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APPLICATION GUIDE

# Optimizing the total cost of ownership of HVAC systems by using variable speed drives



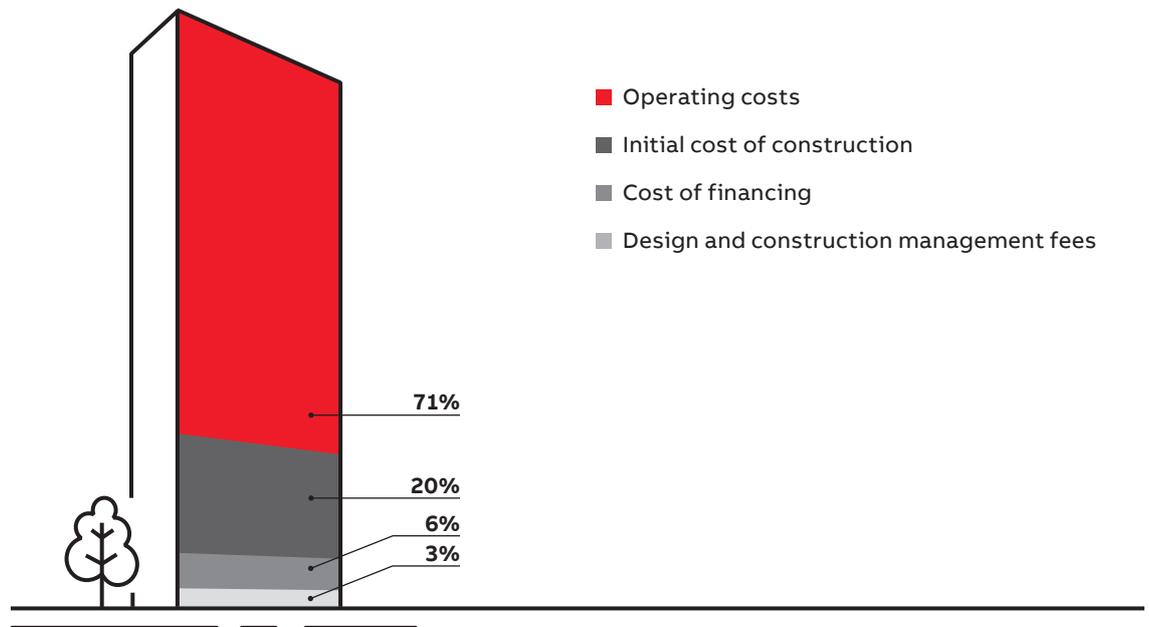
## The large impact of HVAC on a building's total cost of ownership

Total cost of ownership (TCO) is a financial estimation of the direct and indirect costs, including capital costs, operating costs, maintenance and repairs, to name but a few, related to a product or a system over its full lifetime. Understanding the TCO of a building's heating, ventilation and air conditioning (HVAC) systems and their related components from the very beginning of a new or retrofit project can result in both capital and operating cost savings and a much faster return on investment (ROI).

TCO is generally assumed to cover these cost components:



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**Building total cost of ownership**

According to the Builders' Association in the USA the total cost of ownership for an average 40-year-old building is comprised of 20% initial cost of construction, 3% design and construction management fees, 6% financing costs (if paid off in 7 years). And the rest – an enormous 71% – are operating costs including utilities, maintenance, repairs and capital reserve.

Obviously, it is worthwhile to dig a bit deeper into the operating and capital costs, and investigate the role and impact that HVAC systems have on the building's TCO over its lifetime.

