PREDICTING THE ENERGY OUTPUT OF WIND TURBINE BASED ON WEATHER CONDITION

Project Report
Submitted By
Team ID: PNT2022TMID35748

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CONTENTS:

1. INTRODUCTION

1.1 Project Overview

Wind energy plays an important role in providing electricity which is one of the renewable resources. The power produced from wind is a clean and renewable energy resource. The best factor of wind energy over other available renewable resources is that it produces power without burning any fuel or polluting the air. Also, it is an abundant and inexhaustible resource. Wind energy can be obtained by using turbines that convert mechanical energy into electrical energy. The climatic conditions around the farm have an impact on the energy output, and as the climate is unpredictable the production of energy gets affected. A detailed forecast is needed to overcome these problems.Therefore a web application can be developed that predicts the energy that can be harnessed by taking weather conditions into account. If the output of the production from turbines is accurately predicted, the energy providers can be kept away from expensive overproduction. First, we gathered the dataset for our research and divided it into training and testing data. The appropriate model is picked for model development after the data set has been divided. A random forest is a machine learning model that has been chosen for our project. A flask application is created to forecast the result using trained data. This is made available everywhere around the world to predict the output of wind energy using the IBM Watson cloud.

1.2 Purpose

Wind energy plays a major role in meeting the electricity demand in a sustainable way at a world wide range. Due to the shortcomings of non-renewable energy resources, widespread investigation in the past has been done to decrease any future crisis and also techniques or alternatives to overcome the energy crisis. Renewable energy resources are the solution to it. Wind energy comes under this category and if wisely utilized, can meet our energy demands to maximum extent. Wind which is present all over the atmosphere is a lasting element that can be used as it cannot be depleted. Electrical energy

from the wind can be harnessed using the turbines. The turbines present in the windmill convert the mechanical energy into electrical energy. The production of the energy is impacted by the climatic condition present around the farm and since the climate is unpredictable, the energy that is being produced is also unpredictable and it affects the farm operations in system and energy planning. Thus, a precise forecast is imminent to overcome these drawbacks. If the output of the production from turbines is predicted accurately, the providers of the energy can be kept away from expensive overproduction and hence, a web application is proposed which predicts the energy that can be harnessed by taking into consideration various environmental factors and weather conditions.

In our project, firstly we collected the dataset and split it into training and testing data. After splitting the data set, the suitable model is chosen for model building. The selected model for our project is a random forest which is one of the machine learning models. A flask application is made to predict the output with the help of trained data. IBM Watson cloud is used to make this accessible all over the world to predict the wind energy output.

2. LITERATURE SURVEY

2.1 Existing problem

Given the intermittent nature of the wind, accurate wind energy forecasting is significant to the proper utilization of renewable energy sources. In recent years, data-driven models based on past observations have been widely employed in the literature. Various types of data processing methods are successfully applied to assist these models and further improve forecasting performance. Comprehensive research of their methodologies is called on for a thorough understanding of current challenges that affect model accuracy and efficiency. Here, mathematicians and statisticians could make a substantial contribution at the interface of meteorology and decision-making, in connection with the generation of forecasts tailored to the various operational decision problems involved. Indeed, while wind energy may be seen as an

environmentally friendly source of energy, full benefits from its usage can only be obtained if one is able to accommodate its variability and limited predictability. Based on a short presentation of its physical basics, the importance of considering wind power generation as a stochastic process is motivated. The existing approaches to wind power forecasting are subsequently described, with focus on single-valued predictions, predictive marginal densities and space–time trajectories. Upcoming challenges related to generating improved and new types of forecasts, as well as their verification and value to forecast users, are finally discussed.

2.2 References

[1]. Preethi, S., H. Prithika, M. Pramila, and S. Birundha. "Predicting the Wind Turbine Power Generation based on Weather Conditions." In 2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA), pp. 132-139. IEEE, 2021.

[2]. Rashid, Haroon, Waqar Haider, and Canras Batunlu. "Forecasting of wind turbine output power using machine learning." In 2020 10th International Conference on Advanced Computer Information Technologies (ACIT), pp. 396-399. IEEE, 2020.

[3]. Karthik, R., A. Sri Hari, YV Pavan Kumar, and D. John Pradeep. "Modelling and control design for variable speed wind turbine energy system." In 2020 International Conference on Artificial Intelligence and Signal Processing (AISP), pp. 1-6. IEEE, 2020.

[4]. Ansari, Shahbaaz, TG Sampath Vinayak Kumar, and Javed Dhillon. "Wind Power Forecasting using Artificial Neural Network." In 2021 4th International Conference on Recent Developments in Control, Automation & Power Engineering (RDCAPE), pp. 35-37. IEEE, 2021.

[5]. Ren, Zhe, Chengshuai Huang, and Meng Li. "Research on Wind Power Prediction." In 2019 IEEE 3rd Conference on Energy Internet and Energy System Integration (EI2), pp. 1504-1507. IEEE, 2019.

[6]. Weidong, Xin, Liu Yibing, and Li Xingpei. "Short-term forecasting of wind turbine power generation based on genetic neural network." In 2010 8th World Congress on Intelligent Control and Automation, pp. 5943-5946. IEEE, 2010.

2.3 Problem Statement Definition

The aim of our project is to predict the energy output of wind turbine based on weather conditions. If the output of the production from turbines is predicted accurately, the providers of the energy can be kept away from expensive overproduction and hence, a web application is proposed which predicts the energy that can be harnessed by taking into consideration various environmental factors and weather conditions.

