Analysis of Orkney Energy Production and Consumption & DR Suggestions for the Utilization of Curtailed Energy

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Presentation Outline

- Summary
- Business problem overview
- Summary of Analysis Approach and hypothesis
- KPIs
- Results of hypothesis analysis
- DR Strategy
- Summary of Findings & Calculation
- Assumptions

Summary

- **Our objective** - Find out whether there is any business case worth investing money in Demand Response (DR) scheme on Orkney Islands which can help in utilising curtailed energy.
- Available dataset:
  - **Residential Demand Data** - contains data about demand of number of households and mean demand of that households in kw every 30 mins. We are making an assumption that demand stays same for 30 mins
  - **Turbine Telemetry** - contains data about power generated in kw, setpoint in kw and wind speed at interval of 1 min
- After information about energy getting curtailed was obtained, we then:
  - Examine business case of investing money in selling curtailed energy
  - Help individual households in using curtailed energy at discounted price
  - Propose Demand Response strategy provider in implementing DR strategy which utilises curtailed energy. The report tries to find out win-win situation for all major parties involved.

Business Problem Overview

- Orkney Islands has many wind turbines capable of generating 900 kW of power supply per turbine from renewable resources.
- Currently energy produced at Orkney by using these wind turbines easily handles demands of local households of Orkney as well as they are net energy exporter due to surplus energy after local usage. Orkney is connected to GB by interconnector of 40 MW capacity which limits transfer of energy.
- Orkney turbine owners are curtailing any energy which is produced after satisfying local household demands and interconnector capacity of 40 MW.
- This is main concern raised by Orkney turbine owners as they feel that they can get more return on turbines if somehow energy which is getting curtailed due to interconnector capacity get used by Orkney households at discounted price for some purpose(Heating etc.).
- We'll try to find out whether there is any business case to invest in Demand Response Strategy which can help in using these curtailed energy by local Households.It’ll results in win-win situation for turbine owners, local households and DR strategy provider.

Summary of Analysis Approach and hypothesis

Below is the high level approach that we took to analyze the data

Brainstormed potential hypothesis → Decided on hypothesis → Performed data cleaning → Performed data analysis → Evaluated hypothesis → Derived business insight

List Of Hypothesis:

- Minimum wind speed to achieve maximum power output
- Wind turbine needs to be shut down for safety reasons if wind exceeds 25m/s
- More power is supplied in winter season
- Temperature is positively correlated to power supply
- Demand is higher in winter and lower in summer
- Demand is higher on weekend/weekdays
- Curtailment happened mostly on weekends
- More curtailment in summer and winter
- Length of power curtailment in minutes
- set_point =0 means there is a grid wide blackout

KPIs

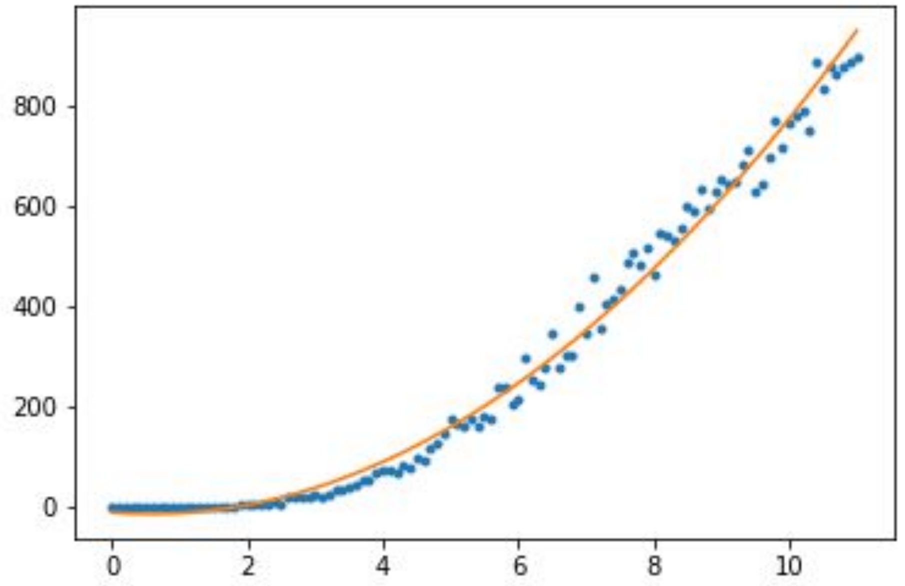
- **Energy Curtailment:** Whenever turbine produce energy which is more than combined Orkney households requirement and 40 MW interconnector capacity then that extra energy is getting curtailed.
- **Loss of Revenue** for turbine owners due to energy curtailment.
- **Use of Curtailed Energy** by Orkney Households at Discounted Price (Room heating etc).
- **DR Penetration:** Level of DR Penetration required to utilise all curtailed energy. DR Penetration % refers to % of total households involved in DR exercise.
- **Cost of DR Implementation**: Total cost required for implementation of DR strategy based on % of DR penetration.

