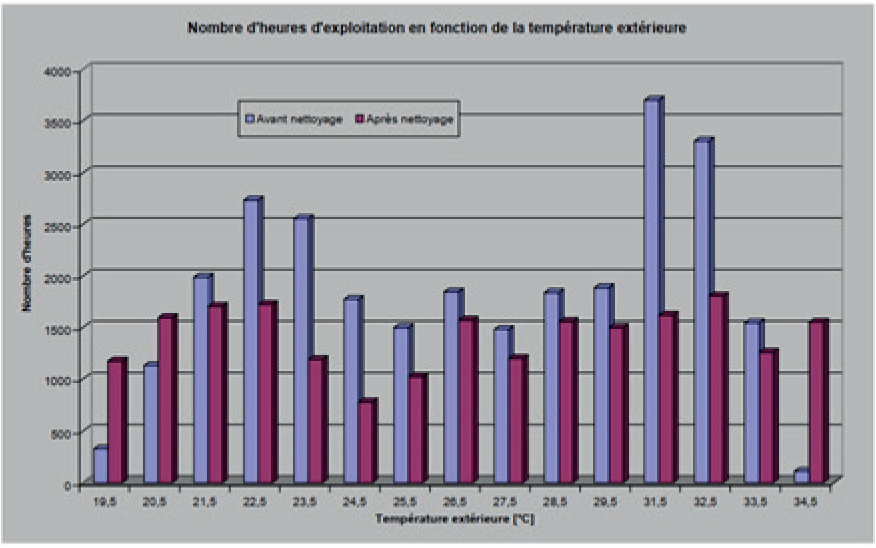
Heat transfer in data centres: the key to controlled energy consumption

Introduction

As data centres move towards ever-increasing power density, proper cooling becomes an increasingly difficult challenge. Consequently, technology is constantly evolving to keep up. On all fronts, efforts are being made to achieve more effective cooling so systems can operate optimally and energy consumption is minimised. Examples of such innovations include equipment that can operate at higher temperatures, liquid cooling, free cooling and adiabatic cooling. The cooling systems for back-up power supplies are also a key component. High-efficiency devices and technology only makes sense if they keep operating in optimum conditions in the long term. Small deviations can have real consequences!

Heat transfer

In designing future data centres, liquid cooling of servers is a serious contender. Air-based heat transfer has its limits and ever-increasing power density causes data centres to hit those limits faster and faster. However, heat transfer is crucial not only inside the data centre but also outside, where heat must be dissipated to water or outside air or (preferably) to a paying customer who can make good use of the heat generated by these data centres. Cooling equipment with inefficient heat transfer can consume up to 30% more energy.



Heat transfer before and after specialised cleaning, displayed in number of running hours

Source: Airport LYON chiller energy saving, 2013

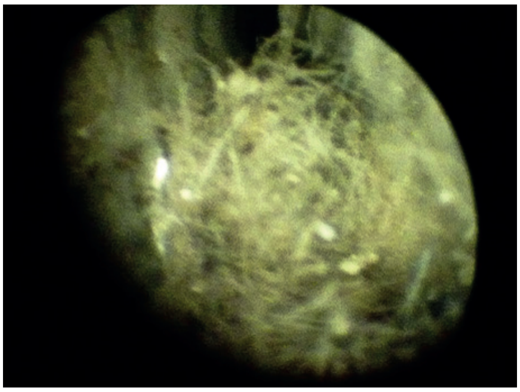
Why does a cooling system lose efficiency over time?

In the years after installation, the cooling capacity of a cooling system often decreases while energy consumption increases. The main cause of this is fouling and corrosion in the heat exchanger. In most cases, this heat exchanger consists of a densely stacked package of aluminium fins with copper tubes running through it. Refrigerant or a glycol-water mix runs through the tubes, while large quantities of outside air are forced past the aluminium fins.

Effect of fouling

Because the fins are very close together, dirt from outside air will always accumulate between them. The smaller the fin spacing, the more dirt will accumulate, leading to fouling of the system. Smaller fin spacing is often considered the best option because of its high nominal efficiency, but that benefit vanishes more rapidly due to dirt accumulation, compared to systems with larger fin spacing (and slightly lower nominal efficiency).

