WHITEPAPER

Energy efficiency in data centers
with motor upgrades

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with motor upgrades

Mega data centers - what we refer to as "hyper-scalers" - can consume 100 times more energy per unit area than an office building.

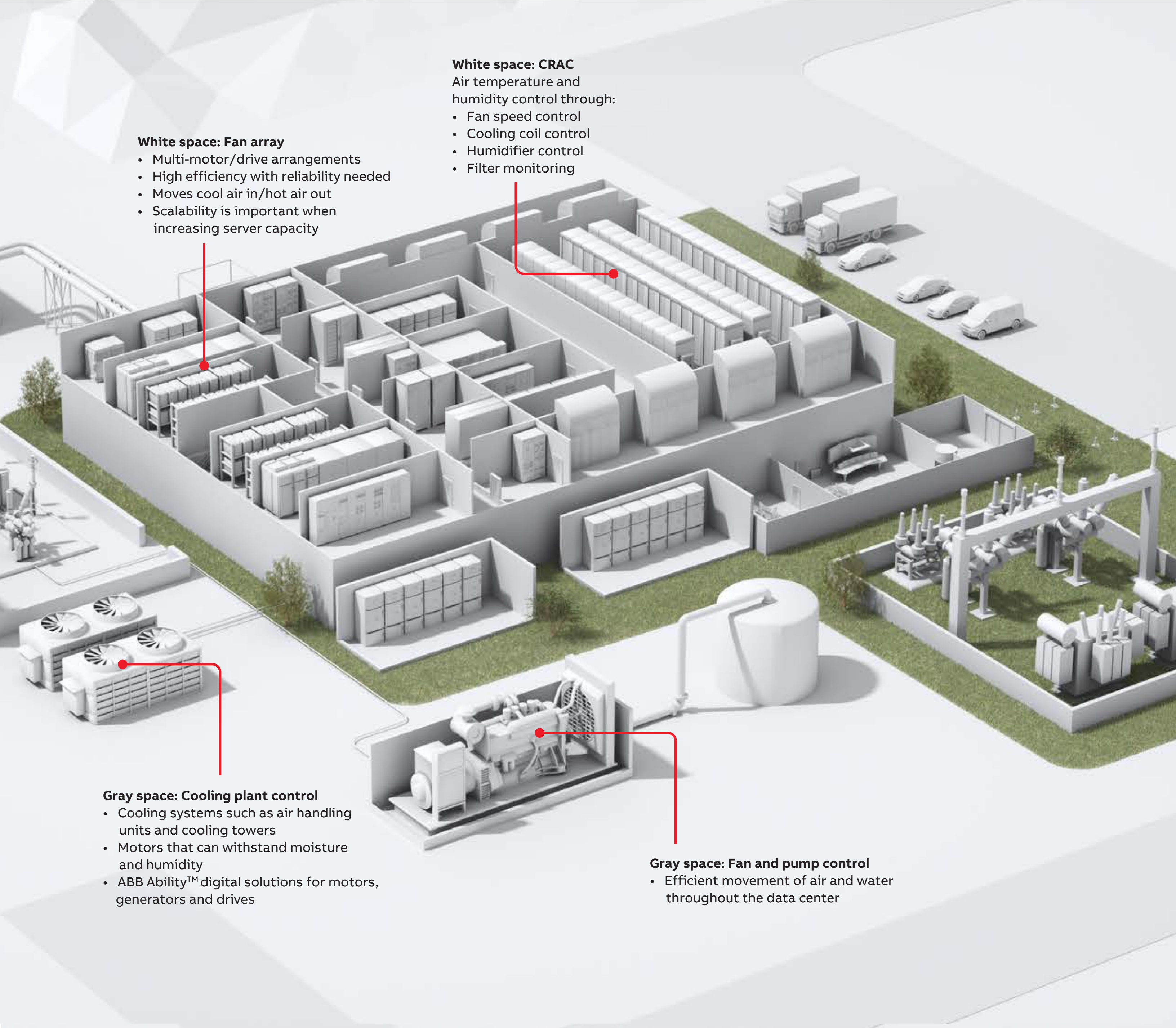
Introduced in 2006, power usage effectiveness (PUE) has become the most used metric for reporting the energy efficiency of data centers. PUE measures how efficiently a data center uses energy; specifically, how much energy is used by the computing equipment (in contrast to cooling and other overhead that supports the equipment).