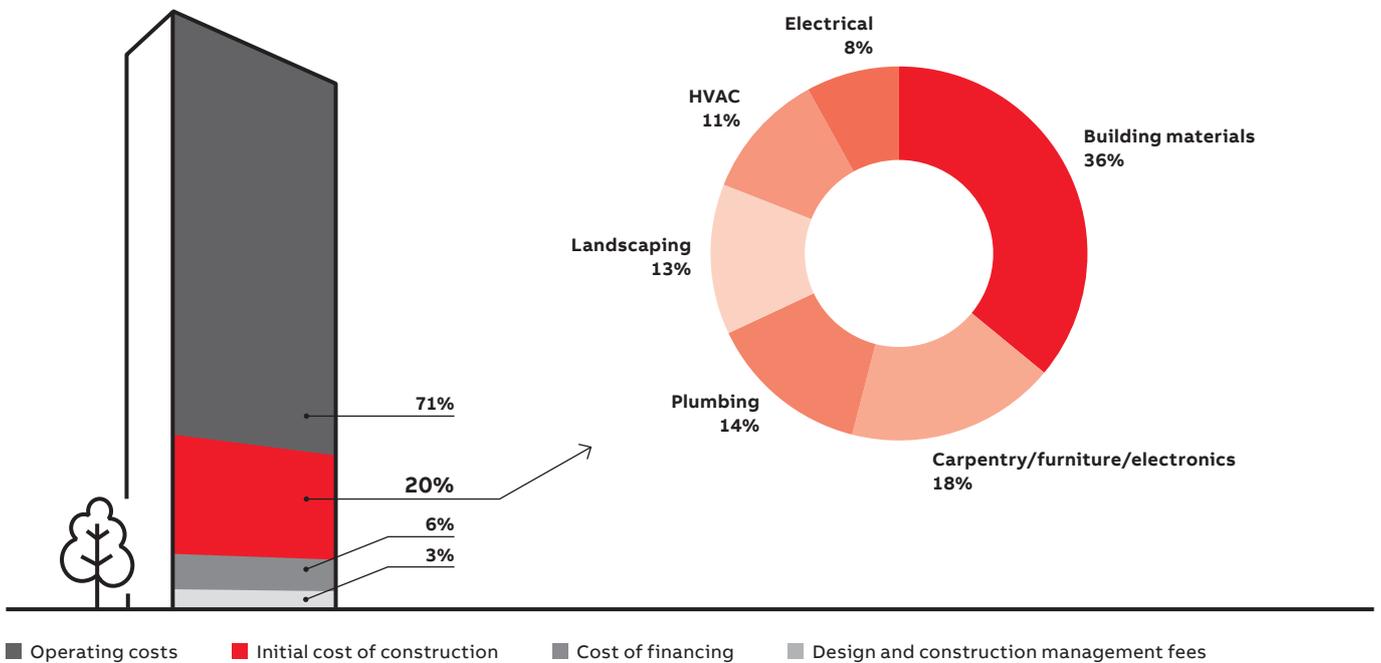
Investing wisely in HVAC automation and control can bring substantial cost benefits, and here is how it can be done.



# Benefits that variable speed drives for HVAC give to a building's TCO

To examine these benefits, let's take a closer look at each of the cost types and see what positive effect HVAC drives can have on those.

Commercial building capital costs breakdown



## Purchase costs

As initial capital investments can easily exceed 20% of a building's lifetime TCO, the building system design should be planned carefully. Most importantly, there should be a clear understanding how each particular solution affects the TCO. As indicated in the chart above by the Builders' Association USA, HVAC and plumbing together can account for about 25% of building capital cost, and electrical systems about 10%, which results in 5% of TCO for

a building with 40-year lifetime period. Optimized capital costs can significantly accelerate the return on investments.

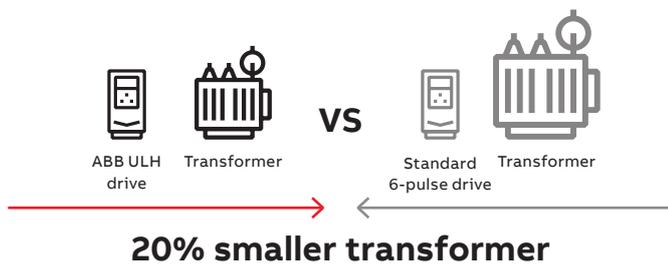
### Saving on power network equipment in greenfield projects

It's well-known that drives save energy in the processes they control, but most types of drives generate electrical harmonics to a power network. If the harmonics content

is too high, it can cause power network and connected equipment malfunctions and even failure, while also decreasing the network efficiency.

