**COVER PAGE FOR THE PROJECT PROPOSAL**

**ANL 488 PROJECT PROPOSAL**

**THE RELIABILITY OF RENEWABLE ENERGY TO REPLACE OIL AND GAS AS OUR ENERGY OF CHOICE**



**Submitted by**

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# Chapter 1.0

## Chapter 1.1 – Introduction

The global energy production stands at a critical juncture, world governments are met with urgent imperatives to shift from fossil fuels to sustainable alternatives. Renewable energy has emerged as a promising replacement to the conventional use of fossil fuels such as oil and gas. Yet, we asked ourselves: can renewable energy truly replace oil and gas as our energy of choice? Is this transition reliable and sustainable?

Renewable energy is a natural source that replenishes itself in a certain time period. It has far lower emissions than burning fossil fuels and reduced negative externalities on the environment.

In light of global warming and the recent Fukushima Daiichi accident, the imperative to reduce climate change, greenhouse gas emissions, and ensuring reliable energy supply has forced governments to invest in renewable energy projects. However, transiting from fossil fuels to renewables are not without its challenges, many renewable energy projects face significant setbacks in achieving their intended targets. This project explores the reliability of renewable energy to replace oil and gas as our energy of choice, shedding light on the challenges and uncertainties that surround renewable energy sources.

Renewable energy does not achieve maximum effectiveness due to a combination of unpredictable weather conditions and suboptimal equipment performance. This has cast doubt over the reliability of renewable energy sources for long term sustainability. For instance, research conducted in China reveals that their wind farm generated a mere 37-45% of its technological potential compared to 54-61% in the United States (Huenteler et al., 2018). The discrepancy in its performance is due to the delays in grid connection and curtailment constraints in grid management. Furthermore, China’s wind farms suffer from suboptimal turbine model selection, poor wind farm siting, and low turbine hub heights (Huenteler et al, 2018). While these factors seem minor individually, their cumulative effect results in the underperformance of China’s wind farms.

Another reason why wind and solar projects fails to meet capacity utilisation target is due to wind generation curtailment and reduced irradiance for solar projects. Wind generation curtailment can occur when electricity supply exceeds demand on the grid, causing the prices go negative. Furthermore, the excess electricity generated threatens to overload the grid’s capacity. Hence, wind and solar farms are curtailed for economic or grid-capacity purposes. This recurring issue led to wind and solar projects consistently falling short on their performance expectations.

The objective of this project is to delve deeper into the reliability of renewable energy sources by conducting a time series forecast and understanding the trend of renewable energy in our society, as well as evaluating the cost efficiency of renewable energy as sustainable alternatives.

## Chapter 1.2 – Business Problem

The business problem at hand is multifaceted, presenting challenges in the energy generation capacity and the cost efficiency of renewable energy.

The first business problem is the lack of energy output from renewable sources. The energy output and its efficiency are primarily driven by uncontrollable factors such as climate change, wind speed, water current and the Earth’s mantle. Additionally, the capacity of renewable energy is further constrained by the limitation of available land and the geographical location of renewable energy plants. These pose significant challenges to ensure that consistent and reliable energy are generated from renewable energy sources.

The second business problem revolves around the high cost of renewable energy production. The cost of renewable energy production encompasses its initial installation cost, operations and maintenance (O&M), and the levelized cost of electricity (LCOE). Balancing these costs factors and keeping cost of production low, to remain economically competitive with conventional energy sources is a business problem that requires data analytics.

## Chapter 1.3 – Business Analytics Problem

The business analytics problem is to determine the most appropriate time series modelling to effectively forecast the growth and energy output of renewable energy sources. This entails a thorough model selection and fitting for the project. This proposal aims to establish a modelling technique that can reliably project future trend in renewable energy production. Furthermore, the model seeks to identify outliers within the dataset, ensuring a more accurate understanding of the implementation of renewable energy sources.

