Predicting the energy output of Wind Turbine based on Weather Conditions

Project Report

1. Introduction:

1.1. Overview:

Wind energy plays an increasing role in the supply of energy worldwide. The energy output of a wind farm is highly dependent on the wind conditions present at its site. If the output can be predicted more accurately, energy suppliers can coordinate the collaborative production of different energy sources more efficiently to avoid costly overproduction.

1.2. Purpose:

It is essential to predict the output of the wind turbine to avoid costly overproduction. Also, we can find out the right location for a wind turbine by predicting the output of wind turbine according to the weather conditions at a particular location.

2. Literature Survey:

2.1. Existing Problem:

The overproduction of electricity by wind turbines proves to be very costly. If we can predict the output of the wind turbine in advance, we can avoid that costly overproduction of electricity.

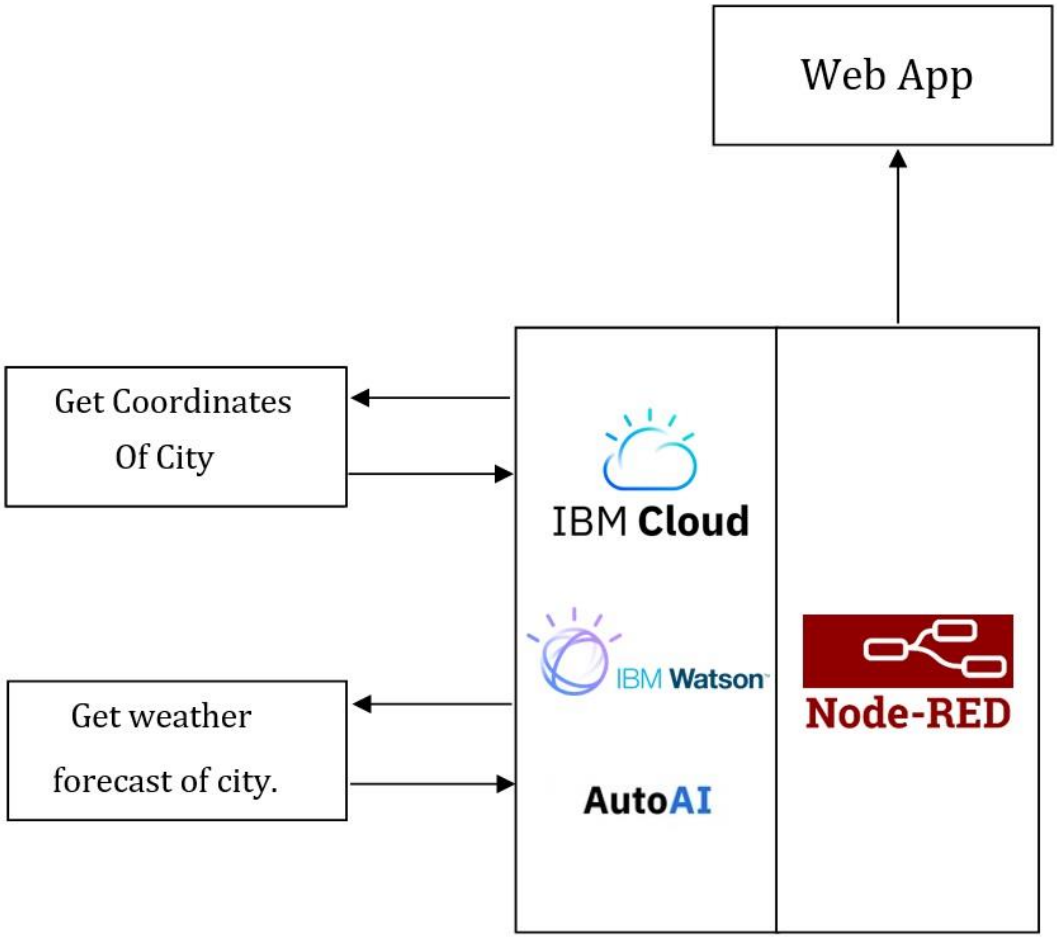
2.2. Proposed Solution:

We will train a machine learning model based on the previous data of the wind turbines which is available and then by

getting the weather forecast of that region we can get the prediction of the energy output of wind turbines.

