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Application Paper | Avoided emissions

Avoided Emissions Calculation:
Danfoss Drives Methodology

A methodology by Danfoss Drives.

drives.danfoss.com

››› Table of Contents

List of Abbreviations

AE	Avoided emissions
EF	Emissions factor
GHG	Greenhouse gas
LCA	Life cycle assessment
RSL	Reference service life
SF	Savings factor

››› Introduction

Avoided emissions refer to the reduction of greenhouse gas emissions achieved by using products or solutions that replace more carbon-intensive alternatives. These emissions reductions occur outside a company's direct operations or value chain but contribute significantly to global climate targets by enabling decarbonization across industries. Given the urgency of climate action, avoided emissions play a crucial role in supporting global net-zero ambitions, particularly in sectors where electrification, efficiency improvements, and smarter energy use can lead to substantial reductions in overall emissions.

In the case of AC drives, also known as variable speed drives, their ability to optimize motor control leads to significant energy savings, reducing electricity consumption and associated emissions. According to the International Energy Agency (IEA)[1] 40% of the world's industrial electric motors do not meet minimum energy performance standards. Improving motor efficiency through AC drives is thus one of the most effective ways to cut global energy demand and emissions. Avoided emissions are therefore a critical component of Danfoss Drives' climate strategy and ambition to become the preferred decarbonization partner for our customers.

To effectively track and report emissions, companies typically follow the Greenhouse Gas Protocol[2] which focuses on value chain greenhouse gas (GHG) emissions categorized into Scope 1, 2, and 3. However, value chain reporting alone does not capture the full climate impact of products that enable emissions reductions elsewhere. Avoided emissions reporting complements value chain emissions accounting by showcasing how a company's solutions contribute to global decarbonization beyond its own operations, often referred to as Scope 4.

Despite the growing recognition of avoided emissions as an essential component of corporate climate strategies, there is currently no universally accepted methodology for their calculation. The World Business Council for Sustainable Development (WBCSD) guidance on avoided emissions[3] offers state-of-the-art guidance on how companies can begin assessing avoided emissions but does not provide detailed methodologies tailored to specific product categories and industries. This lack of standardization can create inconsistencies in reporting, making it challenging to assess the credibility of claimed emissions reductions. Without a transparent approach, there is also a risk of overestimation, misinterpretation, or even greenwashing, undermining the credibility of avoided emissions as a meaningful climate metric.

The methodology described in this document applies existing guidance from the WBCSD to the specific context of AC drives, providing a practical and transparent approach to calculating avoided emissions. It is designed to ensure clarity on how Danfoss Drives estimates the positive climate impact of its products while maintaining accuracy and avoiding overstatement. By offering full transparency on assumptions, data sources, and calculation methods, this methodology aims to enhance trust and credibility in our avoided emissions reporting.

The approach described here can serve as a guide for other stakeholders in the AC drives manufacturing industry, including customers seeking to understand the climate impact of the AC drives they use. As Danfoss Drives continues to support customers in reducing their energy consumption and emissions, a transparent and credible avoided emissions reporting approach is essential in demonstrating our role as a trusted decarbonization partner.

[1] International Energy Agency (2024). Energy Efficiency 2024. https://www.iea.org/reports/energy-efficiency-2024
[2] Greenhouse gas protocol. A Corporate Accounting and Reporting Standard. https://ghgprotocol.org/corporate-standard
[3] World Business Council for Sustainable Development (2023). Guidance on Avoided Emissions: Helping Business Drive Innovations and Scale Solution Toward Net Zero.
https://www.wbcsd.org/resources/guidance-on-avoided-emissions-helping-business-drive-innovations-and-scale-solutions-towards-net-zero/

››› Scope & Context

The aim of this methodology paper is to create transparency concerning how avoided emissions (AE) are calculated for Danfoss Drives products. AE refer to emissions savings achieved by customers using Danfoss Drives' products compared to a reference scenario.

AE does not include any offsetting or carbon credits and is only related to the use of the Danfoss Drives product solutions. It also does not include any efforts towards carbon sinks or carbon removals. The scope is gross AE, meaning that emissions from production of the products or from using the products (e.g. the energy consumption of the drives) are not included as these are reported in the company's Scopes 1-3.

