Machine Learning drives Automated Fault Detection and Diagnostics for predictive maintenance of HVACR

Chillventa Specialist Forums 2024
Chillventa Fachforen 2024

CONNECTING EXPERTS.

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ClimaCheck – optimise and increase reliability

1 Unique Thermodynamic Method

Based on natural laws, shows efficiency at the component level.

More than 100 man-years of experience.

2 Supplies necessary information

A prerequisite for predictive maintenance.

From inspections to 24/7 integrated monitoring.

3 System Efficiency Index (SEI)

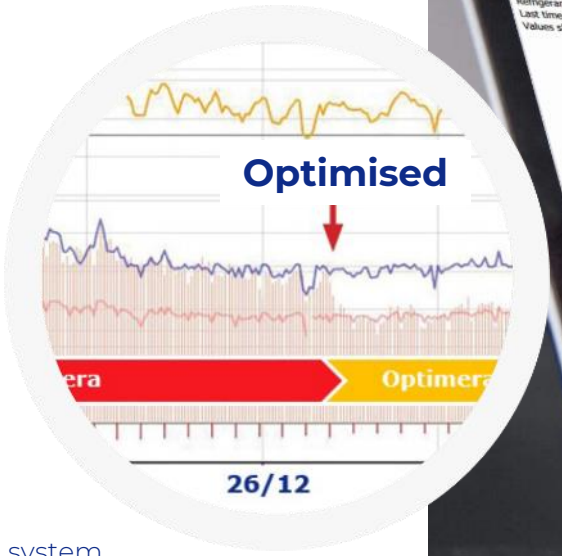
The same KPIs for all systems that do not change continuously as COP, SCOP, SPF, kW/RT.

4 Unit/System Stability

Easy to detect problems and disturbances from external system

5 Refrigerant

Indirect leak detection.



More than a thousand systems monitored 24/7

ClimaCheck

- **Unbiased data on all systems and all continents**
- **All refrigeration, air conditioning and heat pump applications**
  - Office buildings, Hospitals, hotels, Malls
  - Data centers – Chiller, Crac units
  - Industrial refrigeration
  - Supermarket
  - Used by more than 50 OEMs – including Trane, Carrier, JCI
- **Integration in third party platforms or stand alone**

Unbiased method that opens the “black box”

Performance of 60% of energy consumption overlooked

Scheduled maintenance

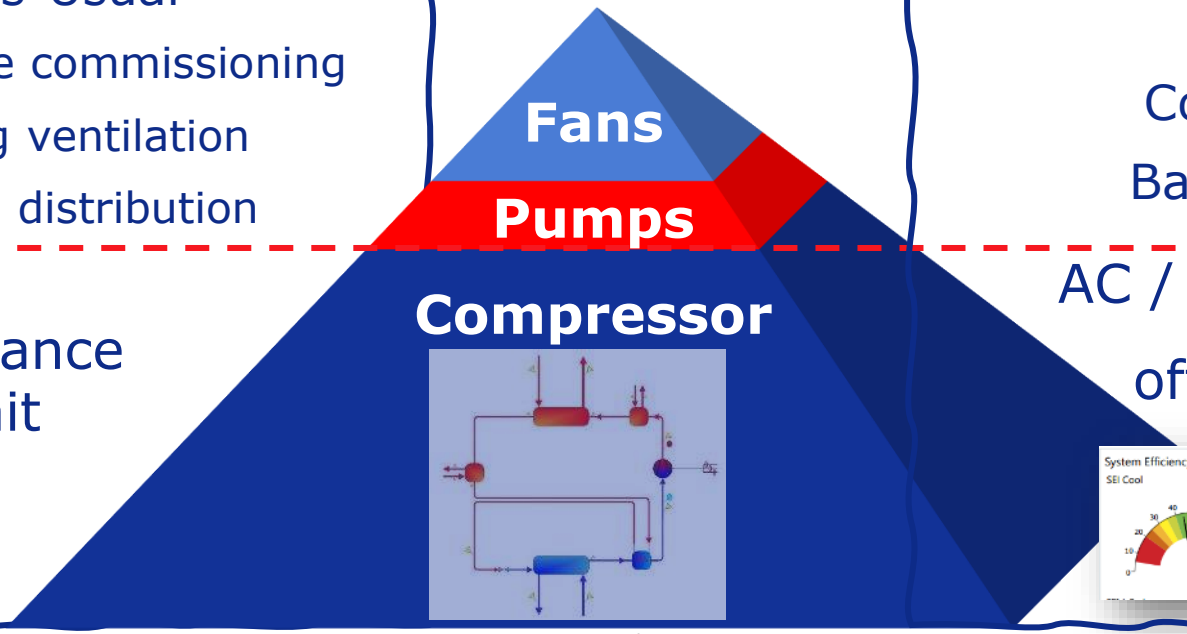
“Business-as-Usual“

Best case - one time commissioning

Initial balancing ventilation

Initial balancing distribution

Performance in unit



Predictive maintenance

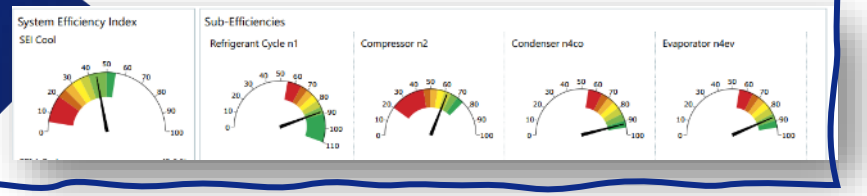
New paradigm

Continuous commissioning

Based on 24/7 performance

AC / Heat Pump /Refrigeration

often use 60% of energy



BCA Green Mark Platinum (peak building cooling load > 500 RT / 1700kW

Measure and Analyse → Verification → Monitor

The ClimaCheck Method

- **100 man-years of experience**
- **Unique method based on thermodynamic**
  - Performance on component level
- **Enables predictive maintenance, AFDD**
- **Result in energy optimisation**
  - 10-30% savings potential

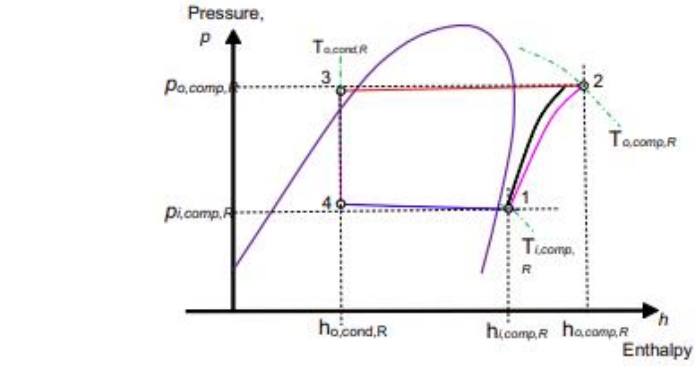


Figure 5.1 The refrigeration process in a diagram of specific enthalpy versus pressure.

