

# Predicting annual refrigeration energy consumption in temperature-controlled facilities

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euramm<sup>o</sup>n Symposium, 4<sup>th</sup> to 8<sup>th</sup> July 2022



The **Smart** Road to  
**NET  
ZERO**

### Score your energy consumption



- › Plot your cold store's energy consumption with the Star SEC App
- › Benchmark your refrigeration system's energy usage against UK's best practice and other refrigeration plants

### Reduce energy consumption, increase reliability and remain compliant



- › Implement opportunities for improving the efficiency and reliability of your refrigeration system
- › Verify your refrigeration system is compliant with regulations and good practice

### Track progress and continuous improvement

- › Are you on track to meet or exceed 2050 Net Zero targets?
- › Are you on track to achieve your long term maintenance goals to increase refrigeration system longevity?

### Measure the performance of your refrigeration system



- › Use smart monitoring to understand the operating efficiency of your refrigeration system
- › Confirm the refrigeration system is operating in an optimised manner

### Assess opportunities for improvement



- › Evaluate corrective actions and improved maintenance requirements
- › Consider low carbon hardware and low maintenance requirements



# Background

- Increasing global energy costs
- International net zero goals
- UK energy targets in the temperature controlled storage and distribution sector to obtain discounts to the Climate Change Levy
- Refrigerant can be 70%+ of site energy consumption
- Poor understanding of performance

***‘What does good look like and how do I achieve it all the time?’***

Energy efficiency improvement – industry target versus performance under the climate change agreement



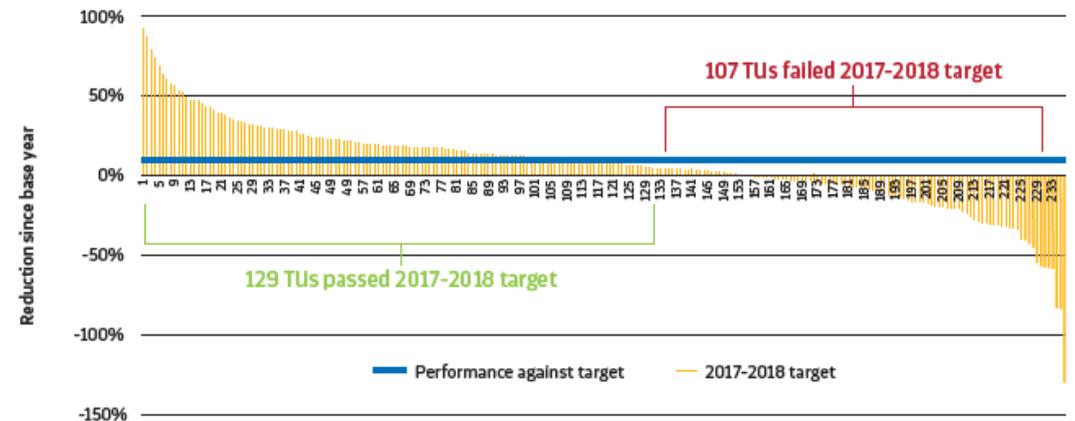
The Government set our industry a target for energy efficiency improvement by 2020 of:

**12%**

By 2018 our industry achieved an energy efficiency improvement of:

**16%**

This was across circa 400 UK cold stores.



Source: Cold Chain Federation

# Questions For A Cold Store Business

- Historic
  - How does my performance compare to last year?
  - How does my performance compare to my competition?
  - How does my performance compare to best practice?
- Future
  - 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?

