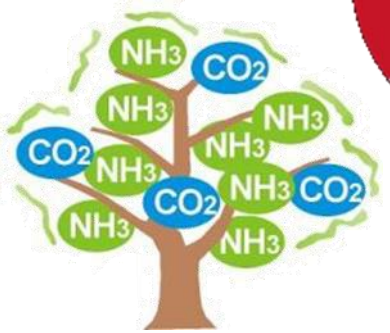
ICR 2019
THE 25th IIR INTERNATIONAL CONGRESS OF REFRIGERATION
August 24-30 | Montréal, Québec, Canada
Hosted by IIF IIR

Rankine 2020 Conference
Advances in Cooling, Heating and Power Generation

GL 2020
14th IIR-Gustav Lorentzen Conference on Natural Refrigerants



Harnessing the Data from Your Refrigeration Systems to Drive Energy Cost Savings

Dr Andy Pearson | Star Refrigeration Ltd

COLD CHAIN FEDERATION

Research Review: 2018 - 2022

Summary

- This review covers findings presented at:
  - International Congress of Refrigeration, Montreal, August 2019
  - Rankine 2020 Conference, Glasgow, July 2020
  - Gustav Lorentzen Conference, Kyoto, December 2020
  - Ohrid Conference, September 2021
- It represents five years of study of industrial refrigeration systems in the cold storage and distribution sector
- The objectives are to understand the reason for wide variation in performance, to recommend remedial measures and to provide methods for justifying improvement activity

Energy use in Industrial Refrigeration Systems

- Reducing energy use is top priority
- But there is still a massive variation from one site to another
- Measuring kWh consumed per year and dividing by store volume gives a useful benchmark between sites and for a single site over a long time
- Store floor area can also be used but can give misleading results
- Best Practice figures from around the world show close agreement on what can be achieved

Factors affecting building energy performance

- Building utilisation – how busy is it?
  - Can product throughput be measured and correlated to energy?
- Weather – how hard does the system have to work to reject heat?
  - Moisture ingress?
  - Solar gain?
  - Heat rejection temperature?
- Fabric condition – how good is the building at stopping heat ingress?
  - Doors?
  - Walls and ceilings?
- Management – how good are the management at stopping heat ingress?
- Refrigeration plant – how well does it handle the load presented?

Five factors which influence energy performance

- Utilisation of the building
- Weather
- Building fabric condition
- Process Management

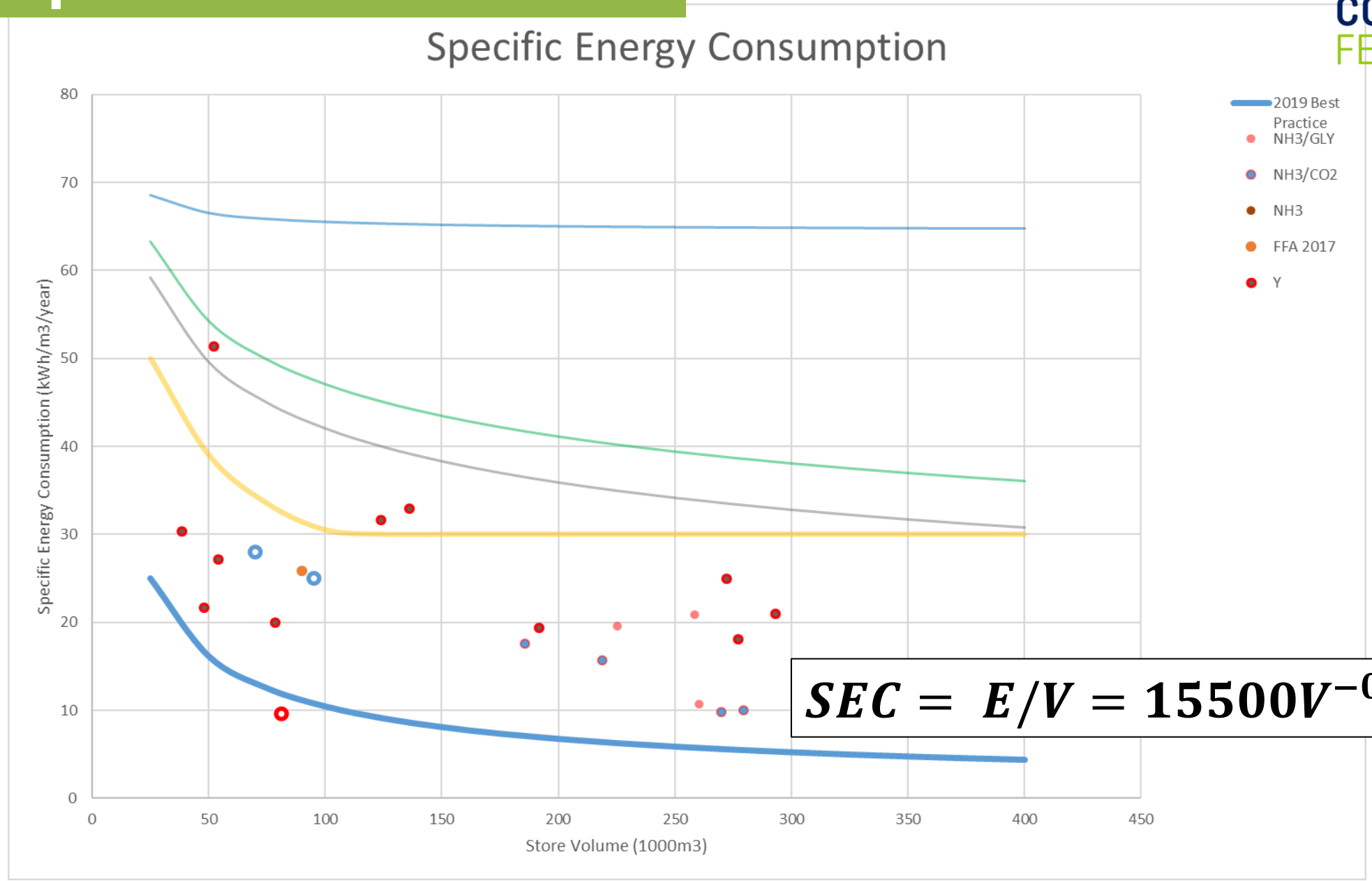
These four factors establish the magnitude of the heat load applied to the refrigeration system and are independent of the coefficient of performance of the refrigeration plant