3. IDEATION & PROPOSED SOLUTION

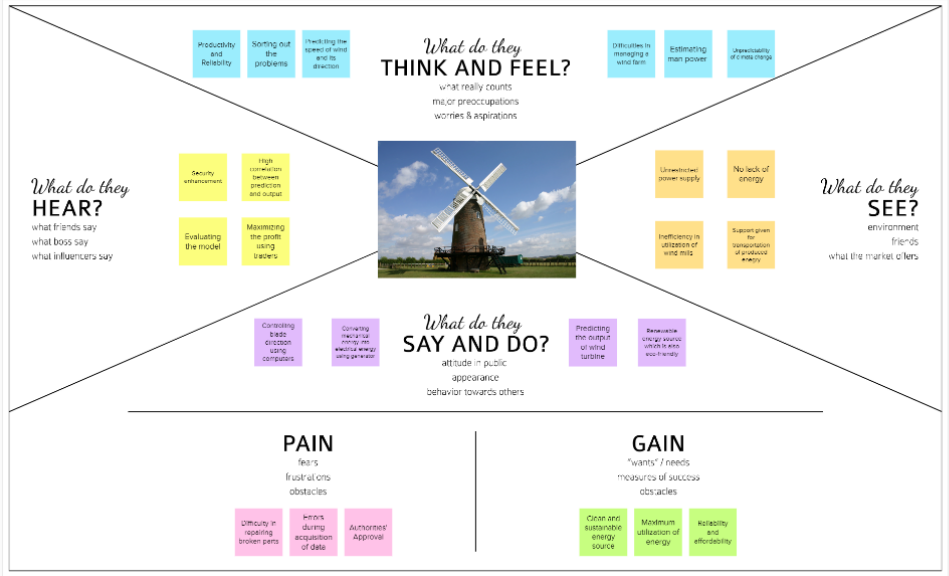
3.1 Empathy Map Canvas

Empathy Map Canvas

Gain insight and understanding on solving customer problems.

1

Build empathy and keep your focus on the user by putting yourself in their shoes.



Share your feedback

3.2 Ideation & Brainstorming

Template

Brainstorm & idea prioritization

Use this template in your own brainstorming sessions so your team can unleash their imagination and start shaping concepts even if you're not sitting in the same room.

- **10 minutes** to prepare
- **1 hour** to collaborate
- **2-8 people** recommended

Before you collaborate

A little bit of preparation goes a long way with this session. Here's what you need to do to get going.

10 minutes

A **Team gathering**
Define who should participate in the session and send an invite. Share relevant information or pre-work ahead.

B **Set the goal**
Think about the problem you'll be focusing on solving in the brainstorming session.

C **Learn how to use the facilitation tools**
Use the Facilitation Superpowers to run a happy and productive session.

Open article →

1 Define your problem statement

What problem are you trying to solve? Frame your problem as a How Might We statement. This will be the focus of your brainstorm.

5 minutes

PROBLEM

Predicting the energy output of wind turbine based on weather conditions

Key rules of brainstorming

To run an smooth and productive session

- Stay in topic.
- Encourage wild ideas.
- Defer judgment.
- Listen to others.
- Go for volume.
- If possible, be visual.

2

Brainstorm

Write down any ideas that come to mind that address your problem statement.

10 minutes

TIP

You can select a sticky note and hit the pencil [switch to sketch] icon to start drawing!

B.Niveditha

- Analysing existing technologies
- Monitoring the weather
- Average power generated
- Performance metrics used are examined

N.Sudarsan Kumar

- Tracking the weather
- Analysing ML algorithms
- System performance is evaluated using necessary metrics
- Efficiency of our system

R.Bhargavi

- System security features
- Ideal platform for implementation
- Promoting the product
- Expandable to other renewable sources of energy

Dampella Shalini Priya

- Cost efficiency
- Reliable under extreme conditions
- Eco friendliness
- Integration with existing technologies

3

Group ideas

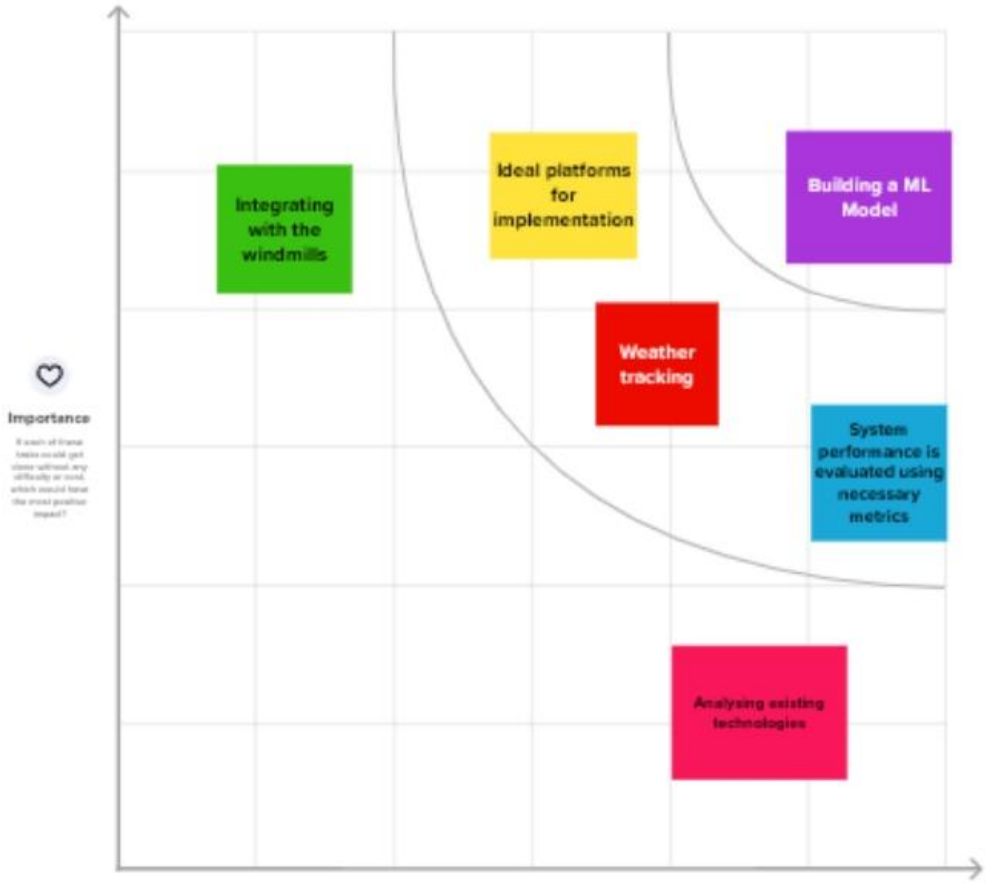
Take turns sharing your ideas while clustering similar or related notes as you go. Once all sticky notes have been grouped, give each cluster a sentence-like label. If a cluster is bigger than six sticky notes, try and see if you and break it up into smaller sub-groups.