Results

Hypothesis: Wind turbine needs to be shut down for safety reasons if wind exceeds 25m/s

Hypothesis: Setpoint =0 means there is a grid wide blackout or turbine is shutdown by owner

Hypothesis: Minimum wind speed to achieve maximum power output. Max power can be reached when wind speed > 11m/s. (approx)



The Power Curve for this Turbine is:

Power_kw = 8.875*wind* ^ *2* - *10.334*wind - 11.683 for wind <= 10.5m/s

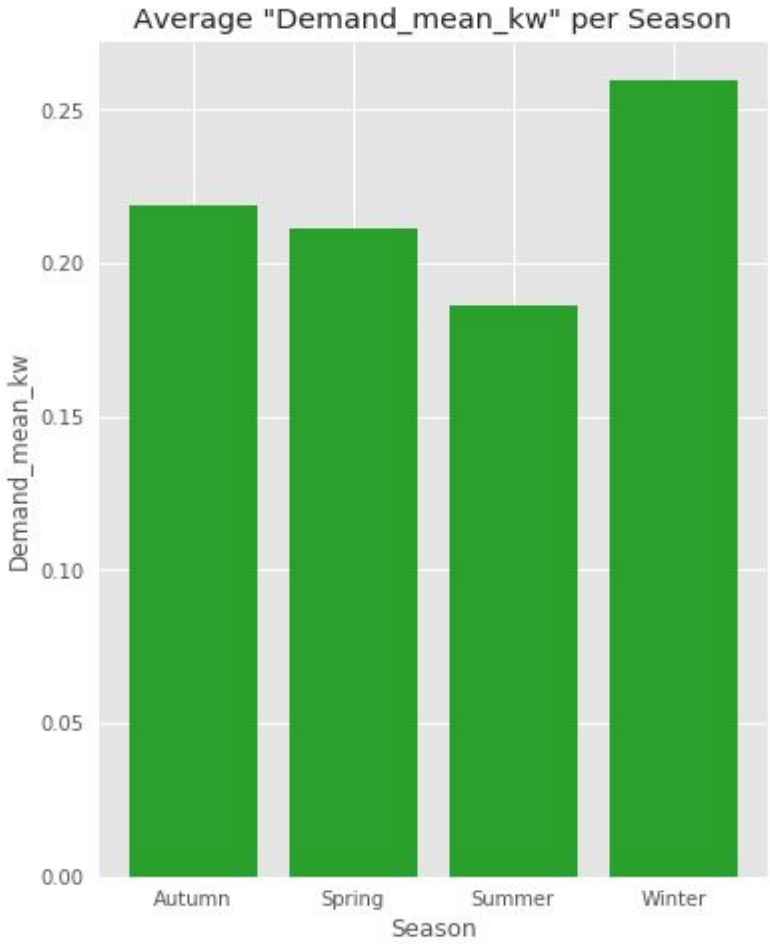
Power_kw = 900 for wind between 10.5m/s and 25m/s

power_kw = 0 for wind > 25m/s

Findings:

- Turbines generate maximum power of around 900 kw touching capacity of turbine at speed of around 11m/s.
- Turbines are shutdown at speed more than 25 m/s.
- Setpoint=0 represents turbine shutdown.

