Analytics in Business
Live Tutorial:
Heat Smart Orkney technical briefing

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Introduction

Problem, context and objective:

- Analyse sources and amount of energy curtailed by wind turbines in Orkney
- Reduce curtailment by increasing residential demand in a flexible way
- Use DR technology from Kaluza to monetise the wasted energy
- Develop a business plan for Kaluza

Contents:

Data and assumptions

- **Nature of the data:**
  - real data is <u>messy and incomplete</u>, and we assess you on the skill you have to deal with this kind of data
  - ok to use additional data as long as you do not completely or substantially replace the dataset given to you
- **Why are assumptions needed?**
- **How to make reasonable assumptions?**
- **Example assumptions:**
  - No. of households, sources?
  - Wind turbine model for all wind turbines
    - same as for the one in the dataset?
    - efficiency assumptions on turbines of different power capacity – ours is 900kW
  - Which year of data collection being used and why: e.g., use all years, or only considering year 2017 etc.
- **Assumptions → Limitations**

Understanding energy curtailment

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- **What is curtailment?**

- **Annual energy curtailment**

Total energy curtailed = Total potential energy − Total residential demand − Total export

- **Two ways of looking at the problem:** discussed later
- **Units**
  - Units of power (kW), One Watt is equal to one Joule of energy per second.
  - Units of energy -> integrate over time -> e.g., kWh (Assuming a uniform rate)

Total potential energy

Conceptual understanding

- Relationship between (wind) speed and energy $\left(\frac{1}{2}mv^2\right)$
- Relationship between energy and power: power is rate of transmission of energy => power is energy integrated over time
- Expected relationship between wind speed and power generated by turbine?

Building a wind turbine power model

- Turbine dataset
- the power in the turbine dataset is the actual power generated.
- **Power curve:** Turbine potential power as a function of wind speed
- Is power curve reasonable? Seasonal trends?
- Do all turbines follow the same power curve? => Assumptions – turbine capacity
- As of September 2018, Orkney had more than 500 turbines

Total potential energy

- **Set point:** Which records to use?
  - What is a set point? – turbine forcibly curtailed by network operator => ensure output is less than or equal to set point
  - Set point allows us to stop generating more energy in aggregate than the infrastructure can cope with.
  - Assume the it is safe to set the set point to any value on or below the maximum output of the turbine. That is part of the turbine's design.

  - When the power is **just below** the set point, it means we generating approximately maximum possible power.
  - When a set point is active, a gust of wind or simply momentum in the blades might be sufficient to **exceed the set point temporarily**. (For the purpose of this case study, please consider whether these instances are actually relevant when looking at the big picture).

  - Note: it is not always the case that energy is curtailed when the set point is below 900 kW. If the wind speed is low, the power generated may be well below the set point, then there may be no curtailment depending on demand etc.

Total potential energy

- Power curve: potential power output for a given wind speed
- Potential energy for a given hour: integrate power over time e.g., 900 kW over 1 hour gives energy 900 kWh
- <u>Remember calculation is an annual calculation, not for a single hour</u>
- Calculate potential energy for <u>all turbines</u>
  - Assumptions on number of turbines in Orkney
  - Assumptions on turbine capacities, efficiencies etc
  - Assumptions on types of turbines : commercial/domestic

- unrealised power

Potential energy	=	Unrealised power	+	Actual generated power

  - useful to compare the actual power generated and the potential power

Total residential demand

- Residential demand dataset
  - Timestamp: the datatime in UTC of the measurement., at the end of the measurement period
  - Demand_mean_kw: the mean demand of the sample of households during the measurement period
  - N_households: The number of households included in the aggregate statistics of the measurement period

- Demand in dataset is averaged over households
  - Assumption needed on number of households to obtain demand in the whole of Orkney
  - There are only 10 385 households in the dataset. There is a column that indicates the number of households sampled to create averages. This should not be confused with the total number of households.
- Time difference between each record is exactly 30 min
  - no dataset can cover all seconds, minutes or hours of the day.
  - Measurements are taken at specific intervals and it is up to you to make assumptions about what happens in between.
  - choose your interval wisely so that it becomes easy to convert between units of energy and power
  - Assumptions needed for electricity demand on an hourly basis