3. Theoretical Analysis:

3.1. Block Diagram:



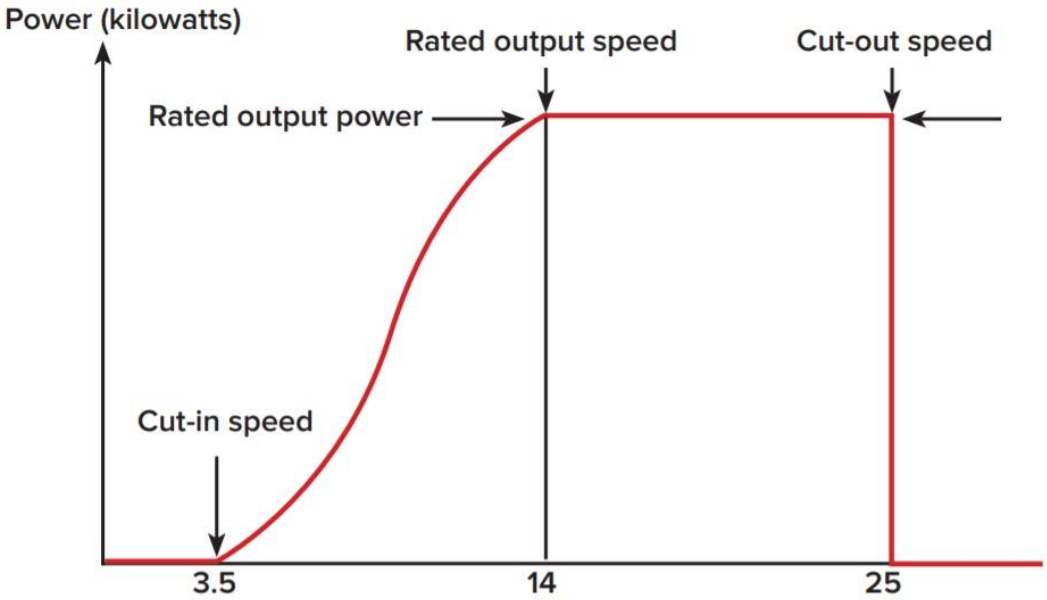
3.2. Hardware/Software Designing:

- We take the city of operations of wind turbine as input.
- Using geocoding API of Google maps platform, we find out the latitudes and longitudes of that city. If the city is not found an error is reported.
- The latitudes and longitudes obtained are then passed to Onecall API of openweathermap which returns the weather forecast of next 7 days of that place.
- We used Watson studio in IBM cloud to create machine learning model.
- Using AutoAI experiment we trained the model on the dataset which we got from Kaggle.

4. Experimental Investigations:

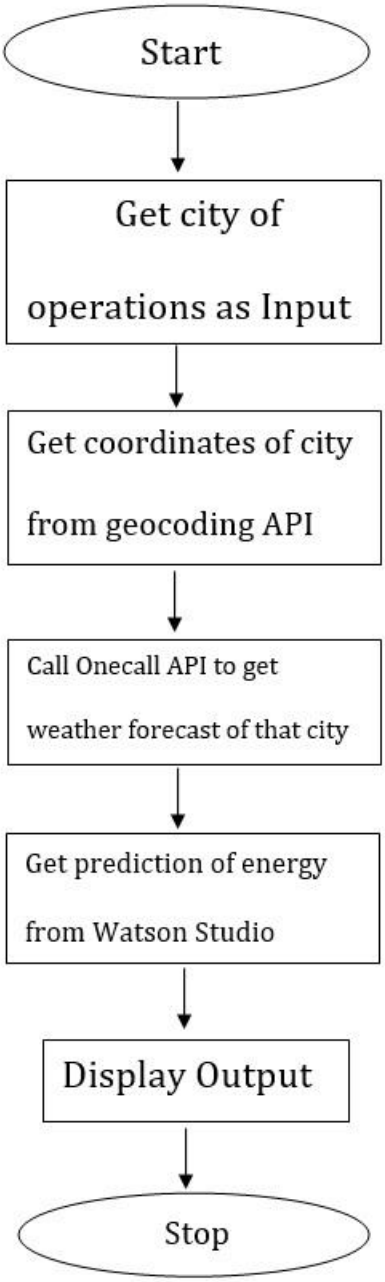
- We need to note that the minimum wind speed which is needed to operate is 3 meter/seconds. And the maximum speed of wind in which wind turbine can operate is 25 meter/seconds.
- The height of hub of wind turbine also affects the output of wind turbine. Every 10 m increase in tower height means wind speeds are 2% to 3% stronger, yielding 3% to 5% more energy.