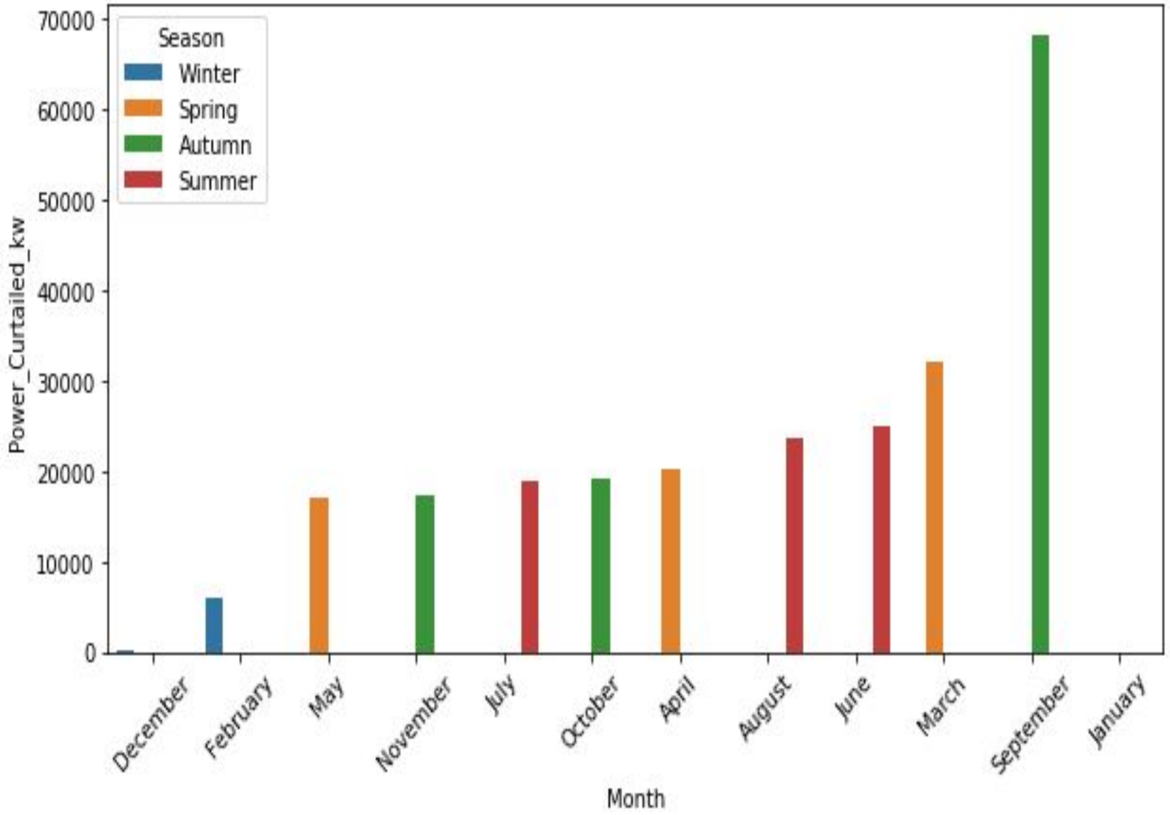
Hypothesis: Demand is higher in winter and lower in summer



Findings:

- Graph shows average demands per households during Autumn, Spring, Summer and Winter seasons.
- Average household demand during Winter is around 0.26 kw whereas during summer it’s around 0.18 kw.

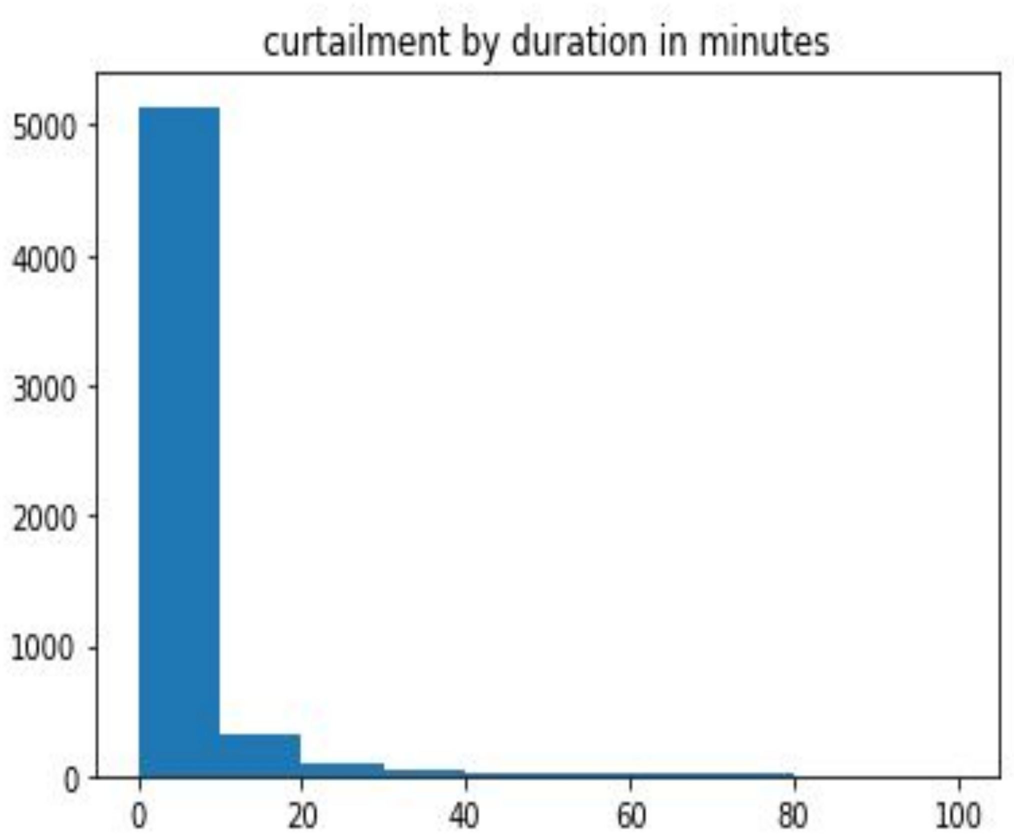
Hypothesis: More curtailment in summer than winter