- Insights on residential demand
  - Observe seasonality trends E.g., what does the residential demand in a 24 hour day look like in summer, spring winter, autumn – this can help inform solutions

Export

- This is optional to consider
- Some of the total potential power is becomes unrealised power; some is used for the Orkney Islands' demand.
- If power is still left over, it may be exported to the mainland, but the maximum is 40 MW per hour.

- state your assumptions about the amount of power exported
- Research: e.g. how much energy exported can depend on seasonality

=> If the total potential generated is more than the total demand, there is energy available for export, e.g., to mainland via a 40 MW cable (remember this limitation!)

Analysing curtailment

Total energy curtailed = Total potential energy − Total residential demand − Total export

- Units: MWh may be more appropriate

- **Insights**
  - How does the total energy curtailed compare to the total potential energy?
  - What does this mean?

  - **Presenting the data**
    - Present the data in a way that would display the relationship between curtailed energy, demand, export etc over a typical day, or over a year etc
    - Presenting data in a way that make it easier to draw insights e.g. trends in the data etc
    - Use the insights drawn to develop energy solutions for Orkney

Analysing curtailment

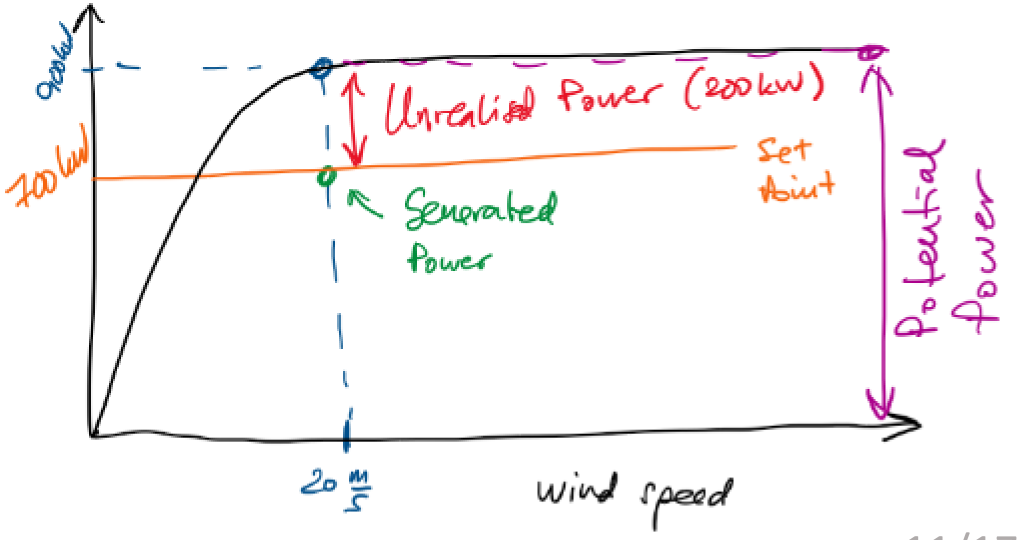
- **Two curtailment approaches**;
  - Energy may be wasted in inefficient generation

Potential energy	=	Unrealised power	+	Actual generated power

  - Energy may be wasted from the energy actually produced

- Therefore, wasted energy is from two sources:
  - Unrealised power (difference between potential and actual)
  - Demand + export is less than the actual power generated

- To consider both to understand where energy is wasted
- For this project: The challenge is **not producing more energy is to waste less.**



Kaluza's Heat Smart Orkney

- Kaluza is the creator of the DR technology inside the Quantum heater system and, the cloud-based platform that orchestrates all devices in real-time to control the DR system.