- The accommodation of larger rotors produces more energy.



Typical wind turbine power outlet with steady wind speed.

5. Flowchart:



6. Result:

We were able to predict the output of wind turbine.

7. Advantages and Disadvantages:

- We will save the costly overproduction of energy.

- We cannot accurately predict the output as the weather forecast as well as the model cant be 100% accurate.
- Other factors affecting energy output are not taken into consideration like humidity, hub height. etc.

8. Applications:

- Application can be used to predict the output of wind turbine at any location around the world.

9. Conclusion:

We can predict the output of wind turbine at any location around the world.

10. Future Scope:

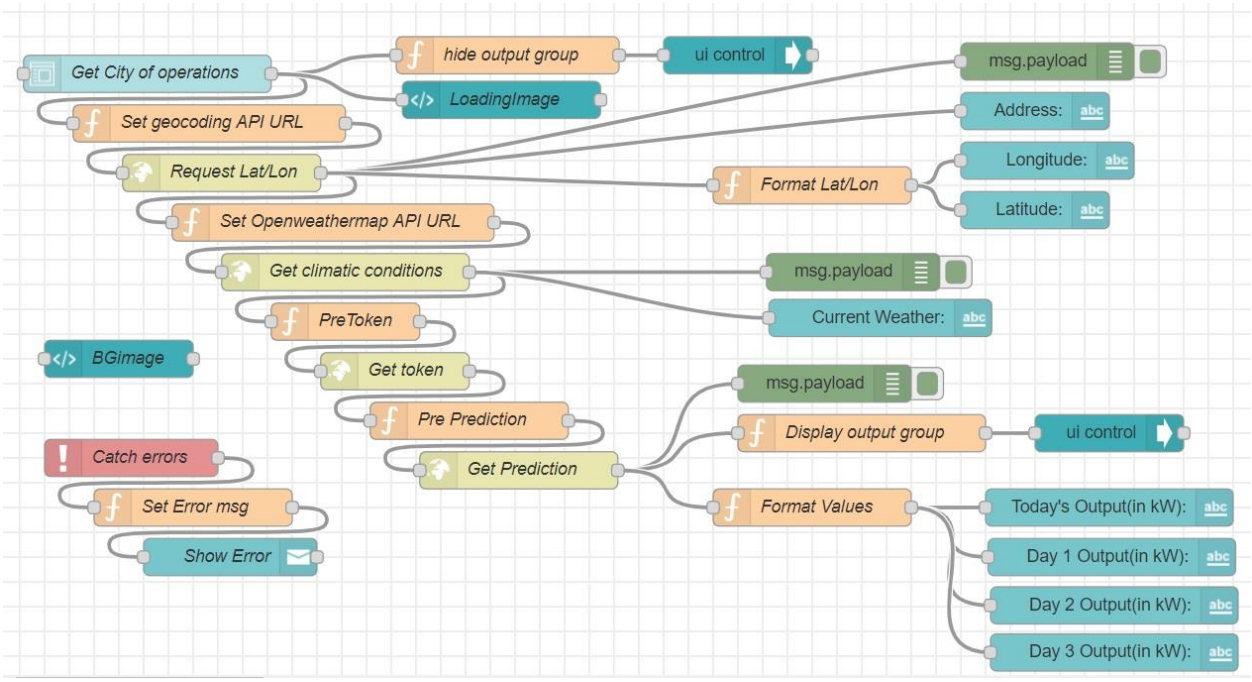
- Other factors affecting the wind turbine can be considered to predict the output of wind turbine more accurately.