Findings:

- Curtailment is more in summer around 2000-2800 kw.
- Winter has least curtailment.
- Autumn have exception with highest curtailment in September.

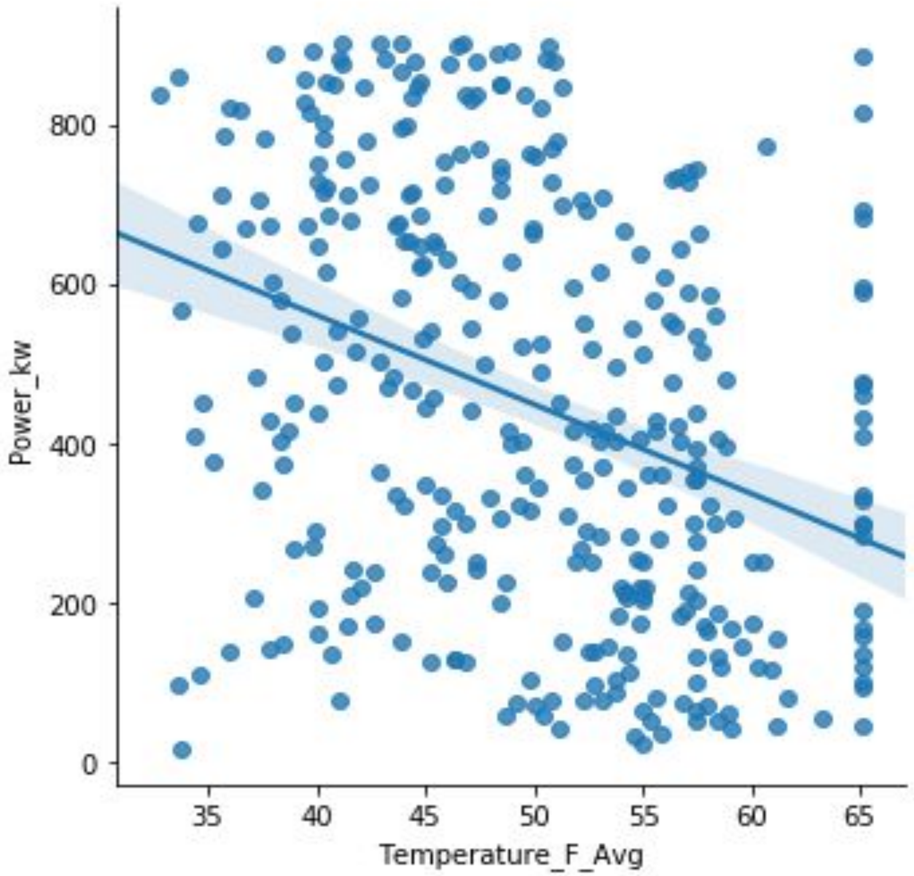
Hypothesis: Analysis of Length of power curtailment in minutes. Most of the curtailments lasted less than 20 minutes. 96% of curtailment lasted less than 20 minutes.



Findings:

- 96% of the curtailment just last 20 minutes.
- Remaining 6% of curtailment last more than 20 minutes.

Hypothesis: Temperature is negatively correlated to Power supply



Findings:

- Power supply generated by turbines is negatively correlated with temperature.
- As temperature increases, power generation decreases.

DR Strategy

Assumptions:

1. There are 10000 households in Orkney Islands.
2. Each household who takes up the DR scheme can turn on their heating storage which increase power by 5kW.
3. Household demand within a 30-minute window is assumed to be constant.
4. We use 2017 data as sample
5. We assume that penetration = number of household installing smart heating storages (5kw). Residential demand is not used for calculation in this case for the reasons.
6. We are actually assuming that the whole electricity demand from a household can be stored hence reducing the curtailment. We think that its not a reasonable assumption since that many of the electricity demand (ie. cooking, watching TV, lighting) from a household cannot be stored like a heater.

DR Strategy (Contd.)