20 minutes

Prioritize

Your team should all be on the same page about what's important moving forward. Place your ideas on this grid to determine which ideas are important and which are feasible.

20 minutes



After you collaborate

You can export the mural as an image or pdf to share with members of your company who might find it helpful.

Quick add-ons

Share the mural
Share a view link to the mural with stakeholders to keep them in the loop about the outcomes of the session.

Export the mural
Export a copy of the mural as a PNG or PDF to attach to emails, include in slides, or save in your drive.

Keep moving forward

Strategy blueprint
Define the components of a new idea or strategy.
Open the template →

Customer experience journey map
Understand customer needs, motivations, and obstacles for an experience.
Open the template →

Strengths, weaknesses, opportunities & threats
Identify strengths, weaknesses, opportunities, and threats (SWOT) to develop a plan.
Open the template →

Share template feedback

3.3 Proposed Solution

S. No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The most popular renewable energy source is wind energy, but it cannot be relied upon indefinitely. Several environmental elements have an impact on the power produced. As a result, it cannot be totally relied upon, which lowers its effectiveness.
2.	Idea / Solution description	In order to integrate with the grid and utilise its maximum potential, machine learning will be used to anticipate the energy output using historical performance data and current meteorological parameters.
3.	Novelty / Uniqueness	This model incorporates the energy outputs from the previous year and correlates them with the weather and other parameters that have an impact. We may input the weather conditions into

		this model to get the energy output. Additionally, based on the anticipated value and actual output value, the algorithm is changed dynamically.
4.	Social Impact / Customer Satisfaction	The use of renewable energy is increased thanks to this concept. It makes wind turbine operating more efficient. This approach is unbeatable due to the implementation costs.
5.	Business Model (Revenue Model)	The ability to enhance energy output will enable wind energy companies to generate more money. Since we can forecast the overall power output at any given moment, wind energy can be relied upon to be a reliable source
6.	Scalability of the Solution	No new hardware needs to be installed at the wind turbine to accomplish this. The weather characteristics can be obtained from the currently installed sensors to predict electricity output. The data may be easily

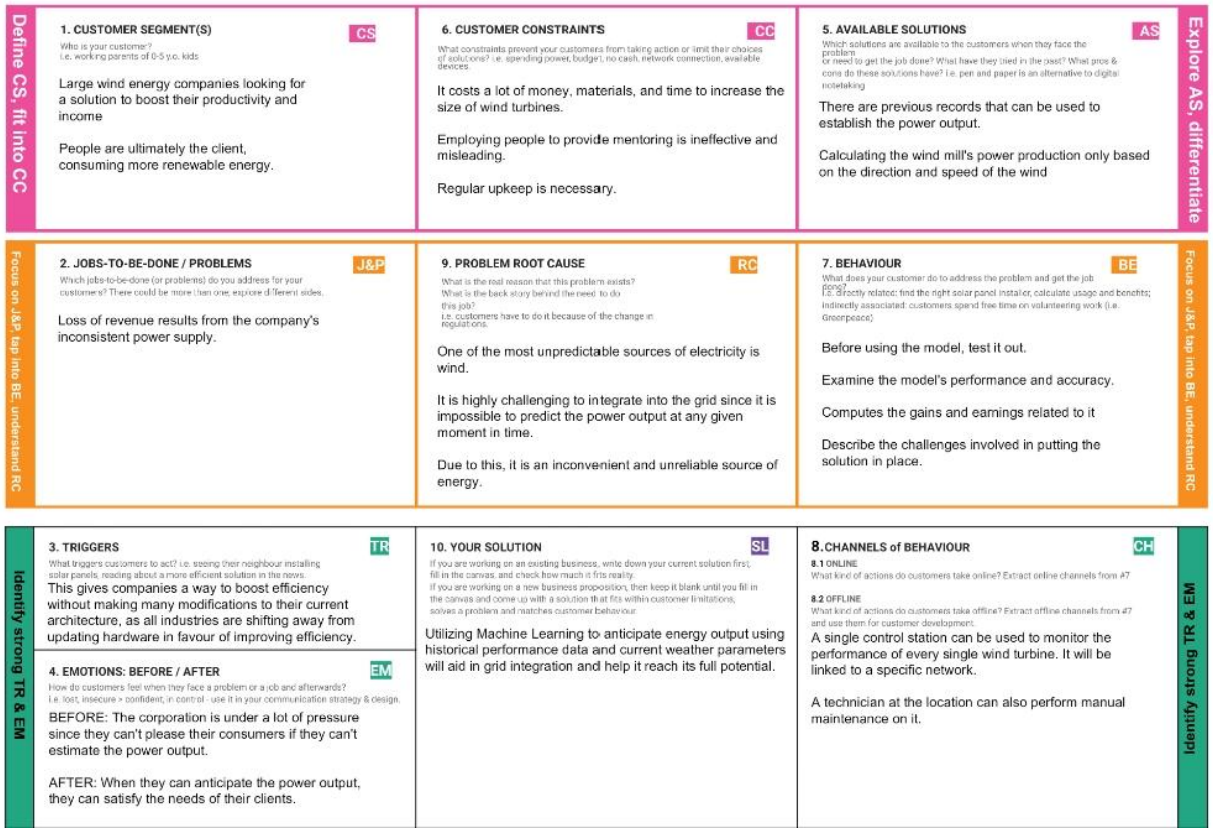
		accessed in real time thanks to weather stations located all around the world. At the wind turbine control centre, the prediction can be made. To obtain correct results, the algorithm can be readily changed to function for every single wind turbine.

