Energy Savings in Building Management

A Practical Approach to Measurement, Benchmarking and Monitoring of Energy Usage in your Building

Introduction

This paper is intended for decision makers in building management that are on the lookout for effective energy saving strategies.

It briefly introduces the main principle of (water cooled) cooling systems, and how to realize energy savings when operating such a system. How do fouling related energy losses occur and how Automatic Condenser Cleaning helps.
The main purpose is to introduce a simple method to quantify the unnecessary energy losses in your operation in a short period of time. It will provide you with the tools to make a well-founded estimation of the economical savings and environmental contribution that you can make with this technology.

Common applications for chillers

- Educational institutions
- Hospitals and medical offices
- Department/ big-box stores / Grocery stores
- Shopping centers / Commercial food preparation Arenas
- Manufacturing (Food, Pharma, Electronics)
- Theater and convention centers
- Hotels / motels, resorts and casinos
- Airports, train and subway stations
- Data centers

Chiller facts

- There are over 40 million chillers in use around the world with a total capacity of 3350 GW.
- On a hot day, the chiller may consume over 50% of a building's electricity consumption.
- 6% of the world's total energy consumption is used for cooling of commercial spaces.
- Chillers may waste up to 20% of their energy on efficiency loss due to fouling.

Major gains can be made with proper management of the chiller, as 1% of the world's energy consumption may be easy to save.

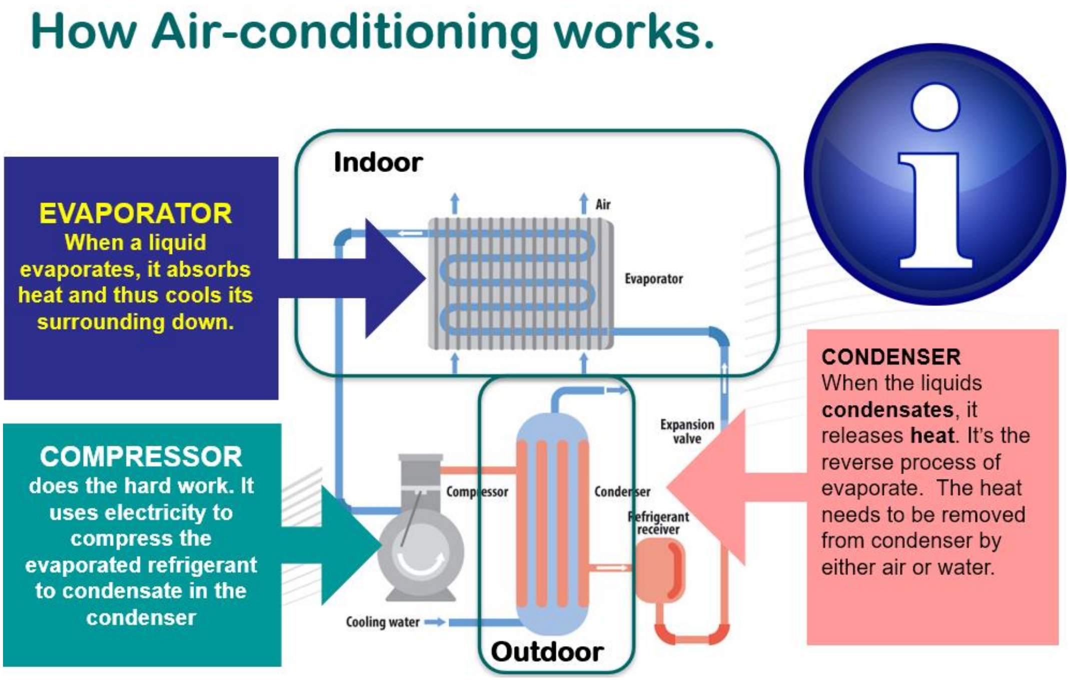
Governments and environmental agencies promote the overhaul of buildings with via financial incentives, soft loans, EPC programs etc.