AC Drives, also known as variable speed drives, are recognized as an energy efficiency solution with direct impact and climate mitigation potential, as AC drives ensure reduced demand for energy input of electric motor-driven applications.

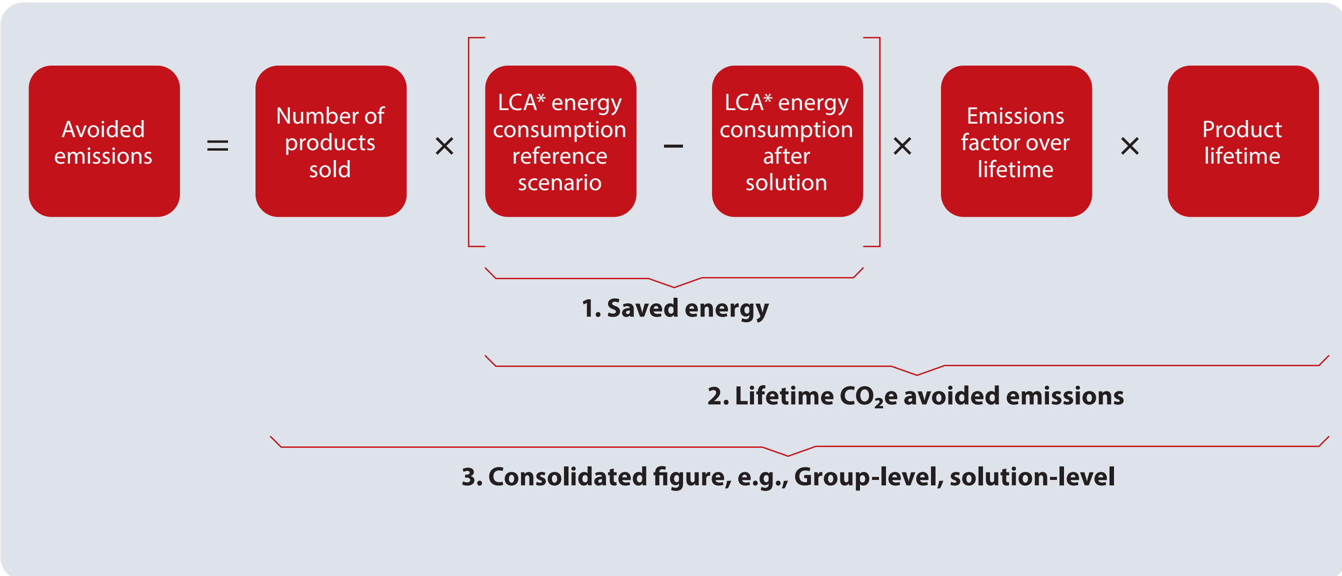

Figure 1: *Formula for calculating avoided emissions.*

Avoided emissions reporting complements value chain emissions accounting by showcasing how much Danfoss solutions contribute to global decarbonization. Avoided emissions are a critical component of the Danfoss decarbonization strategy, as Danfoss strives to become the preferred partner of its customers in decarbonization.

Following the [Science Based Targets initiative (SBTi) Corporate Net-Zero Standard][4], avoided emissions cannot be used to claim carbon neutrality or net-zero status.

No standard yet exists on how to calculate AE, so different companies are defining their own methodologies or following guidelines from international organizations, such as the World Business Council for Sustainable Development (WBCSD). Danfoss has created an AE framework that follows the guidelines from the WBCSD but allows for the specific application to Danfoss products. The methodology described in this paper follows the structure of the WBCSD guideline[3], therefore covering eligibility checks, reference scenarios and the calculation and interpretation of the results. The exact approach for each of the steps has been applied in the product specific context of Danfoss Drives products. The purpose of this methodology is to be used as a stand-alone approach for calculating avoided emissions of AC drives products.