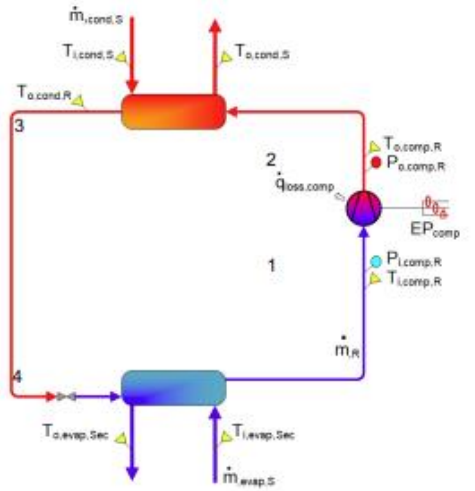
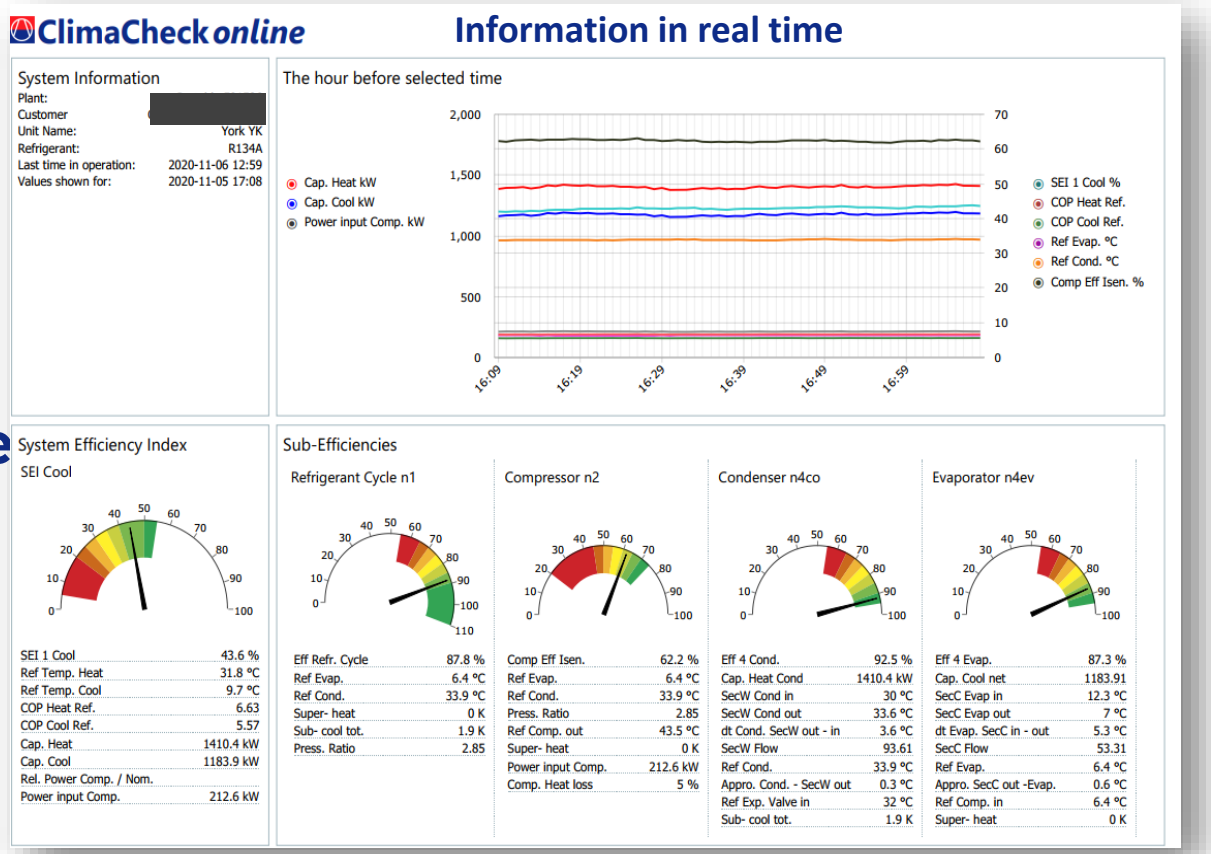


Figure 5.2 Measurement points, (number 1, 2 and 3 according to Figure 5.1) for the internal method (COP).

Dashboard with all KPIs

- Same information as test-rigs
- Performance on component level
- Enables predictive maintenance
- Early warning on any performance
- Pin-point problem when it occur

> Planned actions before problems



Complete service information

All KPIs monitored every minute

The Internal Method – add new information

Automated Fault Detection and Diagnosis

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Unique to pinpoint problem to component that cause it.

		Lennox Prodigy	Carrier WeatherExpert	Trane Precedent, Reliatel, Intellipak	York Simplicity SE, Predator	Switch Automation	ClimaCheck	ECore	Ezenics AFDDI	Honeywell Jade	Pelican Wireless Pearl	Johnson Controls Simplicity SE	Virtjoule	XCSpec Economizer Pro	Transformative Wave eIQ
	Other					*							*		
Diagnostic Capability Level	1–4, according to NREL categorization	2	1	1	1	2	3	2	1	1	1	1	1	1	2

Diagnostic Capability Level (NREL)*

* NREL, National Renewable Energy laboratory under US department of Energy

Automated energy signatures to detect deviations

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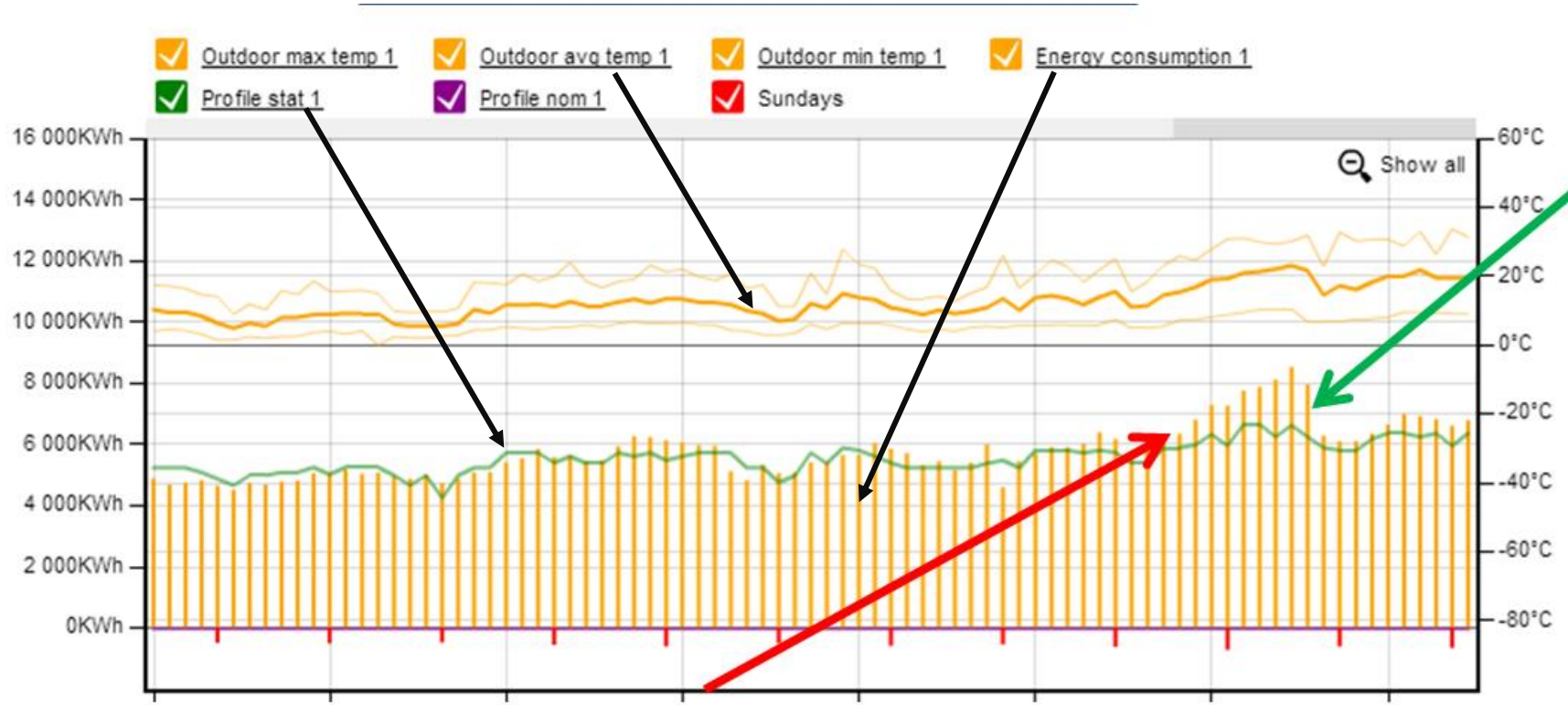