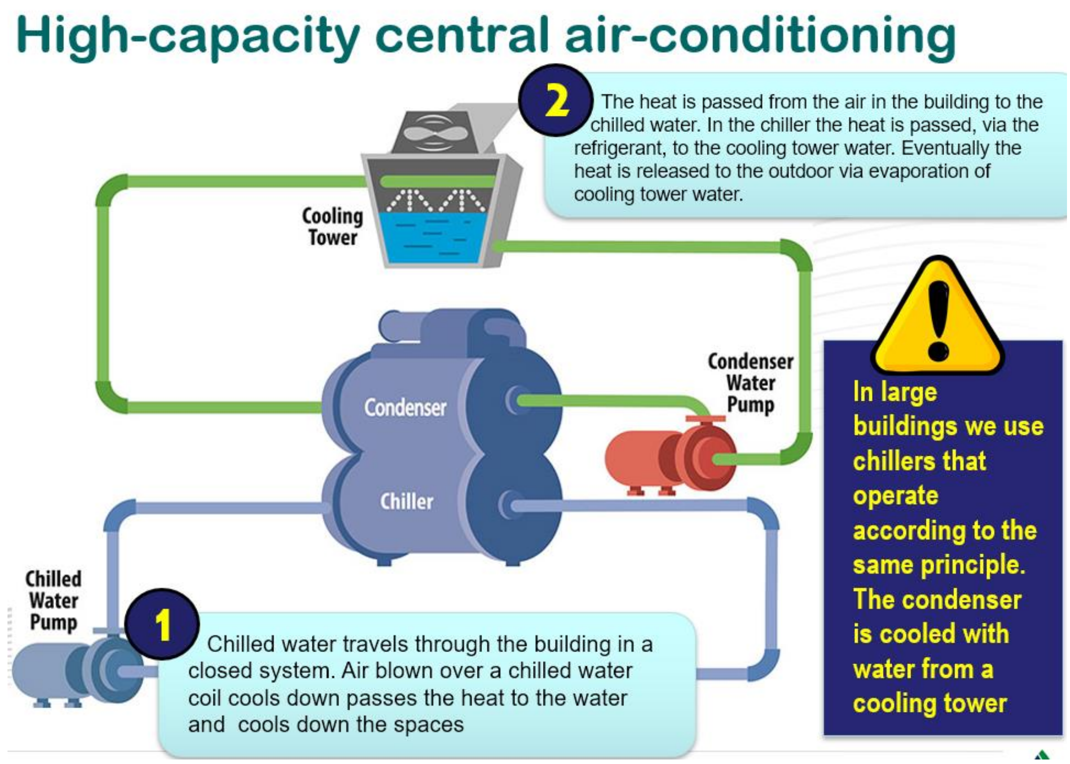
Any responsible building operator pushes energy saving to the top of their agenda. Few realize that Automatic Condenser Cleaning is a simple, proven technology on minimizing fouling losses in chillers. A low hanging fruit that will appear on top when all available energy management strategies are ranked on attractiveness based on CAPEX and ROI.
The **COP** (Coefficient of Performance) of the chillers is indicative for the management and maintenance of the overall heat rejection side of your building and should be considered as a main KPI for the facility management team.

Cooling Principles

Cooling is removal of heat. Just as there is no darkness, but only the absence of light, cold is merely the absence of heat. The cooling system removes heat.

This is achieved by the refrigerant absorbing heat and transporting this to the heat rejection module (the condenser). Heat is absorbed and released via the physical processes of evaporation and condensation.





A practical approach to energy conservation in building cooling

The Energy Savings Journey in building cooling starts with common sense, and a lot of work can be done by your own team before calling in the support of a specialized consultant. The following stages will pass:

1. Critical analysis of energy use and potential savings (both in hardware as well as user behavior), and action where immediate results can be expected with limited investments (stages 1-a and 1-b to be executed concurrently):
    a. The "Building side" (where heat is generated, and cooling is needed)
    b. The "Cooling plant side" (where cooling is generated through removal of heat)
2. Assess existing cooling system and redefine needs on basis of changes that come out of phase 1.
3. Consider and plan high-CAPEX retrofits for structural and long term results

Stage 1-a:
When critically looking at the heat generation, think of:

- **Energy-Efficient Bulbs & Lighting Fixtures**
- **Install Light and Motion Sensors**
- **Sun-Proofing of your Building**
- **Insulation issues (double glass windows and doors, airlock entryways)**
- **Regulate cooling with Thermostats**
- **Plug leaks**

Also, do not underestimate the impact of **user engagement**. Awareness and a sense of responsibility may make a huge difference!

