Monitoring and analysing energy efficiency

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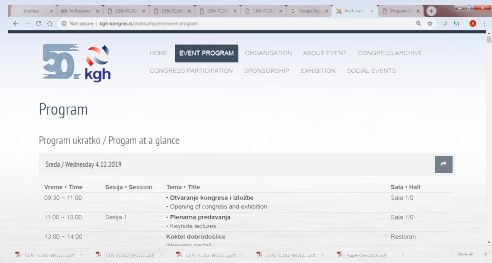
STAR REFRIGERATION

In business to secure a better future



What's on the menu

- Reasons for Inefficiency
- New energy monitoring methods
- New Analysis techniques
  - Accounting for weather
  - Digging for detail
  - Identifying recurring patterns
- Conclusions

Reasons for Inefficiency

- System Architecture
  - Failure to minimise the heat load
  - Poor compressor control
  - Suction pressure too low
  - Discharge pressure too high
  - Heat leakage inside the system
  - Auxiliary power consumption
- Operational Constraints
- Operator Preferences
- Lack of information

How is efficiency measured?

- Often its not! But if it is then….
- A single power meter for the whole site
- A current meter for each large user
  (compressors, maybe larger pumps, probably not small pumps and fans)
- Measurement of instantaneous kWh
- Aggregated kWh figure on a daily or weekly basis (eg pulse counting)
- Full electrical supply monitoring, including
  - Volts on each phase
  - Amps on each phase
  - Power factor

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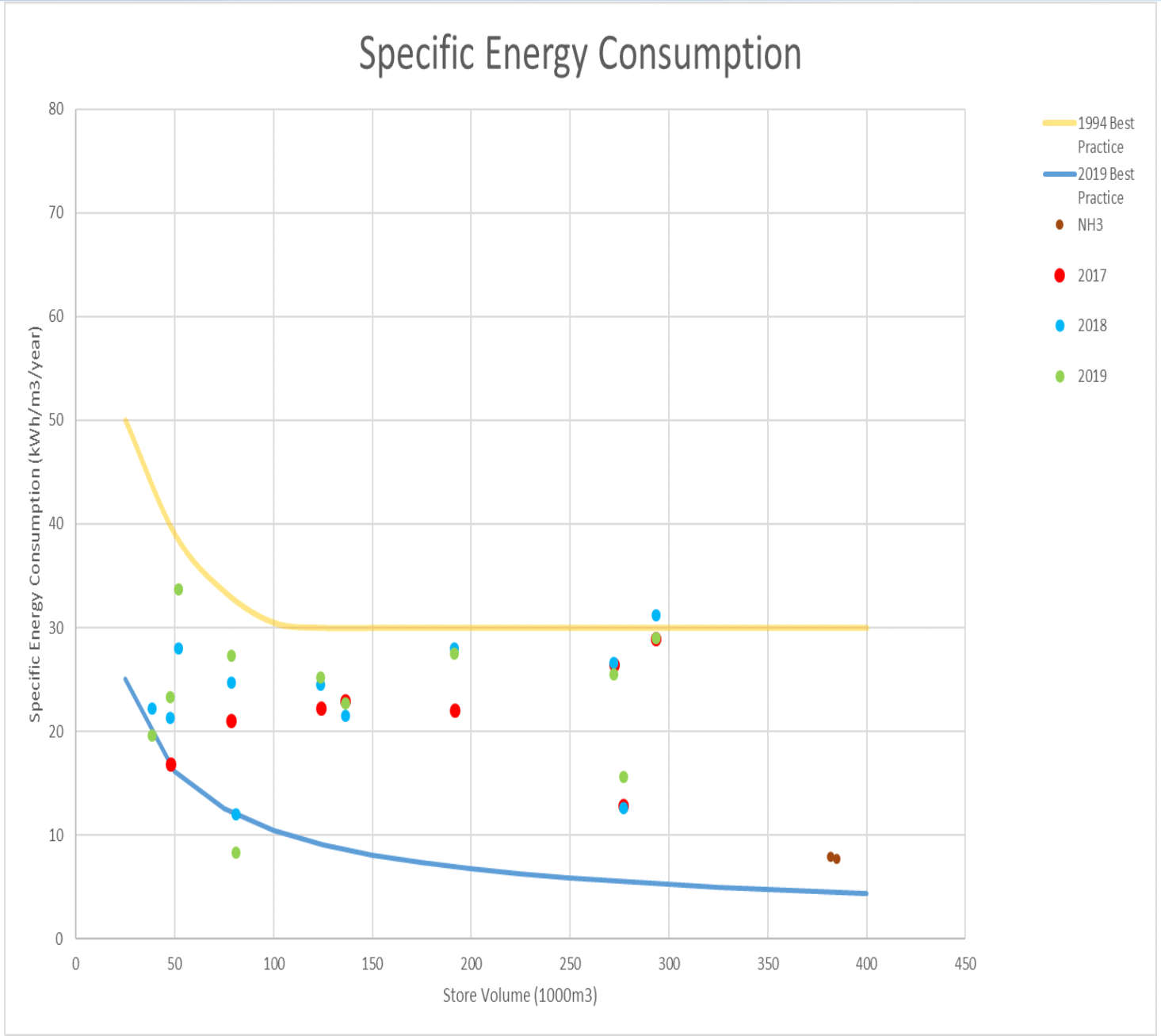
kgh