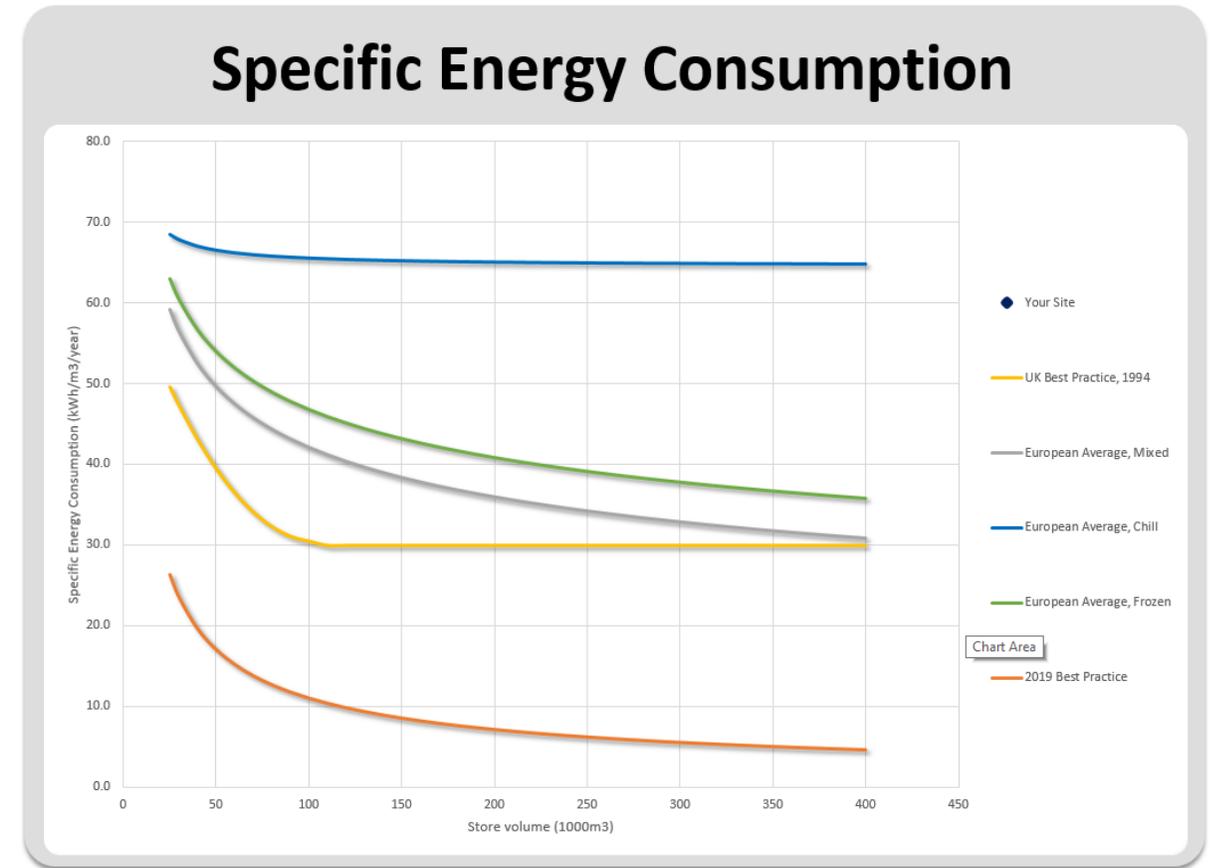
# Background

- Benchmark data available from 1994 and 2013 for Europe
- Five years study of industrial refrigeration systems in the cold storage and distribution sector
- Objectives are to understand the reason for wide variation in performance, to recommend remedial measures and to provide methods for justifying improvement activity.
- Covers different store sizes and refrigerant system types



# Lowering Operating Costs and Moving Towards Net Zero

- Reducing energy use is top priority
- There is a wide variation in energy performance for stores
- Annual performance is used at present for benchmarking
- Annual kWh consumed per year is divided by store volume to provide the annual 'Specific Energy Consumption'
- Using floor area can give misleading results due to variations in building heights
- Studies from around the world have provided useful data of current performance but also what can be achieved through modern best practice



# Benchmarking App

EE 4G 17:48 86%

Search



## SEC Calculator

Star Refrigeration SEC Tool

GET



AGE

4+

Years Old

CATEGORY



Business

DEVELOPER



Star Refrigeration

### Energy Details

Enter your plant details below



### Result

View Comparison

Chill

Store Volume  
100000 m<sup>3</sup>

1 ft = 0.305m | 1 ft<sup>2</sup> = 0.0929m<sup>2</sup> | 1 ft<sup>3</sup> = 0.0283m<sup>3</sup>

Energy Consumption  
3050000 kWh/year

Electricity Cost  
0.15 £/kWh

Refrigeration Related Consumption  
% of stated consumption relating to refrigeration

90%

### Energy Performan



Your Site, Baseline

European Average, Chill

Potential S

## Energy Details

Enter your plant details below



## Result

View Comparison



## Result

View Comparison



## Result

View Comparison

Share PDF

Chill

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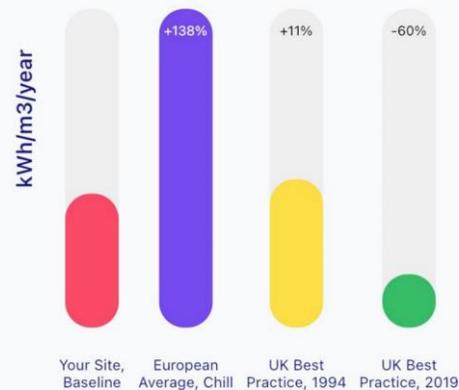
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Refrigeration Related Consumption  
% of stated consumption relating to refrigeration

90%

GO

## Energy Performance Calculator



## Potential Savings

Potential savings for your site versus current best practice



## Savings Comparison

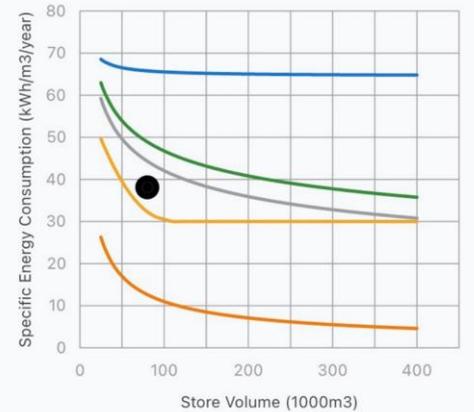


\*European Average based on Evans et al. (2013). 'UK Best Practice' 1994 based on ETSU UK (1994). UK Best Practice 2019 based on Pearson (2019) for a modern, well managed facility. CO<sub>2</sub> equivalent conversion factor 0.2831kgCO<sub>2</sub>e/kWh, per UK gov guidelines.