Max heating units needed to completely avoid curtailment

- A maximum of 178 heating units will be needed to completely offset the total curtailment during the observable period for the single wind turbine.

DR Strategy (Contd.)

Devices requirement to handle curtailed energy of ONE turbine.

Assuming each heater can increase 5kW of power when turned on, different device penetrations can achieve the following result:

- 10 devices is sufficient to offset 12% of energy curtailed from one wind farm.
- 20 devices is sufficient to offset 23% of energy curtailed from one wind farm.
- 50 devices is sufficient to offset 51% of energy curtailed from one wind farm.
- 100 devices is sufficient to offset 83% of energy curtailed from one wind farm.

DR Strategy (Contd.)

Devices requirement to handle curtailed energy of ALL turbine.

Assuming each heater can increase 5kW of power when turned on, different device penetrations can achieve the following result:

- 500 devices is sufficient to offset 11.5% of energy curtailed from ALL wind farms
- 1000 devices is sufficient to offset 22% of energy curtailed from ALL wind farms
- 2000 devices is sufficient to offset 41% of energy curtailed from ALL wind farms
- 5000 devices is sufficient to offset 82% of energy curtailed from ALL wind farms

DR Strategy (Contd.)

DR Penetration:

Assuming that there is a total of 10000 households across the Orkney Island and that one household installs one heater, different household penetrations can achieve the following result:

- 5% households penetration is sufficient to offset 11.5% of energy curtailed from ALL wind farms
- 10% households penetration is sufficient to offset 22% of energy curtailed from ALL wind farms
- 20% households penetration is sufficient to offset 41% of energy curtailed from ALL wind farms
- 50% households penetration is sufficient to offset 82% of energy curtailed from ALL wind farms

DR Strategy (Contd.)

Value of this energy curtailed:

- A total of **3213 pounds** is estimated to be saved from the reduction in curtailment for **one wind turbine**. Assuming that a **smart meter** costs **15 pounds** and all the other fixed costs are 0. Based on the result that a maximum of **178 devices** will be used to offset all the curtailments for a single wind turbine derived from the above analysis, we can get that the profit will be approximately **3213-178* 15 = 543 pounds** for a **single wind turbine** in **2017**.

- A total of **166007 pounds** is estimated to be saved from the reduction in curtailment for **all wind turbines**. Assuming that a smart meter costs 15 pounds and all the other fixed costs are 0. Based on the result that a maximum of 178 devices will be used to offset all the curtailments for a single wind turbine derived from the above analysis, we can get that the profit will be approximately **166007- (178*15* (54750-8250))/900 = 28057 pounds** for **all wind turbines** across the Orkey Islands in **2017**.

Summary of findings (EDA)

Below are list of findings from **Exploratory Data Analysis**:

- Average power supply is around **455 kw** for year **2017**. Average wind speed is around **10.17 m/s**.
- Average residential demand is around **0.21 -0.24 kw** for year **2017**.
- Average demand during **Winter (0.26 kw)** is highest compared to **Autumn**, **Spring** and **Summer (0.19-0.22 kw)**.
- Average demand during **off-peak** hours is around **0.15-0.18 kw**. Also average demand during **peak** hours is **0.29-0.31 kw**.
- The **highest curtailment** can be seen in **Sep** with **68204 kw** in total. What's interesting is although there is high power supply in Jan, no curtailment is spotted.

Summary Of Findings (Calculations)

Below are list of findings from **Calculations:**

- We have come to conclusion that investments in this project (HSO) is **worthy** as it will generate **positive profit** and that **less energy** will be **wasted**, which is more environmentally friendly.
- There were **134 mWh** and **77.6 mWh** curtailments for **2016** and **2017** respectively for the observed single wind turbine.There were **6924 mWh** and **4011 mWh** curtailments for **2016** and **2017** respectively across Orkney Island.
- A total of **166,007** pounds is estimated to be saved from the reduction in curtailment for all wind turbines in **2017** and **28,057** pounds will be generated as profit.

Strengths & Limitations

Strengths:

- Data has been fully explored to find out all possible relation as well as patterns.
- All results are shown with visual proofs.
- Solution achieves 100% usage of curtailed energy in case of proper implementation of DR.

Limitations:

- All calculations are approx.
- Information given is very limited that many assumptions are needed to support the result, which may not be reliable in the real world.
- Costing structure is unclear and during implementation a lot more costing may be involved.
- Wastage during the electricity transmission and storage has not been taken into consideration.
- Data from the demand side is actually important to our analysis but we ignore it due to its unreasonableness.
- A longer period of data may be needed for comparison and time series analysis.

Thank you for listening, any questions?