"THE FUTURE BUSINESS OPPORTUNITY OF THE SERVICE SECTOR IS TO MEASURE AND OPTIMISE.".

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Abstract
Air conditioning and refrigeration use 20% of the global electricity and in many buildings and supermarkets 50% of the energy bill is for the air conditioning and refrigeration. Traditional service has been focused on leak detection and in best cases a list of parameters has been documented. If it cools it works and if failures are kept within a reasonable frequency and cost everybody is happy. Regulatory interventions and customer awareness is slowly starting to change this but the industry is conservative and experience a challenge to get customer to accept higher initial costs by including measuring and validation of performance. New methods allow performance of system and all components to be measured. An increasing number of service companies, consultants and equipment owners are building competence and experience on "measuring and validation" in the field to comply with current requirement. The Energy Performance in Building Directive require "Performance Inspections" and the Directive on Energy Efficiency require on "Energy Audits". There are significant business opportunities for those that build up competence and capacity to take the lead in this field. The presentation cover new methods for performance measurements and visualisation of performance as well as experience from thousands of monitoring projects around the world showing savings of 20-30% at low cost. "To measure is to know" proves to be true.

Key words
Field measurements, Performance Analyses, Air Conditioning, Refrigeration, Heat pumps, SEI, System Efficiency Index, Energy Efficiency, Optimization, Measurement, Validation, Reliability

1 Background

The saving potential from optimising existing systems is the most "low hanging fruit" to reduce the energy consumption in existing buildings. Savings of 10-30% are possible at low or no investments in many not to say most plants. Very few plants have been energy optimised. Most installations are done according to specifications were the refrigeration/air conditioning contractor is doing their part and then plumbing, ventilation, control and electrical contractors fulfil their specifications. There are in most projects no responsibility and no cost assigned to optimise the operation for the actual loads and climate the plant is operating at. Our experiences and i.e. the ASHRAE report for commercial and industrial refrigeration (Royal, 2014) show that "business as usual" for commissioning and maintenance result in that most plants have a much higher Energy consumption than expected. Often savings of 10-30% are achievable through cost-effective optimisation measures. Not less important is that most failures can be prevented through state of the art performance analyses for commissioning, maintenance and monitoring. System Efficiency Index (SEI) and Sub efficiencies offer new possibilities to visualise and communicate performance to equipment owners.

2 System Efficiency Index – SEI a benchmarking parameter for evaluation and optimization.

SEI was introduced at this conference in 2015 (Berglof, 2015). Increasing field experience prove SEI to be a powerful tool for the expert to benchmark systems and pinpoint weak point in systems. It also provides an opportunity to show owners and operators how their system performs and allow them to identify when performance deteriorate without thermodynamic competence.

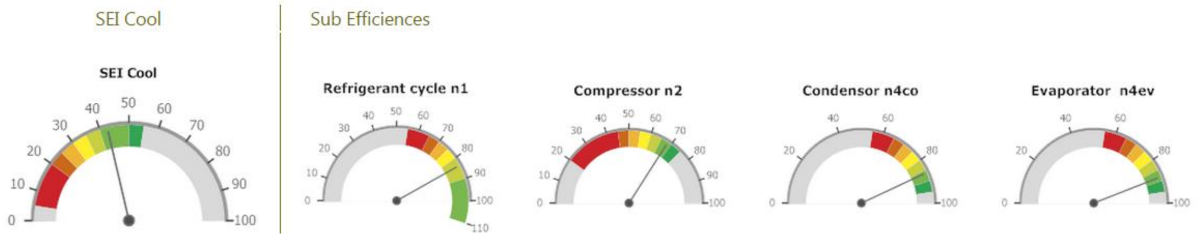


Figure 1, Visualisation of SEI1 and sub efficiencies for a good chiller.

The key performance indicator **SEI,** is the efficiency for a refrigeration, air-conditioning or heat pump system compared to a 100 % efficient system (loss free) at the operating condition it is measured. In a project lead by SP Technical Research Institute of Sweden and financed by the Swedish Energy Agency SEI has been evaluated as a tool to analyse field measurements. Industrial Partners in the project included Institute of Refrigeration in UK and companies from Sweden, UK, Germany and Spain. A report from the project is available to download from Internet (Lane Anna-Lena, 2014) .

$$SEI_{c,i} = \frac{COP_{c,i}}{\dfrac{T_{ref,c,i}}{T_{ref,h,i} - T_{ref,c,i}}}$$

2.1 Sub Efficiencies

The possibility to identify and benchmark weak points contributes to making the SEI concept a powerful tool for fault detection and communication.
The most interesting sub efficiencies for most application are:

- ✓ Cycle efficiency
- ✓ Compressor efficiency
- ✓ Condenser efficiency
- ✓ Evaporator efficiency

As the sub efficiencies and SEI has a low dependence on the operating condition it proves to be a very practical analysing and benchmarking parameter.