# Chapter 2.0 Literature Review

Abolhosseini, Heshmati, and Altmann (2014), stresses the importance of renewable energy sources in mitigating climate change. The authors argue that renewable energy technologies have the potential to reduce carbon dioxide (CO2) emissions significantly by replacing fossil fuels in both the power generation industry and transportation sectors. This assertion aligns with the broader consensus that renewable energy is quintessential for global efforts to combat climate change.

The study also highlights that renewable energy production and supply have been on the rise globally. This is due to technological advancements that have made renewable energy more affordable and economically competitive with fossil fuels. The decrease in cost of renewable energy, combined with its positive externalities, such as environmental benefits, enables renewables to be a viable alternative to conventional energy sources.

Hydropower, wind, solar, and geothermal energy sources are specifically mentioned in the study due to their substantial contributions to the electrical generations as renewable energy sources. Hydropower is recognised as the largest renewable energy source for power generation worldwide (Abolhosseini et al., 2014). Despite its large energy generation, hydropower faces challenges such as high initial investment and reallocation costs, as well as environmental concerns which hinders its widespread adoption.

Wind power has also seen significant growth, especially in countries like China, US, Germany, and Denmark. Wind power's advantages include rapid installation, relatively low investment and O&M cost, and zero fuel costs. However, intermittency of wind turbine and transmission costs remain a challenge for wind power.

Solar power technology has seen developments and cost reductions as of late. US adopted the highly efficient concentrated solar power technology and China's investment in solar power capacity has significantly lowered generation costs. The only issues include the land, material and chemical used and the affected aesthetics of buildings.

Geothermal energy, while a continuous and reliable source, is subject to its geological constraints. Geothermal energy draws heat energy from the Earth’s mantle for electricity generation, it offers an eco-friendly option from natural resources.

Abolhosseini, Heshmati, and Altmann (2014), also discusses the importance of energy efficiency in reducing overall energy consumption and CO2 emissions. Enhancing energy efficiency is considered an essential strategy to complement renewable energy adoption. Energy efficiencies are explored through various technologies, such as electric vehicles, combined heat and power (CHP), virtual power plants, and smart grids.

Electric vehicles (EVs) are noted as a potential solution to reduce emissions in the transportation sector. Transitioning to EVs on a large scale could result in substantial energy savings and emissions reductions. Additionally, the aid of smart grid technologies could further improve the large-scale use of EVs and enhance the efficiency of the EVs’ technology.

CHP technologies are recognised for their ability to improve efficiency by reusing and repurposing waste heat for heating buildings, thereby increasing overall energy efficiency. Virtual power plants and smart grids offer solutions to energy waste, reducing transmission losses and optimising load reductions.

A separate study by Kobos, Erickson, and Drennen (2005), discusses the impact of policies and economics in the renewable energy industry. The authors assert that government financial and institutional support are essential for fostering innovation and growth of renewable technologies.

The study noted that despite the substantial support for renewable technologies provided in the aftermath of the 1970s energy crises, the lack of a cohesive national system of innovation for renewable energy technologies in the US has hindered their progress. Instead, wind energy growth in the US is due to financial incentives and capital cost reductions than domestic technological innovation.

Solar photovoltaic technology, despite early goals of 20 years ago, struggled to gain traction. Oil prices declined during the 1980’s which results in a decline in political support for renewables and reduced research and development (R&D) funding (Kobos et al. 2005). The shortsighted approach to research and innovation has halted the progression of renewable energy goals.

The authors argue that the current state of renewable energy RD&D (research, development, and deployment) may not penetrate the market without sustained support from both the federal level and commercial marketplace. Therefore, adequate funding and appropriate energy policy planning are quintessential for fostering innovation and reducing costs.

Another study by Bull (2021), emphasises the potential socioeconomic, environmental, and community planning associated with the adoption of renewable energy sources.

In the US, the agricultural sector can diversify its income sources by growing crops specifically for energy production as biomass. Rural communities are expected to benefit from the renewable energy usage, leading to greater flexibility in energy choices and enhanced economic potential. This could potentially boost rural economies, create nonfarm jobs, and reduce dependency on oil imports.