Objective: reduce energy curtailment

- "Can we reduce the amount of curtailed energy and monetise this newly generated energy?"
- limiting factor: how much energy can households consume above their normal usage

Solutions:

- Consider possible solutions based on demand e.g. Demand and supply in different time periods of the day and season
    - E.g., demand peaks in morning and after work, low demand at night, E.g., demand peaks in winter
    - Delayed demand: customers cannot always consume energy in real time as excess wind power arises

- Consider possible solutions based on the typical household in Orkney
    - What sources of energy does the typical household use? Electrical heating, fossil fuels etc.
    - Appliances the typical household uses e.g., Electric vehicles, heat pumps, storage heaters etc – hot water cylinders
    - What makes up the demand of a typical household?
    - What is the expected mindset towards HSO? Are households likely to adopt the proposed solutions?
    - Incentives (how would you market your appliance): e.g., free trials, package deals, discounts etc.

Kaluza's Heat Smart Orkney

Solutions:

- Consider the finances of the business: Kaluza
  - Choose appliance(s)
    - assume that every house that uses electric heating will have storage heaters in place
    - selling exercise: selling a device per heater to control them in a smart way.
    - If they have oil heaters, then they would need a full replacement
    - Focus on Storage heaters and/or hot water cylinders
    - if time permits, can discuss how you could expand your analysis into a broader class of electric assets
    - idea is to create flexible demand for which activation is nearly instantaneous -- we can switch on a heater as soon as we observe that there's excess wind power available

  - What is the cost of the DR technology itself?
    - technology hub that controls the heaters (so they can be retrofitted) can be assumed to be around the £100 mark.
    - a Quantum Heater in 2018 was around the £600 mark.
    - We assume there is no further cost required by Kaluza to develop the DR platform i.e. DR platform is ready for implementation

  - Employee salaries
  - Government subsidy or funding
  - Revenue to Kaluza, profit margins Revenue to wind farmers

Kaluza’s Heat Smart Orkney

Analytics: DR penetration levels

- Consider demand response penetration
- this metric is described as the number of households with DR/total number of households (it is a percentage).
- Sensitivity analysis: the level of penetration at which Kaluza might break even
- Energy curtailment as a function of demand response penetration
- ways to increase penetration: approaches designed to encourage people to take on the DR system benefit from an increase in energy consumption - reduces curtailment.

- Consider the finances of households
  - Current energy costs: We can assume typical numbers £50-£100/month/household
  - Some people in Orkney are not currently using electric heating, so they depend on gas, oil or other fuels
  - Household income
  - Costs of purchase or lease, and installation to customers
  - Maintenance costs
  - Can calculate profitability per household, the amount of money spent using their old vs new appliance

Benefits and Limitations

- **Discuss benefits** – financial, societal, environmental
- **Discuss limitations**
  - E.g., Inaccurate modelling, changing prices, wildlife, bans, government support, competition etc
  - E.g., limitations based on assumptions

- **Further advice**
  - No need to consider every single avenue, define your specific project context with your assumptions and associated limitations
  - Follow logical steps and apply reasonable assumptions
  - learn to be comfortable with uncertainty – the project is aimed to be reflective of a real-world situation where the data available is messy and textbook answers are not readily available
  - creative thinking is encouraged – there is no one correct answer, slides provided are a guide only

Structure of the report

- Report format
  - maximise the time you have to work on the research part of the project
  - do not waste time on formatting a fully professional report
  - **Jupyter notebook** is a good way to do this

- Use **storytelling techniques**
  - avoiding direct academic question headers: academic questions need to be answered with the report, but not rule the structure of the report
  - it is **still a business report**, even if done with Jupiter
  - Use an Appendix for heavy duty research data and analysis code and data exploration with clear references in the main text

- Presentation is also based on storytelling
  - conveying highly technical concepts to a non-technical audience less technical detail

- This is an **open-ended assessment with no single right answer**
  - will have different opinions across the teaching team
  - two groups could have very different reports and presentations and yet both get 90%

Good luck!