- Refrigeration Plant

Performance based on CoP of refrigeration

They all have an influence on the amount of energy needed to maintain store temperature

Proposed new metric



$$SEC = E/V = 15500V^{-0.63}$$

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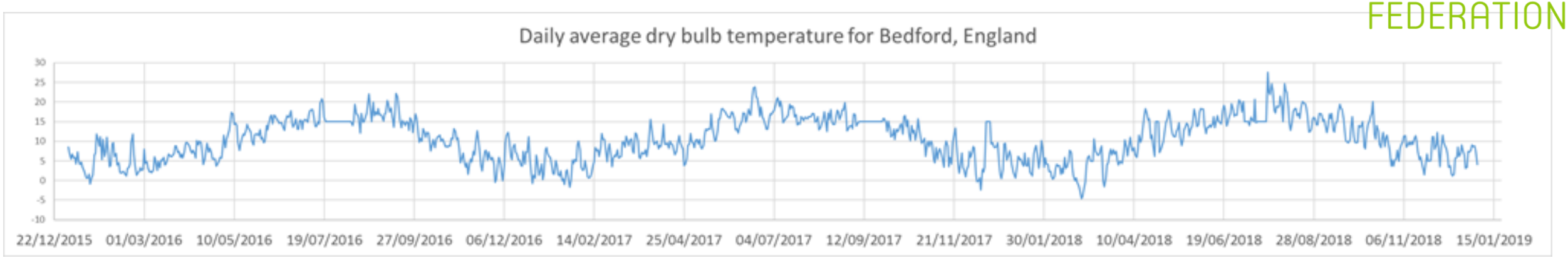
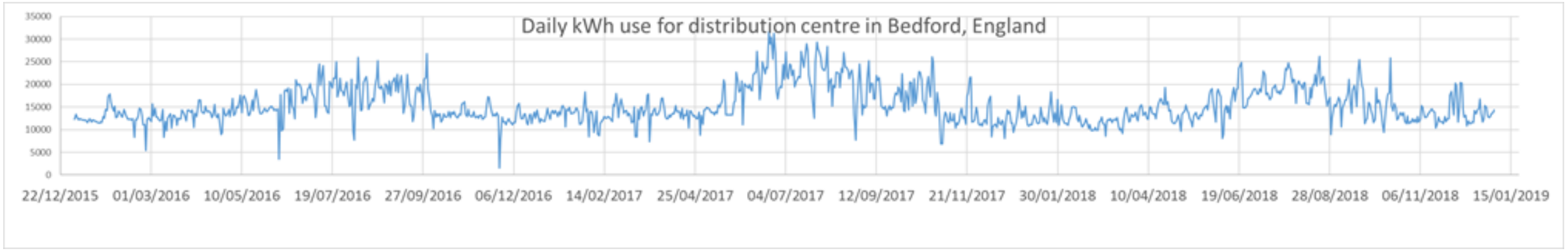
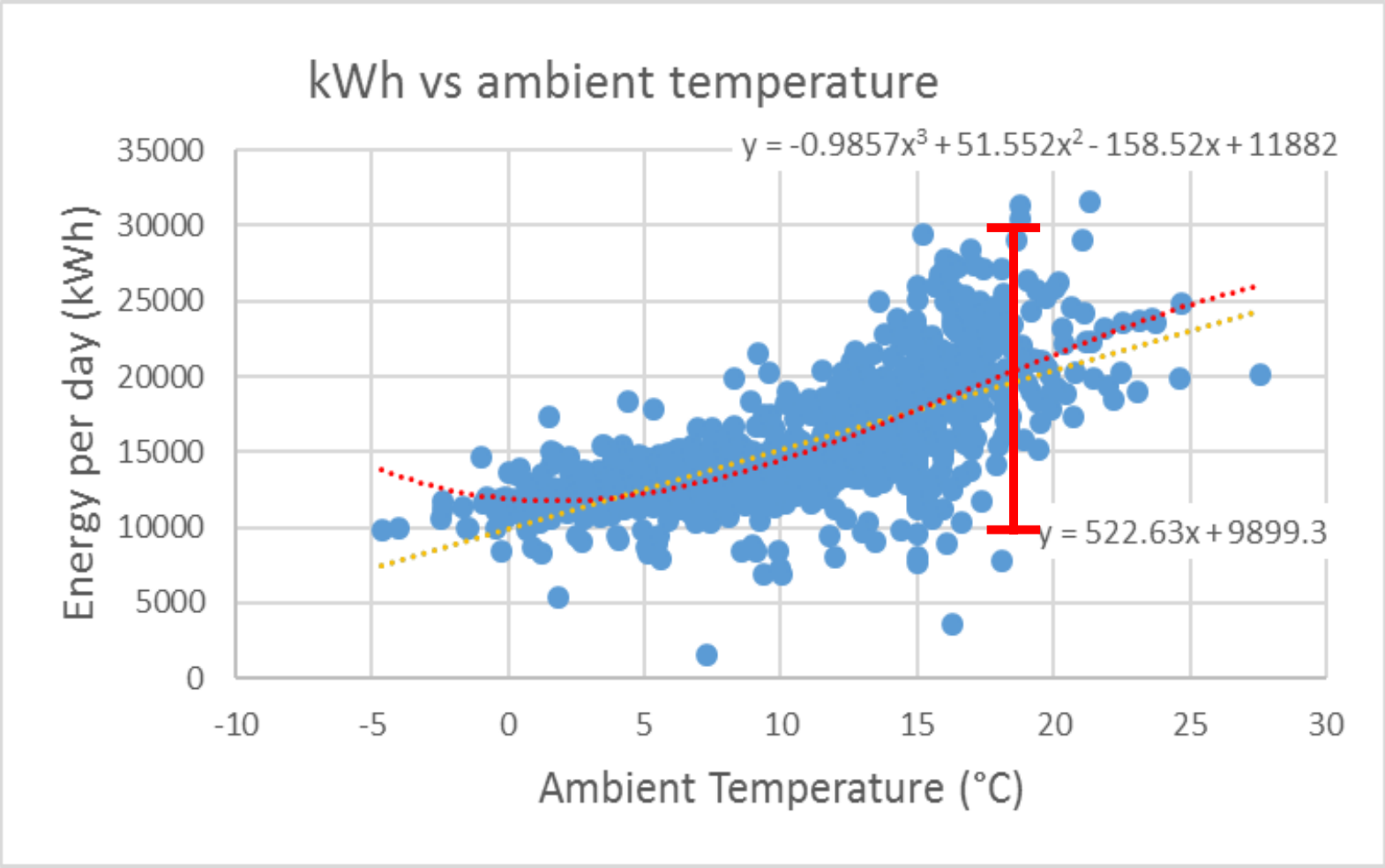