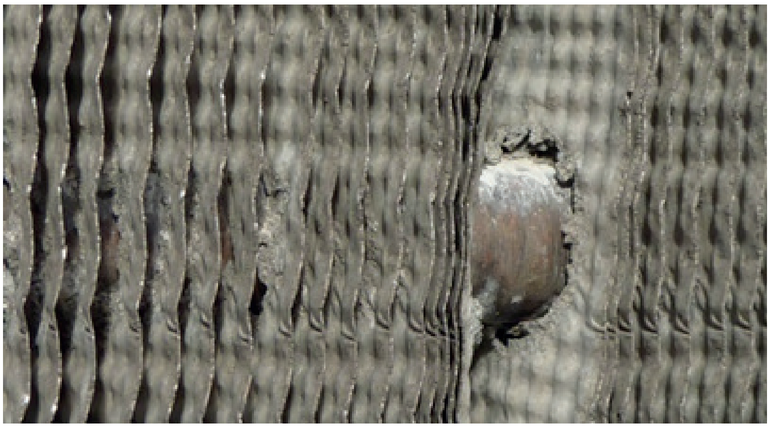
Visible fouling in heat exchanger



Unseen fouling revealed by endoscopic inspection

Corrosion and its impact on cooling systems

Metals are affected by corrosion over time, which is why they are almost always protected with paint, coating or other sealants. The metal parts are among the most critical components of the cooling system, but the heat exchanger is usually left unprotected to cut costs and avoid any insulation impact from the coating.

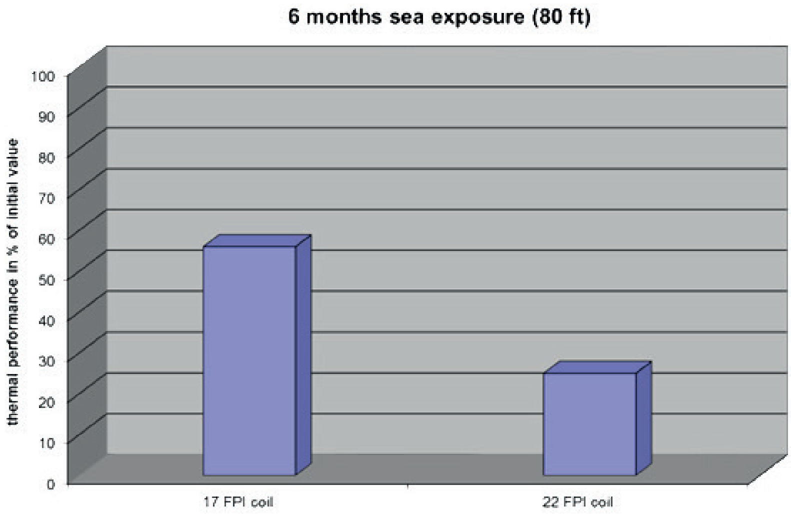


Galvanic corrosion

The metals in a heat exchanger are exposed to large amounts of airborne contaminants, causing accelerated deterioration. However, the biggest challenge is the combination of copper and aluminium in the heat exchanger. In the presence of moisture and dirt, aluminium will corrode even faster in the presence of copper. This is because aluminium is less "noble" (and more reactive) than copper, creating a potential risk of ***galvanic corrosion***. This is a common problem in heat exchangers and has a very negative impact on heat transfer efficiency. Roughly 70% of the total heat transfer takes place through the aluminium fins, but this heat must first be transferred from the copper tubes into the aluminium. Any deterioration in the connection between aluminium and copper leads to a proportionate decrease in heat transfer.

Adiabatic cooling often involves water atomisation systems. This atomisation provides a short-term capacity increase and can ensure that a smaller installation still provides sufficient cooling capacity on peak days in outdoor temperatures. However, water atomisation accelerates the corrosion process in the heat exchanger. Galvanic corrosion poses the most risk, leading to reduced capacity of the installation within 3 years. Limiting operating hours of the atomisation system and providing proper water treatment cannot prevent a permanent reduction in the installation's efficiency. If an additional full anti-corrosion treatment is applied to the heat exchanger, this effect is eliminated.