To avoid harmonics-related issues, power network components are typically significantly oversized. For example, in standard drives with basic harmonic mitigation built-in (AC or DC choke) the level of current harmonics measured in total harmonic distortion value (THDi) is about 40%. To manage this increased harmonics current it is required to oversize cables by about 10%, transformers by 35%, and power generators 2-2.5 times.

The massive oversizing can be avoided if drives based on active front end technology are applied. They generate only 3% THDi compared to about 40% THDi of standard drives. This requires only a relatively small oversize margin for transformers and generators – the most expensive elements of a power network.



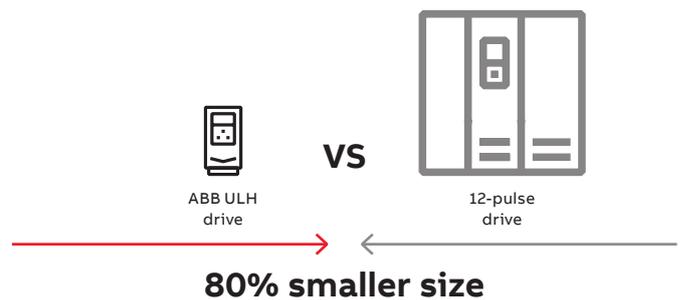
**Saving on power system redesign in retrofit projects**

Retrofit projects where the power network is already established and almost fully loaded usually have much less flexibility for adding extra loads. Improving the energy efficiency of retrofit buildings, at the same time, almost always involves variable speed drives to capture most of the efficiency gains. Choosing standard drives with relatively high harmonics content (40% THDi) might demand the installation of a bigger cabling system for the building to carry the increased current. This is a very costly procedure. And it's even more costly to replace already existing transformers and generators with bigger ones, which sometimes can be required.

This is where ultra-low harmonic (ULH) drives by ABB can play a crucial cost efficiency role. They do not require significant oversizing of power network equipment – typically only 10% for transformers instead of the normal 35% when using standard drives – saving substantial costs also in retrofit projects.

**Saving on space**

Of course, there are alternatives to ultra-low harmonic drives present in the market, e.g. harmonic filters or multi-pulse drives. But one good thing to understand is that the cost of purchase for a standard drive plus filter package can be close to ultra-low harmonic drives with harmonics mitigation built-in.



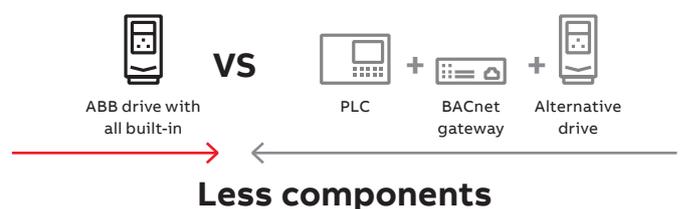
At the same time ultra-low harmonic drives are way more compact which results in space saving in buildings. This means smaller electrical and mechanical rooms in new developments, so the freed space can be used for commercial or residential purposes.

In retrofit projects, there simply can be not enough space to fit drive equipment, and the smaller it is, the bigger the chance the renovation will go smoother with no need to find extra space for new equipment.

It's also good to understand that power network components downstream the harmonic filter still need to be oversized, as the filter filters harmonics only upstream, towards the transformer.

**Saving on automation and control costs**

Another good way to save on a building's capital costs by using variable speed drives is to choose models with BACnet built-in, since BACnet is the most common building automation protocol worldwide. BACnet-enabled drives allow to save on external gateways. Furthermore, if choosing models with wide control capabilities, PLC functionality can be compensated partly or entirely by the drive. This can easily save hundreds of USD for the customer on purchase costs only.



## Cost of installation and commissioning

### Optimizing installation costs

Installation costs can depend a lot on the labor rate, so the less components the system has and the more straightforward the installation process is, the more savings on installation costs it's possible to achieve.

