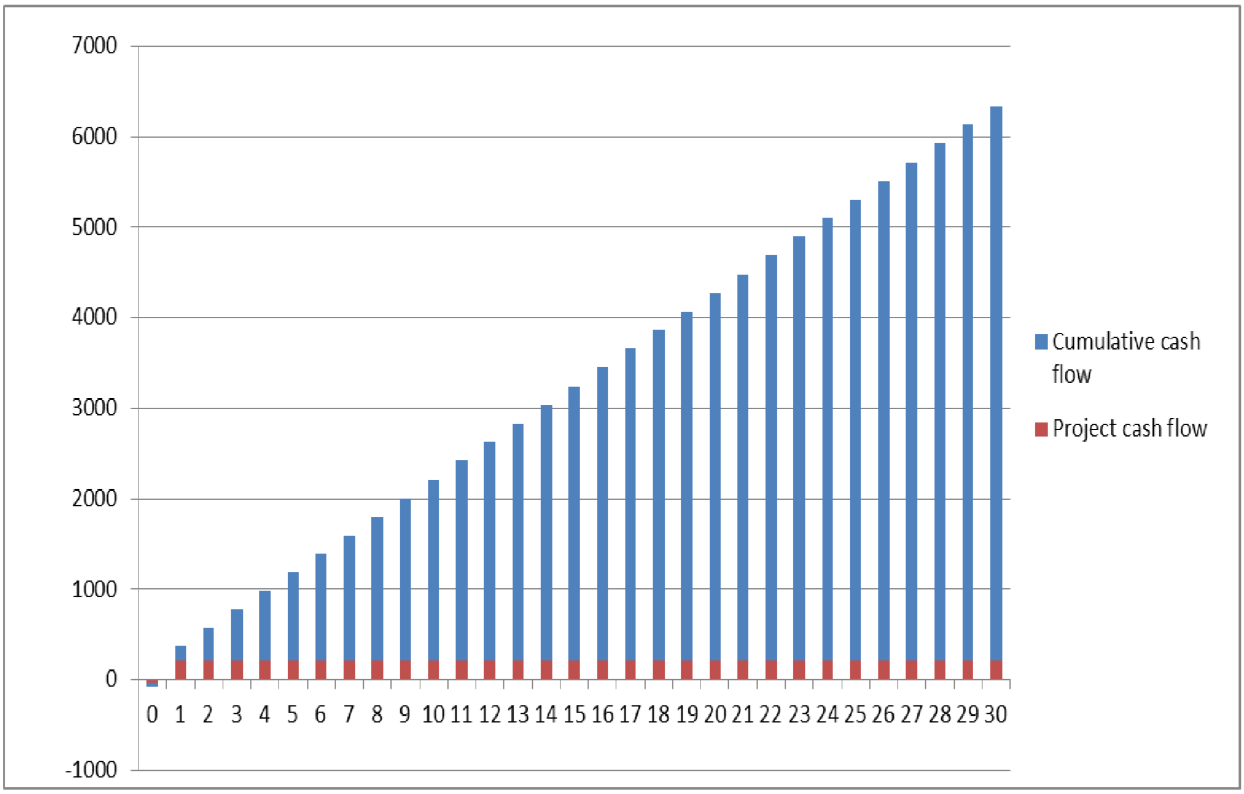
After carrying out the cash flow calculation for a period of 30 years, the value of the payback period and the cumulative cash flow are shown.

Year	Project cash flow	External cash flow	Minimum Cash flow	Cumulative cash flow
Units in 10^3 EUR				
0	-39.714	35	-4.7138	-39.714
1	205.576	-8.3463	197.23	165.862
2	204.669	-8.4367	196.233	370.532
3	204.669	-8.5347	196.135	575.201
4	204.669	-8.6411	196.028	779.871
5	204.669	-8.7566	195.913	984.54
6	204.669	0	204.669	1189.21
7	204.669	0	204.669	1393.88
8	204.669	0	204.669	1598.55
9	204.669	0	204.669	1803.22
10	204.669	0	204.669	2007.89
11	206.136	0	206.136	2214.02
12	206.136	0	206.136	2420.16
13	206.136	0	206.136	2626.3
14	206.136	0	206.136	2832.43
15	206.136	0	206.136	3038.57
16	206.136	0	206.136	3244.7
17	206.136	0	206.136	3450.84
18	206.136	0	206.136	3656.97
19	206.136	0	206.136	3863.11
20	206.136	0	206.136	4069.25
21	206.136	0	206.136	4275.38
22	206.136	0	206.136	4481.52
23	206.136	0	206.136	4687.65
24	206.136	0	206.136	4893.79
25	206.136	0	206.136	5099.93
26	206.136	0	206.136	5306.06
27	206.136	0	206.136	5512.2
28	206.136	0	206.136	5718.33
29	206.136	0	206.136	5924.47
30	206.136	0	206.136	6130.61