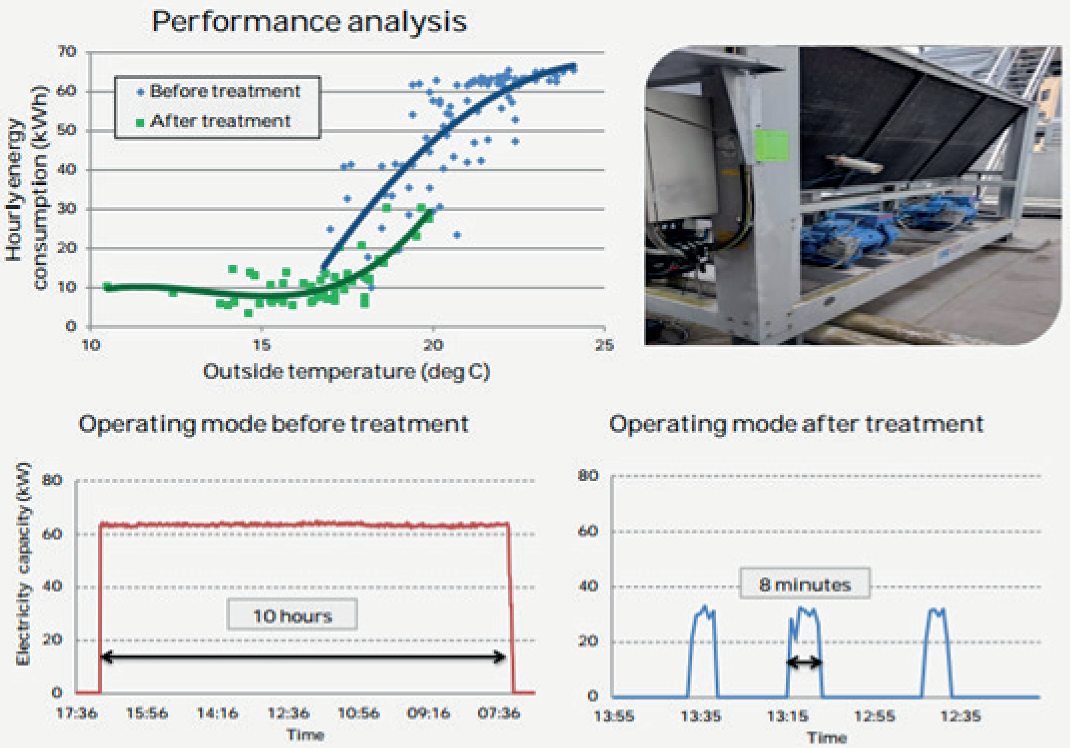
The chosen type of heat exchanger also affects future efficiency of the installation. Heat exchangers with very densely packed fins often have a high nominal heat transfer rate and thus appear cheaper when purchased. However, the loss of cooling capacity due to fouling and corrosion will be much faster. The chart below shows an example of capacity loss for heat exchangers with different fin spacing.



Capacity loss for heat exchangers with different fin spacing in a coastal environment

Source: Carrier Kure Beach

The reduced efficiency of the cooling system means that the system will consume much more energy to dissipate the same amount of heat. A lower part load and more running hours leads to higher consumption.
Unless corrosion and fouling in the heat exchangers are sufficiently controlled, energy consumption can rise sharply. Depending on the type of heat exchanger and the corrosiveness of the environment, this increase may be as much as 30%. This can be attributed in part to more running hours for the cooling fan, but is mainly caused by the additional power consumption from the compressor.



Yearly savings

Baseline		**Post-retrofit period**	
Total energy consumption	122,768 kWh	Total energy consumption	101,137 kWh
Electricity bill	18,170 $	Electricity bill	14,968 $
Corresponding CO2 emissions	15.8 tonnes	Corresponding CO2 emissions	13.0 tonnes

Savings

Energy	21,630 kWh	-17.6%
Financial	3,201 $	
CO2 emissions	2.8 tonnes	

Chiller energy consumption reduced after heat transfer improves due to treatment

Source: Blygold AUT energy saving Report

A chiller's efficiency is assessed by looking at the Energy Efficiency Ratio (EER). This is the ratio between the electrical power consumed and the cooling power supplied. The EER changes in response to outside temperature: at higher temperatures, efficiency goes down. EER can be determined based on the nominal catalogue values of a chiller, for example.

Effect of condensing temperature on cooling system efficiency
Based on sample catalogue values for a water chiller.