BACnet-enabled drives can ensure 30 to 40% savings in BMS installation costs due to reduced wiring and no external gateways needed. This is the result shown in [Damansara City project with BACnet enabled ABB drives for HVACR.](#)

Similar situation happens when installing electrical system components. If harmonics mitigation is required, ABB offers ULH drives with all-in-one. Only three wires in and three wires out instead of additional filter installation or complex wiring in multi-pulse drive installations with numerous components to connect.

### Commissioning cost reduction

Commissioning is a quality assurance process verifying that the systems installed during building construction or renovation meet the design requirements. Commissioning

is usually run by third party consultants during the construction process. Even if the building and its systems' design are optimized, their actual implementation during construction needs to be verified. The Builders' Association in the USA states that payback on commissioning costs is under 5 years on average, which can have a substantial impact on the building TCO.

HVAC system commissioning can become easier and faster with ABB's variable speed drives. They allow effortless integration into the building management system (BMS) thanks to controllers and most common building automation protocols being built-in, including Modbus and BACnet. This helps avoid external gateways and PLCs in the installation, decreasing overall complexity, commissioning and troubleshooting efforts.

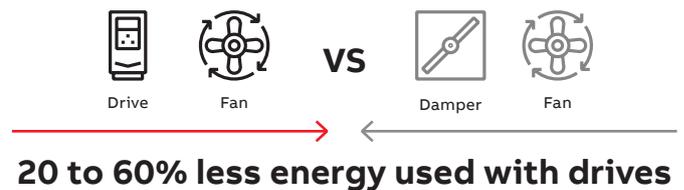
First start assistants in ABB drives easily guide through the parameter setup for HVAC application control, with no time wasted on studying instructions. Furthermore, the drive configuration can be copied to the rest of the drives with wired or wireless tools, to save even more time in the commissioning phase.

## Cost of running

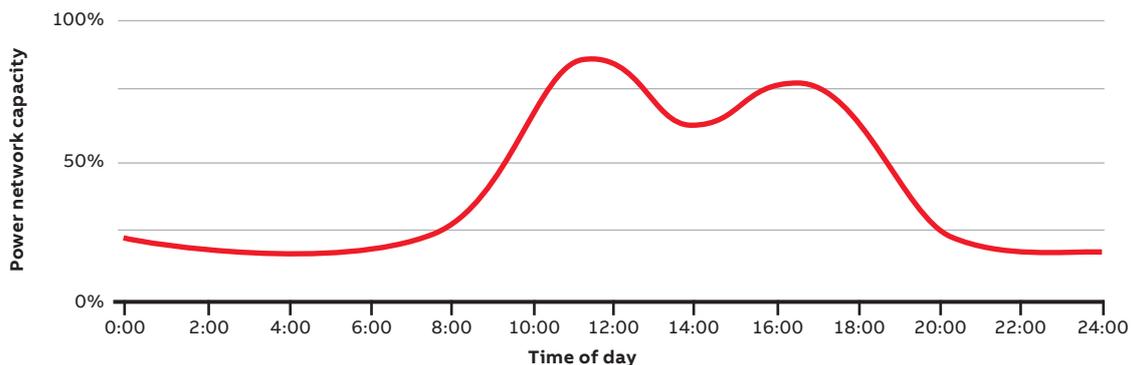
### Energy savings with variable speed drives for HVAC

Essentially, the biggest reason that variable speed drives are applied in building HVAC systems is to save energy. Building HVAC needs are never uniform as they fluctuate widely depending on weather conditions and building occupancy, but the HVAC equipment is sized for peak loads which almost never happen. Drives can automatically adjust motor speeds of HVAC applications like fans, pumps or compressors to a building's needs, so only the precisely required amount of heating or cooling is generated. Thus, drives save on average 20 to 60% of energy consumed

by HVAC in comparison to traditional control methods like valves or dampers. This fact substantially reduces a building's operating expenses – by 5 to 10%.