Table 5.1: Cash flow



Graph 5.1: Project Cash flow vs External Cash flow (Loan influenced) (in 10^3 EUR)



Graph 5.2: Project vs Cumulative cash flow

The cash flow for a particular year for the project is calculated from the Revenue from power generation, by deducting the operating costs with depreciation, and income tax. A sample calculation for T-10 is shown below:

Revenue generated = 279888 EUR

Operating costs excluding depreciation and interest payments= -27748 EUR

Depreciation of the asset at 10th year= -2344 EUR

$EBIT_{10}$= 249795.94 EUR

Income tax (18% of EBIT) = -44963.27 EUR

Hence, Project cash $flow_{10}$= 279888 + (-27748-2344-44963.27) = 204699.63 EUR

6. Results and Discussions

Econometric One Equation Model:

A regression analysis is a type of statistical procedure that can be used to estimate the relationship between a given variable and another variable. It can also be used to model the future relationship between the two. According to the model, GDP of India is the dependent variable and the other independent variables are Investments on Renewable energy production, Exports and Imports. The correlation matrix, unit root tests and statistical verification of the model, along with the R-squared tests proves the stability of the data set and it is strong to being stationary.

The linear regression model known as the ordinary least squares method is used to estimate the unknown parameters of a given dataset. It minimizes the sum of the observed responses and the predicted responses by the linear approximation. The method is ideal for estimating the errors in the model when the regressor is not random and the errors are homoscedastic.

From the OLS estimation, satisfying results have been observed, since the GDP increases linearly with the increase in the investments on the production of renewable energies and exports, which is logical, as the revenue from taxes are properly being used in the production of energy and it indeed yields a greater GDP. Similarly, with increased exports, it implies more inflow of cash in to the economy from the external market, contributing to an increase in GDP. But on the other hand, the increased imports have to impact the GDP negatively, since the money is leaving to foreign market. Thus theory is being supported by the model, as it implies that with increase in imports by 1 Billion EUR, there is a decline of GDP by 858.218 billion EUR.

When it comes to the determination of trend of the GDP, the co-efficient of elasticity calculations help with the prediction of GDP, provided that the other independent factors are in accordance with the previous years, meaning that if no significant compromise is made to investments and exports in a negative way, it more likely for the GDP to increase in the following years. That is exactly shown in the scenario simulation section, where it has been predicted that the GDP will increase by 0.7% if the investments made on the production of renewable energy is increased by 25% at 2021. Hence with those conditions, the GDP is predicted to be 312975.6 Billion EUR.

Cost Analysis of a SHP:

Instead of reporting amounts that are in accordance with generally accepted accounting principles (GAAP), an economic balance sheet uses market values to measure an organization's financial position. This approach allows investors to gain a deeper understanding of the company's operations and cash flows. Besides being able to identify the multiple types of assets and liabilities that an organization has, the economic balance sheet also provides a basis for assessing the value of the company.

The proposed Small hydro power plant is expected to operate at a maximum efficiency with a power generation of about 2963.52 MW a year, with generating revenue close to 279,888 EUR. Indeed, this is just for the power generated, which has to be transformed from AC to DC by a transformer, depending upon the voltage requirement, it has to be step-up or step-down transformer. Those power grid oriented technical elements were not considered as it is same that of a conventional non-renewable energy production method. When they are considered in the sheet, of course the technical assets value will pump up, decreasing the payback period from 3 months to several more months. But, narrowing down to just the energy generation, the cash flow has a greater trend on the positive side, even considering the loan borrowed from the bank to invest on the necessary assets. No calculations were done for Net Present Value and Internal rate of Return, as the assets considered do not reflect reality, since transformers and power transmission grids are excluded from the study considering their complexity.