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## Specific Energy Consumption

- Your Site
- European Average, Chill
- UK Best Practice, 1994
- European Average, Frozen
- European Average, Mixed
- 2019 Best Practice



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# Factors Affecting Specific Energy Performance

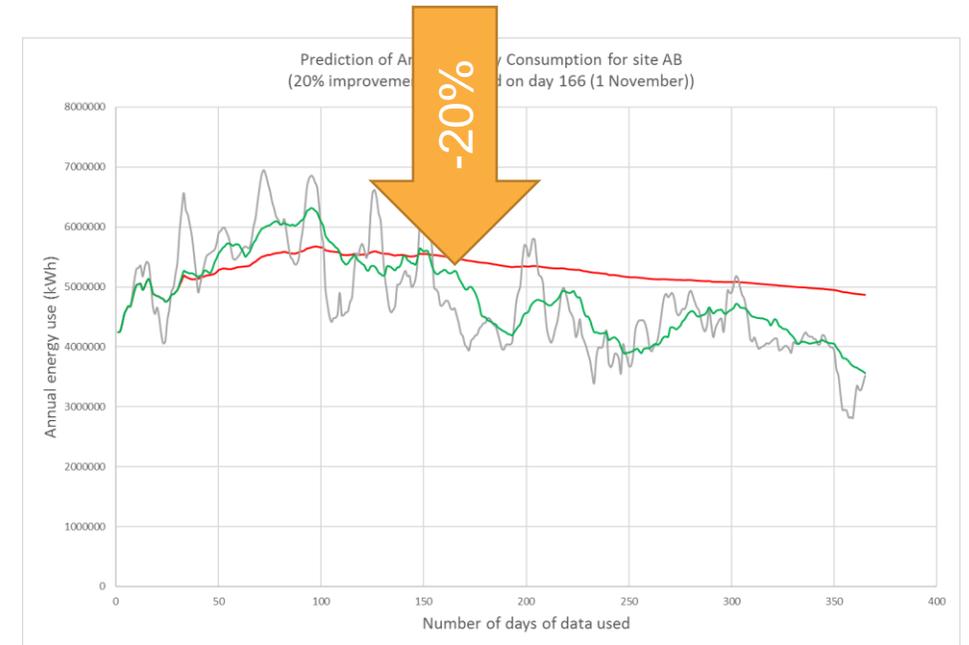
- Building utilisation – how busy is it?
  - Can product throughput be measured and correlated to energy?
- Weather – how hard does the system have to work to reject heat?
  - Moisture ingress
  - Solar gain
  - Heat rejection temperature
- Fabric condition – how good is the building at stopping heat 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?

# Refrigeration Factors Affecting Energy Consumption

- Applying a change to the refrigeration system can affect energy consumption. Examples include:
  - Replacement of a component (e.g. compressor, condenser)
  - Adding variable speed drives
  - Retrofitting the control system
  - Adjusting a setpoint
  - Cleaning heat exchangers (e.g. air coolers, condensers)
- There may also be a change of use or operator behaviour (e.g. store temperature, door operation)
- When a change occurs it is important to understand the effect of the change on SEC quickly
- If not, the reason for change is forgotten or other changes will be implemented which will mask the effect
- The ability to assess future SEC helps identify when an adverse change occurs and enables corrective action to be taken before the financial impact becomes too severe

# Assessing SEC – Daily Prediction

- Future prediction is as dynamic method of performance tracking based using historic data to trend 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



# 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

# Using SEC For Business

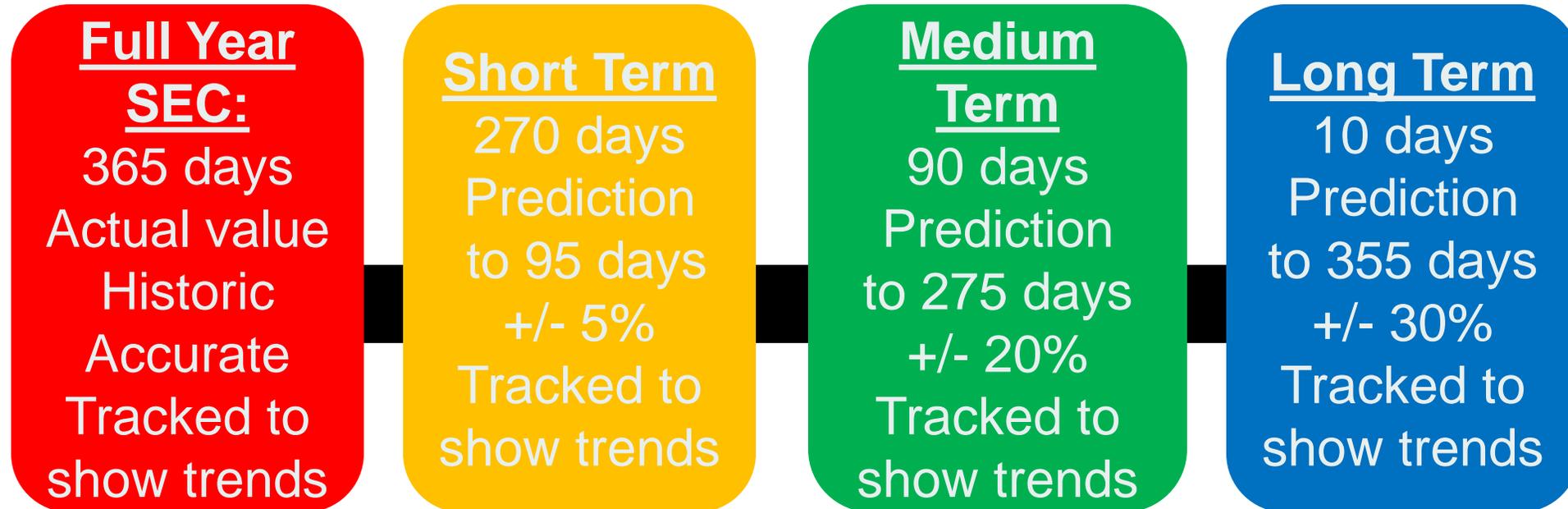
SEC prediction can help to control business operating costs, but there is a balance:

**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  
 $\pm 30\%$ \*

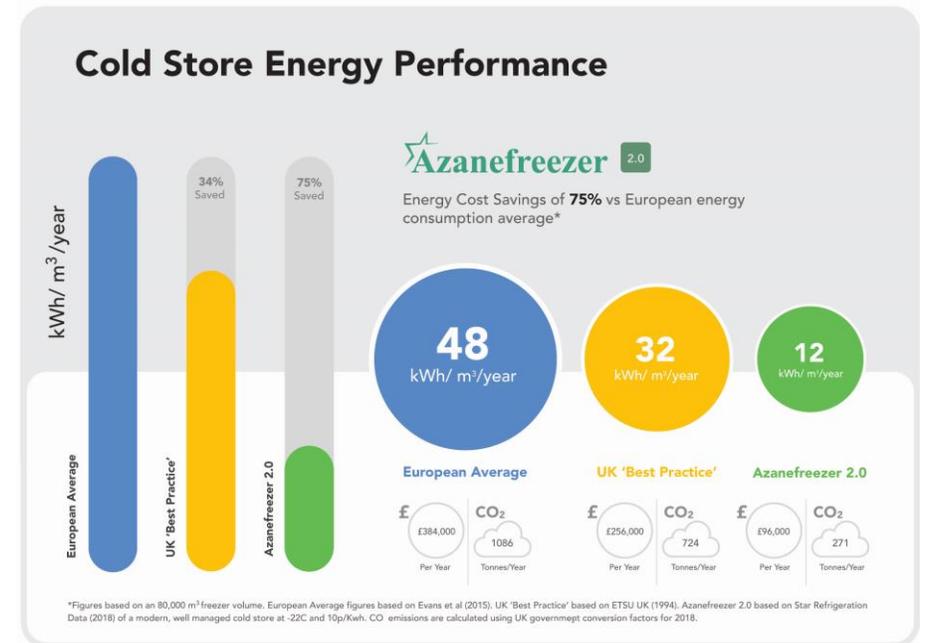
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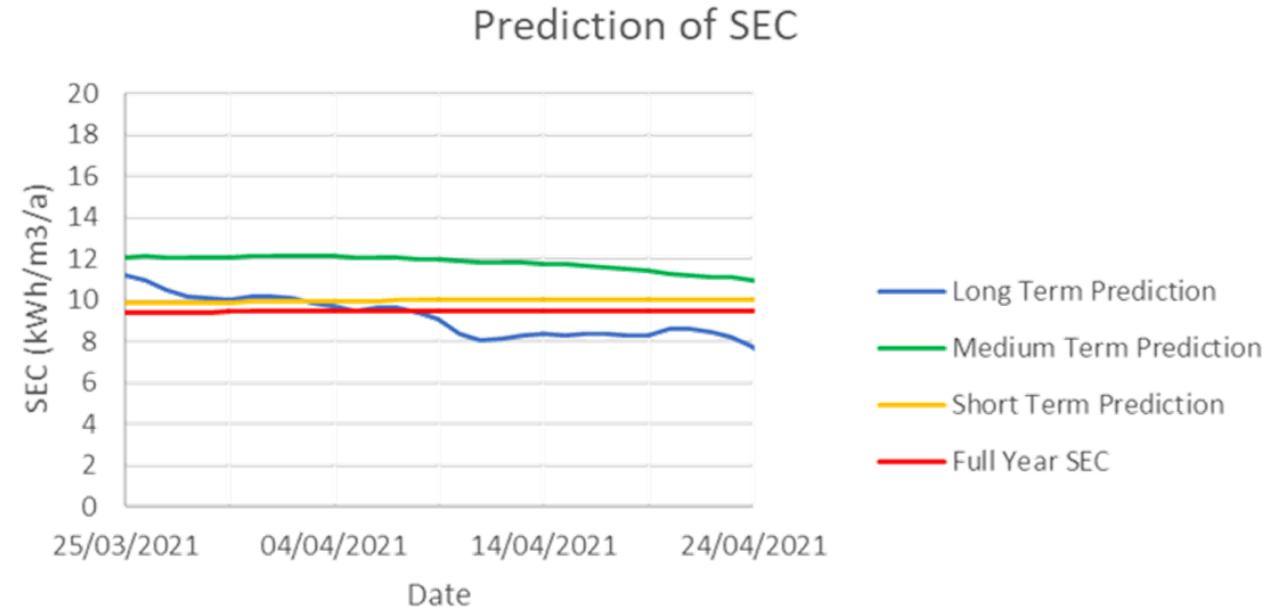
# Case Study – UK Cold Storage Facility

- 81,000 m<sup>3</sup> cold store @ -22°C
- Two low charge ammonia packaged systems
- Daily energy data taken from 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