Nominal full-load values according to standard Eurovent conditions & water inlet/outlet temperature: 12 °C / 7 °C

Outside air temperature (air in) °C	Cooling capacity kW	Energy consumption kW	Energy efficiency ratio kW/kW
35	499	191.2	2.61
25	556	161.2	3.45

Besides the impact of increased outdoor temperatures, fouling and corrosion can also cause a cooling system's condensation temperature to rise. The efficiency of the cooling system is thus negatively affected by corrosion and fouling of the heat exchangers in the system.

Cooling capacity loss due to 1°C increase in condensation temperature: 1%
Increase in energy consumption due to 1°C increase in condensation temperature: 1.8%

We can assess whether the heat exchanger is functioning properly by looking at the ***condenser split & condenser approach***. These two values are hardly affected by outside temperature and can therefore be used to compare current values to the nominal value for the system.

Focusing on the heat exchanger of a cooling system

The ***condenser split*** is the temperature difference between ambient and refrigerant condensing temperature. This value will be between 15 and 30 K (Kelvin), depending on the type of heat exchanger (or coil). The higher the efficiency of the coil, the lower the condenser split will be.

The condenser approach is the difference between refrigerant condensation temperature and the temperature at which the air leaves the condenser coil. The closer these two temperatures are to each other, the better the heat transfer and efficiency of the system.

These two parameters give a quick indication of the increased power consumption and reduced cooling capacity of a chiller. The following example shows a simplified calculation for power consumption of a chiller in London before and after treatment against fouling and corrosion.

	Before treatment (first visit)	**After treatment (second visit)**
Ambient temperature °C	10.6	18.4
Condensation temperature °C	34.9	34.7
Condenser split K	24.3	16.3
Extracted heat kW	102	118
Condensation temperature °C	34.9	34.7
Condenser outgoing air °C	23.3	31.8
Condenser approach K	11.6	2.9

As can be seen from the reduced condenser split and condenser approach, the efficiency of the heat exchanger has been greatly improved by the treatment. Thanks to the improved efficiency of this condenser heat exchanger, the entire chiller operates more efficiently.

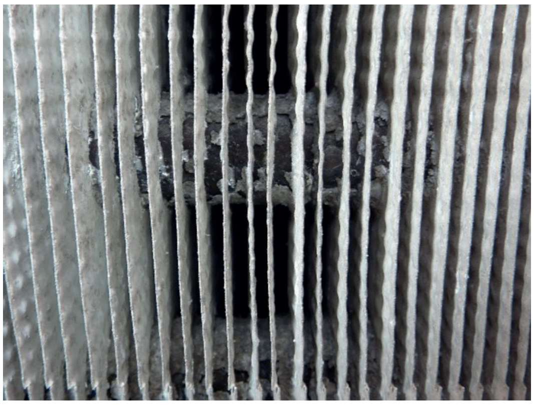
For a quick indication of savings, we can use the catalogue values from the table above:

Cooling capacity loss due to 1°C increase in condensation temperature	: 1 %
Increased energy consumption due to 1 °C increase in condensation temperature	: 1.8 %

This machine delivers :1% x 8 = 8% less cooling power
and thus consumes :1.8 % x 8 = 14.4 % more energy.

If reduced cooling capacity has to be compensated by more running hours, energy consumption will increase even further. This requires a more detailed calculation. Using this approach, the costs of the treatment are recovered within 3 to 17 months (depending on part-load to full-load ratio).

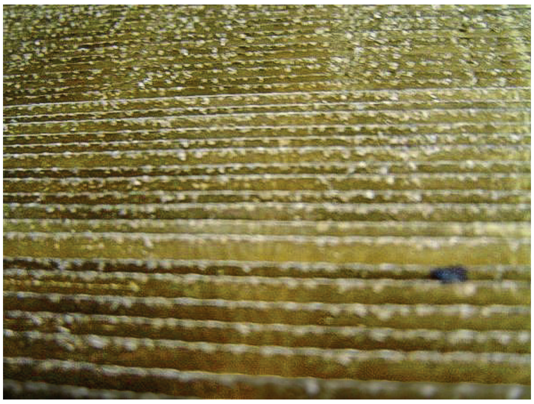
Preventive and corrective treatment to prevent capacity loss and shorter lifetime