Current Economic Status:

India's GDP contracted by 24.4% from April to June of 2020. According to the country's national income estimates, the economy contracted by 7.4% from July to September of that year. This means that the country's overall economy contracted by 7.3% during the 2020/21 financial year. Studies have proved that India’s economy is al a victim to the COVID pandemic. The pandemic could be held accountable for the drastic drop in the GDP, which is proven by the decreased exports of textile and agricultural products, and increased import of medicinal and surgical goods. It is expected that the GDP projected for 2023 should have a surge, to rise from the downfall due to COVID.

7. Conclusion

The regression analysis performed, with the stationary data set proves that the renewable energies production has positive influence on the GDP, and exports, which implies that the Indian Economy has been backed up by the production of renewable energies. The trend predicted has also proved that increased investments in the production of renewable energies also would favor the improvement of Indian Economy in future. Coming to the employment opportunities, there was a massive hike in the unemployment rate, 8% at the year 2020, which then went down by 2.2%, at the year 2021. So, provided with the worse pandemic conditions, growth opportunities still continue to persist in the Indian Market. Higher the employment rate, higher the amount of goods and services produced, which impacts the Economy in a positive way. This attracts the foreign market to either opt for the products and goods available in the Indian market or to directly invest in the Indian market, in other words, increased Foreign Direct Investments.

The economic balance sheet and cost analysis performed for the SHP, has shown a greater payback period, just within 3 months of the project. But indeed, other necessary technical assets involving the conversion of AC to DC transformation, as those are the same, when it comes to conventional non-renewable energy production methods. So, understanding the logic, the prime element required for the energy production, which is the fuel itself, is available abundant in nature for free. This eliminates the requirement for huge investments in the extraction sites for radioactive products or other non-renewable fuels. Collectively, it can be concluded that the broadening of renewable energy production and existing knowledge in this field would make sure India to hit its target to be a developed country in the mere future.

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9. Appendix

1. Data Set - units in Billion EUR:

Year	GDP	GOVERNMENT SPENDING	EXPORTS	IMPORTS
2001	61029	0.2008656	63.3984	67.8288
2002	53410	0.0178464	76.388	81.64
2003	59952	0.011128	94.4736	98.8728
2004	62338	0.4154072	131.716	144.8824
2005	70803	0.1823536	167.2736	191.0896
2006	78807	0.1674296	207.9688	239.1584
2007	76960	0.4842552	263.2032	314.912
2008	78345	0.3841344	300.456	364.9672
2009	103896	0.219076	284.7	361.0672
2010	107744	0.3877328	390.364	467.9688
2011	117595	2.0289568	465.2752	589.3368
2012	215488	1.1638744	466.336	594.1624
2013	153920	0.6098664	491.0672	548.6624
2014	155382	0.727792	487.084	550.4096
2015	233112	0.831688	433.4616	483.704
2016	192400	2.2860968	457.2256	499.3768
2017	215488	0.895908	518.1904	605.3008
2018	243963	2.0251816	560.1856	664.5704
2019	246272	0.8570016	550.1808	625.6432
2020	310800	0.43145	493.116	482.45

2. OLS Model (Source – Gretl)

```
Model 1: OLS, using observations 2001-2020 (T = 20)
Dependent variable: GDP

                       coefficient   std. error   t-ratio   p-value
  --------------------------------------------------------------
  const                  7684.30      19139.6       0.4015   0.6934
  GOVERNMENTSPENDI~      4280.05      17529.4       0.2442   0.8102
  EXPORTS                1371.74        327.636     4.187    0.0007   ***
  IMPORTS                -858.218       290.405    -2.955    0.0093   ***

Mean dependent var   141885.2   S.D. dependent var   79397.02
Sum squared resid    2.14e+10   S.E. of regression   36571.03
R-squared            0.821338   Adjusted R-squared   0.787839
F(3, 16)             24.51818   P-value(F)           3.18e-06
Log-likelihood      -236.2876   Akaike criterion     480.5751
Schwarz criterion    484.5581   Hannan-Quinn         481.3526
rho                 -0.204185   Durbin-Watson        2.282518

Excluding the constant, p-value was highest for variable 2 (GOVERNMENTSPENDING)
```

3. Turbine chosen - https://www.fstgenerator.com/3x630kw-francis-turbine-product/