Stage 1-b:
The chiller plant efficiency can be improved through both operations and maintenance adjustments, and may prove to have a big impact with minimal investments:

- Properly sequence chillers so that each one is loaded enough to keep it in its most efficient zone

- Monitor outdoor conditions and reset the chilled-water temperature accordingly to match chiller output to the actual load.

- Monitor outdoor conditions and reset the condenser-water temperature accordingly.

- Properly sequence cooling towers by closely monitoring outdoor conditions and achieve optimum condenser temperature.

- **KEEP YOUR CHILLERS CLEAN,** consider automatic brush cleaning. Fouling leads to an increase in condenser temperature and each single °C increase in condenser temperature results in 2.5% efficiency loss.

- Prevent scale formation in cooling towers to ensure optimal performance.

The total electricity consumption of your chiller room should be the reference against which you measure your current and future performance in cooling. It is the sum of the following consumption figures:

- Chillers
- Chilled water pumps
- Cooling water pumps
- Cooling towers

Stage 2:
After completing stage 1 with its immediate results and projected improvements based on planned investments, you can recalculate your total (future) cooling demand. As the heat load will decrease by a fair bit, often >10% you critically re-assess your cooling system.
The following list presents efficiency opportunities to consider for chilled-water systems.

- Insulate chilled-water pipes.

- Replace standard-efficiency or oversized pumps with highly efficient units sized for the newly reduced loads.

- Control chilled-water pumps with variable-frequency drives (VFDs).

- Upgrade the chiller compressor.
  For centrifugal compressors, consider installing a VFD's or small separate chillers for extended periods with very low loads.

- For chillers without a VFD, use low-voltage soft starters.
  Soft starting itself does not save energy, but it does enable shutting off chillers that are otherwise left running because operators are concerned about wear and tear from frequent starts.

- Replace an old or oversized standard-efficiency chiller with a properly sized high-efficiency water-cooled unit. Early retirement may yield substantial savings and attractive paybacks through efficiency improvements.

- Install plumbing to connect multiple cooling towers or multicell towers in parallel and VFDs to control cooling tower fans.
  This step allows the chiller plant to use excess cooling tower capacity at part-load conditions and save on fan energy, as described above.

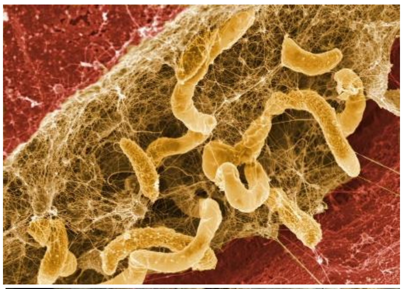
- Install plate heat exchangers to allow cooling towers to produce chilled water when weather conditions permit transferring heat directly from the chilled water circuit to the condenser-water loop. Chillers can be shut down if the wet-bulb temperature is low enough.

With gratitude to: Energy Star, the independent U.S. Environmental Protection Agency (EPA) endorsed institute for simple, credible, and unbiased information that consumers and businesses rely on to make well-informed decisions on Energy management.

www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH9_HVAC.pdf

How fouling impacts chiller performance

The condenser holds hundreds of tubes that receive water from the cooling tower.