Detection And Repair

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German Energy Agency, dena, push benchmarking

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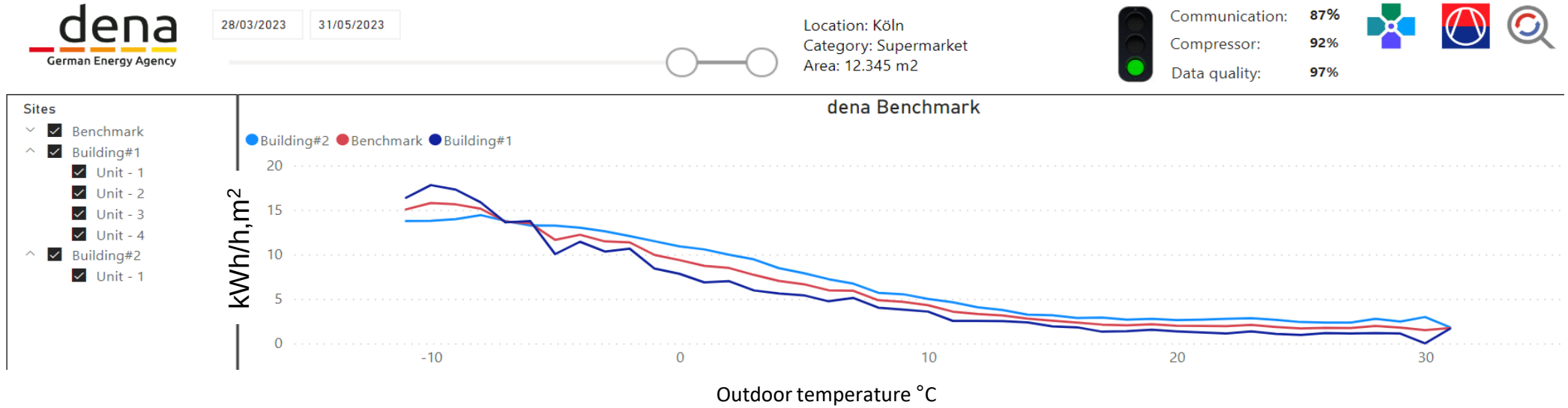
A. **Energy signature = average consumption at each outdoor temperature**
   > Benchmark regardless of location

B. **Normalisation on e.g. m²**
   > Benchmark" regardless of size

C. **Categorisation makes benchmarking relevant e.g. supermarket, hotel, office building +++**



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Two master thesis on Machine learning

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- **Mater thesis**
  - At Division of information Science and Engineering at KTH
  - At Department of Energy Technology at Royal Institute of Technology
- **Digital Twins integrated in next release of ClimaCheck online.**

- **R&D continues in project financed with 400 000 Euro by Swedish Energy Agency with research partners Rise and Halmstad University.**

Digital Twins (ML) will drive the change to AFDD

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- **Automated Fault Detection and Diagnosis**
  - Air condition, refrigeration and heat pumps
    - Often the largest energy user
    - Highly dynamic systems
    - Are assumed to work well if it cools/heat to the right temperature – **not true!**
  - Traditional service – scheduled service – alarms
    - Service visits are not documenting performance
    - Alarms come to late – system has failed or goods/room is out of acceptable range

Systems behaviour predictable by Digital Twins

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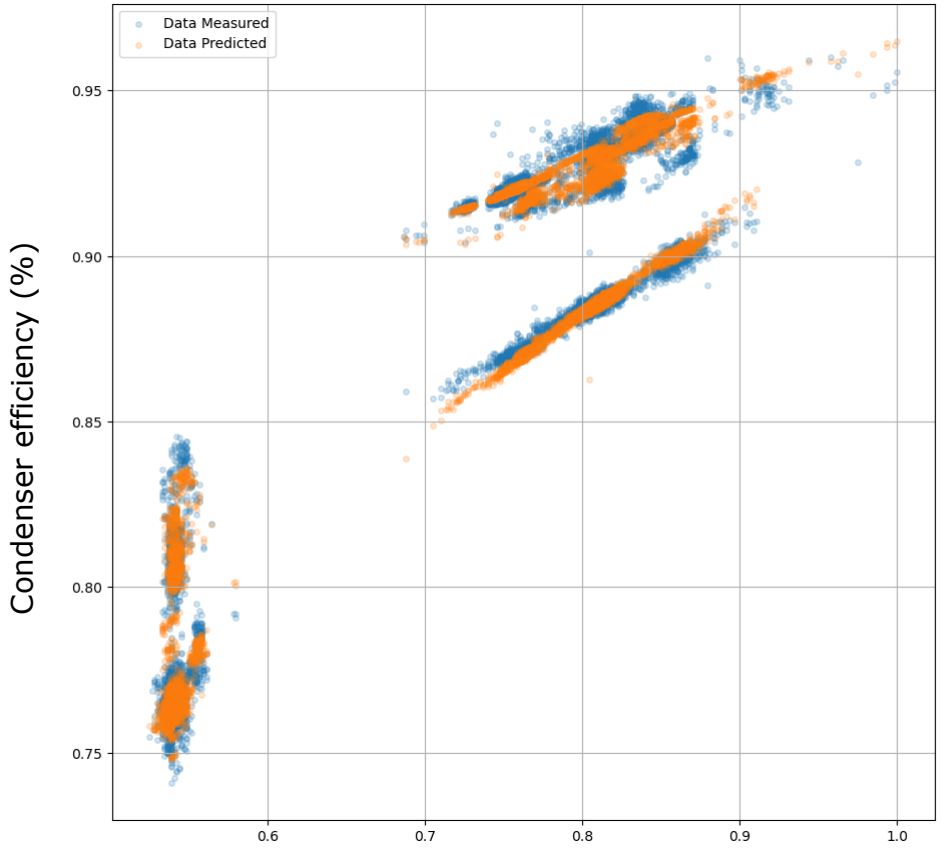
- **Blue is measured performance**
- **Yellow is predicted performance from Digital Twin – new level of AFDD**