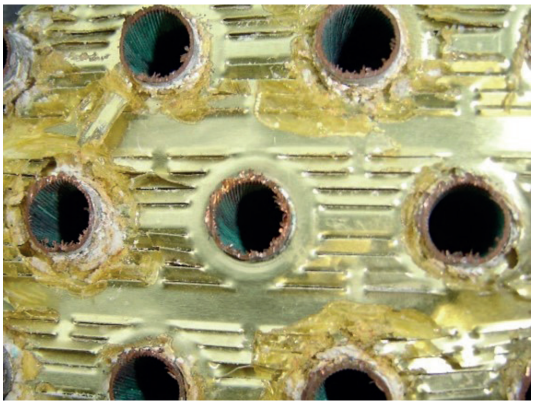
Heat exchanger with internal fouling (not visible from outside)

Generally speaking, 3 options are available for protecting heat exchangers.

1. Pre-coat: In this option, the aluminium is coated with a thin protective layer before being processed into heat exchanger fins. The fins are stamped from the coated aluminium. This easily accessible option is often offered by the chiller manufacturer. The disadvantage is that the coated surface is cut apart during stamping, revealing unprotected aluminium in the most critical areas, such as at the front of the coil and along the raised edge around the copper tubes. In addition, there is a capacity loss compared to catalogue cooling capacity, since a coating layer is applied between the copper and aluminium.



Corrosion on the cutting edge of pre-paint fins



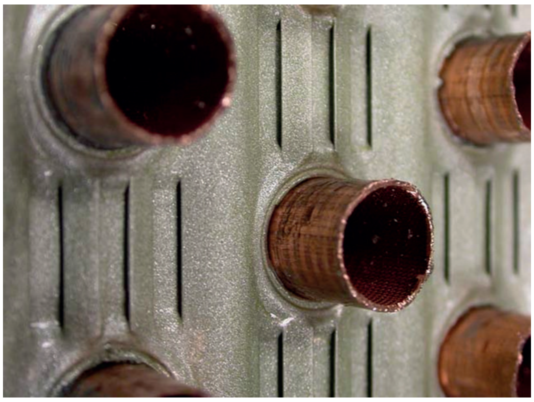
Galvanic corrosion

2. Front coating: An alternative to pre-coat protection is to apply a coating after the heat exchanger has been manufactured. Since fully treating the densely packed fins is a complex undertaking, this coating is often only applied to the outside of the heat exchanger. This protects the intake side, but does not provide any protection for the vulnerable surfaces around the copper tubes. Because only part of the heat exchange surface is treated, such factors as thermal conductivity and air flow resistance after coating are not very relevant.

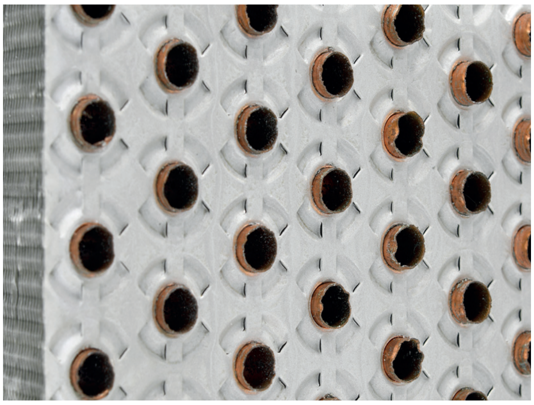
Cosmetic coating

Cosmetic coating with galvanic corrosion

3. Full after-treatment: To prevent corrosion on all vulnerable parts of the heat exchanger, it is necessary to apply a protective coating to all heat exchange surfaces after the heat exchanger has been manufactured. This complex treatment involves using specialised application techniques to apply a heat-conductive coating. This prevents higher air resistance and thermal resistance. Because the surface to be treated is much larger than the intake surface, ranging from 45 times to as much as 250 times larger, such treatments require a lot of coating and their application is time-consuming.