"Do you think these two ever fit together?"

Al Gore, "An Inconvenient Truth"



- 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

- 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 +/- 10,000 kWh on a daily reading of around 15,000 kWh
- A +ve discrepancy figure indicates actual power lower than predicted
- This could be explained by the plant being off for maintenance
- A -ve figure is harder to explain: power higher than predicted?
- Smoothing effect of daily average might be hiding something else

Why predict SEC

- When operating conditions are deliberately changed…
  - Cleaning the condenser
  - Replacing a compressor
  - Repairing a control system
  - Adjusting a setpoint
  - Modifying operator behaviour (eg dock doors, product temperature)
- … it is important to understand the effect of the change ASAP
- Otherwise the reason for change will be forgotten or other changes will be implemented which will mask the effect
- Frequent assessment of future SEC also helps to identify when an adverse change occurs and enables corrective action to be taken before the financial impact becomes too severe

Displaying SEC

There are two ways to show the Specific Energy Consumption of a cold store.

One is as a point on a graph compared to other cold stores of a similar type.

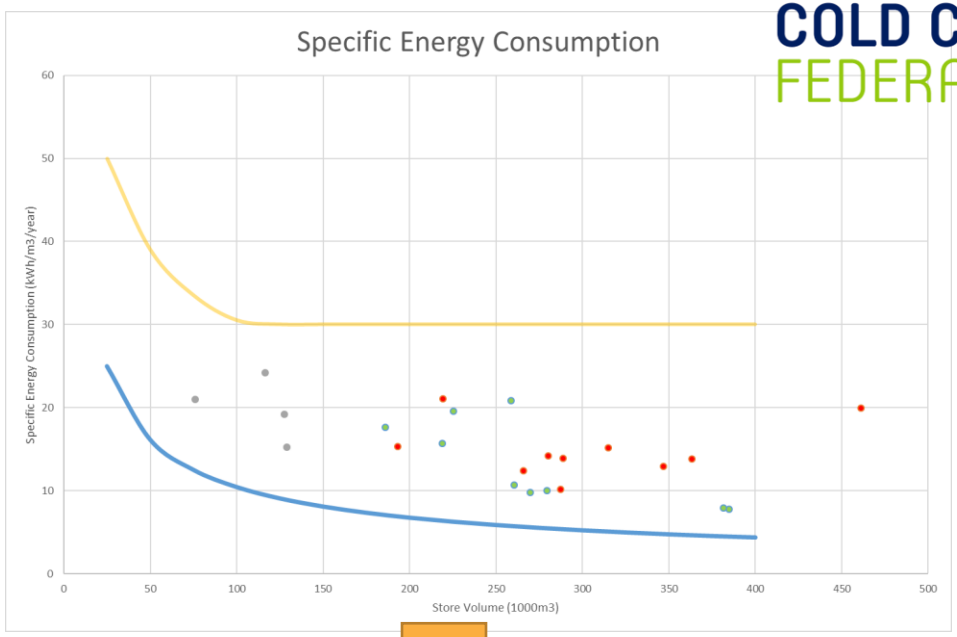
The graph has store volume on the x-axis and SEC on the y-axis

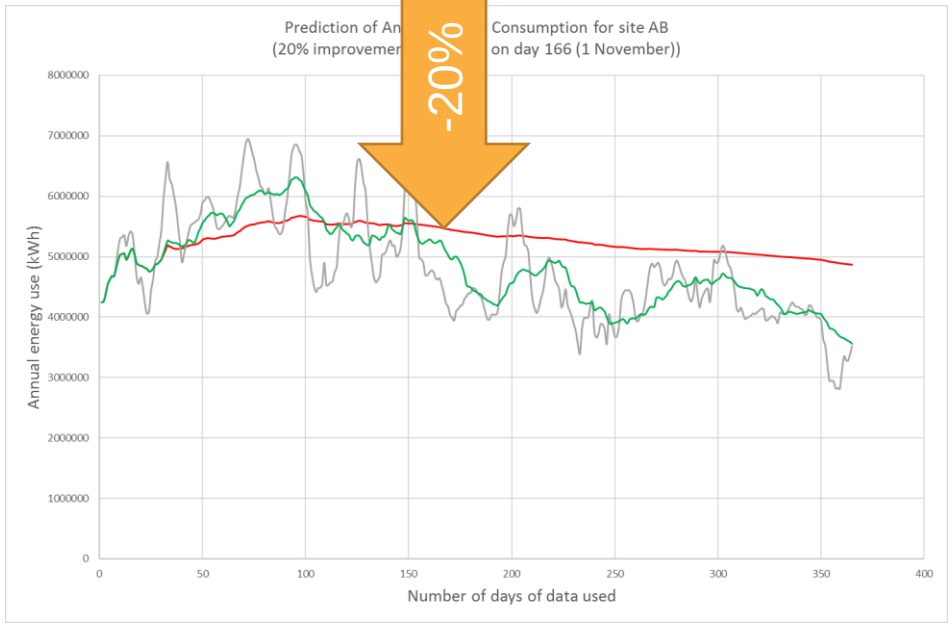
The other is as a historic trend to show how the SEC is developing over time