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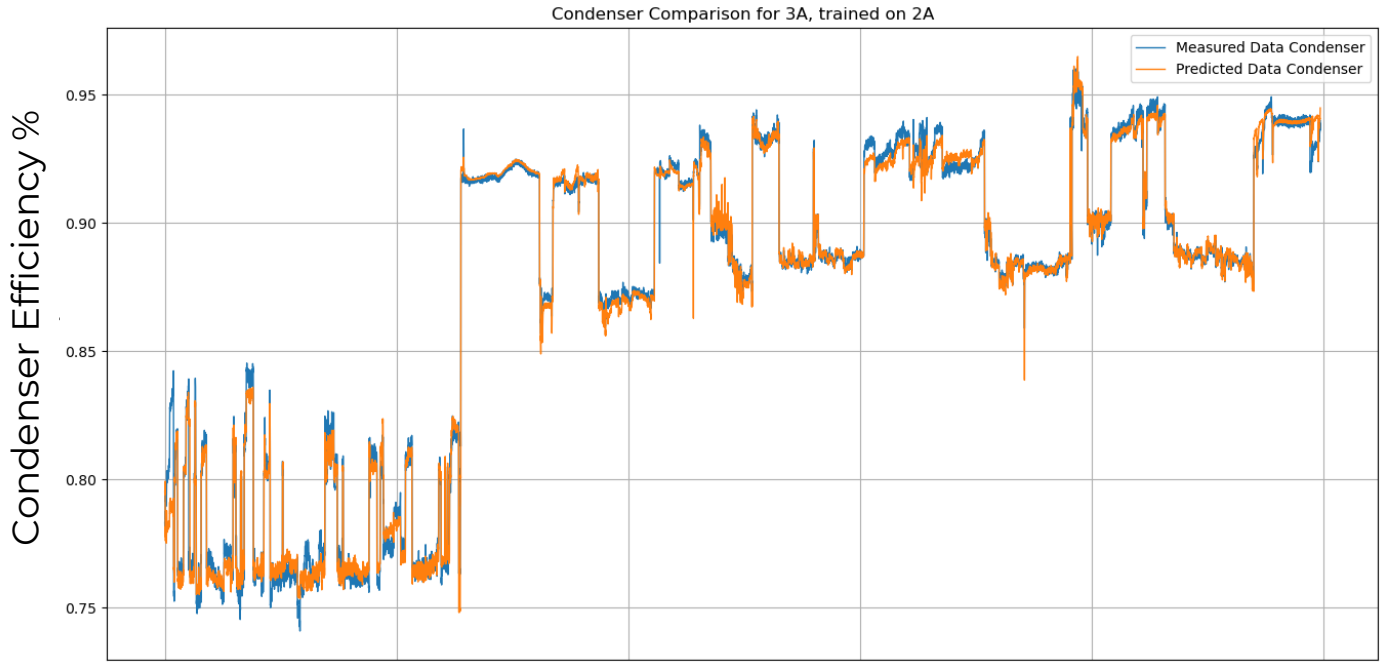
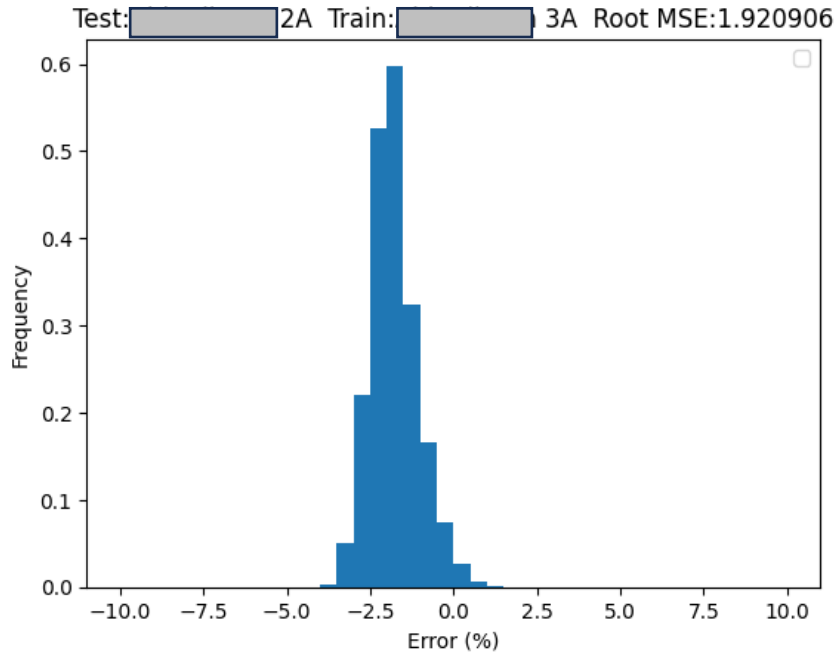
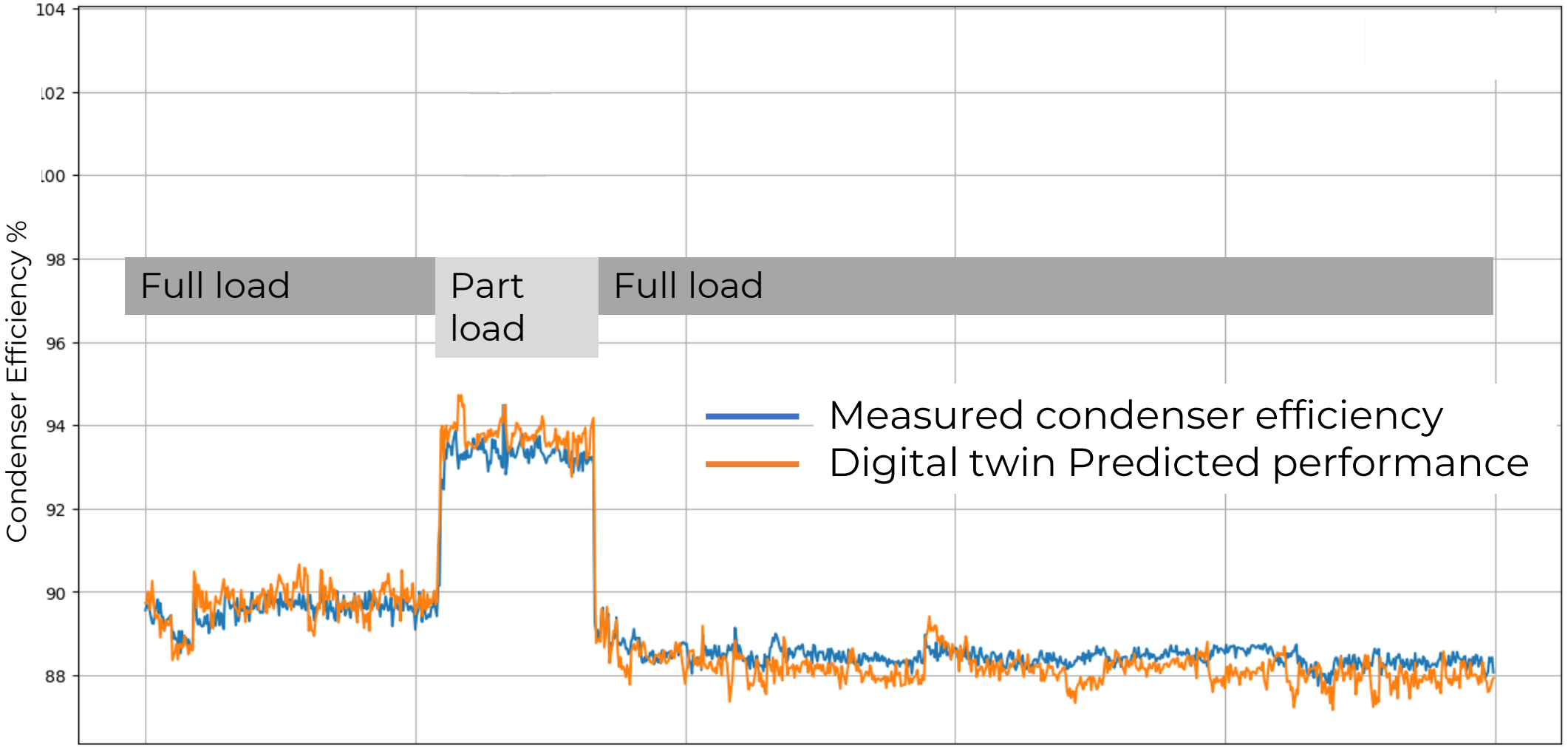
ClimaCheck has proven that Digital twins works

- ClimaCheck has a unique market position by combining data collection from thousands of systems over more than 15 years using unique method and digital twin ML technology.
- We can generate performance predictions for all types of HVACR systems.
- Enables effective predictive maintenance with AFDD (Automatic Fault Detection & Diagnosis)