### Typical energy use in commercial buildings



**ROI example based on energy savings**

A good example is a recent case with an ABB HVAC drive used in the renovation of a ventilation system in one of the commercial buildings in Lyon, France. The drive replaced the traditional outlet damper controlling the airflow in the building. This resulted in ventilation energy savings of around 50%, helping the building to meet its sustainability goals. Over a year these savings totaled 40 900 kWh, cutting the building's annual energy bill by €6 543, which delivered the projected return on investment in about 2 months.

- Fan power 37 kW, nominal volume flow 10 m<sup>3</sup>/s, pressure increase 0.03 bar
- Annual fan running time 4 380 h
- Duration curve 90% flow – 5%, 80% flow – 5%, 70% flow – 10%, 60% flow – 50%, 50% flow – 15%, 40% flow – 10%, 30% flow – 5%
- Energy price €0.16/kWh
- France CO<sub>2</sub> emissions multiplier 0.06 kg/kWh
- Investment cost €1 200

**Calculate potential savings** with VSDs for your project using our EnergySave calculator <https://energysave.abb-drives.com/>

**Results**

**40.9 MWh**  
Annual energy savings

**50.2%**  
Annual energy savings percentage

**67 days**  
Direct payback time

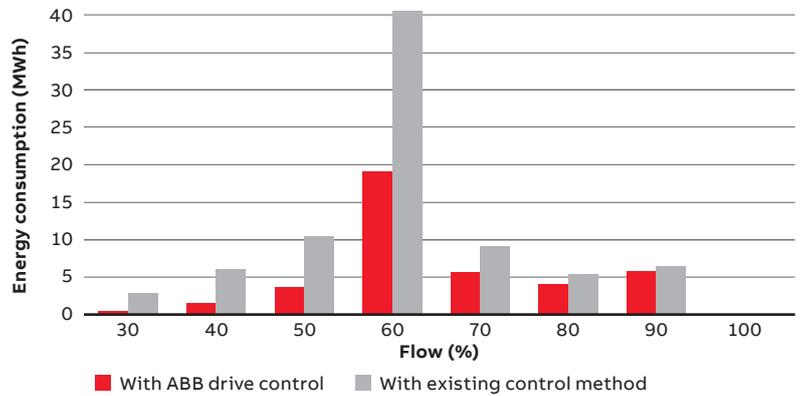
**81.5 MWh**  
Annual energy consumption with existing control method