3.4 Problem Solution fit

Project Title: Predicting the energy output of Wind Turbine based on Weather Conditions

Project Design Phase-I - Solution Fit Template

Team ID: PNT2022TMID35748



4. REQUIREMENT ANALYSIS

4.1 Functional requirements

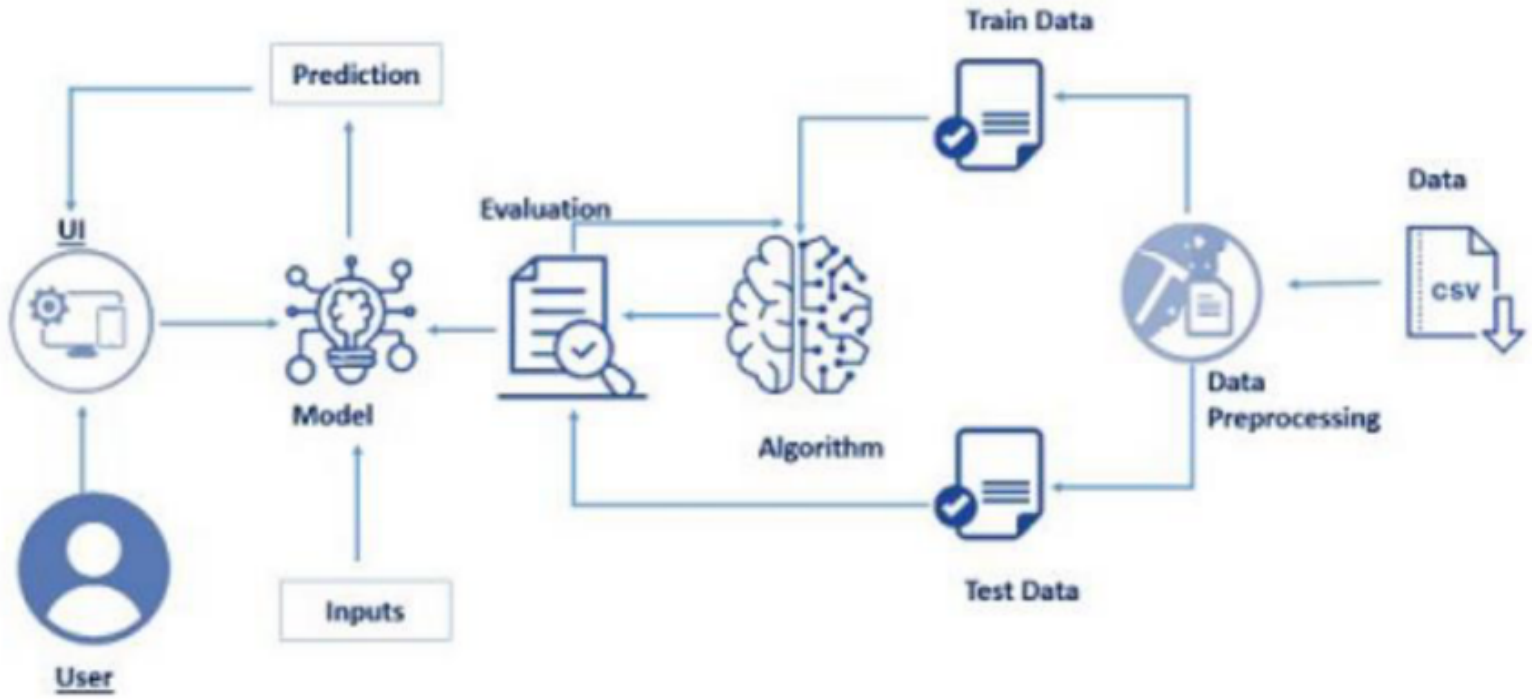
FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	User Registration	Registration through Form Registration through Gmail Registration through LinkedIN
FR-2	User Confirmation	Confirmation via Email Confirmation via OTP
FR-3	User Application	Filling of application Modification of application Verification of application
FR-4	Predicting Output	Checking weather of a city Input different attributes Predict the output