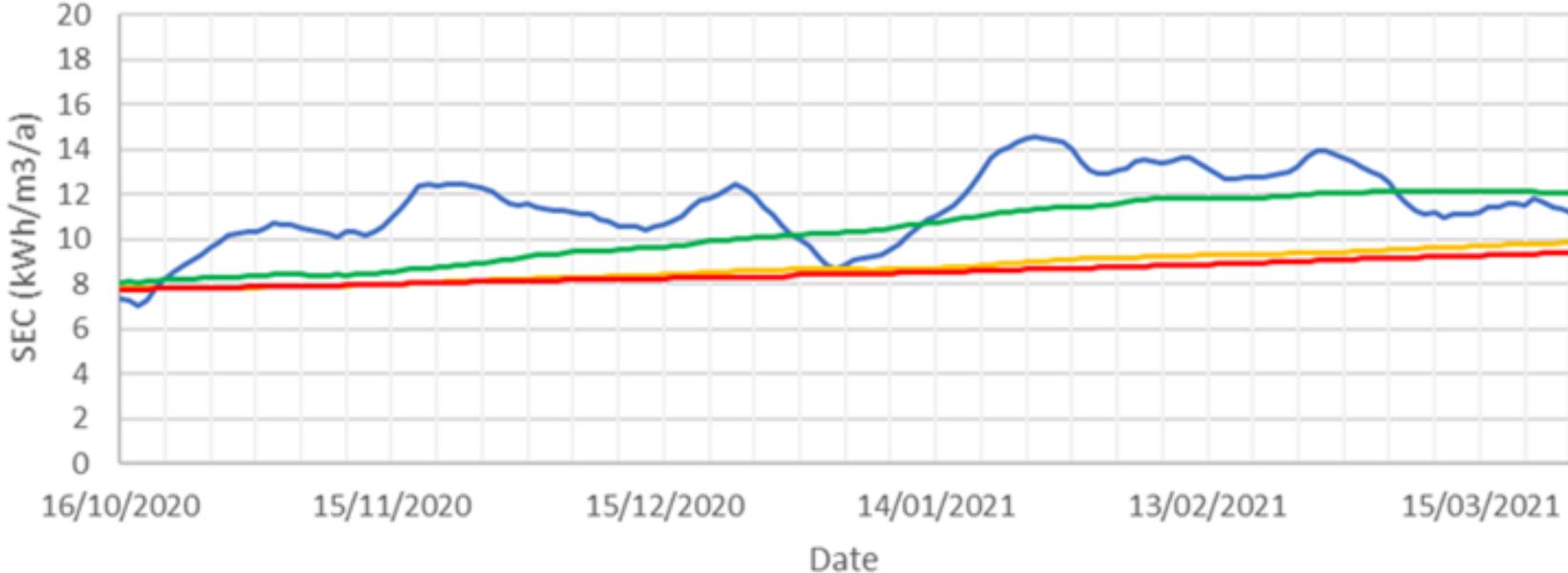
# Case Study – UK Cold Storage Facility

- 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 – UK Cold Storage Facility

Prediction of SEC



# Case Study – UK Cold Storage Facility

SEC on 5 Oct 2020  
**7.78**

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

Predictions  
Long Medium Short  
7.18 8.06 7.81

One month later...

SEC on 5 Nov 2020  
**7.91**

The long term prediction is now the highest

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

Predictions  
Long Medium Short  
10.48 8.41 7.89

Six months later...

SEC on 24 April 2021  
**9.46**

The medium term prediction is now the highest

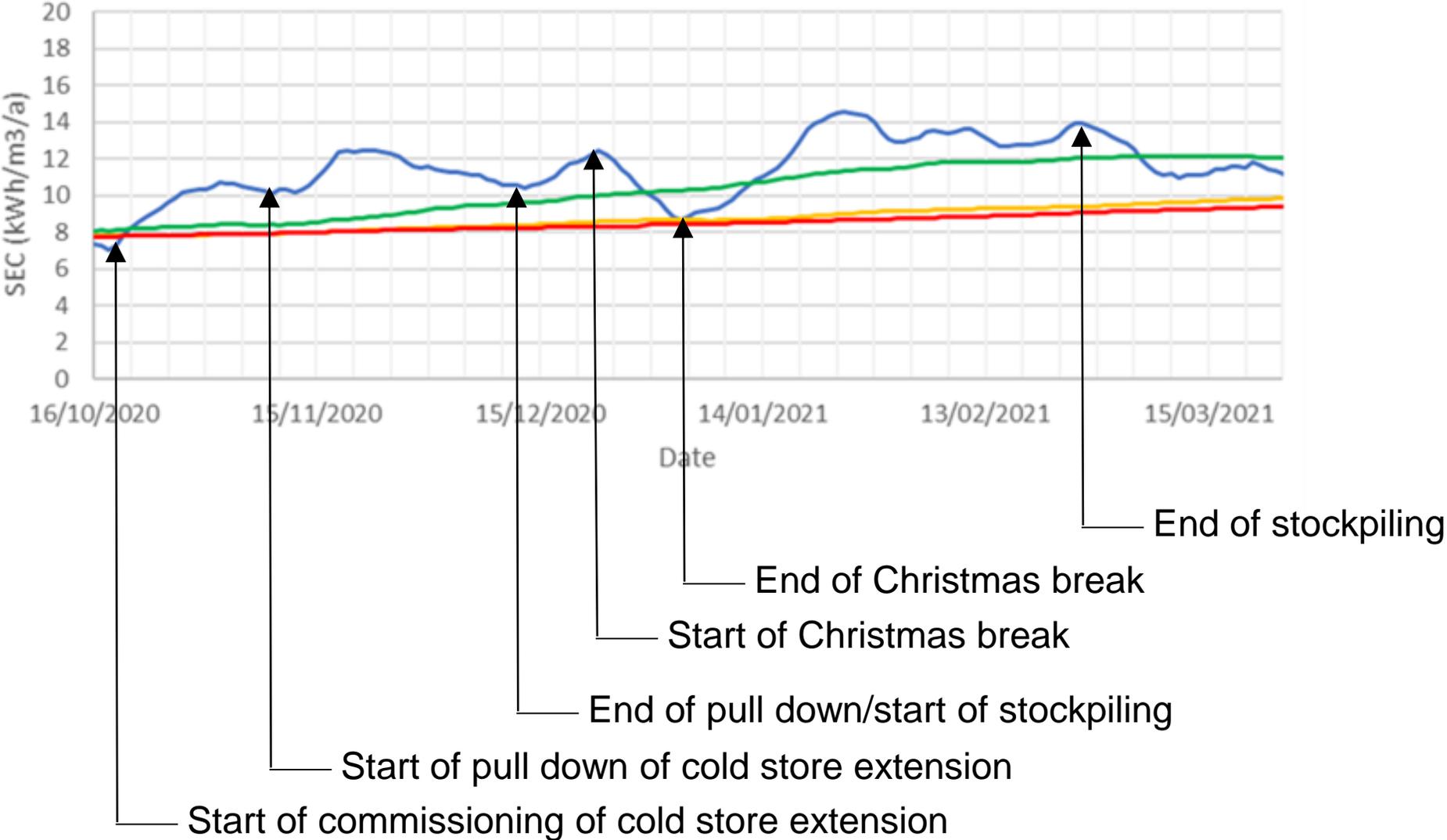
The change was temporary and the long term trend is downwards again