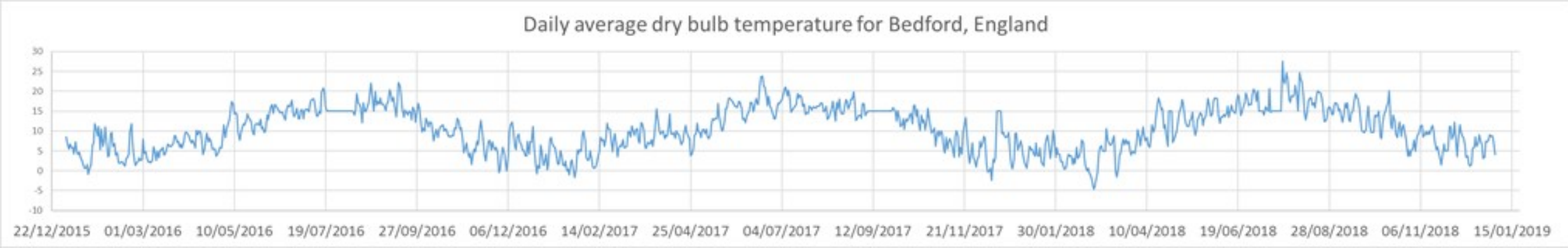
Some other initial observations

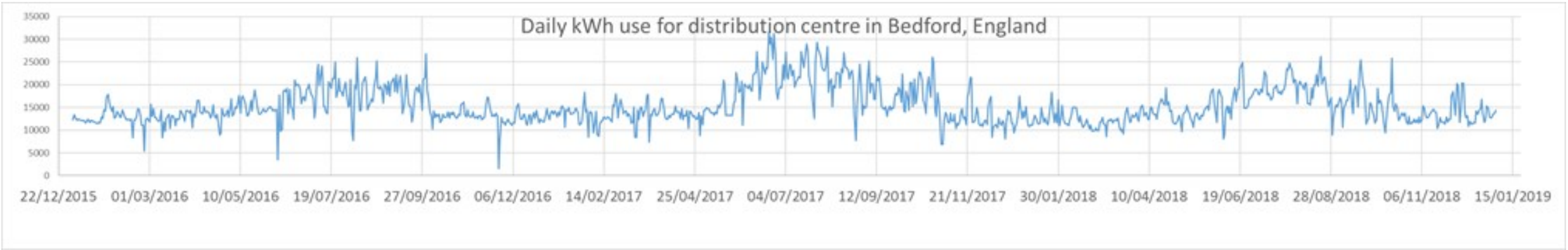
- CoP is not a useful measure of cold store efficiency
  - It is difficult to measure accurately
  - It doesn’t address most of the common faults listed earlier
  - It is easy to imagine a very bad system with a good CoP
- Measuring refrigeration performance without relating it to level of business activity is also not useful
  - No connection between business management and plant management
  - Could be input of throughput numbers to refrigeration control system
  - Or in a cold store counting door opening number and duration
  - These are almost never done