4.2 Non-functional Requirements:

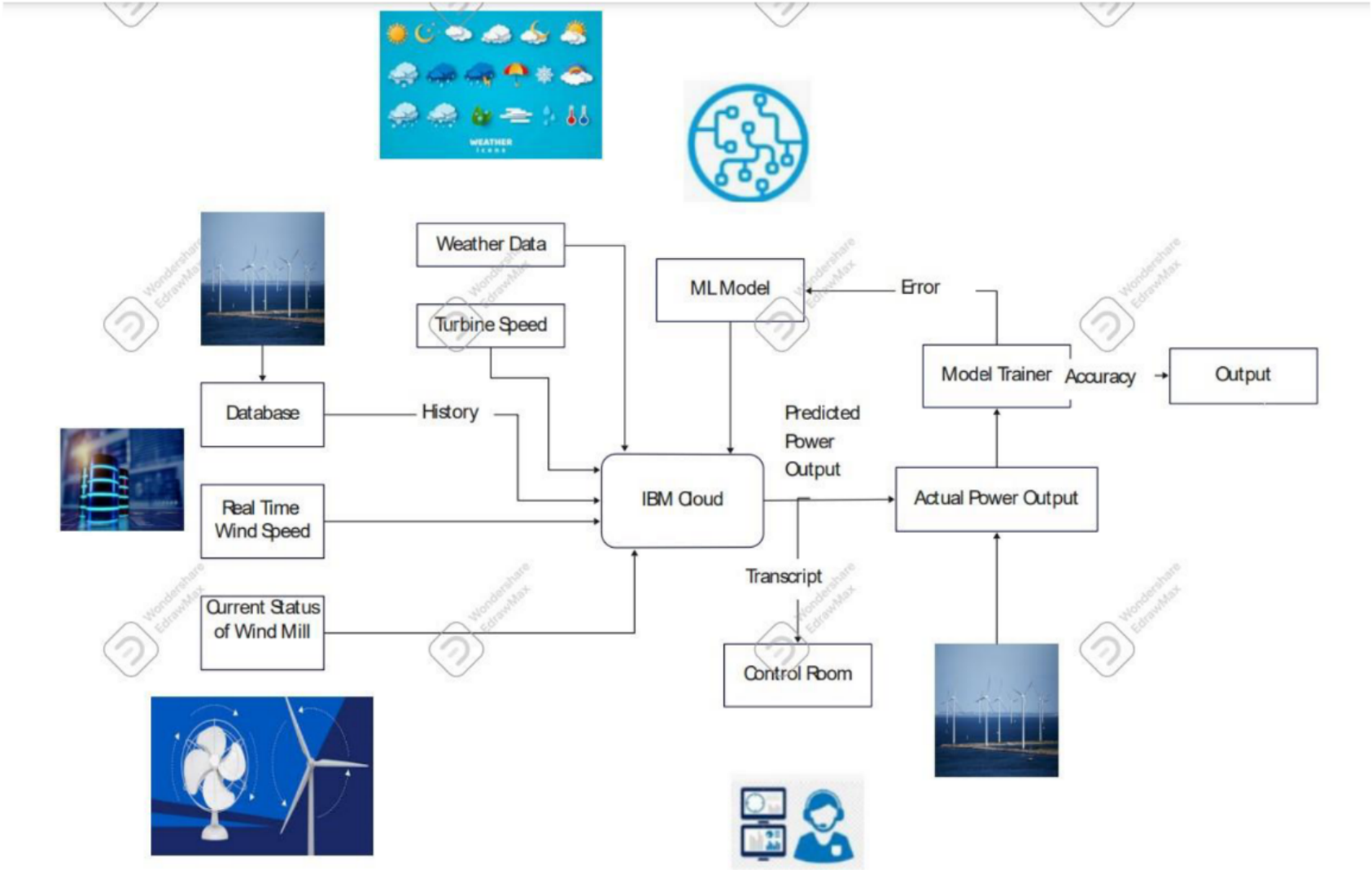
FR No.	Non-Functional Requirement	Description
NFR-1	Usability	Simple and understandable UI. Easy to navigate Smooth and seamless Easy to comprehend
NFR-1	Security	Restricted access to data. Login verification Registration verification Upholding privacy of user
NFR-1	Reliability	Backup to prevent data loss Negation of data loss due to lag.
NFR-1	Performance	Web based application. Requires minimum Intel Pentium 4 processor, 4 GB RAM, 1280x1024 screen with application window size 1024x680
NFR-1	Availability	Platform independent support.
NFR-1	Scalability	Can operate efficiently across multiple devices with varying hardware and software specifications

5. PROJECT DESIGN:

5.1 Data Flow Diagrams:



5.2 Solution & Technical Architecture:



5.3 User Stories:

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	Sprint-1
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1
		USN-3	As a user, I can register for the application through Facebook	I can register & access the dashboard with	Low	Sprint-1
		USN-4	As a user, I can register for the application through Gmail	I can receive confirmation email & click confirm	Medium	Sprint-1
	Login	USN-5	As a user, I can log into the application by entering email & password	Able to login	High	Sprint-1
	Dashboard	USN-6	As a user, I should be able to access the dashboard with	Access the dashboard	Medium	Sprint-1

			everything I am allowed to use.			
Customer (Web user)	Registration	USN-7	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	Sprint-1
		USN-8	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1

User Type	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Acceptance criteria**	**Priority**	**Release**
		USN-9	As a user, I can register for the application through Facebook	I can register & access the dashboard with Facebook Login	Low	Sprint-1
		USN-10	As a user, I can register for the application through Gmail	I can receive confirmation email & click confirm	Medium	Sprint-1

	Login	USN-11	As a user, I can log into the application by entering email & password	Able to login	High	Sprint-1
	Dashboard	USN-12	As a user, I should be able to access the dashboard with everything I am allowed to use.	Access the dashboard	Medium	Sprint-1
Admin	Register	USN-13	As an admin, I should be able to register myself as one using unique email and password.	I can access my account	Medium	Sprint-4
	Login	USN-14	As an admin I should be able to login myself as one using unique email and password.	Able to login	Medium	Sprint-4
	Dashboard	USN-15	As a admin, I should be able to access the dashboard with everything I am allowed to use.	Access the dashboard	Medium	Sprint-4

6. PROJECT PLANNING & SCHEDULING:

6.1 Sprint Planning & Estimation:

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task Story	Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	5	High	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint-1		USN-2	As a user, I will receive confirmation email once I have registered for the application	5	High	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint-1		USN-3	As a user, I can register for the application through Google	5	Low	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya

Sprint-1		USN-4	As a user, I can register for the application through Gmail	5	Medium	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 1	Login	USN - 5	As a user, I can log into the application by entering email & password	5	High	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 2	Dashboard	USN - 6	Once logged in, I can access my dashboard	6	Medium	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 2	Web Access	USN - 7	As a user, I can acc ess the website to predict the turbine power	7	High	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 2	Prediction	USN - 8	As a customer, when I	7	High	Niveditha. B

			enter the detail the website should predict the approximate turbine power			Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 3	Analysis	USN - 9	As a customer, I wish to store my predictions and make analysis	10	Medium	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 3	Security	USN -10	As a customer I expect my data to be secured	10	Medium	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya
Sprint - 4	Database Access	USN -11	As an administrator, I should maintain the website and keep updating it regularly	20	Medium	Niveditha. B Sudarsan Kumar. N Bhargavi. R Dampella Shalini Priya

6.2 Sprint Delivery Schedule:

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed (as on Planned End Date)	Sprint Release Date (Actual)
Sprint-1	20	6 Days	24 Oct 2022	29 Oct 2022	20	29 Oct 2022
Sprint-2	20	6 Days	31 Oct 2022	05 Nov 2022	20	04 Nov 2022
Sprint-3	20	6 Days	07 Nov 2022	12 Nov 2022	20	12 Nov 2022
Sprint-4	20	6 Days	14 Nov 2022	19 Nov 2022	20	19 Nov 2022

7. CODING & SOLUTIONING:

7.1 Features:

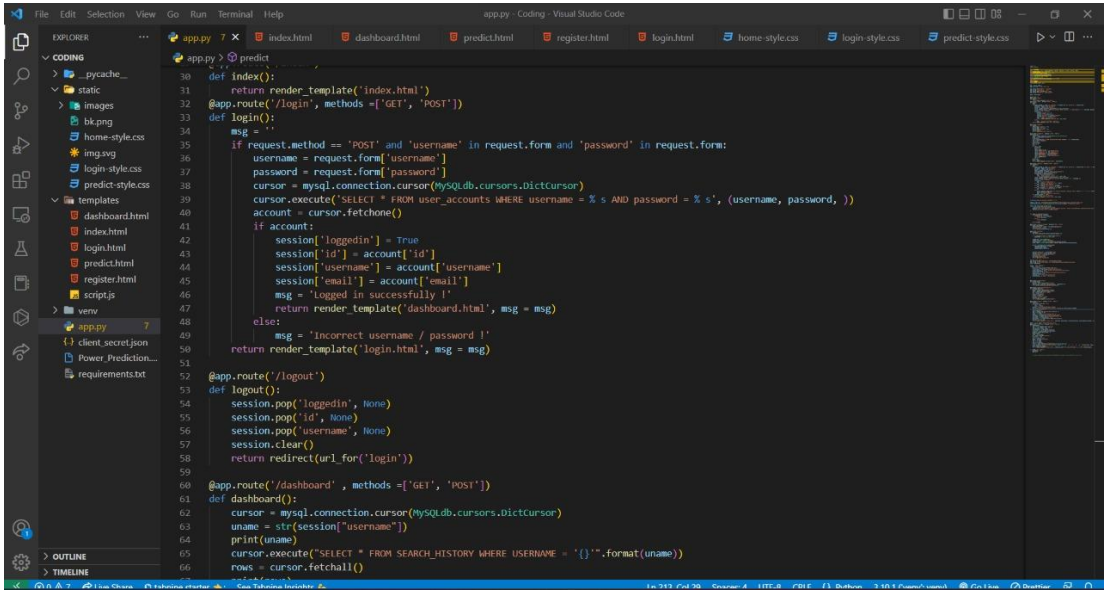
- We have built a web application to predict the wind energy
- We have used to build the model
- We can enter the city name to get the values
- The application consists of the home page, login page and actual website. The user history can be viewed.
- The home page takes us to the login page which can be done using existing google or github accounts.
- After login, the actual prediction page opens and here we can type in the city name to get the current wind speed and humidity along with temperature.
- Prediction can be done by clicking the “PREDICT” button.
- The output will be displayed with a unit kWh.
- The application is responsive and dynamic.
- There is ease of use for the user.
- IBM Watson cloud has been used so anyone can access it from anywhere.

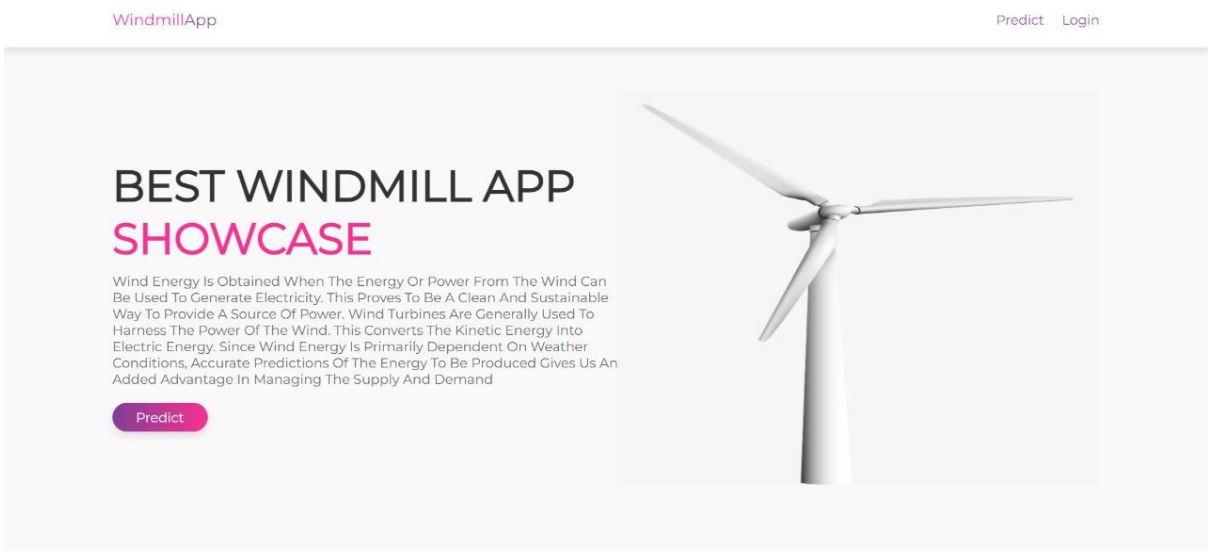
8. TESTING:

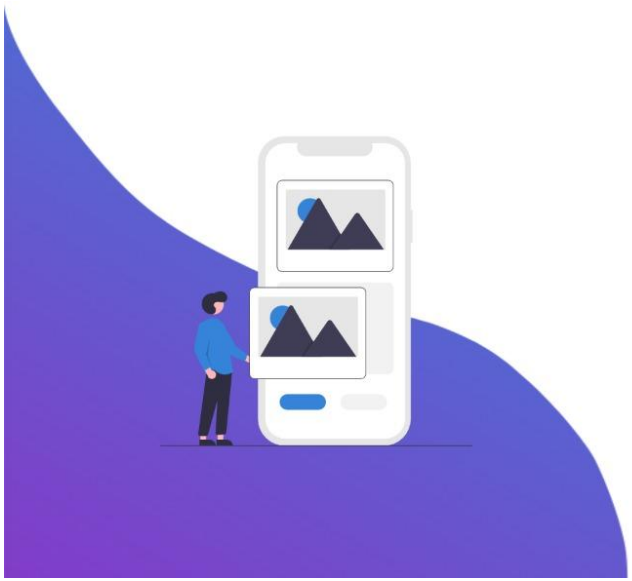
8.1 Test Cases:

1. Opening of the application to home page
2. Login page for the user
3. Login through google account
4. Prediction page where we need to enter the city name to get weather conditions
5. Display of prediction with wind speed using the clicking of button “PREDICT”
6. Viewing of user history