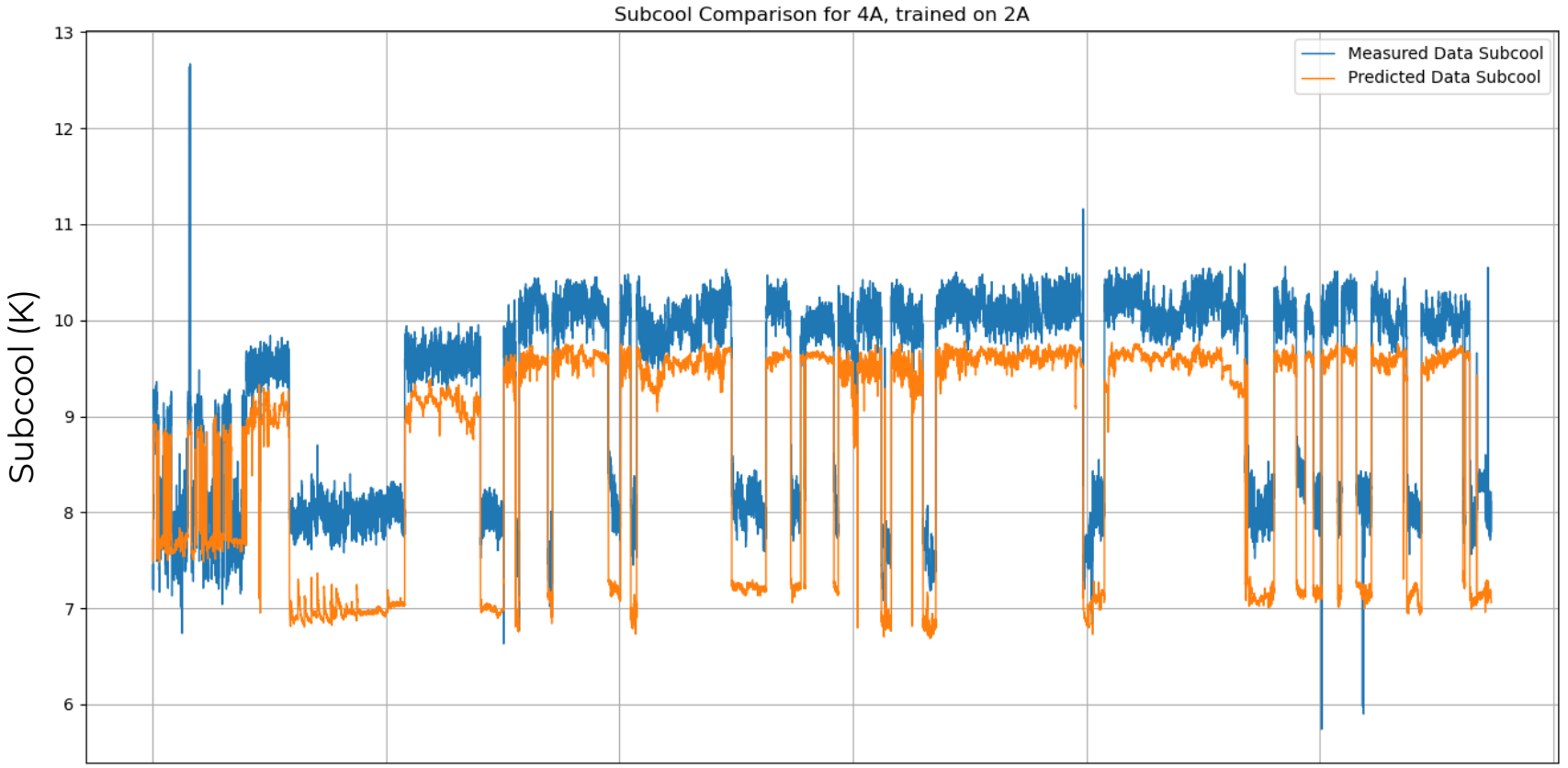


Machine learning (AI) makes AFDD more efficient



Automated AFDD minimise engineering hours and improve accuracy

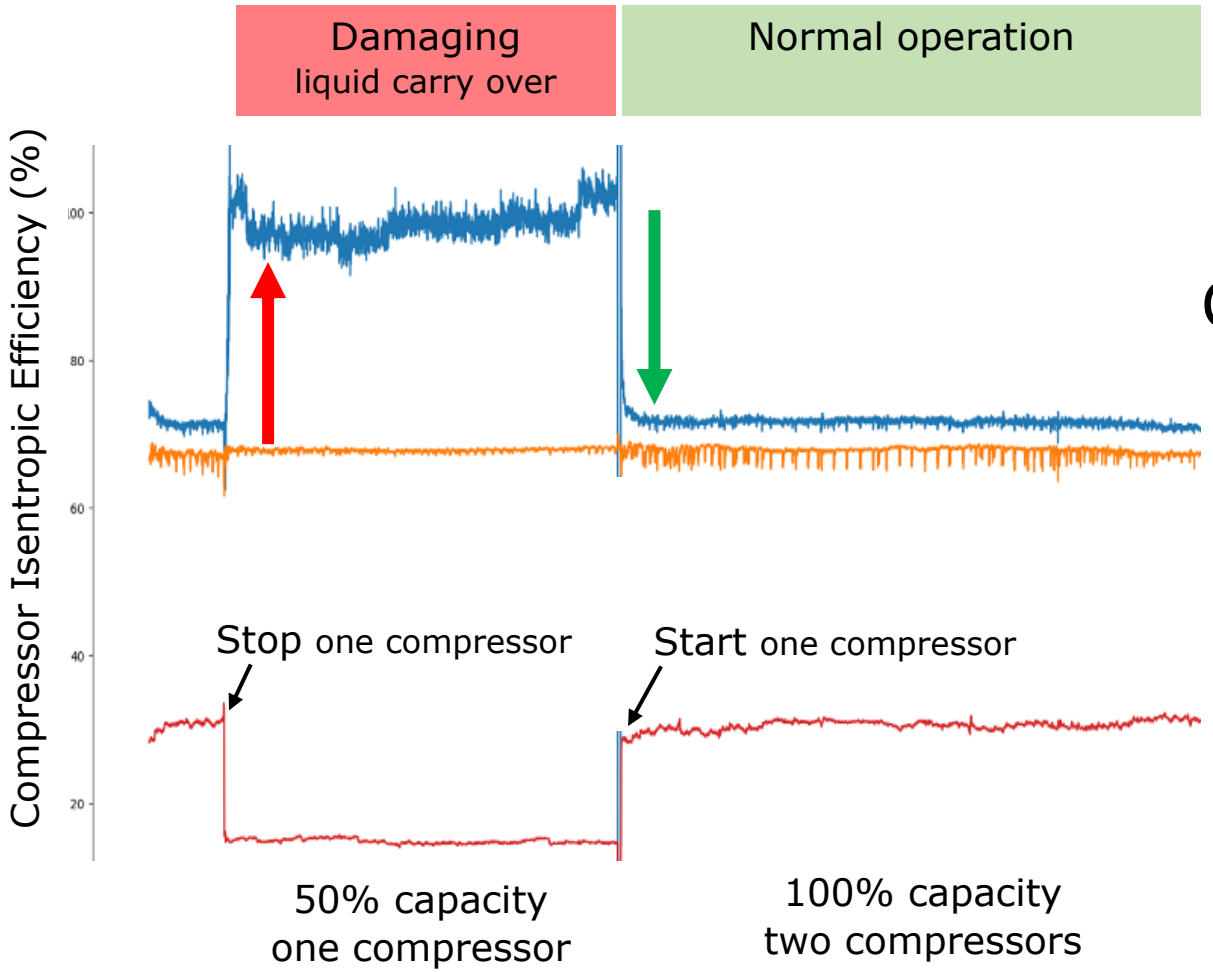
Subcool measured slightly more charge than twin



Refrigerant charge defines subcool and is key for reliable efficiency.

Monitoring changes versus Digital Twin is one indicator for indirect leak detection.