This has time on the x-axis and SEC on the y

This is not the same as the daily kWh usage, it is the daily prediction of annual SEC

It can be based on yesterday, last, week, last month or rolling 12 month average





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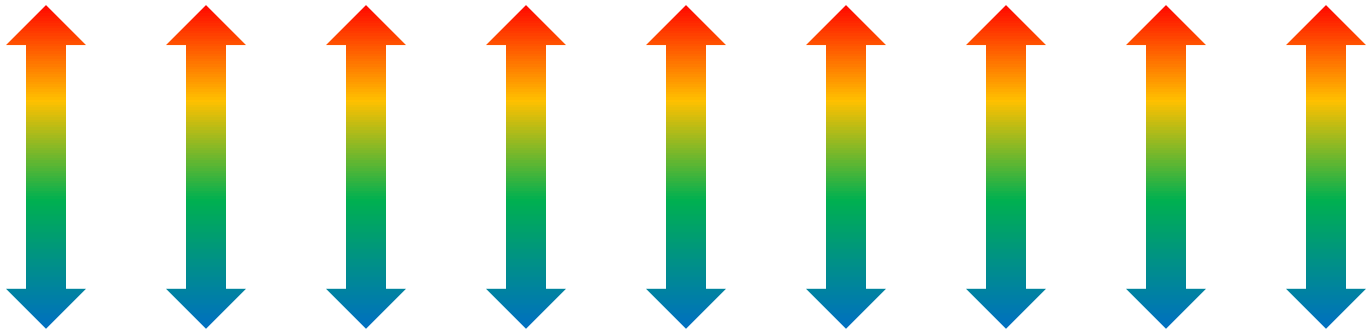
Questions for a Cold Store Business

How is my performance compared to last year?

How is my performance compared to my competitors?

How is my performance compared to best practice?

Past



What can I do to make my performance better?

What do I need to do to keep my performance good?

What will the effect of this maintenance intervention be on performance?

Future

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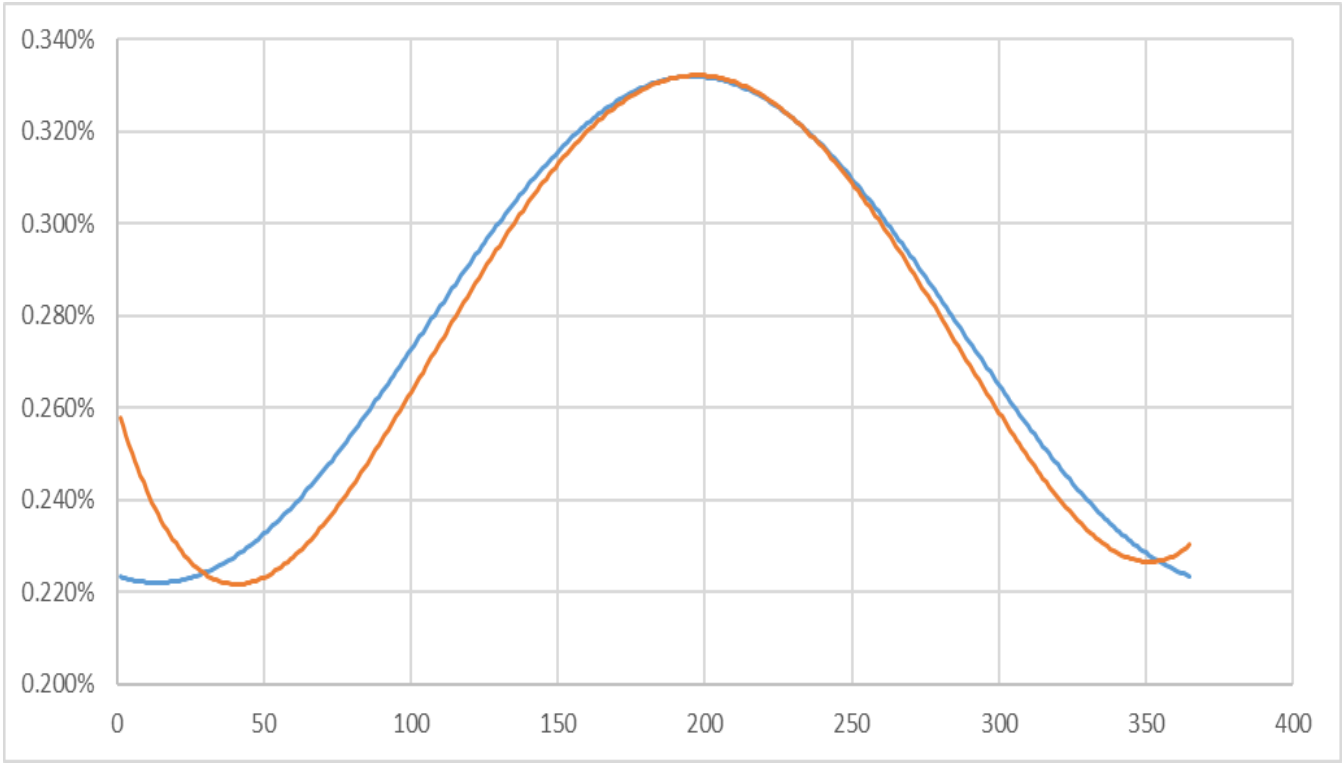
Predicting SEC