3 Energy signatures as a tool for validation of optimisation

Performance can be measured and analysed but require an expert to evaluate and identify optimisation opportunities. Most equipment owners are mainly interested in costs and reliability and need information converted to kWh, Euro and Co2 emissions to become interested. In refrigeration and air conditioning systems with dynamic loads and changing ambient conditions the energy consumption will change by the hour.

Energy signatures will be a key to create cost effective methods to predict, validate and benchmark performance.
An energy signature in its most simple form establish kWh per hour at each occurring temperature for a site. Figure 2, Typical energy signature for a supermarket in Sweden and one in Greece. It shows how kWh/h consumption depends on ambient temperature but can still be compared for overlapping temperatures and normalised to desired indicator of size. Energy signatures are a necessary component to predict energy consumption in a plant and can be generated by measurements. In real life, it becomes slightly more challenging as load pattern in a supermarket or commercial property also varies with if store/office is open or closed. To create high and low load profiles are for many types of plants not a challenge.

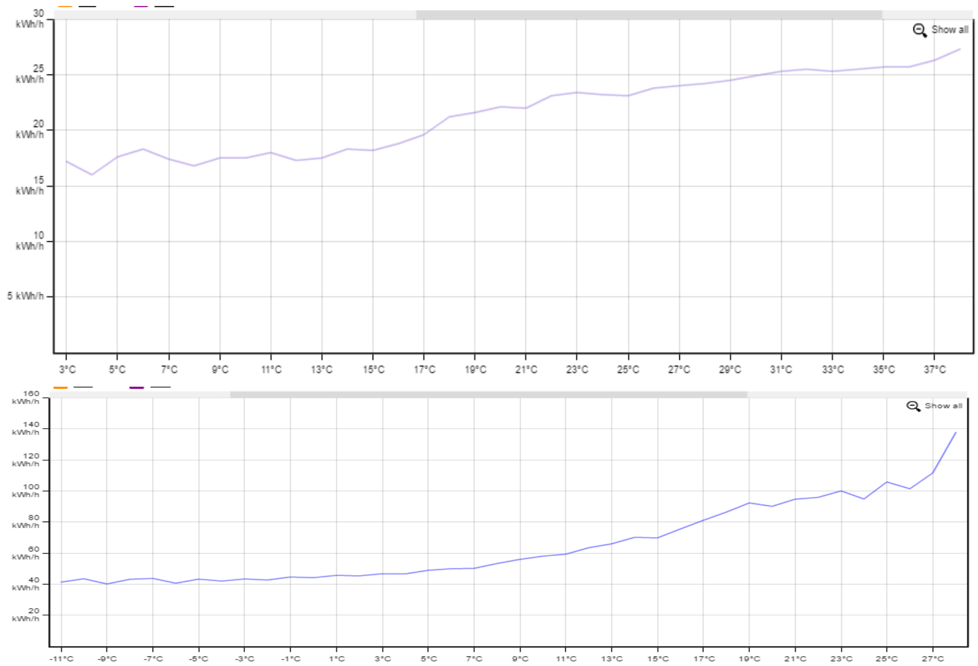


Figure 2, Typical energy signature Greece and Sweden

With climate data for a location the energy signatures will facilitate the possibility to get annual consumption as well as predict energy/Euro/CO2 savings from a predicted measure.
As the energy signature allows that measurements done over periods with quite different ambient condition it becomes a necessary tool to validate impact of measures. There are way too many case studies done to show the savings of measures than compare a time period without taking energy signature into account. Two weeks with the same average will not generate the same energy consumption if the temperature amplitude is higher one of the weeks. Figure 3, Energy optimisation of supermarket Figure 3 below show energy optimisation in a supermarket of METRO SA through low cost optimisation measures based on measure – analyse – optimise – validate. Pink bars represent kWh/24 hours. Achieved savings are difference between actual consumption after measures and blue baseline energy signature.