Presentation of energy data for cold stores



Data Analysis I – accounting for weather

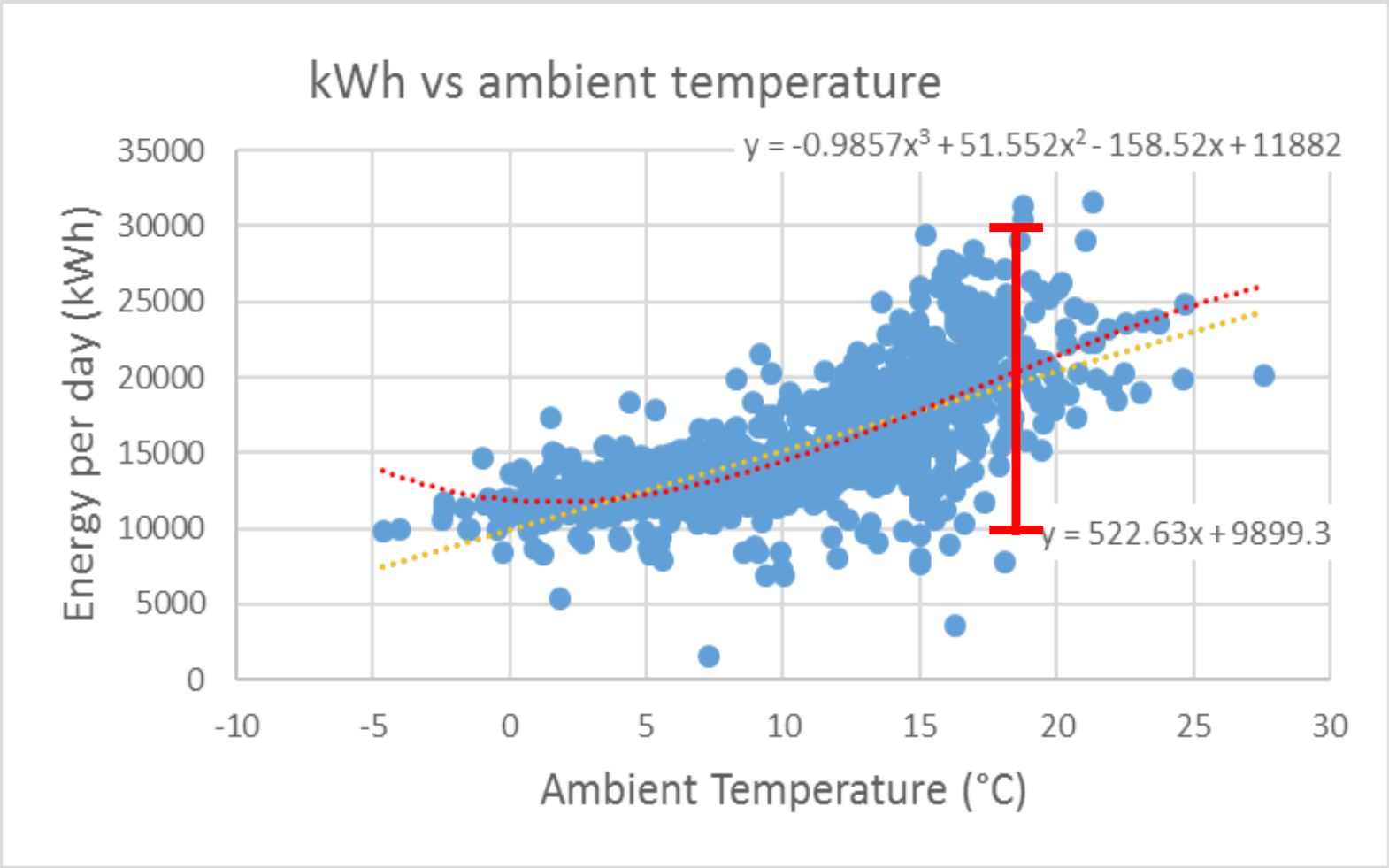




"Do you think these two ever fit together?"