8.2 User Acceptance Testing:







WELCOME BACK

Please, provide login credential to proceed and have access to all our services

Username

Password

SIGN IN

Else Sign In With

New User? Register

Sign in with Google

Choose an account

to continue to Flask App Google Log In


Sudarsan N
sudarsanmitc@gmail.com

S
Sudarsan Kumar
sudarsankumarbackup00@gmail.com

M
Mal Mal
maldocs007@gmail.com
Signed out

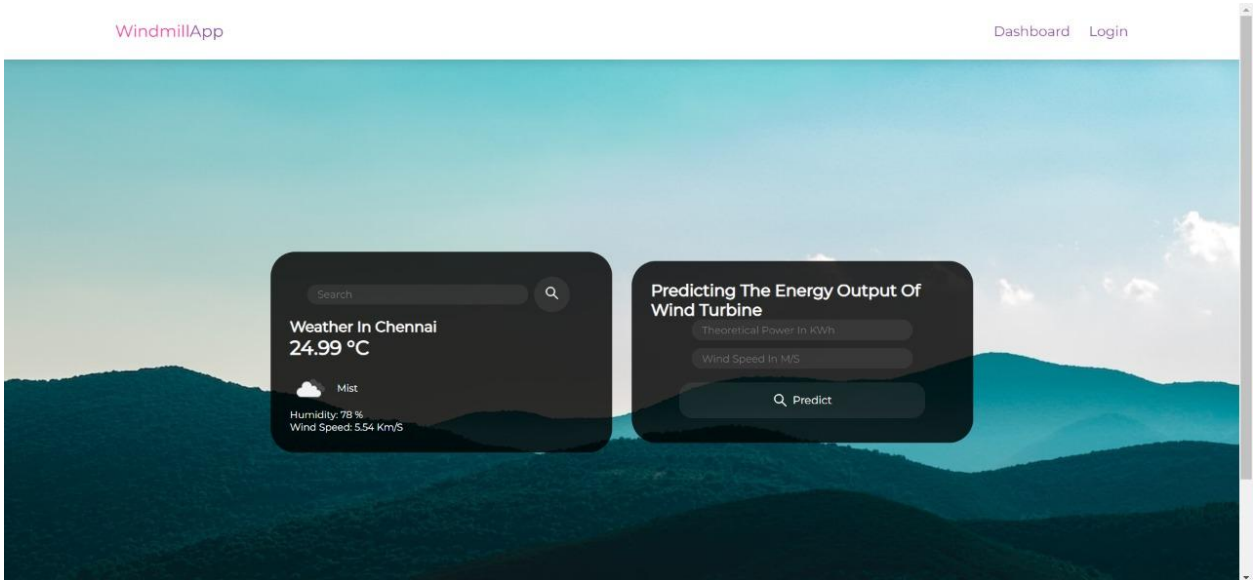

Barghavi parthiban
sp.barghavi23@gmail.com
Signed out

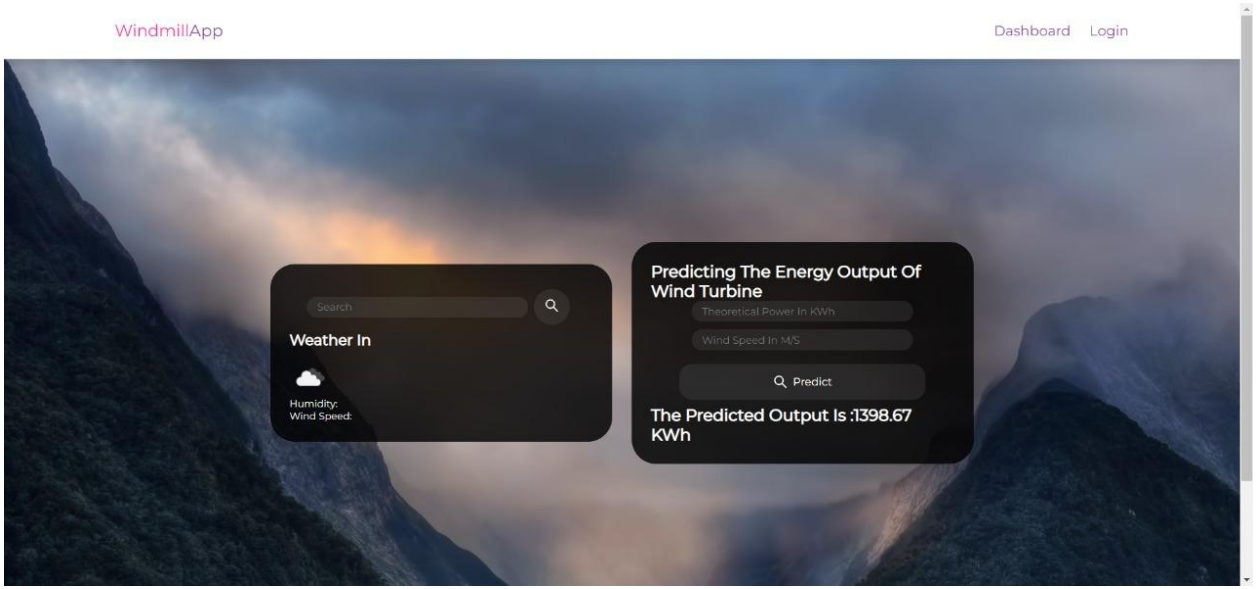

Sudharsan GV
gvsudhar20@gmail.com


Rubak Preyan
rubakkeerthi123@gmail.com
Signed out

Use another account

To continue, Google will share your name, email address, language preference, and profile picture with Flask App Google Log In


WindmillApp
Dashboard
Login
Search
Weather In Chennai
24.99 °C
Mist
Humidity: 78 %
Wind Speed: 5.54 Km/S
Predicting The Energy Output Of Wind Turbine
Theoretical Power In KWh
Wind Speed In M/S
Predict


WindmillApp
Dashboard
Login
Search
Weather In
Humidity:
Wind Speed:
Predicting The Energy Output Of Wind Turbine
Theoretical Power In KWh
Wind Speed In M/S
Predict
The Predicted Output Is :1398.67 KWh

WindmillApp

Predict Logout

USER HISTORY

Count	Search Date	Search City	Theoretical_Power_Curve (KWh)	Wind Speed (M/S)	Output
1	2021-11-17	CHENNAI	27.3	27.3	27.3
2	2022-11-19	Chennai	416.3289078	5.31133604	345.08
3	2022-11-19	Trichy	416.3289078	5.31133604	345.08

9. RESULTS:

9.1 Performance Metrics:

We evaluated the Performance using the Metrics, MAE, MSE, RMSE, R2, Accuracy score.

Evaluation metrics

MAE, MSE, RMSE, R2, ACCURACY

MAE	161.23
MSE	142925.86
RMSE	178.13
R2	0.9122
ACCURACY	92

10. ADVANTAGES AND DISADVANTAGES:

ADVANTAGES:

- Wind is a reliable and infinite renewable energy resource
- Wind energy is cost effective, and prices are dropping still
- Wind energy reduces carbon emissions when used instead of fossil fuels
- Few running costs when the turbines are up and running.

- Offshore wind farms can take advantage of offshore wind flow, without affecting the landscape view.
- It also doesn't interrupt the farmland operations
- Advances in technology have transformed preliminary wind turbine designs into extremely efficient energy harvesters.

DISADVANTAGES:

- Wind energy can be unpredictable as the amount of electricity generated is dependent on the speed and direction of the wind
- Wind farms can affect the visual appearance of the landscape
- Wind turbines can damage the habitats of birds and marine life.
- Wind farms can be expensive to construct
- Wind turbines can be quite noisy, which is why they're mostly found in very rural areas where most people don't live.

11. CONCLUSION:

The inventions that we create and discover must benefit the people while not harming nature at the same time. We must leave the resources without depleting them for the next generation. Wind energy can be seen as a very clean and renewable source of electricity and energy. These types of energy sources such as wind, solar and water must replace the exhaustion of non-renewable resources such as coal and petroleum so that we can provide a better future for the upcoming generations.

12. FUTURE SCOPE:

Engineers are in the early stages of creating airborne wind turbines, in which the components are either floated by a gas like helium or use their own aerodynamics to stay high in the air, where wind is stronger. These systems are being considered for offshore use, where it is expensive and difficult to install conventional wind turbines on tall towers. Trees, which can withstand gale forces and yet move in response to breezes from any direction, also are inspiring new ideas for wind energy technology. Engineers speculate about making artificial wind-harvesting trees. That would require new materials and devices that could convert energy from a tree's complex movements into the steady rotation that traditional generators need. The prize is wind energy harvested closer to the ground with smaller, less obtrusive technologies and in places with complex airflows, such as cities.

APPENDIX:

Github: https://github.com/IBM-EPBL/IBM-Project-5040-1658746388

Project Demo Link: https://drive.google.com/file/d/1p4dHTDKgoOERzgxabQDBsvLtXqtagUiY/view?usp=share_link