Detected damaging liquid carry over to compressor



Compressor efficiency

Blue is measured efficiency
Orange is digital twin prediction

Electrical Power

Comparison SEI two designs for same application

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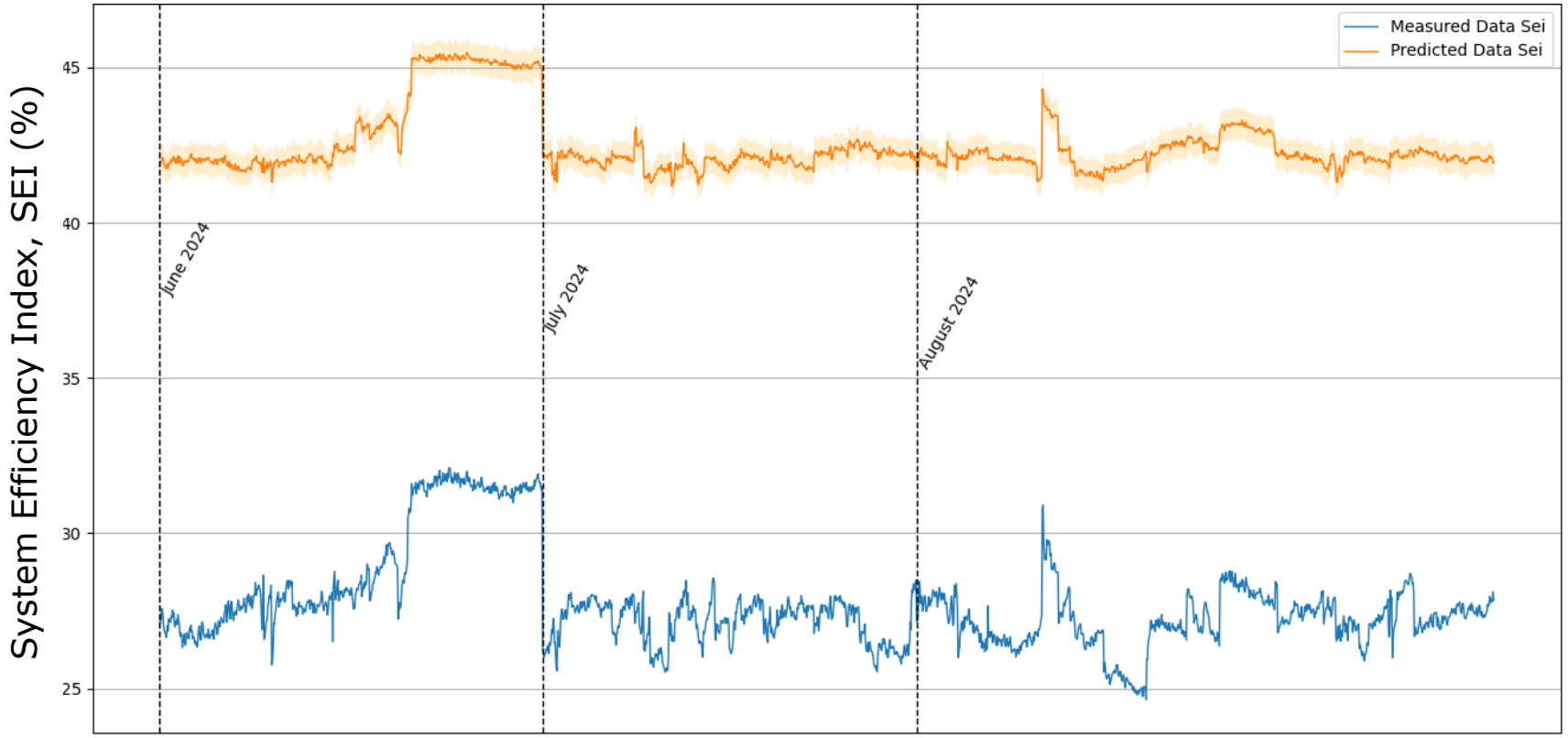

High efficiency

Low efficiency
+50% energy

Predicted is Digital twin at identical conditions of the measured system

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141 586 kWh saving May-August 2022 = >50%

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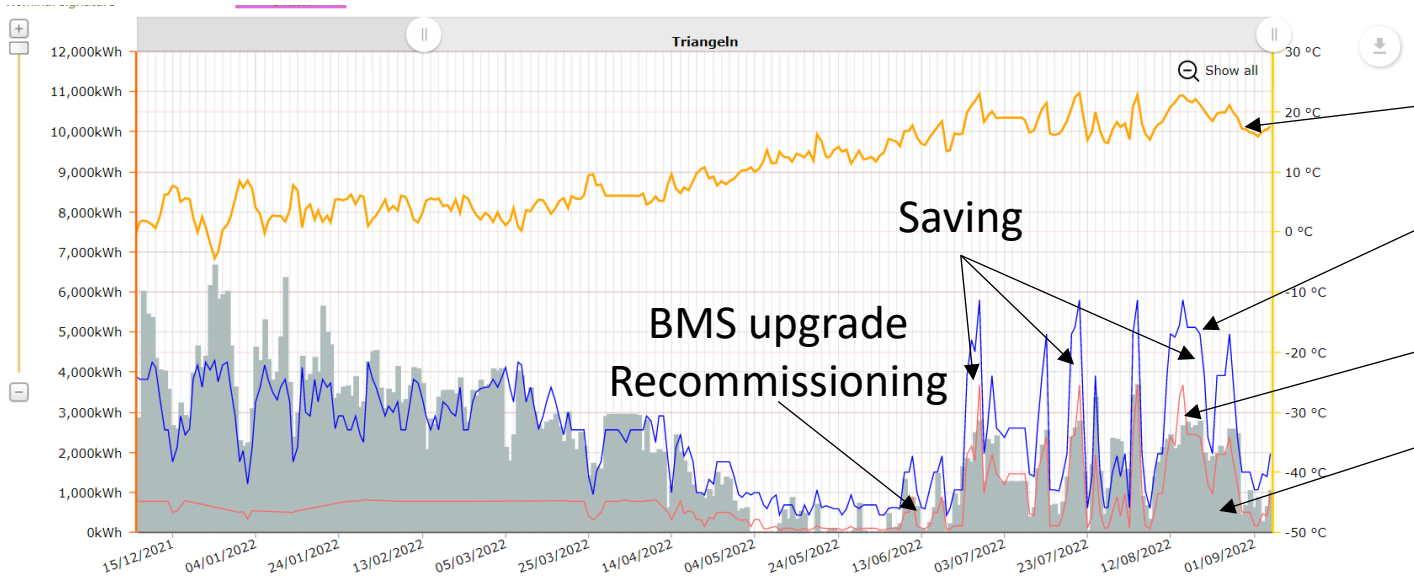
	Baseline energy signature (blue line)	Energy consumption post (grey bars)	Difference in comsumption
May	25 974 kWh	6 027 kWh	-19 947 kWh (-77%)
June	61 403 kWh	25 389 kWh	-36 014 kWh (-58%)
July	82 008 kWh	46 444 kWh	-35 564 kWh (-43%)
Aug	111 042 kWh	60 981 kWh	-50 061 kWh (45%)
Total	**280 427 kWh**	**138 841 kWh**	**-141 586 kWh (-50%)**



Graph 12 months (24 hour values)

Yellow line = ambient temperature

Blue line = expected consumption with baseline performance

Red line = Post measure energy signature

Grey bars = compressor energy per 24 hours

No change of equipment!
No compressor alert after

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Important and new information of operation