Urban and suburban communities are expected to change by the restructuring of the electric industry, there will be more options for distributed energy resources and increased energy efficiency in buildings. These changes will be facilitated by advances in information technology and renewable energy technologies, leading to smart buildings and transportation systems.

In the context of international socioeconomic equity, renewable energy technologies are seen as tools for improving the quality of life for marginalised populations. These technologies provide electricity to areas without access to reliable energy sources, which reduces gender disparities and promotes entrepreneurship to manufacture, sell, and service renewable energy systems (Bull, 2021).

In the environmental perspective, Bull (2021) emphasises the substantial environmental damage caused by conventional energy production and use, including air pollution and CO2 emissions. Renewable energy is presented as a solution to these environmental challenges, especially to avert greenhouse gas emissions.

To conclude, the literature review highlights the reliability of renewable energy as a viable replacement for oil and gas. Renewable energy sources such as hydropower, wind, solar, and geothermal, can reduce CO2 emissions, combat climate change, and ensuring reliable energy supply. However, challenges such as intermittency, initial investment costs, and policy support must be addressed for wider adoption.

Time series forecasting models helps to address some of the challenges faced:

Addressing Intermittency – Due to the intermittent nature of energy generation for wind and solar power. Time series forecasting models can analyse historical data and generate accurate predictions of energy production patterns. This reduces the unpredictability of renewable energy sources, allowing grid operators and energy planners to anticipate periods of low generation and ensure a consistent power supply.

Grid Integration – The integration of renewable energy into existing power grids requires precise forecasting of energy generation. Time series models provide accurate predictions of renewable energy output, enabling grid operators to balance supply and demand effectively.

Policy Support – Government officials rely on data insights to make informed decisions about renewable energy projects. Time series forecasting models can provide long-term projections of renewable energy generation, helping stakeholders allocate resources efficiently. These models offer a degree of confidence to investors regarding the expected performance of renewable projects, enabling a greater support from investors and stakeholders.

Investment into R&D – Research efforts to improve the efficiency and reliability of renewable energy technologies often involve analysing historical data. Time series forecasting can identify trends and predict the potential impacts of advancements in renewable energy technology. This accelerates the development and deployment of more reliable renewable energy solutions.

In summary, time series forecasting models can offer insights into energy generation intermittency, grid integration, policy decisions, and the support of R&D efforts. These models can forecast renewable energy production level and consumption, as well as aid in the eventual goal of replacing oil and gas with sustainable renewable energy sources. Therefore, we should use time series forecast models to reinforce the reliability of renewable energy as our energy of choice.

# Chapter 3.0 Data Understanding and Preparation

## Chapter 3.1 Data Understanding

The dataset encompasses renewable energy sources from across six major regions and continents, including Oceania, South America, North America, Asia, Europe, and Africa. This dataset spans from 1965 to 2021, providing an extensive historical data on renewable energy production, measured in electricity generation (TWh).

Electricity generation (TWh) represents the total electricity produced by various sources, including electricity plants, combined heat and power plants (CHP), and distributed generators. To put this into perspective, 1 TWh equates to 1,000 GWh or 1,000,000 MWh. The average household typically consumes approximately 800 to 1,000 kWh.

This electrical generation measurement is taken at the output terminals of these generation facilities, accounting for both on-grid and off-grid generation. It also accounts for the electricity self-consumed within energy sectors, not just the electricity fed into the grid.

A diagram of different types of wine

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Fig 1: Renewable energy sources

As shown in Fig1, our data analysis will focus on comparing the five major renewable energy sources: hydropower, wind, solar, bioenergy, and geothermal. Hydropower encompasses various forms of renewable hydropower, including pumped storage. Wind energy is divided into offshore and onshore wind energy. Solar energy includes both solar photovoltaic and concentrated solar power. Lastly, bioenergy consists of solid biofuels and biogas.