**6,543 €**  
Annual financial savings

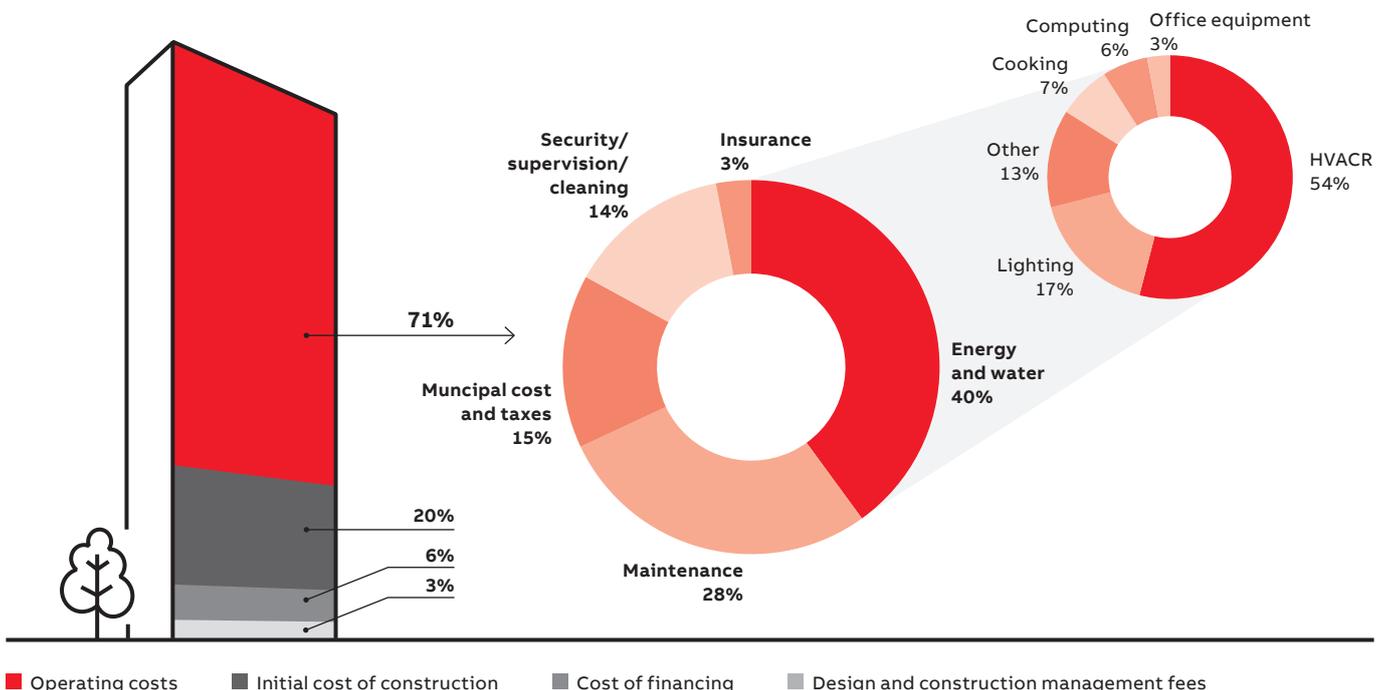
**40.6 MWh**  
Annual energy consumption with ABB drive control method

**2.5 t/year**  
CO<sub>2</sub> reduction

**Total energy consumption**



**Commercial building operating costs breakdown**



### Energy savings thanks to BMS

With BACnet-enabled drives as part of the BMS it is possible to monitor the HVAC energy usage in the whole building and optimize it further to maximize energy savings. Various consulting companies confirm that a properly functioning BMS with most of building system components integrated delivers energy efficiency savings in the order of 15-20%.

### Energy efficiency of power networks

Besides HVAC system efficiency, drive technologies can affect the efficiency of the building power network.

Thus, the lower the harmonics content drives introduce, the lower the overall line current, and the lower the power network losses as a result.

More and more utilities start charging for increased harmonics content, so applying advanced drive technologies like ABB's ULH drives with total current harmonic distortion THDi below 3% can help building owners avoid this kind of problems.

**40% THDi means  
16% higher network energy losses**

### Total line current $I_{rms}$ and relative Joule losses as a function of the THDi harmonic content

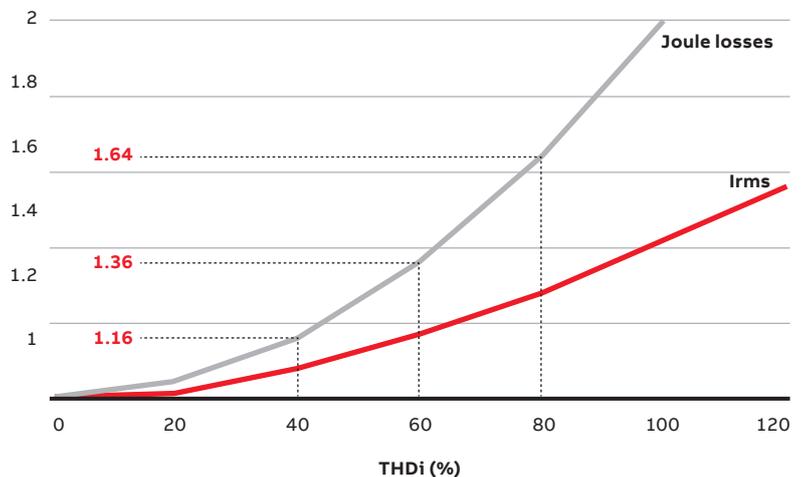
The passage of electric current through a conductor produces losses resulting in heat:

$$P = I^2 \cdot R$$

The transmitted active power is a function of the fundamental current  $I_1$ .  
When the current contains harmonics, its total value  $I_{rms}$  is greater than the fundamental current  $I_1$ .

$$I_{rms} = I_1 \cdot \sqrt{1 + TDDi^2}$$

The harmonic currents cause increased Joule losses in all conductors they flow through.