An ideal PUE is 1.0; however, this rating is not realistic for large-scale data centers, because this would mean there is no energy loss in powering up their facility. Class leading PUEs of 1.06 have been achieved in small facilities, while the largest data centers achieve an average of 1.82. There are many opportunities to improve overall PUE scores by focusing on the facility as a whole and upgrading existing motor systems.

Targeting both white and gray spaces to achieve PUE

Data centers are divided into two main areas: white and gray spaces. White spaces are locations inside the data center, including server rooms, clean rooms and other areas, that need precise climate control. Gray spaces are the areas outside of the data center, and these areas contain the support equipment like cooling towers and compressor rooms that help keep the inside areas of the data center cool. A typical data center could have around 500 motors in its HVAC system, making energy management very important. To make the HVAC systems more efficient, data centers often control fans, pumps and compressors with variable frequency drives (VFDs) to ensure only the energy required is being used.

Most data centers focus on the white space to improve PUE, but the way to improve white space is to ensure gray space equipment performance is operating as efficiently and reliably as possible.



Data Center PUE

Equipment in and around the data center needs to be considered for optimal performance and improved PUE. The more efficient each process is, the more efficient the entire facility can perform.

How is PUE measured?

The calculation is straight-forward: where P_{Total} is the total power consumed by a data center, P_{IT} load is the power consumed by IT equipment, which means a big portion of energy is consumed by data center cooling and power supply systems.

Factors that drive up the PUE include:

- Poor motor control or use of inefficient motors in cooling applications resulting in power losses
- Poor interaction between cooling system components or system imbalance resulting in power losses
- Harmonics and reactive power in the network generating losses in the form of heat

Real cooling equipment efficiency has to be evaluated based on wire-to-fluid efficiency, so both electrical and mechanical performance of the equipment should be considered. Ultra low-harmonic drives and high-efficiency variable speed motors improve data center PUE by increasing the efficiency of both the cooling and power supply while reducing the power required to cool the system.

$$PUE = \frac{P_{Total}}{P_{IT\ load}}$$

Total facility power

Power losses

- batteries
- transfer switch
- UPS
- PDUs
- transformers
- rack distribution units
- breaker panels
- distributed wiring
- lighting
- generators
- etc

Cooling

- chillers
- chilled water pump
- cooling towers
- condenser pumps
- dry coolers
- CRACs & CRAHs
- fans and fan arrays
- humidifiers
- In-row coolers
- In-rack coolers
- In-chassis cooling
- etc

IT equipment

- servers
- storage
- Telco
- etc

Improving your PUE

Why should we focus on data centers? Because they use a lot of electricity and a lot of motors. Two percent of the worlds' electricity is used by data centers (Figure 1). Data centers are expected to grow and their energy demand will increase 8 times by the year 2030. More than 40 percent of the energy used by data centers is used by the cooling system, which is equal to the energy used by the servers to store and retrieve data (Figure 2). Using the most efficient motors available will help reduce the energy consumed.

Let's take a look at efficiency improvement opportunities within the gray space.

The more efficient the data center's engineering networks, the closer the PUE is to 1.0. For instance, if natural cool air is not readily available, a facility may spend a large portion of its cost in cooling gray spaces. Some newer data centers have found ways to use water-cooling techniques, and they choose locations for the campus in areas that are not typically humid or hot. But even with "free air" cooling, gray space cooling and pumping are still required to keep the building operating at the right ambient conditions.