- Real historic data from over twenty sites was analysed for three years
- Curves were fitted to the annual data using a polynomial and a sine wave
- $P = an^4 + bn^3 + cn^2 + dn + e$
- a = 1.861 x 10^{-12}, b = 1.462 x 10^{-9}, c = 3.41 x 10^{-7}, d = 2.1 x 10^{-5} and e = 0.0026
- $P = -f sin\left((n+g)\frac{2\pi}{365}\right) + h$
- f = 0.55 x 10^{-3}, g = 78 and h = 0.00274



Other Considerations

- For more complex plants other considerations will also come into play:
  - “is the energy requirement seasonal?”
  - “is the energy use affected by production throughput?”
  - “is the heat load constant or variable?”
  - “what parameters drive the variability?”
- For process loads additional information is required but the methodology is still valid and the opportunities for making savings are even greater
- The most important factor for successful use of the SEC predictor is an understanding of what is driving variability in the energy use

The next step – using SEC for business

SEC prediction can help to control business operating costs, but there is a balance:

Lots of data:
Slow to gather
Slow to react
Historic
Accurate
Subject to other changes

Minimal data:
Early info
Rapid
Current
Imprecise
Influenced by recent events

Research Review: 2018 - 2022

The next step – using SEC for business

SEC prediction can help to control business operating costs, but there is a balance:

Full Year SEC:
365 days
Actual value
Historic
Accurate
Tracked to show trends

Minimal data:
10 days
Predicts the SEC value in 355 days time
Accurate to +/-30%*

* If nothing else changes…

Research Review: 2018 - 2022

The next step – using SEC for business

SEC prediction can help to control business operating costs, but there is a balance:

Full Year SEC:
365 days
Actual value
Historic
Accurate
Tracked to show trends

Short Term
270 days
Prediction
to 95 days
+/- 5%
Tracked to show trends

Medium Term
90 days
Prediction
to 275 days
+/- 20%
Tracked to show trends

Long Term
10 days
Prediction
to 355 days
+/- 30%
Tracked to show trends

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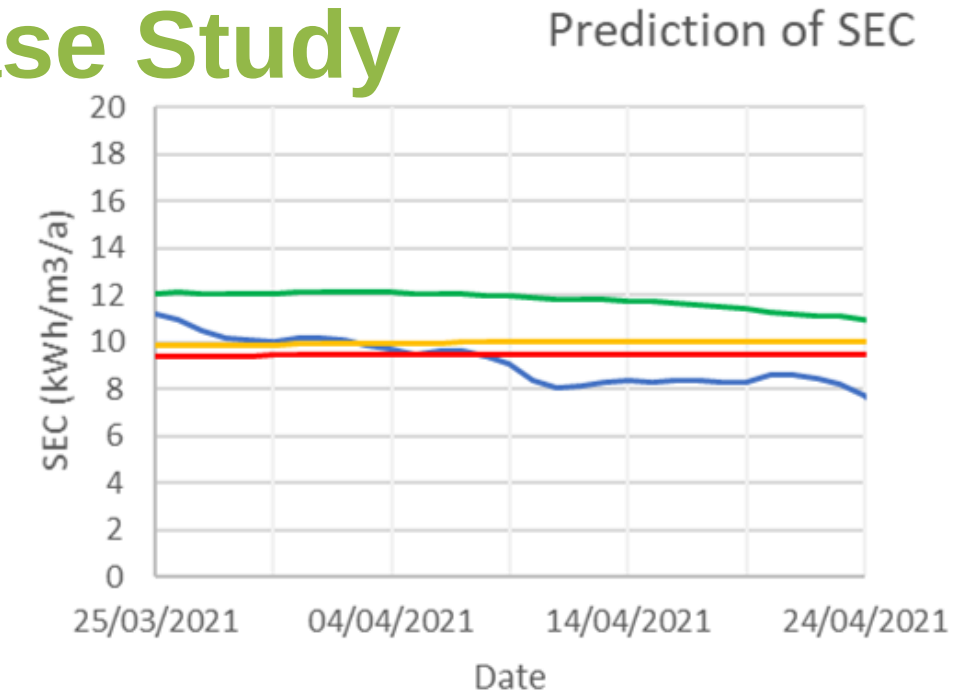
Case Study

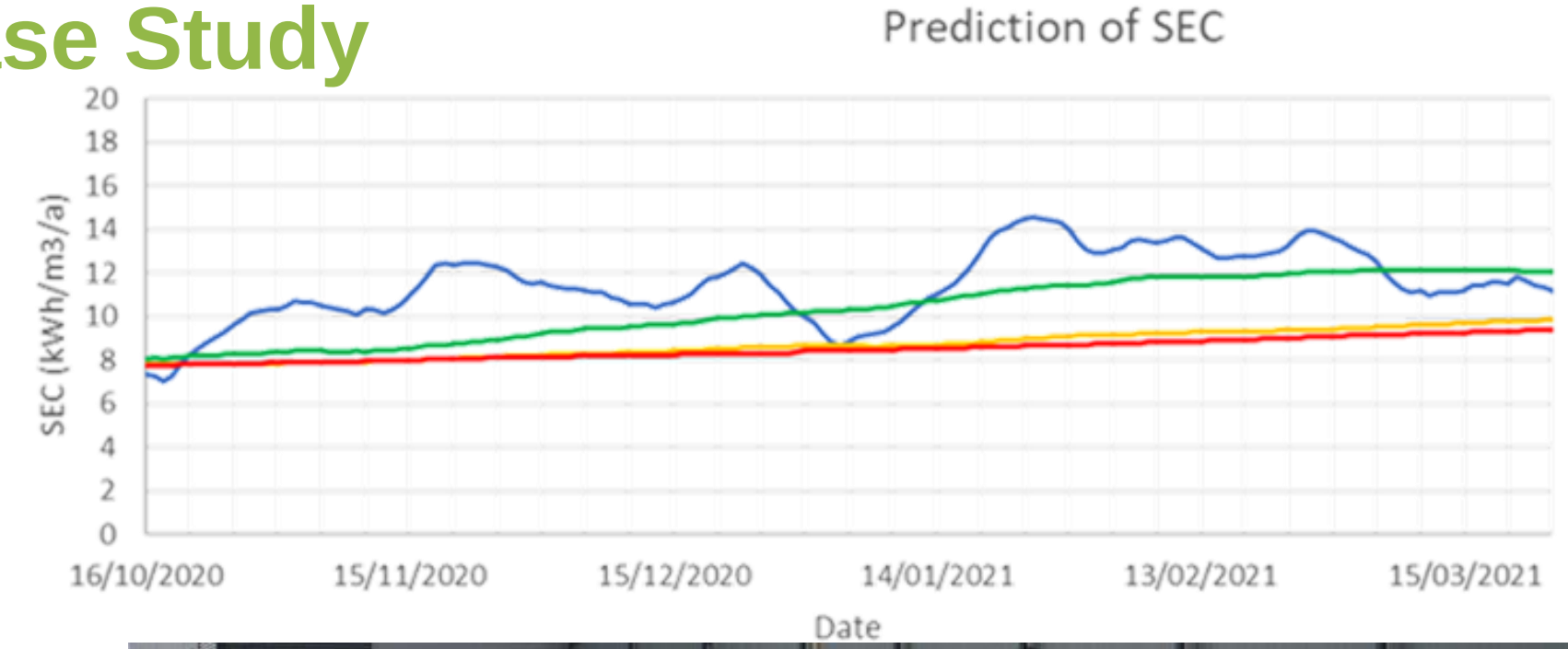
- Daily energy data was taken from a cold storage site and analysed as if it were being collected live
- Long, medium and short term predictions were calculated on a daily basis and compared with the actual SEC figure for the most recent 365 days of data