3-row full treatment with metallic coating



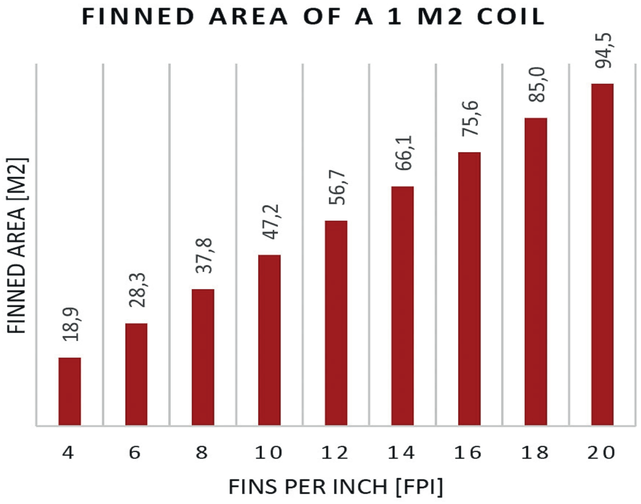
8-row full treatment with metallic coating

How many m² will be coated?

This is a relevant question. The following explanation shows the difference between full corrosion protection and merely 'cosmetic' treatment.

An average heat exchanger has perhaps 75 m² [2] of heat exchange surface that needs to be coated for each for every m² of visible surface! There is a huge difference between coating the entire heat exchange surface or just the visible side.

Companies that only need the dimensions of the visible surface to quote a price therefore do not intend to coat the entire heat exchange surface. If full anti-corrosion treatment is provided, the price for coating a heat exchanger of 1m² with 2 rows can never be comparable to a 1 m² heat exchanger with 4 rows.



Disclaimer
Many variables are involved in calculating m², so all data used in these examples are indicative only.
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Conclusion: controlled energy consumption of cooling systems

To ensure that cooling systems perform according to nominal values in the long term, close attention must be paid to the condition of the heat exchangers.

Purchasing choices

Choices made during the purchase determine total costs over the lifetime of the installation.

Relevant considerations:

- Adiabatic cooling with diffusion or not
- Fin spacing
- Metal thickness and quality
- Perforated fins or not

Anti-corrosion treatment

Required to maintain heat transfer from copper tubes to aluminium fins.

Relevant considerations:

- Preferably applied preventively before installation
- Complete full-through treatment, not just the front (cosmetic treatment)
- Apply heat-conductive coating

Maintenance of heat exchanger

Although corrosion-free coils will accumulate dirt less quickly than degraded coils, dirt accumulation in the heat exchanger cannot be completely prevented. Periodic cleaning remains necessary to clear out any fouling.

Relevant considerations:

- Deep cleaning using high pressure
- Cleaning from the inside out

The removal of clearly visible fouling is usually covered under general maintenance contracts. Periodic cleaning is carried out using brushes, vacuum cleaners and water hose. However, dirt accumulation between the fins is an equally important problem, affecting lifetime and cooling capacity.

Specialised cleaning is highly recommended here, preferably in combination with an endoscopic inspection. The inspection gives a good indication of the current condition of the heat exchanger. If necessary, this can be combined with a chiller analysis to determine whether the heat exchanger and chiller are still performing at optimal levels. Some measurements can be done remotely, others only in the field.

Endoscope inspection between heat exchanger fins

Notes

BLYGOLD

Blygold improves climate installations

Our improvements are achieved by:

- Cleaning and maintenance
- Coating components with in-house heat-conducting PoluAl coatings
- Optimising and upgrading the technology in existing installations
- Performing measurements and inspections and providing advice

We ensure that climate systems continue to deliver excellent performance for many years, achieve high efficiency and remain in good condition for longer. This guarantees continuity.

Blygold Netherlands has four branches and around 100 permanent employees. We also have our own coating application hall and a certified and independent laboratory for inspections, measurements and Legionella prevention.

PoluAl coatings

Our proprietary heat-conductive PoluAl coatings have formed the basis of our business for over 45 years, offering high-quality protection against aggressive conditions and corrosion. With these coatings, you can rest assured that your climate system will operate optimally.

Quality

- ✓ Over 45 years of experience
- ✓ Unique application techniques
- ✓ Unrivalled test results
- ✓ All trained & qualified applicators
- ✓ ISO, VCA** Certified

Innovation

- ✓ Revolutionary R&D
- ✓ In-house laboratory
- ✓ Deep understanding of the market
- ✓ Global awareness of customer needs
- ✓ Problem solving mentality

Sustainability

- ✓ Extended lifetime
- ✓ Energy saving & eco friendly lifecycle
- ✓ Reduced costs
- ✓ Maintenance friendly
- ✓ Corporate Social Responsibility

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