[3] World Business Council for Sustainable Development (2023). Guidance on Avoided Emissions: Helping Business Drive Innovations and Scale Solution Toward Net Zero.
https://www.wbcsd.org/resources/guidance-on-avoided-emissions-helping-business-drive-innovations-and-scale-solutions-towards-net-zero/

[4] Science Based Targets. (2024) SBTi Corporate Net-Zero Standard Criteria. Version 1.2, March 2024. https://sciencebasedtargets.org/net-zero.

General Approach

The following section will provide a general overview of the approach taken to calculate avoided emissions for Danfoss Drives.

Structure

The WBCSD's Climate Avoided Emissions Guidance outlines various steps to ensure trustworthy avoided emissions claims:

1. Eligibility Check – First, one must ensure that the company claiming avoided emissions has proper credibility towards the climate transition and that the product solutions have a direct impact that aligns with sustainability transition pathways.
2. Reference scenario – Second, one must select trustworthy reference scenarios to ensure eligible AE comparisons.
3. Calculations – Third, one must ensure when conducting AE calculations that a set of trustworthy principles are followed in a transparent manner.
4. Reporting & Communication – Lastly, one must ensure that the avoided emissions are communicated in a transparent manner externally to avoid greenwashing allegations.

This methodology requires that Step 1 (Eligibility Check) has been carried out prior to applying the proposed calculation method. In general, Danfoss has a commitment towards promoting sustainability continuously through offering energy-efficient solutions, has defined SBTi goals, and publicly discloses Scope 1, 2 and 3 value chain emissions through annual reporting[5]. Additionally, AC drives are a recognized energy efficiency solution, as described by The European Commission, in Annex I of the Commission Delegated Regulation (EU) 2021/2139[6].

The methodology builds further onto specifically Step 2 (Reference Scenario) & Step 3 (Calculation), as this paper aims to offer a more concrete and robust guideline to the practical implementation of the framework. The methodology follows all the requirements laid out in the WBCSD guidelines, such as the exclusion of all fossil fuel-related activities and avoiding double counting. The section "Recalculation Policy" later in this paper explains in detail when recalculation is necessary, for example in regard to ongoing work from organizations such as CEMEP: The European Committee of Manufacturers of Electrical Machines and Power Electronics https://cemep.eu/

Parameters

For the calculation of avoided emissions on a company level three primary categories of parameters are considered. The three categories of parameters are the following:

1) A geographical aspect of the use of AC drives products
2) The reference scenarios as outlined by the WBCSD (2023)
3) The data regarding the use phase parameters for products causing avoided emissions

The last two categories of parameters (category 2 & 3) are part of the WBCSD guidelines, while the first category of 'Geographical assumptions' are included to add extra granularity and accuracy when calculating the AE of the Danfoss Drives segment. The parameters regarding these three categories will be expanded upon in the following sections.

Following the WBCSD Guidelines (2023), there are various levels of specificity when reporting AE, based on the preciseness of the data (Figure 2).

		Solution		
Reference scenario	Specificity level	Solution-specific	Company-specific	Statistical
	Solution-specific	Very high	High	Medium-high
	Company-specific	High	Medium	Medium-low
	Stastical	Medium-high	Medium-low	Low

Figure 2: *A matrix displaying the specificity levels of calculating avoided emissions (taken from the WBCSD's Avoided Emissions framework).*

To calculate AE credibly, it is important to specify the appropriate reference scenarios and gather data for the Danfoss Drives solutions, both at least at a company-specific level, to reach a 'Medium' specificity level as minimum.

[5] Danfoss. Sustainability. https://www.danfoss.com/en/about-danfoss/company/sustainability/
[6] The European Commission (2021). Commission Delegated Regulation (EU) 2021/2139. European Union. https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=celex%3A32021R2139

Data collection

To increase the accuracy of the calculations, this methodology for Danfoss Drives is taking an industry-specific approach, looking from the level of specific industries and applications. This is to be able to collect more granular data and necessary assumptions from relevant industry experts as the data and assumptions can vary based on application and thus industry. The methodology for calculating company-wide avoided emissions consists of examining, for each application, the geographic, regional end-use location of products and subsequently collecting data for the relevant reference scenarios.