Predictions  
Long Medium Short  
6.94 10.98 10.04

This still has to work through to the medium term prediction

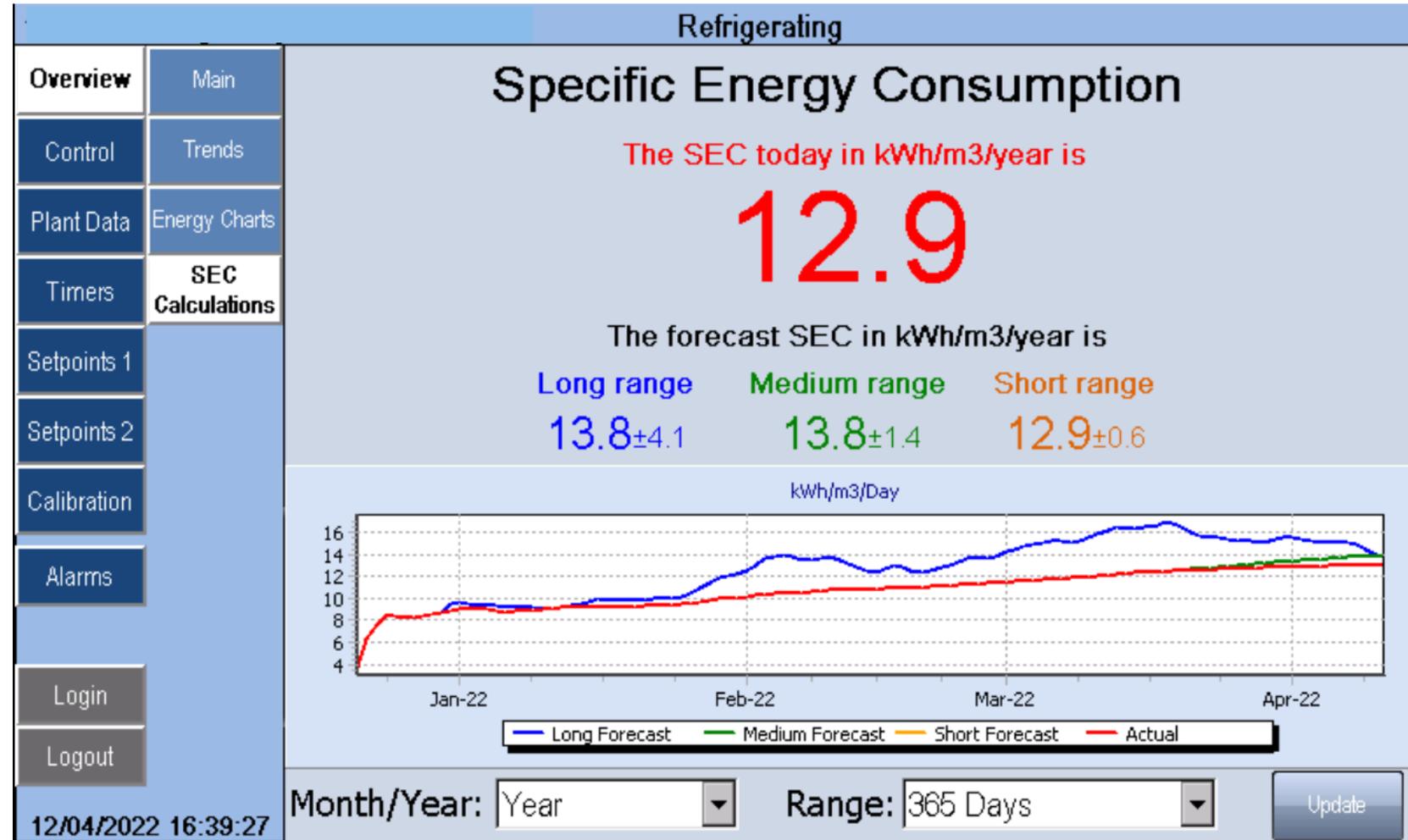
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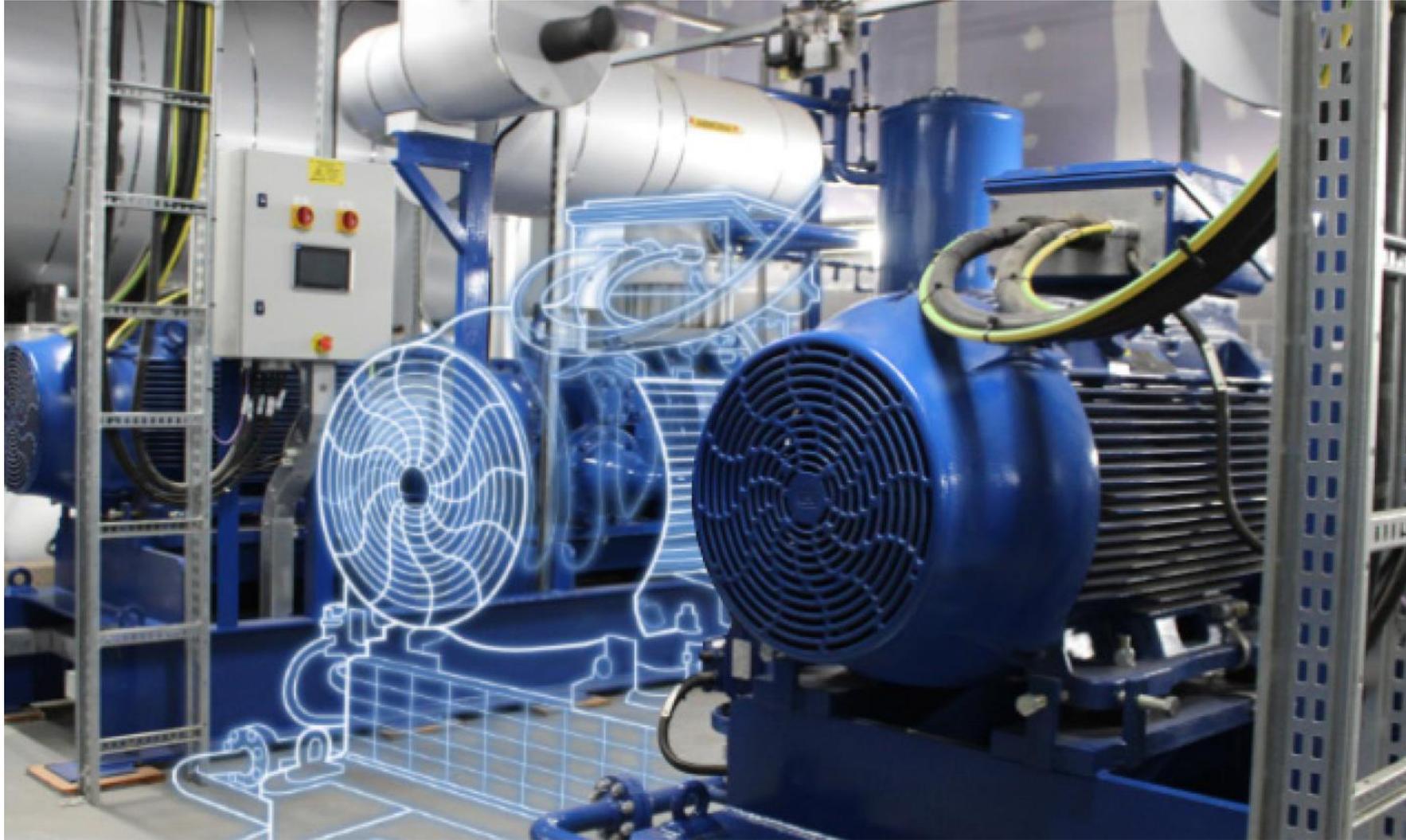