Global electricity consumption

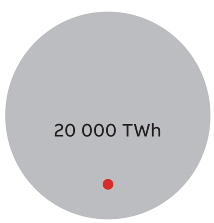


Figure 1 - 2% of world electricity is consumed by data centers

Typical data center energy use

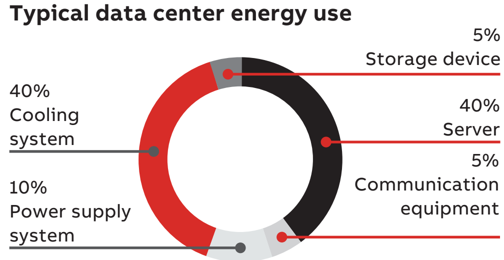
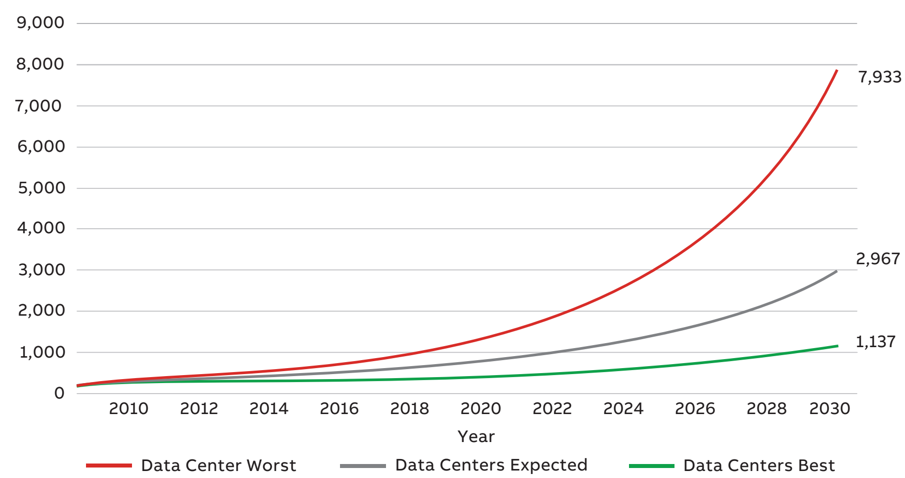


Figure 2 - The same amount of energy is required for cooling systems as powering servers. And yet, the focus on cooling systems is not as predominate as keeping the servers up and running.

Electricity usage (TWh) of Data Centers 2010-2030



Data center energy demand is expected to increase 8 times by 2030

Investments in cooling systems have to take into account scalability, permitting future increases in heat loads as server density increases. Data center cooling systems are sized for peak loads at the worst cooling conditions. As the energy demand continues to rise for data centers, it must be offset by gray space cooling methods as well as white space.

Choosing the right motors

Different motor types have different efficiency levels and operating parameters, and not all are meant to be paired with a VFD. Careful consideration to how the motor will need to perform is the first critical step in reducing your gray space energy losses.

1. **Harsh environments**
When making considerations for gray spaces, equipment such as cooling towers, condensers or pumps is often located outdoors and subject to extreme temperature fluctuations and harsh environments. Ensuring your motor is properly protected is key to equipment reliability and longevity. Severe duty construction, sealing protection, corrosion resistance and drains for optimal moisture removal are features that should be considered when selecting motors for outdoor use.

2. **Safety and overall system effectiveness**
Upgrading from belt-driven to direct drive motors improves the overall system. Removing wear items such as gearboxes, belts, couplings and jack shafts will not only improve end-to-end efficiency, but operator safety too.

3. **Improving efficiencies**
Most motors used in white spaces tend to be located inside in relatively clean environments with temperature and moisture control. Optimizing efficiency and uptime is important. Motors used to run fans, pumps and compressors in data centers do not operate at full load or speed all the time. To achieve the greatest energy savings, it is crucial to ensure that VFDs are integrated into the motor operation. Selecting an inverter-duty motor that includes some form of motor bearing protection is important. An ultra-premium (IE5+) efficient motor reduces energy loss by up to 40 percent compared to standard induction motors (NEMA Premium).

1. Motor protection

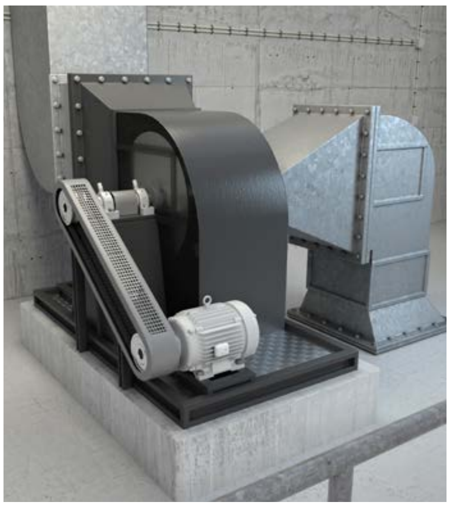
Protection against environmental factors is key to reliability and increased total cost of ownership (TCO) in outdoor applications such as chillers, cooling towers, pumps and compressors. There are a few features to consider to maximize your motor performance in humid and wet environments:

Housing material: When your motor is located outdoors, it is important to have a robust housing design. Severe duty cast iron construction or rolled steel will allow a motor to withstand dust, debris, and temperature fluctuations.
Combating moisture: Ingress protection is important for motors that may be subject to rain, sleet, snow, or moisture build-up. Multiple seals will help keep contaminants out of the motor and bearing and improve motor longevity. Many motors will come with moisture resistant copper windings, doubled dipped and baked. This helps protect the electrical windings and prevent shortages. Strategically placed drains for optimal moisture removal help prevent moisture buildup. If the motor is in a cooler area, condensation may build up and operators may want to consider space heaters to protect the electrical windings.
Corrosion resistant: Stainless steel nameplate and hardware are recommended for outdoor motors as they are subject to wear and corrosion. The maintenance process much easier when the nameplate is legible, and the hardware is not corroding.
Bearing protection: If running the motor with a VFD, it's important to have some form of bearing protection, such as a shaft grounding device or insulated bearing. This will prevent shaft currents form ruining your motor bearings.
Condition monitoring: Changes in temperature and vibration in your motor can indicate potential problems in your equipment. If your equipment is outdoors, out-of-site, or in a hard-to-reach area, it may be beneficial to add a smart sensor to monitor the health of your equipment. This will allow you to plan maintenance in advance and unplanned downtime can be avoided.

Careful consideration of motor protection options can help optimize the performance of your motor, thus extending its life. A motor that doesn't fail is a motor that improves your PUE.

2. Direct drive for safety and system efficiency improvements

Many of the fan applications used in data centers are becoming small while increasing in numbers. Moving from traditional large fans to smaller arrays optimizes the cooling process in data centers. In addition, shifting from belted motor applications to direct drive fans allows for better system efficiency and a safer operating environment.



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Cooling towers have historically been a big cost and energy strain on many facilities because they are difficult to install, maintain and manage. A direct drive cooling tower motor that uses a VFD, for instance, can eliminate the drive shaft, gearbox, couplings and bearing that are supporting the connection between the fan and motor. A direct drive solution has less wear items, less vibration, and reduces loss by approximately 50 percent[(3)].

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01
Older fan system that has belted application running a large fan
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02
Newer fan array with multiple motors directly mounted to smaller fans stacked together
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03
Traditional configuration
During testing, both towers were instrumented, and the traditional geared system was evaluated against a direct drive solution. Each tower had the same five-blade, 18-foot diameter fan, with pitch and tip clearance adjusted to identical settings. Performance results, which were verified by a third party, indicated the direct drive version reduced losses in the system by approximately 50 percent and provided a measured power savings of 11.8 percent when compared to the traditional geared system, with high-speed noise reduction from 82.3 dBA to 74.4 dBA. Vibration was also reduced.

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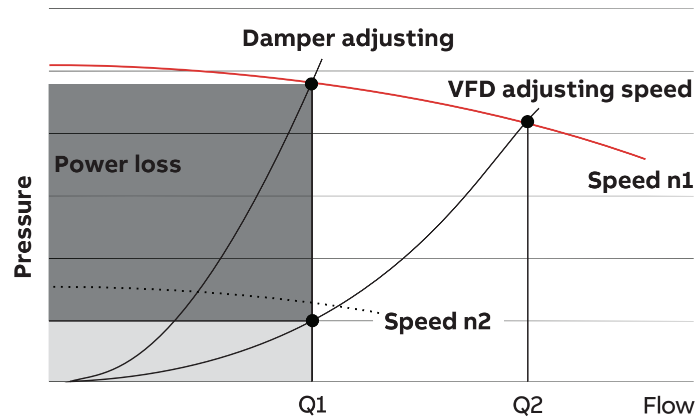
04
Direct Drive System

3. Efficiency optimization thru variable speed

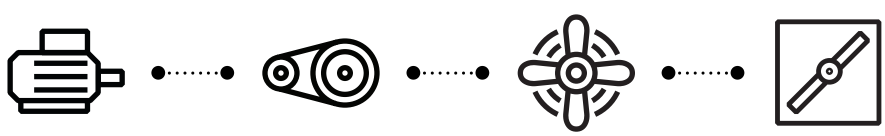
Variable frequency drives
Because fans run at partial loads most of the time, variable frequency drives can save energy by an average of 20 to 60 percent compared to traditional damper or valve control methods. Such massive energy savings are possible because drives are able to adjust the motor speed of fans, pumps and compressors directly to meet the current needs. Variable speed control delivers the full benefit of running HVAC applications at partial load, allowing accurate control of ambient CO_2 levels, temperature, and humidity for the best facility performance.