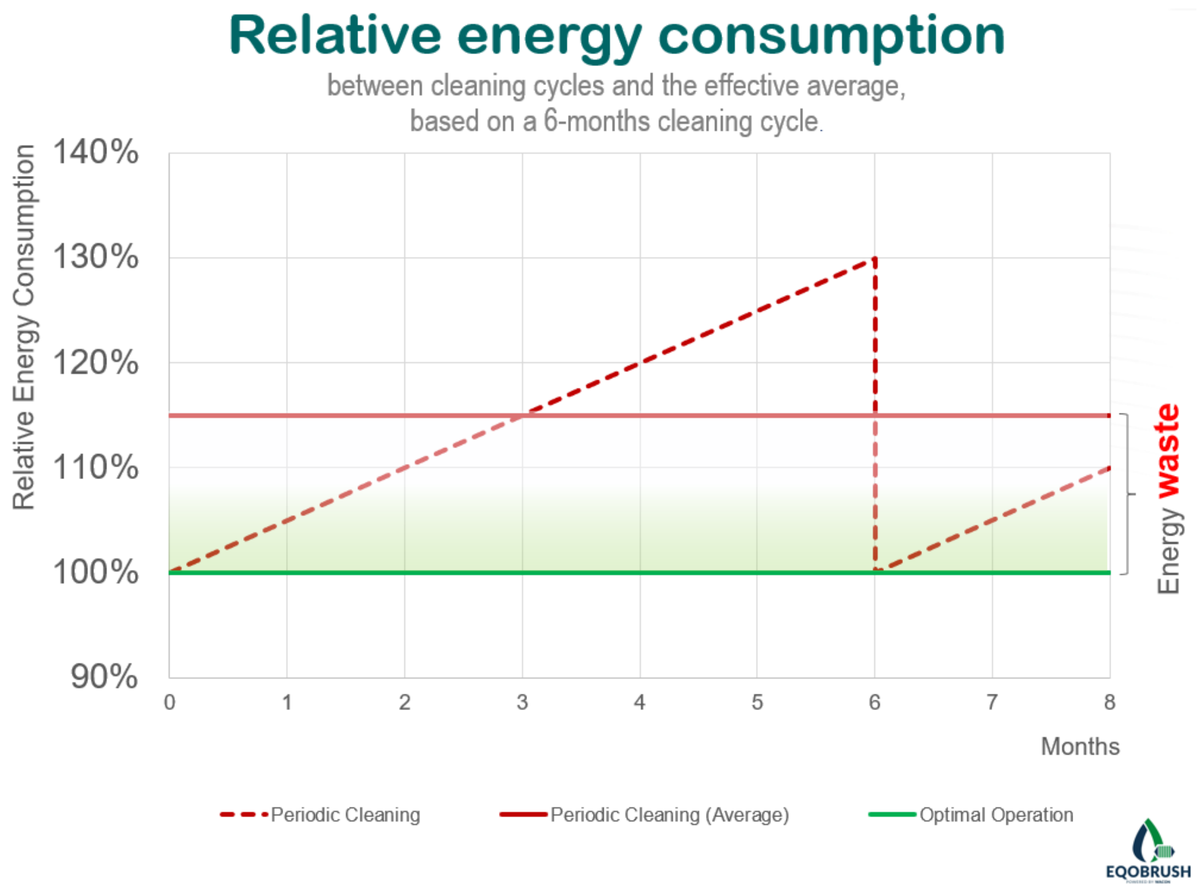
If fouled, the heat exchange process is hindered and the compressor needs to deliver more pressure to accomplish the condensation process.

Fouling Impact on Energy Use

The relation between scale build-up and the increase in power consumption is illustrated in the Fouling Factor Table.	Fouling Factor [m2*K/kW]	Scale thickness [mm]	Power increase required [%]
	**0.000**	0.000	0.00%
	0.0001	0.03	1.1%
	0.0005	0.15	5.5%
	0.0010	0.30	11.0%
	0.0020	0.61	22.0%
	0.0030	0.91	33.0%
	0.0040	1.22	44.0%

1 mm fouling → 30% power consumption increase

If not addressed, fouling buildup will increase the relative energy consumption until it reaches unacceptably high levels (which may manifest in the chiller not being able to deliver the required cooling). It will then be dealt with via a cleaning interruption.

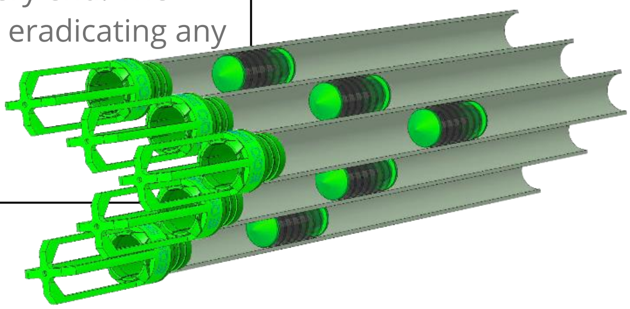


Automatic Brush Cleaning of Condenser Tubes

The cavemen started brushing their teeth regularly once they found out that "fresh" build-up is easy to remove, as opposed to leaving it untouched and allow scaling. That's exactly what the tubes of your heat exchanger or condenser need: **regular brushing to clean any build-up before scaling sets in**.
An Automatic Brush Tube Cleaning System (ATCS) accomplishes exactly that during normal operation of your system. You're assured that those tubes are kept as pristine as gun barrels, without interruption of operations.