Al Gore, "An Inconvenient Truth"

Data Analysis I – accounting for weather



- Actually not as well as you might think
- Yes, there is a correlation
- But there is also a wide variation in kWh at a given ambient
- This is typically +/-50% of the daily energy figure

Data Analysis I – accounting for weather

- When the weather regression is backed out of the daily readings, based on average ambient for that day the daily variation can be seen
- This is +/- 1500 kWh on a daily reading of around 15000 kWh
- That's better than the weather correlation suggested
- Smoothing effect of daily average might be hiding something else

Data Analysis II – Spotting recurring behaviour

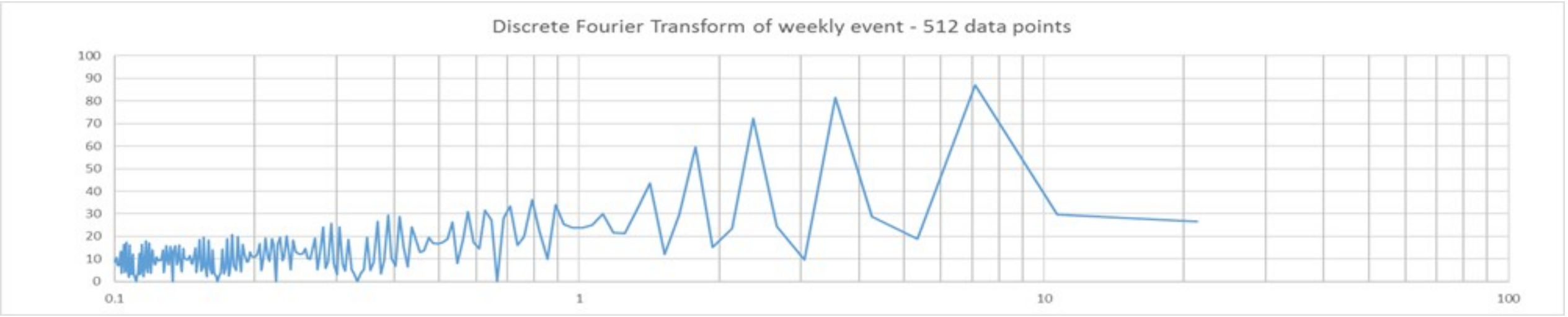
- Any set of data (kWh per day, compressor run signal, door openings…) can be analysed by transform to look for recurring patterns
- The pattern might be caused by a weekly work schedule (eg factory not working production at weekends)
- But it could also be caused by
  - Lead/lag changeover of compressors
  - Different shift workers behaviour
  - Other external influences
  - …and many, many more…

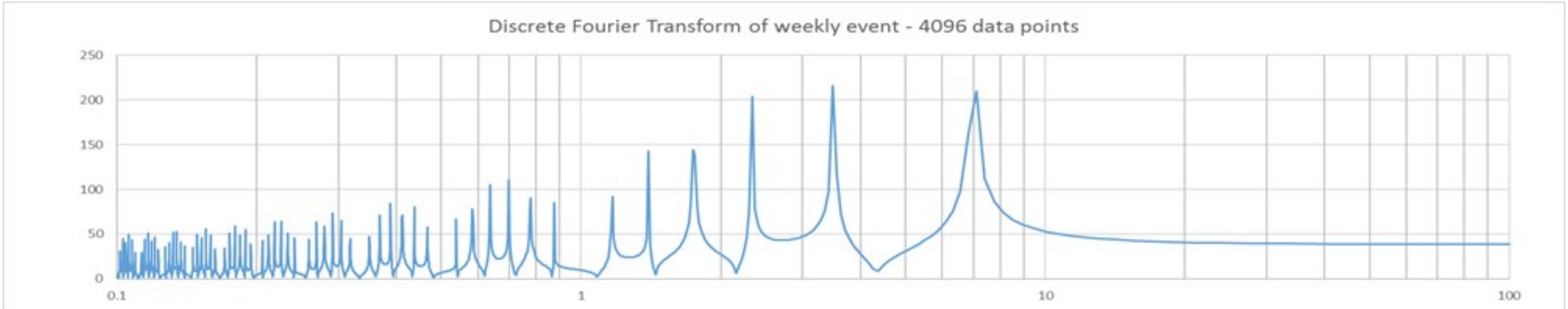
Data Analysis II – Spotting recurring behaviour

- Fourier transformation is a mathematical technique to take a complex signal and represent it as a series of sine waves of different amplitude and frequency
- This is usually used to spot prominent tones in noise signals or resonances in vibrating systems
- Here it is applied to energy use measured at hourly, daily or weekly intervals

Data Analysis II – Spotting recurring behaviour

- A large number of data points are needed and they need to span the recurring cycle several times