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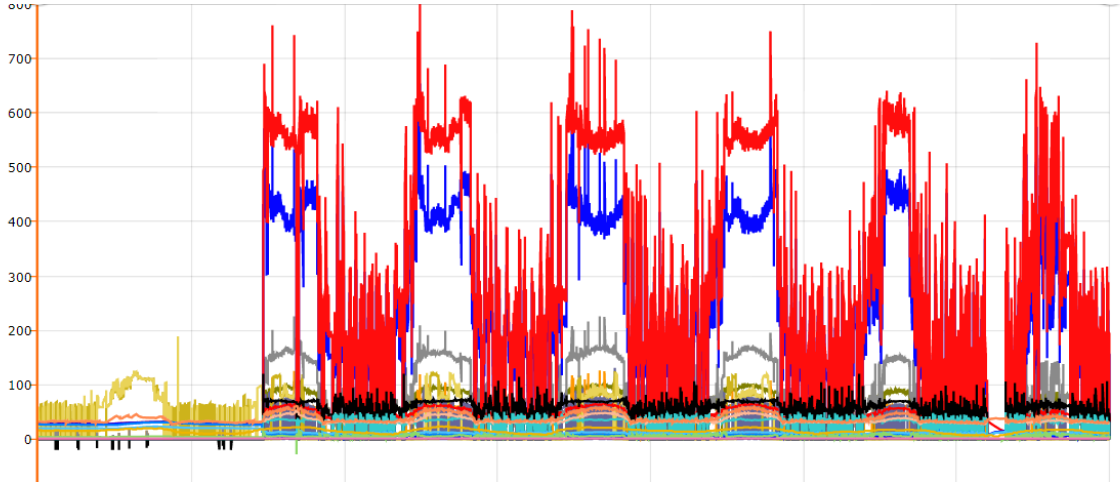
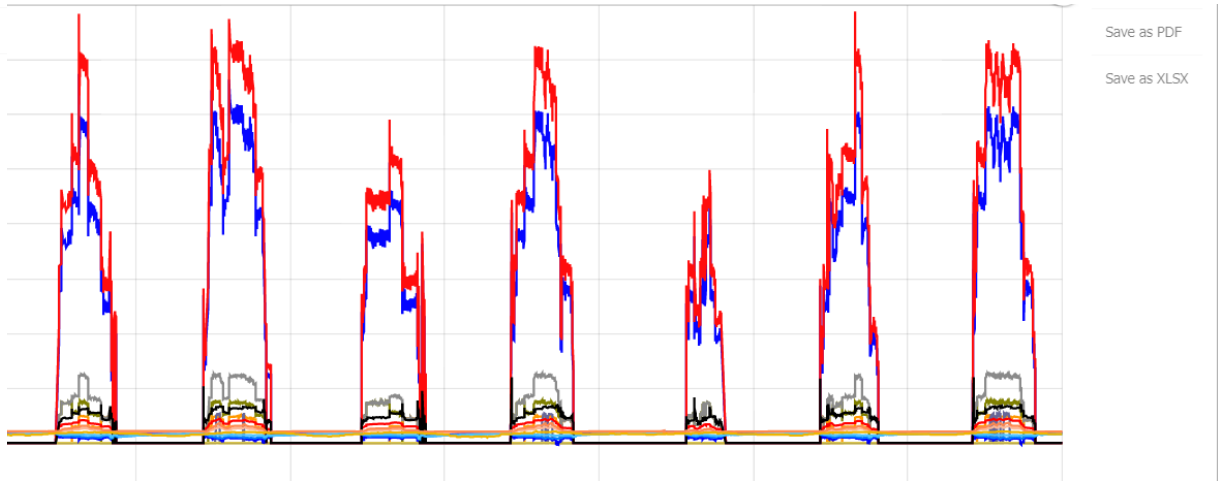
Before



After



Controls stabilised – **no more tripping** of screw chillers

Red – heating capacity

Blue - cooling capacity

Grey - power

Peak shaving – Smart grid - IKEA Uppsala, Sweden

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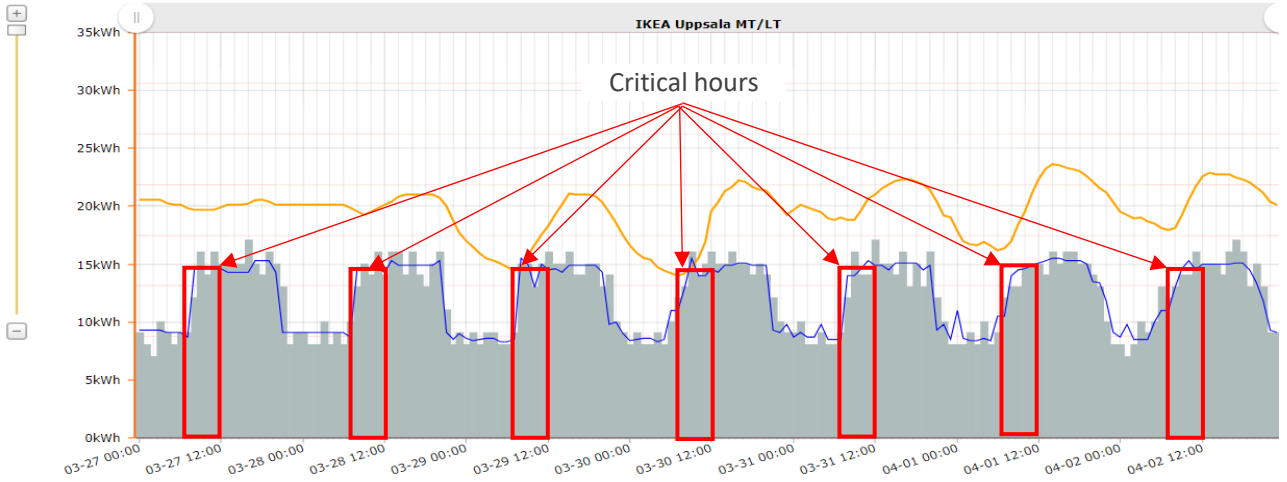
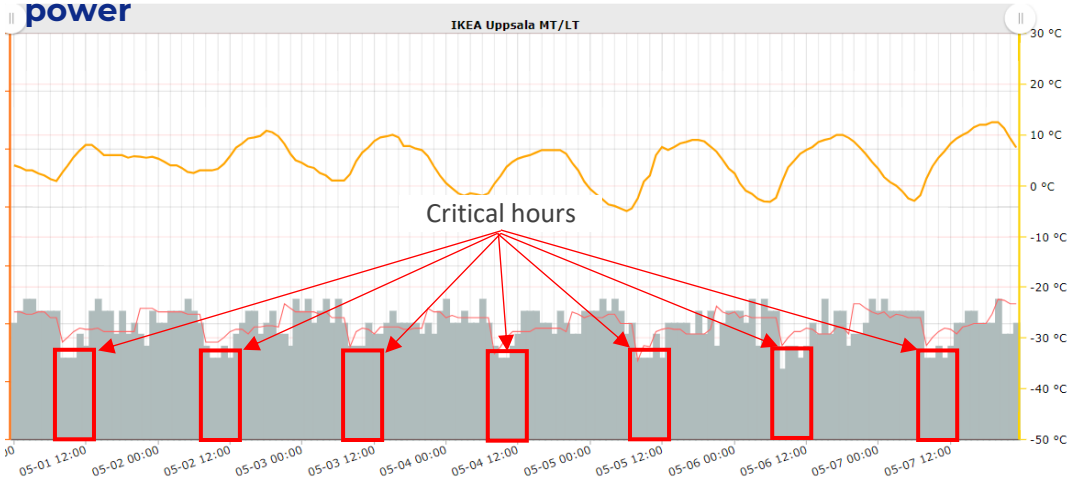
Baseline Basic optimisation done



Result of Adjustment of setpoints/control of maximum power



Result: 50% power reduction during critical hours
Consumption was moved to nighttime with lower energy prices and power tariff for peak load hours are reduced.
Considerable energy saving, because of higher COP when cooling produced at night when colder outside.
Performance optimisation ~20%

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Banner Health – 10 Hospitals of 25 hospitals

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VALUE DELIVERED (Phase I, 4.2M ft2)

– $3.8M annual savings

– 14M kWh annual energy savings

– Exceeded estimates by ~$1M

Continuous work with fault detection on chillers stops performance drift

- In the last 6 months alone, 24 issues have arisen that typically reduce chiller efficiency by 10% to 15%. However, some issues have impacted efficiency by as much as 40%.