### Cost of maintenance

Building systems maintenance has a significant impact on the operating costs – about 30% – and the TCO as a result. Maintenance implies functional checks, repairing, or replacing necessary parts. The less the need for regular maintenance check-ups and the longer the intervals between the maintenance actions, the lower the overall maintenance costs.

Here are several examples of how ABB drives and services can support you with this.

- Drives can set alarms for maintenance actions like filter cleaning, as a clogged filter causes HVAC systems to use 15 % more energy, according to the U.S. Department of Energy.
- Drives can help to equally distribute working hours between e.g. pumps in pumping stations, so the equipment lasts longer, and wear is minimized.
- Drive-based detection of a motor bearing failure helps identify the problem early enough and conduct preventive maintenance to avoid costly consequences.
- Drives also have built-in alarms for their own maintenance

as well, e.g. for cooling fan replacement, run time counters, control board temperature monitoring.

- Planned maintenance check-ups can be optimized with ABB Ability™ Remote Monitoring service, which helps determine whether or not the physical presence of personnel on site is needed, thus relieving unnecessary pressure on in-house maintenance teams.
- ABB's global service network and preventive maintenance contracts increase the speed of response for critical issues.

It's also important to consider the ease of repairability of the HVAC solutions when making an equipment choice. Integrated motor drives might seem to be a more compact variant that eliminates some installation effort, but they are prone to fail faster due to both increased vibrations of electronics mounted on the motor and higher temperatures.

When it comes to servicing drive systems, it's easier to repair or replace standalone drives than integrated ones, whereas technologies like EC fans have to be completely replaced. This causes increased costs, and also negatively affects the building's sustainability efforts.

## Cost of malfunction/not running



### Cost of comfort and safety

HVAC can play a critical role in keeping a building operating smoothly, comfortably and safely. But when there is an HVAC failure, this can lead to discomfort for the occupants, and in worst cases make it impossible for people to remain in the building.

Living standards are continuously increasing. Developers are willing to invest in building comfort control and smart solutions, since it translates into a higher attractiveness to future owners or leasers. The more digital the building is, the more advanced, transparent and flexible its management systems, resulting in occupant comfort and safety at optimal costs.

Issues with poor HVAC can also cause occupant illnesses and decreased productivity resulting in unwillingness to continue renting or owning the space. The inability of building systems to ensure safety in case of fire can cause high fines and legal issues for the developers and owners.

### Drive features to increase comfort

ABB's HVAC drives provide precise comfort control in normal situations by ensuring proper temperature, humidity and air exchange rate in the space.

- The drive's built-in HVAC protocols allow easy integration into a BMS for precise environment control according to a building's everchanging needs.
- Quieter HVAC operation – for increased comfort – is possible thanks to the drive's ability to skip acoustic resonance frequencies.

In case of a fire emergency, the drives easily become part of the building fire suppression strategy.

- The built-in override mode helps ensure safe evacuation routes by pressurizing corridors and staircases, while extracting smoke for better visibility and easier access for firefighters.
- The override mode also allows it to ignore non-critical faults and warnings, running fans as long as the situation requires.
- Motor phase loss detection feature allows the drive to inform the BMS about any broken cables for usually

not running applications like smoke extraction fans, so immediate actions may be taken without the risk in the future.

The result is saved lives and minimized property damage. Thus, the ability of the building systems to safely manage emergency situations also affects TCO.

### Cost of proper environment

Costs of HVAC downtime can be even higher for mission critical facilities like data centers where cooling failure even for just a few minutes can cause IT equipment shutdown, leading to serious financial losses. According to multiple studies, data center downtime costs on average \$5,600 per minute. The hourly costs range between \$140,000 and \$540,000. And reputational damage may suffer even higher costs thereafter.