11. Bibliography:

- https://hpi.de/friedrich/docs/paper/RE1.pdf
- https://www.kaggle.com/berkerisen/wind-turbine-scada-dataset
- Onecall API

Appendix

A. Node-red Flow**:**



[

{

"id": "7c1100f9.da75e",

"type": "tab",

"label": "WindTurbine Prediction",

"disabled": false,

"info": ""

},

{

"id": "cae69998.aef438",

"type": "http request",

"z": "7c1100f9.da75e",

"name": "Request Lat/Lon",

```
    "method": "GET",
    "ret": "obj",
    "paytoqs": false,
    "url": "",
    "tls": "",
    "persist": false,
    "proxy": "",
    "authType": "",
    "x": 183,
    "y": 150,
    "wires": [
        [
            "fa1a7902.ada2d8",
            "12839570.be0ddb",
            "c662d478.fc7408",
            "bdb1a6a.1d6f558"
        ]
    ]
},
{
    "id": "fa1a7902.ada2d8",
```

```
        "type": "debug",
        "z": "7c1100f9.da75e",
        "name": "",
        "active": true,
        "tosidebar": true,
        "console": false,
        "tostatus": false,
        "complete": "false",
        "x": 850,
        "y": 60,
        "wires": []
    },
    {
        "id": "1907d284.d2279d",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Set geocoding API URL",
        "func":
"msg.url=\"https://maps.googleapis.com/maps/api/geocode/json?address=\"+msg.payload.City+\"&key=AIzaSyDKKDdXYmp7YywBLXwFoPbO4SBc76IU1RE\"\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
```

```
    "x": 173,
    "y": 110,
    "wires": [
        [
            "cae69998.aef438"
        ]
    ]
},
{
    "id": "42629cf9.a6e174",
    "type": "ui_form",
    "z": "7c1100f9.da75e",
    "name": "Get City of operations",
    "label": "",
    "group": "ecf93b5a.172ac8",
    "order": 1,
    "width": 0,
    "height": 0,
    "options": [
        {
            "label": "City of Operations",
```

```
        "value": "City",
        "type": "text",
        "required": true,
        "rows": null
    }
],
"formValue": {
    "City": ""
},
"payload": "",
"submit": "submit",
"cancel": "cancel",
"topic": "",
"x": 123,
"y": 70,
"wires": [
    [
        "1907d284.d2279d",
        "4d9ad28f.c308ac",
        "abd80025.d2242"
    ]
```

```
        ]
    },
    {
        "id": "12839570.be0ddb",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Set Openweathermap API URL",
        "func":
"msg.url=\"https://api.openweathermap.org/data/2.5/onecall?lat=\"+msg.payload.results[0].geometry.location.lat+\"&lon=\"+msg.payload.results[0].geometry.location.lng+\"&%20exclude=daily&appid=78ef7084e563cc27617684be82413071\"\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
        "x": 273,
        "y": 190,
        "wires": [
            [
                "a3c7283c.48ed98"
            ]
        ]
    },
    {
```

```
    "id": "6565d8b9.38daf8",
    "type": "debug",
    "z": "7c1100f9.da75e",
    "name": "",
    "active": true,
    "tosidebar": true,
    "console": false,
    "tostatus": false,
    "complete": "false",
    "x": 693,
    "y": 230,
    "wires": []
},
{
    "id": "a3c7283c.48ed98",
    "type": "http request",
    "z": "7c1100f9.da75e",
    "name": "Get climatic conditions",
    "method": "GET",
    "ret": "obj",
    "paytoqs": false,
```

```
        "url": "",
        "tls": "",
        "persist": false,
        "proxy": "",
        "authType": "",
        "x": 283,
        "y": 230,
        "wires": [
            [
                "6565d8b9.38daf8",
                "b23e6f18.f328d",
                "8aa5b06c.6cee1"
            ]
        ]
    },
    {
        "id": "b23e6f18.f328d",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "PreToken",
        "func":
"global.set(\"ws\",msg.payload.current.wind_speed)\nglobal.set(\"ws1\",msg.paylo
```

ad.daily[1].wind_speed)\nglobal.set(\"ws2\",msg.payload.daily[2].wind_speed)\ngl
obal.set(\"ws3\",msg.payload.daily[3].wind_speed)\nvar
apikey=\"pnG9aGYncp8NVklcND_3-
dQddBypOEW_ShEYRiOArP7D\"\nmsg.url=\"https://iam.cloud.ibm.com/identity
/token\"\nmsg.headers={\"content-type\":\"application/x-www-form-
urlencoded\"}\nmsg.payload={\"grant_type\":\"urn:ibm:params:oauth:grant-
type:apikey\",\"apikey\":apikey}\nreturn msg;",