How to keep heat exchanger tubes clean using cleaning brushes

The brush cleaning system consists of two catch baskets and one nylon brush for each heat exchanger tube. Both baskets are permanently fitted to the pipe ends and serve to accept the brushes. By reversing the direction of the cooling water flow, the brush is pressed through the tube and at the other end it is accepted by the basket. When the cooling water stream is diverted again in the normal direction, also the brush will return into the catch basket located at the delivery end. The inner walls of the tubes thus being cleaned now eradicating any fouling or scaling.



How to measure the impact of fouling in your operation?

To check the fouling impact, we compare the electricity consumption of the operation of a fouled chiller to a clean chiller. We provide a guideline how this can be accomplished, based on a realistic chiller room setup:

- 3 x 1000 RT chillers: A, B and C.
- 1x 400 ton chiller D.

- Conditions required for the test:
  - Have chillers A and C with the same specifications available. Make sure they are set up with identical cooling tower configuration.
  - Clean chillers B and D (or 1 and 4) before starting the test.
  - Select 2 time windows (a stretch of a few days or a week) for measurement that have an (nearly) identical cooling requirement or heat load.

- Testing procedure:
  - Period 1:
    - Set Chiller A as the main unit to run continuously during the testing period's required activity time (e.g., in a factory, run 24/7, in a shopping mall, run during opening hours).
    - Chiller C will not be used in this period.
    - Set the kWh meter values on all the chillers to 0 (or register the kWh value before starting the test)
    - At the end of the testing period, register the values of all the kWh meters and calculate the total electricity consumption of all the chillers in the test period.

  - Period 2:
    - Repeat the procedure as described for Period 1, only replace Chiller A with Chiller C.

- Calculation of fouling loss:
  - Compare the total energy consumptions (sum of all the chillers) for the different testing periods.
  - The difference in electricity consumption (Period 2 will be higher than period 1) should be contributed to the fouling. Simply multiply by the kWh price to arrive at economic fouling cost.
  - As the total heat load is assumed equal over the periods, it is not a requirement to quantify this.

Sample results:

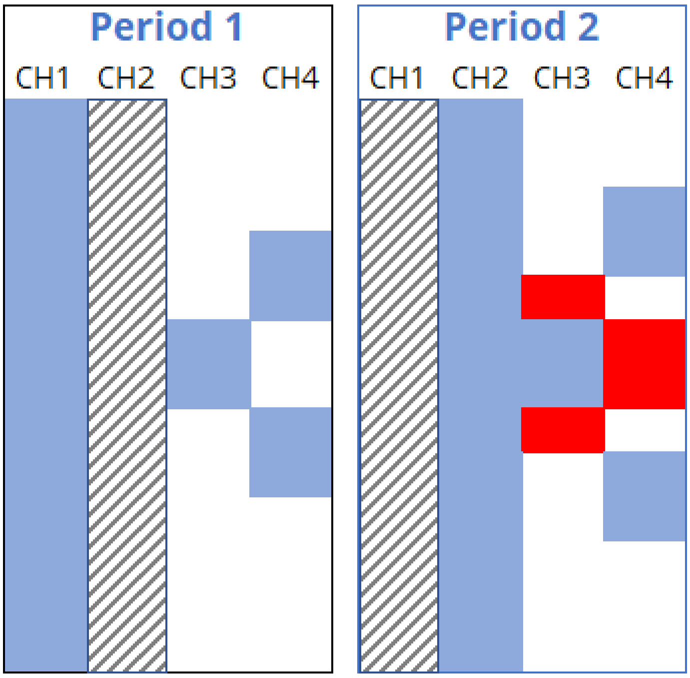
	RT	kW	Load	kW-actual	Running hours	kWh in test	**Remark**
	Period 1						
Chiller A	1000	600	95%	570	84	47880	During test run 7x12 hours
Chiller B	1000	600	95%	570		0	Was not used during test
Chiller C	1000	600	95%	570	14	7980	Kicked in 7 x 2 hours
Chiller D	400	240	95%	228	28	6384	kicked in 7 x 4 hours
				Total Electricity Period 1		**62244**	
	Period 2						
Chiller A	1000	600	95%	570		0	Was not used during test
Chiller B	1000	600	95%	570	84	47880	During test run 7x12 hours
Chiller C	1000	600	95%	570	24.5	13965	Kicked in 7 x 3.5 hours
Chiller D	400	240	95%	228	42	9576	kicked in 7 x 6 hours
				Total Electricity Period 2		**71421**	

Electricity waste attributed to Fouling:	9177
As percentage :	19%
Economic Loss $ 0.10 per kWh	$ 918

The additional Energy use in Period 2 is considered loss to be contributed to fouling in Chiller B. To calculate the percentage it is compared to Chiller A's consumption in the test period 1.