# Case Study – UK Cold Storage Facility

- 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



# Digital Twin - Detailed Plant Analysis



# Digital Twin – Methods of Data Collection



A standalone datalogger and set of sensors is installed



Data the client already has is sent on to the Ethos system



Data is taken from the existing PLC using a NUC

# Digital Twin – Remote Monitoring and Analysis

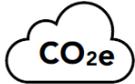


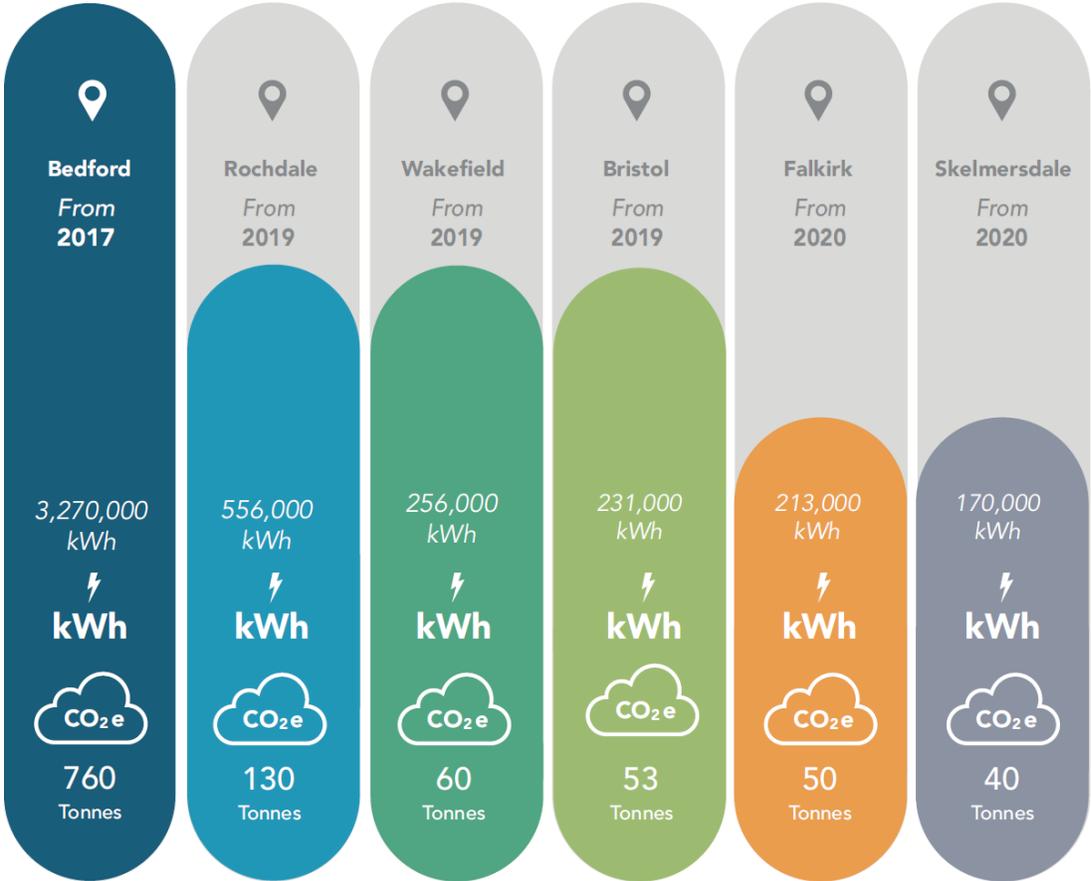
# Case Study – ASDA Distribution Centres