Case Study



- The full year figure was rising slightly…
- …but short term prediction was higher
- Medium term prediction was high…
- …but falling, and
- Long term prediction was the lowest
- This indicates that there has been a recent improvement, and the full year figure can be expected to fall further

Case Study



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Case Study

SEC on 5 Oct 2020

7.78

Predictions

Long	Medium	Short
7.18	8.06	7.81

The long term prediction is the lowest, showing that recent improvements have been made

The short term prediction is close to the full year figure, so the change is gradual

One month later…

SEC on 5 Nov 2020

7.91

Predictions

Long	Medium	Short
10.48	8.41	7.89

The long term prediction is now the highest

The change was recent so hasn't affected the short term prediction

Six months later…

SEC on 24 April 2021

9.46

Predictions

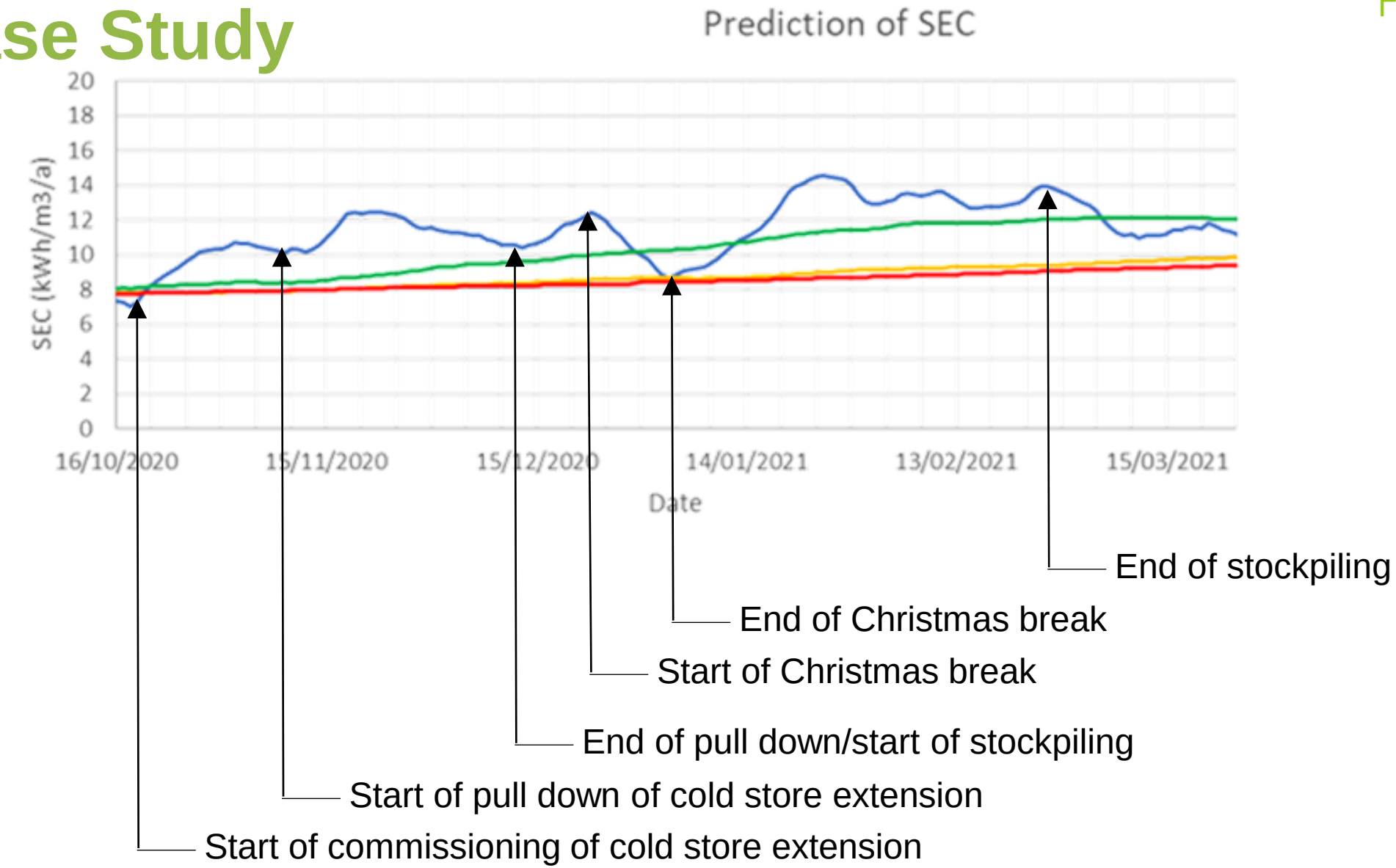
Long	Medium	Short
6.94	10.98	10.04

The medium term prediction is now the highest

The change was temporary and the long term trend is downwards again

This still has to work through to the medium term prediction

Case Study


Prediction of SEC
SEC (kWh/m3/a)
20
18
16
14
12
10
8
6
4
2
0
16/10/2020
15/11/2020
15/12/2020
14/01/2021
13/02/2021
15/03/2021
Date