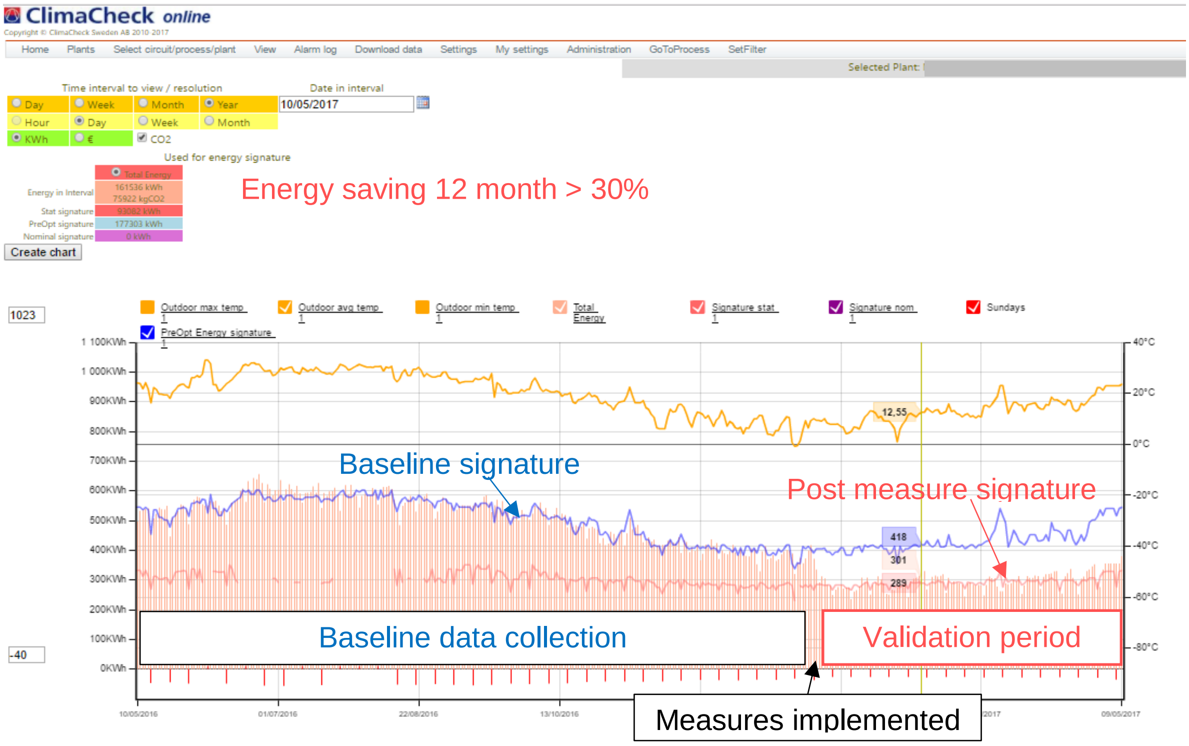


Figure 3, Energy optimisation of supermarket

4 Example of Plant Evaluation

Refrigeration and air condition plants are all unique and it require competence and experience to optimise these systems. The old saying “do not fix something that is not broken” is a major challenge when optimisation measures are suggested. When nobody knows that there are problems it is not tempting to invest in commissioning or re-commissioning as it can be a waste of money. It has required a convincing sales person to get people to invest when a specific saving can be guaranteed. This is gradually changing with new regulations and when many equipment owners are employing energy coordinators that are building up their own experience and competence.

4.1 The METRO Supermarket optimisation

The above displayed example of energy saving in the supermarket METRO SA is very typical for many supermarket projects. This supermarket had two traditional R404A racks where measures had been taken on the MT with a variable speed drive on one compressor and on the condenser fans. Through performance analyses during the baseline period the following energy optimisation opportunities were identified:

A. High set point for LT condenser fan control.
B. One scroll compressor on LT with poor efficiency that could be replaced before failure to save on repair cost and future energy
C. Adjustment of controls to decrease start/stop operation and improve life time expectancy.
D. The refrigeration system is undercharge and so the efficiency is reduced.

Figure 1Figure 4 below shows the improvement of COP of the LT rack from replacement of compressor with poor performance and lower condenser pressure.