"outputs": 1,

"noerr": 0,

"x": 283,

"y": 270,

"wires": [

[

"bea2e847.fc5ab8"

]

]

},

{

"id": "bea2e847.fc5ab8",

"type": "http request",

"z": "7c1100f9.da75e",

"name": "Get token",

"method": "POST",

"ret": "obj",

```
        "paytoqs": false,
        "url": "",
        "tls": "",
        "persist": false,
        "proxy": "",
        "authType": "",
        "x": 323,
        "y": 310,
        "wires": [
            [
                "71631efc.8ddc6"
            ]
        ]
    },
    {
        "id": "71631efc.8ddc6",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Pre Prediction",
        "func": "var ws = [global.get('ws')]\nvar ws1=[global.get('ws1')]\nvar
ws2=[global.get('ws2')]\nvar ws3=[global.get('ws3')]\nvar
token=msg.payload.access_token\nvar instance_id=\"45e2eaca-feeb-42e4-97e2-
30fe56e21947\"\nmsg.url=\"https://eu-
```

gb.ml.cloud.ibm.com/v4/deployments/970cac1e-f3c2-42b7-bb27-85076aca4e81/predictions\"\nmsg.headers={'Content-Type': 'application/json',\"Authorization\":\"Bearer \"+token,\"ML-Instance-ID\":instance_id}\nmsg.payload = {\"input_data\": [{\"fields\": [\"Wind Speed (m/s)\"], \"values\": [ws,ws1,ws2,ws3]}]}\nreturn msg;",

"outputs": 1,

"noerr": 0,

"x": 383,

"y": 350,

"wires": [

[

"129a43bb.a50bac"

]

]