A study commissioned by Emerson shows that **15%** of data center outages are due to cooling system failures

### Drive features to prevent downtime

To avoid the costly consequences of HVAC failure, ABB drives and services can offer multiple solutions that ensure increased system reliability. Among these are:

- Soft start and stop function to minimize wear and tear on HVAC equipment for longer uninterrupted operation and reduced electrical and mechanical stress.
- Undervoltage compensation so HVAC equipment can ensure nominal performance regardless power quality.
- Elimination of electrical harmonics that are harmful to power networks and connected equipment.
- Supply phase loss detection allowing the drive to derate its output, so the controlled application would still run at reduced speed.
- Intelligent pump control that kicks in a stand-by unit if the duty unit fails.
- Remote condition monitoring to make sure required maintenance is done before a breakdown failure occurs.

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## ABB's HVAC drives and services portfolio to optimize a building's TCO

We offer a wide selection of drives for building HVAC systems – wide power range, various construction types and protection classes – but all with intuitive user interface, built-in application features and strong service support 24/7.





### With ABB Ability™ digital services



#### Solid fact-based decision making

Get the facts, and the history, to help run your HVAC more efficiently and safely.



#### Always stay one step ahead of problems

Recognize early signs of possible failures and assess the risks, before they turn into serious operational issues.



#### Find the root cause of process issues

Remotely access data from ABB drives built-in sensors to track the cause of problems. Get back to smooth operation quickly with data back-ups.



#### Remotely analyze and optimize drives

Get critical drive information anywhere anytime – even in difficult to access sites, or when a site visit is impossible.

### ABB drives portfolio

For half a century, ABB has been leading the way in optimizing HVAC systems in buildings by using drive control. The new series of HVAC dedicated variable speed drives provides comfort and safety for occupants or a specific environment for equipment like data center servers, while ensuring reliable and energy efficient HVAC processes.

We offer a wide range of drive designs, powers, voltages and protection classes so even the most demanding requirements in HVAC can be satisfied. Our standard HVAC dedicated ACH580 drives include wall-mounted, module and cabinet versions and options like mains disconnect and C1 EMC filtering.

For installation compactness, the ACH480 drive is available to meet even the most difficult space limitations without compromising on HVAC functionality.

And for maximized process reliability, ACH580 ultra-low harmonic HVAC drives are present in ABB's portfolio. They eliminate harmonic disturbances in the power network to ensure better power quality and reliability, efficiency and lifetime for the connected equipment. Should voltage fluctuations occur in the network, the drives are ready to compensate by providing nominal voltage at the application end. Mission critical processes like data center cooling or operating theater air conditioning benefit most from ABB ultra-low harmonic drive technology, also thanks to the savings made on transformer and generator sizing, which is influenced by power quality.

### ABB services portfolio

A fleet of services including digital services ensure support of your building HVAC control 24/7 throughout its lifetime. Training, installation and commissioning, technical support and repairs, engineering and consulting, upgrades and retrofits, maintenance, replacement and end-of-life services are all available for ABB HVAC drives.

ABB Ability™ digital services include remote Condition Monitoring for system performance transparency, so efficiency or reliability problems can be spotted remotely right away.

- With the Alarm Management, you'll receive instant alerts when the drive values change, enabling you to make fast maintenance decisions without the need to be on-site.
- The Asset Health service performs asset data comparisons to spot inconsistencies in operations, so required maintenance actions can be taken.
- The Backup Management feature keeps you always up-to-date on the settings of a large installed base.
- The Remote Assistance provides expert support for any issues with your drives, saving time and money as remote troubleshooting can start as soon as a fault occurs, and with no need to divert maintenance resources on-site.

Now it's your choice to invest in drive technology for your HVAC systems wisely, so the most optimal TCO can be reached throughout your building lifetime.





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For more information, please contact  
your local ABB representative or visit

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