Chiller Activity in Testing Periods

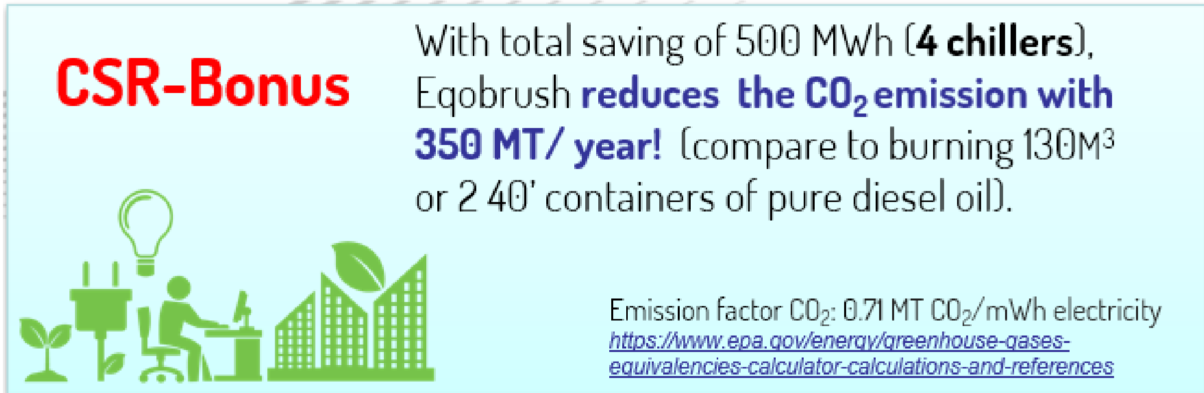
Time	DB	WB
9:00:00 AM	26.0	25.4
10:00:00 AM	26.4	25.1
11:00:00 AM	32.0	25.4
12:00:00 PM	34.0	25.5
1:00:00 PM	36.2	26.0
2:00:00 PM	36.4	25.6
3:00:00 PM	34.6	25.3
4:00:00 PM	32.8	25.6
5:00:00 PM	31.1	24.9
6:00:00 PM	30.0	25.1
7:00:00 PM	28.0	25.5
8:00:00 PM	27.0	24.9
9:00:00 PM	26.0	25.5



Weather conditions (overcast and WBT) and building heat load was very similar in both periods.

Sample Discussion and Conclusions:

- Albeit somewhat simplified, this approach gives a clear indication of excess energy consumption in the fouled setup.
- In period 2, during which the main cooling was delivered by chiller 2, considerably more electricity was used to cool the building that was operating under very similar conditions. The extra efforts are delivered by Chillers 3 and 4 (indicated in red).
- In comparison to the performance of the clean chiller 1 in period 1, Chiller 2 demonstrated a performance loss of 19%, which is labeled as “Fouling Loss”.
- Weekly fouling loss in Chiller 2 adds up to over US$ 900.
- Extrapolating over the complete operation (uncleaned) this would reach 19% of 62,000 kWh = 11,780 kWh in this week (US$ 1,178) equal to 500 MWh annually (80% of this weekly high on average) or 350 MT CO_2



Closing remarks:

Constant endeavors to minimize energy waste will help your company's economy and the environment and should therefore be on anyone's agenda. Recently even more prominently, influenced by public opinion and government encouragements.

What does not get measured, cannot be managed. This applies to your energy consumption as well. After deciding on an energy-saving journey, big steps can be taken even before the experts come in. Baseline benchmarking and ongoing monitoring, KPI's for the team in charge and last, but not least. obvious investments that come with limited CAPEX but bring high ROI.

Eqobrush falls in this very category and with the measurement approach that this paper presents, you will easily be able to put a number to the fouling waste and losses that can soon be a problem from the past.