The graph shows how power consumption changes when decreasing the flow rate from Q1 to Q2 with a damper and a VFD. The damper doesn't decrease the speed of the application but creates the resistance to decrease the flow, so the energy gets wasted (power loss square in the graph). The VFD decreases the application speed as well (from n1 to n2) making it consume less energy, so no energy gets wasted.

Conventional ventilation system
System efficiency = 69%

Input power 145



Standard Motor efficiency **91%**

Belt Drive efficiency **98%**

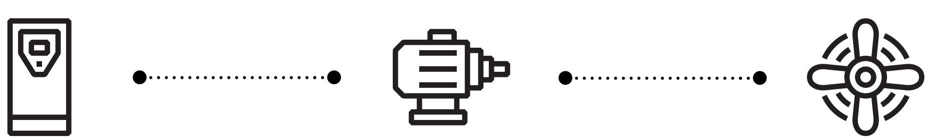
Fan efficiency **78%**

Damper efficiency **99%**

Ouput power 100

Energy-efficient ventilation system
System efficiency = 83%

Input power 121



Variable Speed Drive efficiency **98%**

Energy-efficient Motor efficiency **96%**

Better Fan efficiency **88%**

Ouput power 100

In addition to cooling reliability, energy savings and safety, there are many other benefits to using VFDs and high-efficiency motors on motor-driven applications.

White Space Areas		
Challenges	**Solution**	**Benefit**
Equipment uptime	To increase motor reliability, the bearings need to be protected from shaft grounding. Utilize a shaft grounding brush or insulated bearing.	Smooth motor performance means the operation will run cooler and with less energy loss. This is also a more sustainable solution as facilities will experience longer equipment operating life.
	Condition monitoring will create an alert when there are issues with motor performance.	Predictive maintenance will prolong the performance of your equipment and prevent unplanned downtime.
High electricity consumption	Today, ultra premium (IE5+) efficient motors are available to greatly reduce electricity consumption over the life of the motor.	It's possible to reduce electricity consumption by 40% by adding a VFD to the motor. Using a highly-efficient motor and drive package will optimize system performance by using only the electricity needed.
	VFDs bring energy savings for pumps with half the speed meaning only 1/8 power is needed	Typically, between 20 to 60 percent energy savings compared to throttle control systems
High fan maintenance or replacement costs in case of integrated speed control solutions (i.e. EC fans)	Stand-alone VFDs	VFDs mounted separately from motors eliminate the need for a complete fan unit replacement in the case of component failure, significantly reducing the cost.
High fan installation costs	One VFD can control multiple motors in fan arrays	Reduced installation costs while ensuring required redundancy level

Gray Space Areas		
Challenges	**Solution**	**Benefit**
Chillers/compressors are the biggest single electricity consumers	Highly efficient motor and drive packages will help drive down electricty consumption.	It's possible to save significant electricity costs as the right compressor speed and load are achieved.
	Motor features such as humidity/weather proof seals, gaskets and bearing protection	These features increase the reliable performance of your chiller / compressor.
Cooling tower maintenance and energy costs	Gearbox failures, oil leaks, misaligned drive shafts and vibration often occur in traditional cooling tower systems which contain a motor, drive shaft and gearbox. Replace these with a direct drive option to eliminate the maintenance of a gearbox and other wear	A direct drive option reduces maintenance time and cost, but more importantly, the inefficiencies that wear items cause will be eliminated. This provides higher efficiency, lower energy costs, and lower maintenance costs.
Direct-on-line starting creates pressure shocks and damaging pumps, seals, pipe joints and valves	VFD allows for soft startup and stops to help avoid pressure peaks and water hammer	Increased lifetime of pump and piping system and decreased operating costs.
Pump uptime	Condition monitoring indicates mechanical failures like bearing wears and pipe leakage	Reduced cooling system downtime and increased reliability

All of these considerations will help a user achieve a lower PUE ratio and improve the overall uptime of the data center.

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BR266 03.2022