## Ethos Energy and Carbon reduction for ASDA

Total Savings:

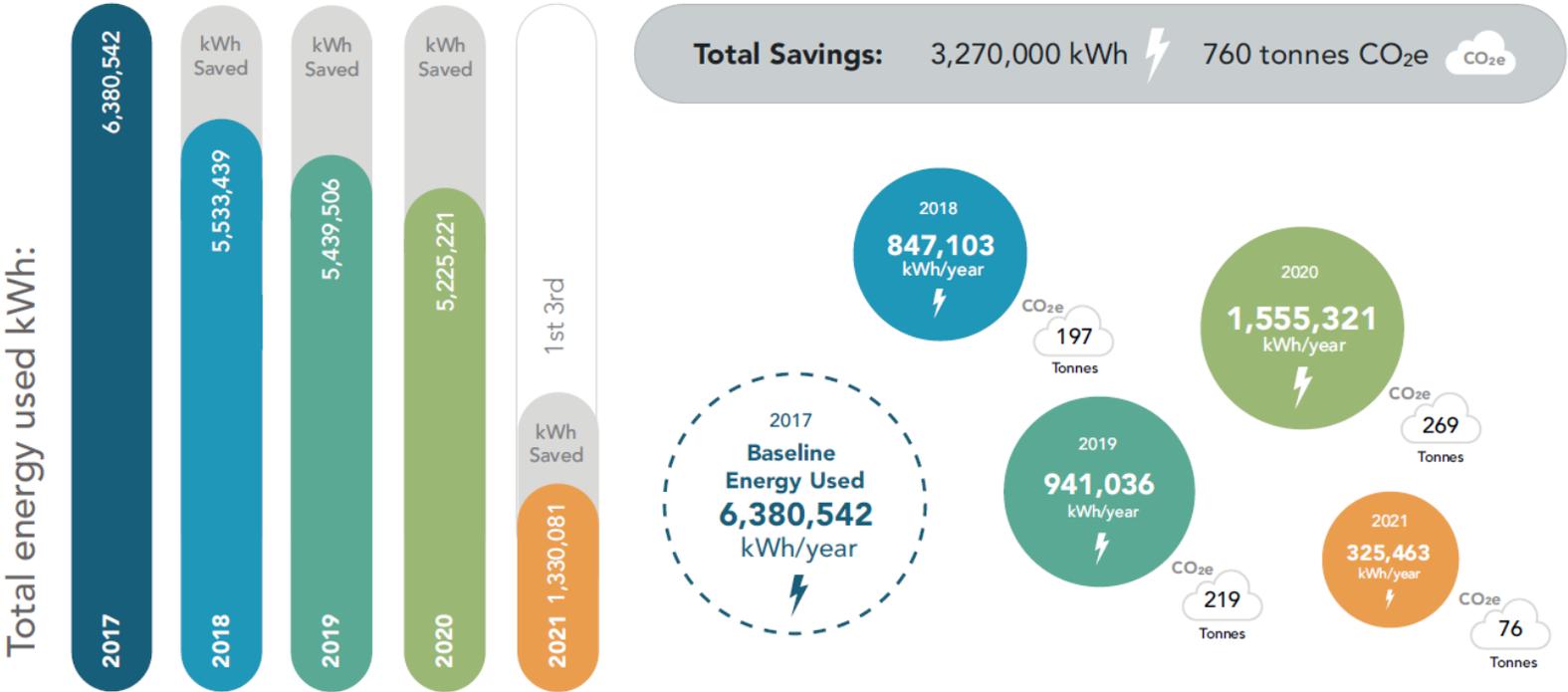
  
**4,696,000**  
 kWh

  
**1,093**  
 tonnes CO<sub>2</sub>e



# Case Study – ASDA Distribution Centres

## ASDA Bedford



\* Energy savings measured from January 2018 and referred to 2017 energy consumption. Energy costs represented at an indicative industry averaged of 12.5p/kWh. Emissions based on 0.23314 kg CO<sub>2</sub>e. <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020>.

# 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.
- Creation of a digital twin can further enhance energy savings by highlighting where performance has drifted from design and suggesting improvements

**eurammon e. V. is always available as a sparring partner for questions on refrigeration with natural refrigerants.**

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