The input data types are continuous values: hydropower, wind, solar, bioenergy and geothermal.

## Chapter 3.2 Data Preparation

The dataset was prepared through merging of multiple datasets. The merger allows the dataset to be more comprehensive by extending its historical data back to 1965 from beyond 2000. This expansion of dataset will increase the accuracy of our project models, enabling a more precise model against an extended timeline of data.

Missing values which primarily stemmed from gaps in early 1965 to 1971 records are addressed using Excel’s tools. The missing values are imputed with a fixed value of 0, ensuring the dataset’s integrity for the analysis of renewable energy trends across the decades.

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Fig 2: Before filling the missing values

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Fig 3: After filling the missing values

# Chapter 4.0 Proposed Modelling and Evaluation

## Chapter 4.1 Proposed Model

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Fig 4: General statistics for renewable energy across the world

Using Python to plot the graphs, we can discern distinctive trends with the data of renewable energy for the world. A linear trend graph can be observed for hydropower and geothermal. Conversely, an exponential trend graph provides the most accurate fit for wind, solar and bioenergy, depicting their accelerating growth trends.

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Fig 5: Linear trend graphs of hydropower and geothermal

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Fig 6: Exponential trend graph of wind, solar and bioenergy

Based on the results, it is evident to employ ARIMA modelling for forecasting hydropower and geothermal. Conversely, for wind, solar, and bioenergy, exponential smoothing provides a more suitable approach for forecasting.

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Fig 7: ACF and PACF of hydropower

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Fig 8: ACF and PACF of geothermal

As seen in Fig 7 and 8, there are 4 and 2 significant lags in hydropower and geothermal respectively in the ACF plot, while both cut-off after lag 1 in PACF. As a result, we can conclude that both hydropower and geothermal use AR(1) process.

## Chapter 4.2 Preliminary Evaluation

Both the ARIMA and exponential smoothing model prove to be suitable for time series forecasting, and they are expected to produce highly accurate results regarding the trends and forecasts of renewable energy sources. A preliminary evaluation of the dataset indicates that all models consistently depict an upward trend in the growth of renewable energy. This trend highlights the substantial investments directed towards renewable energy sources. As a result, we observe an increase in energy generation from renewable plants as they become more favorable over traditional fossil fuels.

# Chapter 5.0 Proposed Schedule

The project milestones are as follows:

|  |  |
| --- | --- |
| Date | Description |
| 16 June 2023 | Session 0 with supervisor |
| 12 August 2023 | ANL488 Seminar 1 |
| 21 August 2023 | Session 1 with supervisor, Preparation of Proposal |
| 8 September 2023 | Proposal submission |
| 18 September 2023 | Session 2 with supervisor, Presentation |
| 2-6 October 2023 | Oral presentation |
| 30 October 2023 | Session 3 with supervisor, Report Submission |
| 6 November 2023 | Final Report Submission |

The projected timeline is as follows:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 16 Jun 23 | 12 Aug 23 | 21 Aug 23 | 8 Sep 23 |
| Session 0 with supervisor |  |  |  |  |
| Search for new data sources and create dataset | 58 days | |  |  |
| ANL488 Seminar 1 |  |  |  |  |
| Prepare proposal draft, clean dataset |  | 10 days | |  |
| Session 1 with supervisor |  |  |  |  |
| Experiment with various models, complete proposal |  |  | 19 days | |
| Proposal submission |  |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 18 Sep 23 | 2-6 Oct 23 | 30 Oct 23 | 6 Nov 23 |
| Session 2 with supervisor, modelling result fine-tuning |  |  |  |  |
| Prepare for Oral Presentation | 15 days | |  |  |
| Oral Presentation |  |  |  |  |
| Revised feedback from Oral Presentation |  | 29 days | |  |
| Session 3 with supervisor, Final Report review |  |  |  |  |
| Revised and correction to Final Report |  |  | 8 days | |
| Final Report submission |  |  |  |  |

# References

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