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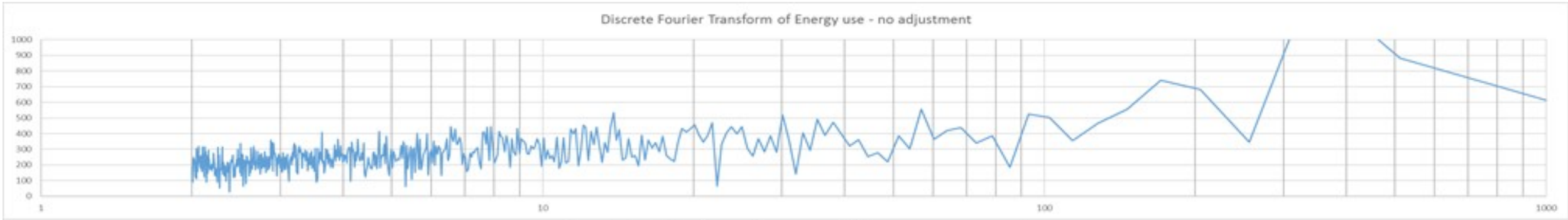

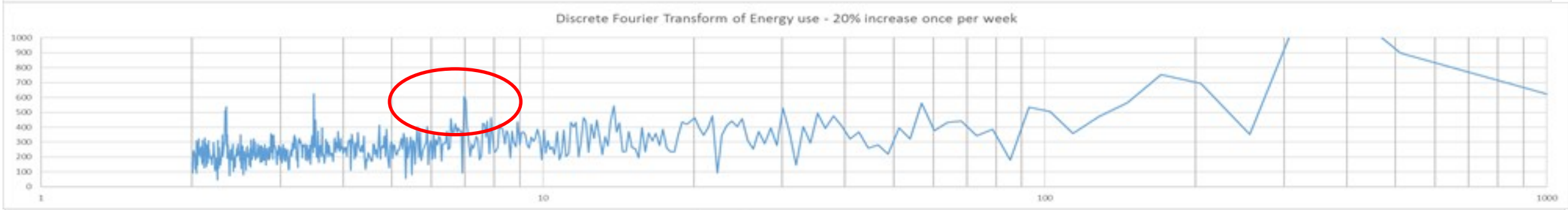

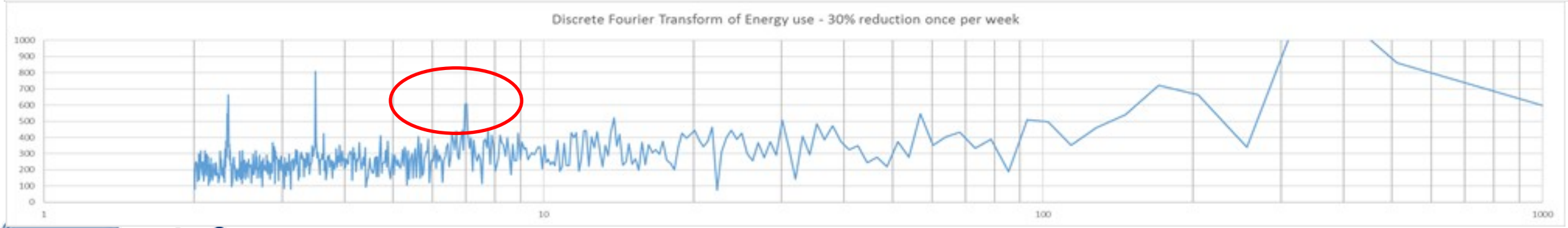

Data Analysis II – Spotting recurring behaviour

Limitations of Fourier Analysis

- It is important to match the sampling rate to the number of samples required for the full span of the period in question
  - But more samples makes the calculation much slower
- It is possible in a spreadsheet
  - But the process is then limited to 4096 data points (just under 6 months of hourly readings or just under 3 days of minute by minute readings)
- For sudden changes the output can be difficult to interpret
- If two separate events occur with the same frequency (for example high energy use on Wednesday and low use at the weekend) the output will not differentiate (it will only show that there is a weekly pattern)

Conclusions

- Collect meaningful data
  - Power meters on each major piece of equipment
  - Sufficient memory to record large amounts of data
  - Comparison of items is very useful but only if they are me
- Data should be correlated to ambient
- And if possible to other effects – eg business activity
- Look for patterns, but be careful:
- Beware of aliasing (one input, many outputs or many inputs, one output)
- Data shou
  (eg measu