End of stockpiling
End of Christmas break
Start of Christmas break
End of pull down/start of stockpiling
Start of pull down of cold store extension
Start of commissioning of cold store extension

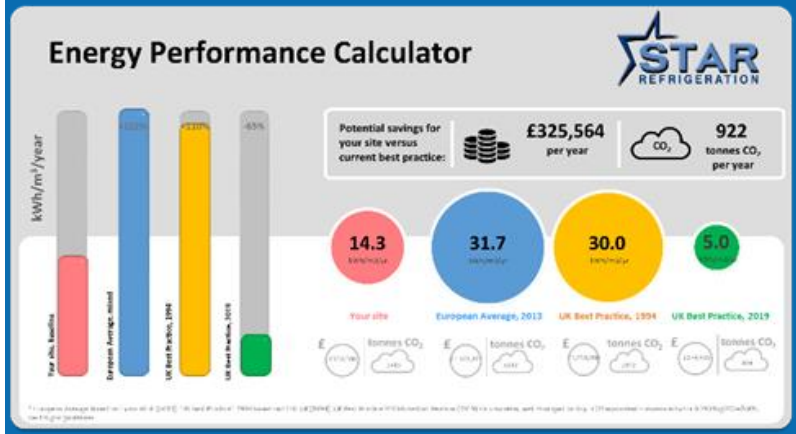
Development of analysis tool

- An excel based analysis tool gives a means of achieving a quick estimate of SEC for a facility
- It does not need daily readings, only a kWh reading with a start and finish date and of course the volume of the store
- The output is an estimate of SEC together with the upper and lower bounds based on the error calculation

Site name	Project X	
Volume of store	280,000	m3
First day of year	01/01/2019	1
Date of first reading	04/02/2019	35
Date of last reading	06/10/2019	279
Total kWh recorded	2,649,415	kWh
Number of days	245	
SEC Estimate	13.21	kpma
Upper limit of SEC	13.87	kpma
Lower limit of SEC	12.55	kpma
margin of error	5.0	%

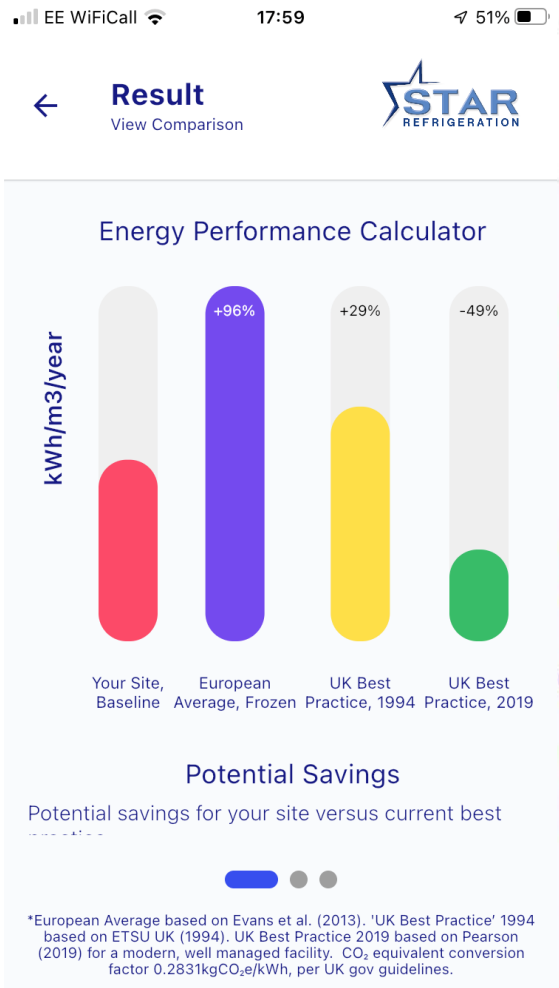
Development of analysis tool

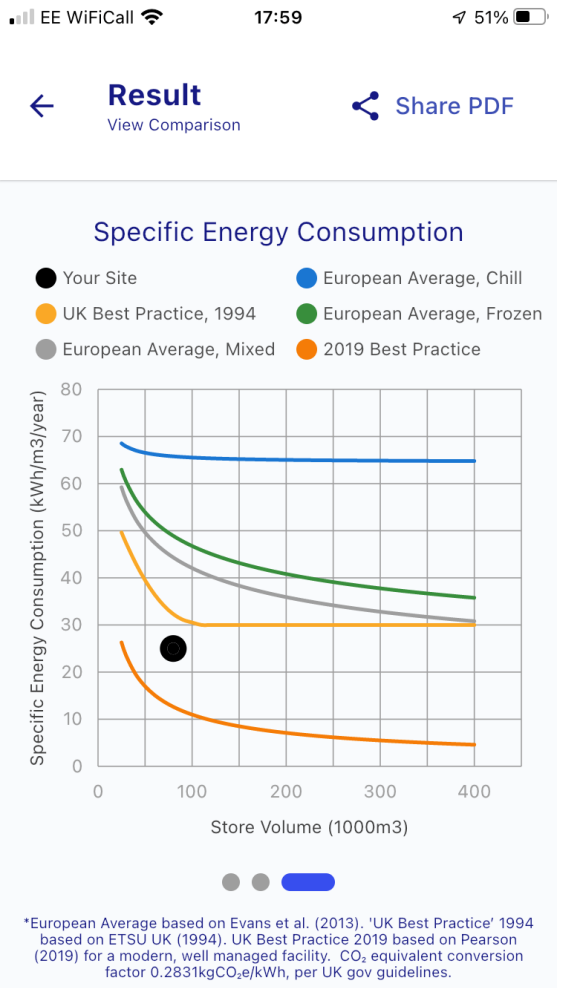
- The output can also be displayed as an infographic giving comparisons with best practice and typical average performance values
- The infographic also gives an estimate of energy cost and CO_2 emissions that would be saved if the store was improved to the best practice benchmark