},

{

"id": "129a43bb.a50bac",

"type": "http request",

"z": "7c1100f9.da75e",

"name": "Get Prediction",

"method": "POST",

"ret": "obj",

"paytoqs": false,

```
    "url": "",
    "tls": "",
    "persist": false,
    "proxy": "",
    "authType": "",
    "x": 423,
    "y": 390,
    "wires": [
        [
            "68d3bdd.ea28244",
            "efab750d.f25648",
            "6d92a917.3f2568"
        ]
    ]
},
{
    "id": "68d3bdd.ea28244",
    "type": "debug",
    "z": "7c1100f9.da75e",
    "name": "",
    "active": true,
```

```
    "tosidebar": true,
    "console": false,
    "tostatus": false,
    "complete": "false",
    "x": 670,
    "y": 320,
    "wires": []
},
{
    "id": "a0dff020.8c866",
    "type": "ui_ui_control",
    "z": "7c1100f9.da75e",
    "name": "",
    "events": "all",
    "x": 900,
    "y": 360,
    "wires": [
        []
    ]
},
{
```

```
        "id": "efab750d.f25648",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Display output group",
        "func": "msg.payload={\"group\": {\"show\":
[\"Energy_Prediction_Output\"], \"hide\":
[\"Energy_Prediction_Loading...\"]}}\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
        "x": 700,
        "y": 360,
        "wires": [
            [
                "a0dff020.8c866"
            ]
        ]
    },
    {
        "id": "4d9ad28f.c308ac",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "hide output group",
```

```
        "func": "msg.payload={\"group\": {\"hide\": [\"Energy_Prediction_Output\"], \"show\": [\"Energy_Prediction_Loading...\"]}}\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
        "x": 414,
        "y": 55,
        "wires": [
            [
                "bc5db13b.c9329"
            ]
        ]
    },
    {
        "id": "bc5db13b.c9329",
        "type": "ui_ui_control",
        "z": "7c1100f9.da75e",
        "name": "",
        "events": "all",
        "x": 600,
        "y": 55,
        "wires": [
            []
```

```
    ]
},
{
    "id": "fd564834.4efb98",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 1,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Latitude: ",
    "format": "{{msg.payload.results[0].geometry.location.lat}}",
    "layout": "row-spread",
    "x": 840,
    "y": 180,
    "wires": []
},
{
    "id": "cc37b8e7.1aec88",
    "type": "ui_text",
```

```
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 2,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Longitude:",
    "format": "{{msg.payload.results[0].geometry.location.lng}}",
    "layout": "row-spread",
    "x": 850,
    "y": 140,
    "wires": []
},
{
    "id": "c662d478.fc7408",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 3,
    "width": 0,
    "height": 0,
```

```
    "name": "",
    "label": "Address:",
    "format": "{{msg.payload.results[0].formatted_address}}",
    "layout": "row-spread",
    "x": 840,
    "y": 100,
    "wires": []
},
{
    "id": "8aa5b06c.6cee1",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 4,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Current Weather:",
    "format": "{{msg.payload.current.weather[0].description}}",
    "layout": "row-spread",
    "x": 715,
```

```
    "y": 267,
    "wires": []
},
{
    "id": "716789d.d300478",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 5,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Today's Output(in kW):",
    "format": "{{msg.payload.predictions[0].values[0][0]}}",
    "layout": "row-spread",
    "x": 900,
    "y": 420,
    "wires": []
},
{
    "id": "2b62ff86.86ea3",
```

```
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 6,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Day 1 Output(in kW):",
    "format": "{{msg.payload.predictions[0].values[1][0]}}",
    "layout": "row-spread",
    "x": 902,
    "y": 460,
    "wires": []
},
{
    "id": "4f562192.faf4a",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 7,
    "width": 0,
```

```
    "height": 0,
    "name": "",
    "label": "Day 2 Output(in kW):",
    "format": "{{msg.payload.predictions[0].values[2][0]}}",
    "layout": "row-spread",
    "x": 904,
    "y": 499,
    "wires": []
},
{
    "id": "9fdee6bc.a2c3a8",
    "type": "ui_text",
    "z": "7c1100f9.da75e",
    "group": "88e9327d.58647",
    "order": 8,
    "width": 0,
    "height": 0,
    "name": "",
    "label": "Day 3 Output(in kW):",
    "format": "{{msg.payload.predictions[0].values[3][0]}}",
    "layout": "row-spread",
```

```
        "x": 904,
        "y": 537,
        "wires": []
    },
    {
        "id": "6d92a917.3f2568",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Format Values",
        "func": "var ws=global.get('ws')\nvar ws1=global.get('ws1')\nvar
ws2=global.get('ws2')\nvar ws3=global.get('ws3')\nif(ws<3 ||
ws>25)\n{\n    msg.payload.predictions[0].values[0][0]=\"Wind Turbine cannot
operate due to weather
conditions.\"\n}\nelse\n{\n    msg.payload.predictions[0].values[0][0]=msg.payloa
d.predictions[0].values[0][0].toFixed(1)\n}\nif(ws1<3 ||
ws1>25)\n{\n    msg.payload.predictions[0].values[1][0]=\"Wind Turbine cannot