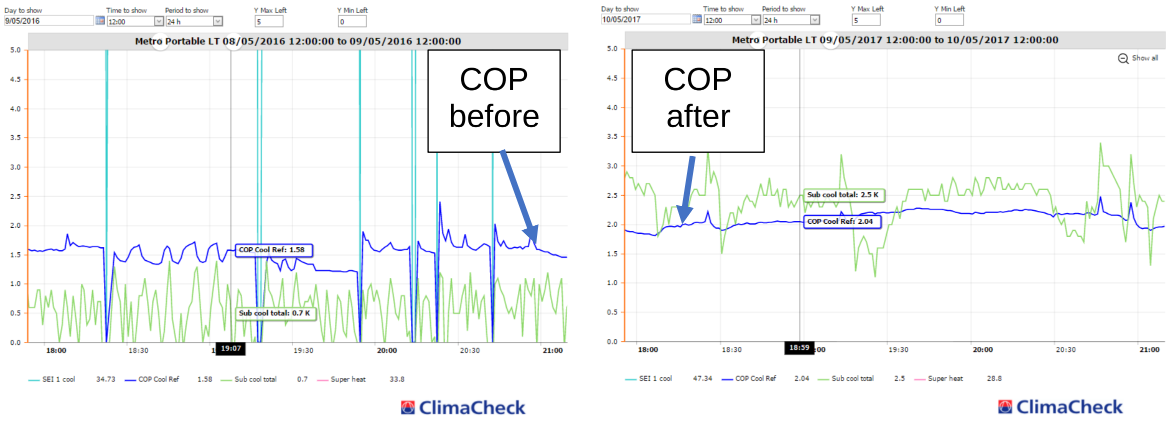


Figure 4, COP before and after measures

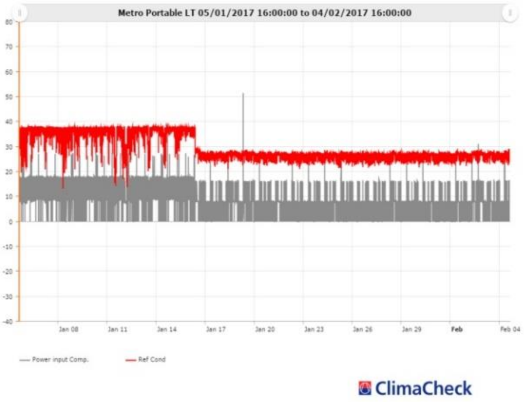


Figure 5, Power before and after measures

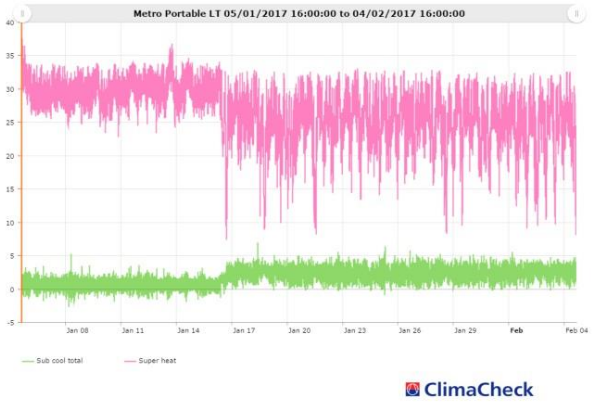


Figure 6, Subcool and Super heat before and after measures

Figure 5 depicts the great decrease in power and so in energy consumption of the compressors because of the change in condensing temperature.

Figure 6 shows also the great decrease of superheat and increase of subcool because of charging the system with the proper amount of refrigerant.

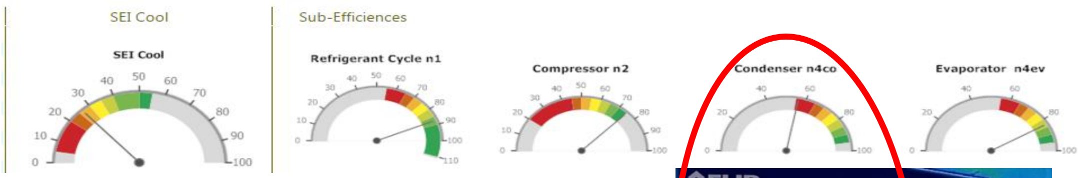
4.1.1 Results of the Optimization

A. Reduction of the energy consumption by **29%.**
B. Yearly energy savings equal to **45.000 kwh/year**.
C. Estimated yearly financial savings: over **5.000 euros/year** (0,11 euro/kwh) with zero capital cost of investment.

4.2 Air cooled chiller

SEI dashboard in below show low total SEI and poor sub efficiency for condenser. A IR picture visualise the higher sub cool and higher discharge temperature of incoming tube.
Poor condenser efficiency can be the result of:

- Fouling of condenser
- Too much refrigerant charge
- Insufficient air flow



IR picture show:

A. Higher discharge temperature due to higher pressure
B. Low temperature in bottom of condenser in spite of higher condensing e.g. sub cool is higher and in larger part of condenser. This reduces surface for condensing.

Figure 7, Air cooled chiller with too much refrigerant charge

5 Proposed future measures based on these data

A. Accurate modelling of the system and calculation of the proposed measures before making the changes
B. An accurate prediction of any payback period for any investment for improving efficiency
C. Step control of our system
D. From the above supermarket example the following possible measures are instructed:

- Stabilise inverter for fan - now fluctuates from 5-20 Hz with constant compressor capacity
- Stabilise compressor control
- Possible investment in EC fans to create stable operation of fans
- New more efficient Air-Curtains in freeze rooms
- Insulation on suction line is not optimal but likely costly to improve

6 Business opportunities in energy optimisation of refrigeration and air conditioning plants

There are an increasing number of companies working with energy optimisation pushed by authorities committed to decrease climate warming and increasing awareness among equipment owners. Energy efficiency and sustainable is becoming a key question for future competitiveness. The conservative “business as usual” companies that see failures as profitability are still dominating the industry but is unlikely to be sustainable. When focus is moving from keeping the temperature to cost effective cooling and preventive maintenance to avoid downtime and repair costs new skills, tools and methods are required.

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