Deployment of analysis tool

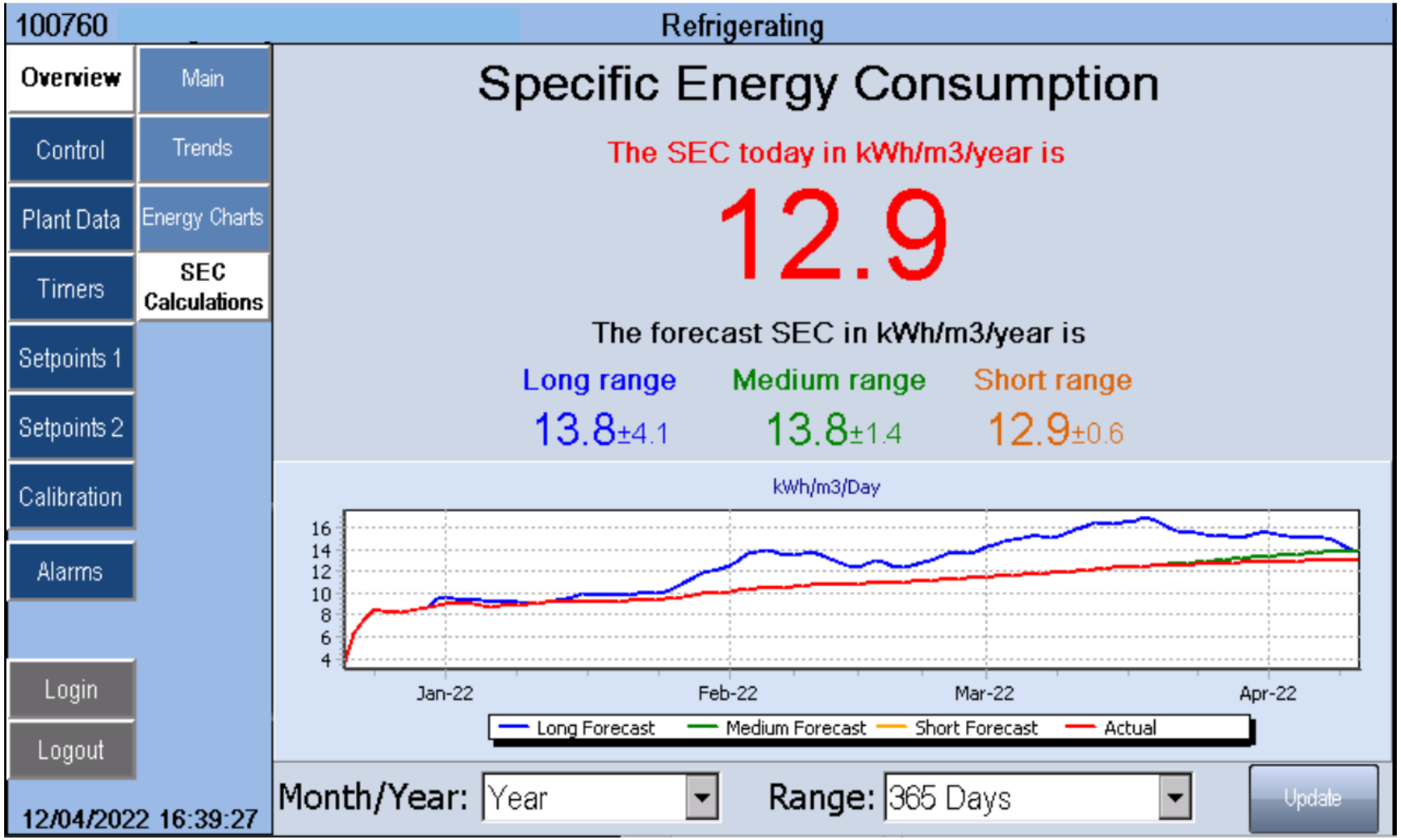
- An app is available to enable easy calculation and sharing of SEC
- Just search “SEC Calculator” in the app store
- There’s no need to register – but it is better if you do





Deployment of prediction tool

- The long, medium and short term predictions shown are now included in Star's standard HMI software for new plant
- This can also be retrofitted to existing systems
- And is available in Ethos



Conclusions

- SEC is a necessary tool in managing energy consumption of cold stores
- It can motivate a policy of continual improvement through wise investment
- It is necessary to extrapolate the effect of change to gain quick feedback
- Data gathering and analysis is essential – before and after the change
- The effect of change should be evident within a few days
- This can be easily retrofitted to existing sites
- It helps to manage operating costs, giving better control of maintenance activities and investment decisions.

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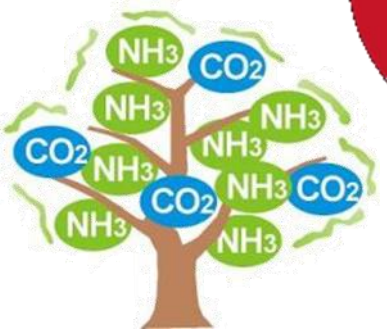

COLD CHAIN FEDERATION

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…coming soon: SEC in the Southern Hemisphere

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7th IIR Conference on Sustainability and the Cold Chain

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Thank you

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