*- The corrections to these chillers are delivering over **$130 000/year** in electricity.*

More information, Webinar and FDD

Case – Banner Health, Hospitals in USA

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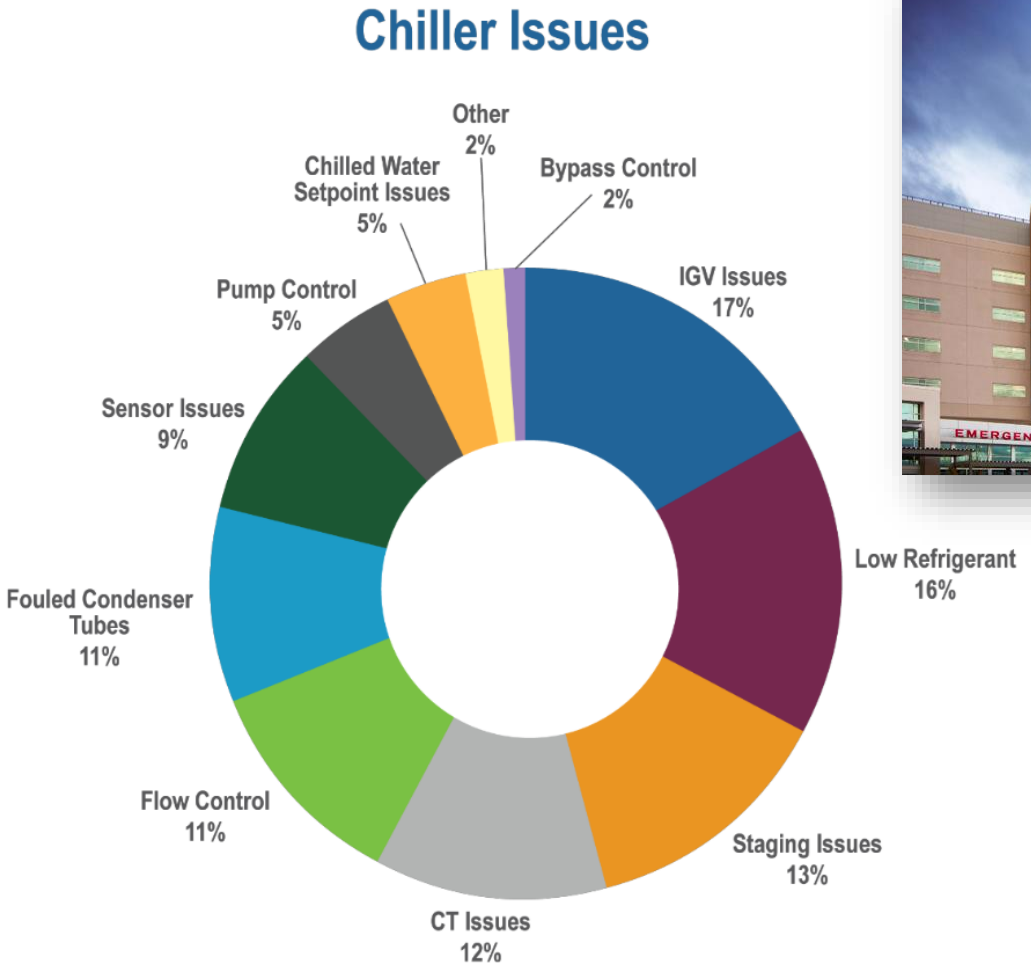
78 CHILLERS

BETWEEN 2019 - 2021

109 NEW ISSUES

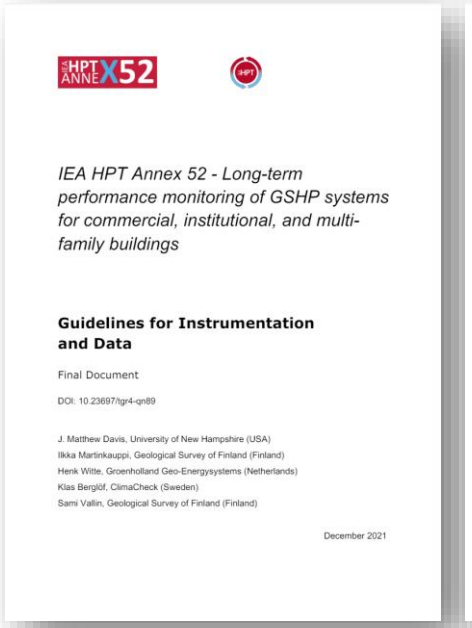
47% CHANCE OF DEVELOPING A NEW ENERGY-WASTING ISSUE

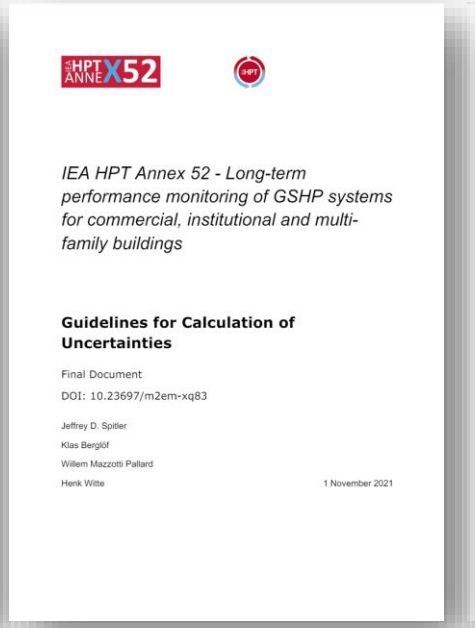


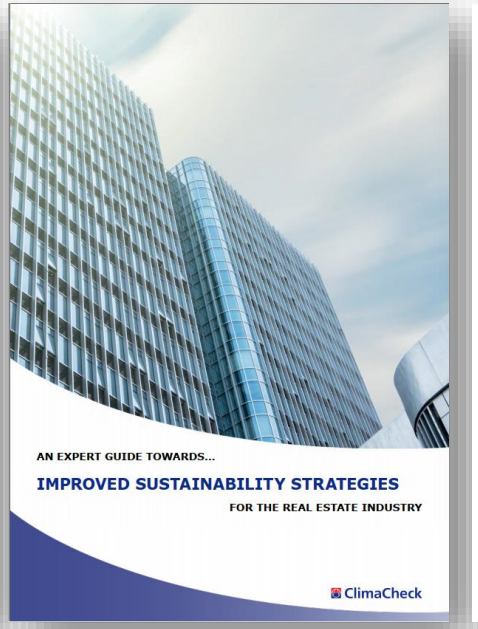
Banner Health®

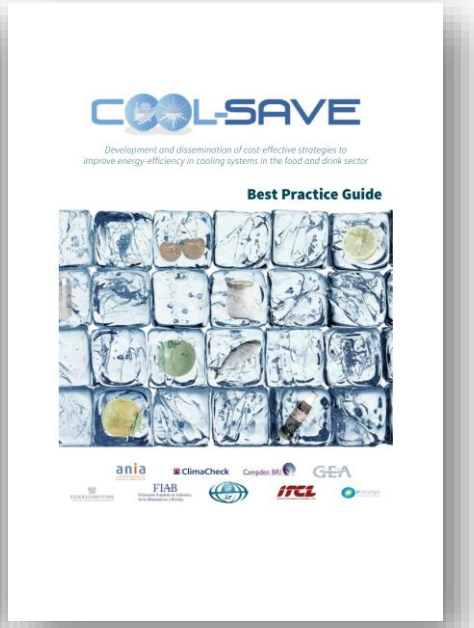
Additional information and links

- IEA Annex52
  - Guideline for Instrumentation and Data – Final Document.
  - Guideline for Calculation of Uncertainties – Final Document.
- Guide to implement Predictive Maintenance (free download)
- Method and guidelines to establish System Efficiency Index during field measurements on air conditioning and heat pump systems
- COOL-SAVE – Energy audit report and energy saving strategies









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