operate due to weather
conditions.\"\n}\nelse\n{\n    msg.payload.predictions[0].values[1][0]=msg.payloa
d.predictions[0].values[1][0].toFixed(1)\n}\nif(ws2<3 ||
ws2>25)\n{\n    msg.payload.predictions[0].values[2][0]=\"Wind Turbine cannot
operate due to weather
conditions.\"\n}\nelse\n{\n    msg.payload.predictions[0].values[2][0]=msg.payloa
d.predictions[0].values[2][0].toFixed(1)\n}\nif(ws3<3 ||
ws3>25)\n{\n    msg.payload.predictions[0].values[3][0]=\"Wind Turbine cannot
operate due to weather
conditions.\"\n}\nelse\n{\n    msg.payload.predictions[0].values[3][0]=msg.payloa
d.predictions[0].values[3][0].toFixed(1)\n}\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
```

```
        "x": 660,
        "y": 420,
        "wires": [
            [
                "716789d.d300478",
                "2b62ff86.86ea3",
                "4f562192.faf4a",
                "9fdee6bc.a2c3a8"
            ]
        ]
    },
    {
        "id": "bdb1a6a.1d6f558",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Format Lat/Lon",
        "func":
"msg.payload.results[0].geometry.location.lng=msg.payload.results[0].geometry.location.lng.toFixed(2)\nmsg.payload.results[0].geometry.location.lat=msg.payload.results[0].geometry.location.lat.toFixed(2)\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
        "x": 660,
```

```
        "y": 160,
        "wires": [
            [
                "cc37b8e7.1aec88",
                "fd564834.4efb98"
            ]
        ]
    },
    {
        "id": "c5e2ee0c.06b61",
        "type": "ui_template",
        "z": "7c1100f9.da75e",
        "group": "ec230b40.efb708",
        "name": "BGimage",
        "order": 0,
        "width": 0,
        "height": 0,
        "format":
"\n<html>\n <head> \n <style>\n body{\n background-
image:url('https://scx2.b-
cdn.net/gfx/news/2018/windfarmperf.gif');\n background-repeat: no-
repeat;\n background-size:
cover;\n }\n </style>\n </head>\n <body></body>\n</html>",
        "storeOutMessages": true,
```

```
        "fwdInMessages": true,
        "resendOnRefresh": true,
        "templateScope": "global",
        "x": 100,
        "y": 300,
        "wires": [
            []
        ]
    },
    {
        "id": "abd80025.d2242",
        "type": "ui_template",
        "z": "7c1100f9.da75e",
        "group": "8b1366b6.2faf68",
        "name": "LoadingImage",
        "order": 1,
        "width": 0,
        "height": 0,
        "format": "<img ng-
src=\"https://media0.giphy.com/media/3oEjI6SIIHBdRxXI40/200.gif\" />",
        "storeOutMessages": true,
        "fwdInMessages": true,
```

```
    "resendOnRefresh": true,
    "templateScope": "local",
    "x": 409,
    "y": 91,
    "wires": [
        []
    ]
},
{
    "id": "f6335e51.88416",
    "type": "catch",
    "z": "7c1100f9.da75e",
    "name": "Catch errors",
    "scope": null,
    "uncaught": false,
    "x": 110,
    "y": 380,
    "wires": [
        [
            "6048b3eb.db4ccc"
        ]
```

```
    ]
},
{
    "id": "f51ce605.d89518",
    "type": "ui_toast",
    "z": "7c1100f9.da75e",
    "position": "dialog",
    "displayTime": "3",
    "highlight": "",
    "sendall": true,
    "outputs": 1,
    "ok": "OK",
    "cancel": "",
    "raw": true,
    "topic": "Error",
    "name": "Show Error",
    "x": 190,
    "y": 460,
    "wires": [
        []
    ]
```

```
    },
    {
        "id": "6048b3eb.db4ccc",
        "type": "function",
        "z": "7c1100f9.da75e",
        "name": "Set Error msg",
        "func": "msg.payload=\"City entered cannot be found!!!<br>Please enter another city.\"\nreturn msg;",
        "outputs": 1,
        "noerr": 0,
        "x": 160,
        "y": 420,
        "wires": [
            [
                "f51ce605.d89518"
            ]
        ]
    },
    {
        "id": "ecf93b5a.172ac8",
        "type": "ui_group",
        "z": "",
```

```
    "name": "Input",
    "tab": "6babdb60.bb5384",
    "order": 1,
    "disp": true,
    "width": "6",
    "collapse": false
},
{
    "id": "88e9327d.58647",
    "type": "ui_group",
    "z": "",
    "name": "Output",
    "tab": "6babdb60.bb5384",
    "order": 2,
    "disp": true,
    "width": "6",
    "collapse": false
},
{
    "id": "ec230b40.efb708",
    "type": "ui_group",
```

```
    "z": "",
    "name": "message",
    "tab": "d673e337.30ba5",
    "order": 1,
    "disp": true,
    "width": "6",
    "collapse": false
},
{
    "id": "8b1366b6.2faf68",
    "type": "ui_group",
    "z": "",
    "name": "Loading...",
    "tab": "6babdb60.bb5384",
    "order": 3,
    "disp": true,
    "width": 4,
    "collapse": false
},
{
    "id": "6babdb60.bb5384",
```

```
        "type": "ui_tab",
        "z": "",
        "name": "Energy Prediction",
        "icon": "dashboard",
        "disabled": false,
        "hidden": false
    },
    {
        "id": "d673e337.30ba5",
        "type": "ui_tab",
        "z": "",
        "name": "welcome",
        "icon": "dashboard",
        "order": 1,
        "disabled": false,
        "hidden": false
    }
]
```