For Danfoss Drives, several different application types are considered, in line with the different industries Danfoss Drives serves, such as HVAC, Water & Wastewater, and Food & Beverage. This is done to ensure that application-specific data and assumptions can be gathered since each application-type has its own characteristics.

In general, AC drives manufacturers often have little information on the exact use location and reference scenarios of their products. Therefore, the expertise of industry experts and other industry-specific data can be used to serve as input. In case first-hand data is available, this should be used instead.

To gather data regarding all AC drives sold in a year covering relevant reference scenarios and geographical scopes, interviews and surveys with relevant industry experts are conducted. This approach consists of interviewing at least one or two internal (or external if available) industry experts for each application to gain an understanding of the end use application of the product and collect initial input regarding the geographical location as well as reference scenarios. Following completion of the interviews with industry experts, a survey is created to scale up the data gathering and get a greater picture of geographical scope and reference scenarios for the applications.

Data gathering is to be conducted annually through the survey, which shall be refined based on feedback or if shortcomings are identified in the questions and/or target audience. Ideally, every application should be represented by a similar number of experts in the survey to ensure alignment in data reliability. At the moment, no public data is available regarding market average performance of AC drives or minimum requirements. If in the future this data does become available, it will be used for the relevant reference scenarios instead of the input from internal experts.

The data needs to be sufficient in terms of quality and quantity to be representative of reality. To be considered sufficient quality, the data needs to be up to date (no older than 2 years) and cover the entirety of the reporting period. The data also needs to be technology-specific and be assigned to a specific application type. More information about the specific data gathering concerning the three categories of parameters of geography, reference scenario and use phase parameters, will be expanded upon in the following sections.

All emissions from oil & gas-related applications are excluded in the AE calculations as these applications do not meet the eligibility criteria as referred to in Step 1 (Eligibility Check). This is because sales to the oil & gas industries do not align with the global sustainability transition pathway.

››› Geography

Context

Data on the installed location for Danfoss Drives products is needed to improve the accuracy of AE calculations. This is because if a global emissions factor (EF) is used for all products, it will not consider the fact that different regions and countries have varying grid mixes with distinct emissions associated with them. By refining the geographical accuracy of the sold products, regional EFs can be applied, leading to a more accurate picture of the AE. For example: If most products are installed in Europe, (with a lower EF than the global average) and the global EF is utilized, then the AE would be overestimated. Alternatively, if the global EF is utilized but most products are installed in China (with a higher EF than the global average), then the AE would be underestimated. It is therefore necessary to determine, as best as possible, the use location of the products in terms of geographical regions.

Approach

As mentioned before, AC drives manufacturers often do not have first-hand data on where the AC drives end up being used. Therefore, sales data is used to define the geographical location of sold or installed products. To validate the information acquired from sales data, interviews are conducted with various internal experts for each application, where two outcomes are possible:

- It is confirmed that the product is installed in the same region as where it is sold
- It is confirmed that the product is most likely not installed in the same region as where it is sold, and the industry expert provides an estimated split of the sold products over the geographical regions

This methodology is based on several geographical regions where the sales occur.

Emissions factors from the International Energy Agency (IEA)[7] at the regional level are applied. The IEA provides EFs annually for every country and region. The forecasts provided by IEA over time are based on conservative assumptions on the uptake of renewable energy globally. To determine the EFs for years in between, linear interpolation is used for the countries making up each of the regions. The 'Limitations' chapter outlines the potential limitation of this approach.

Certain industries, such as the marine industry, are powered by sources of energy other than electricity, namely fuel. Hence a different approach is taken to calculate the AE of this industry, where the EF should represent the fuel rather than a region's electricity grid.

[7] International Energy Agency(2024) Emissions Factors 2024 https://www.iea.org/data-and-statistics/data-product/emissions-factors-2024

››› Reference Scenarios

Context

For the reference scenarios the WBCSD guidelines are used as a starting point and then further refined to better fit the Danfoss Drives specific needs. The reference scenarios are of importance for the calculation as they affect the baseline for comparison, and thus, the amount of AE that can be claimed. In general, the figure below (Figure 3) displays the function of the reference scenario:

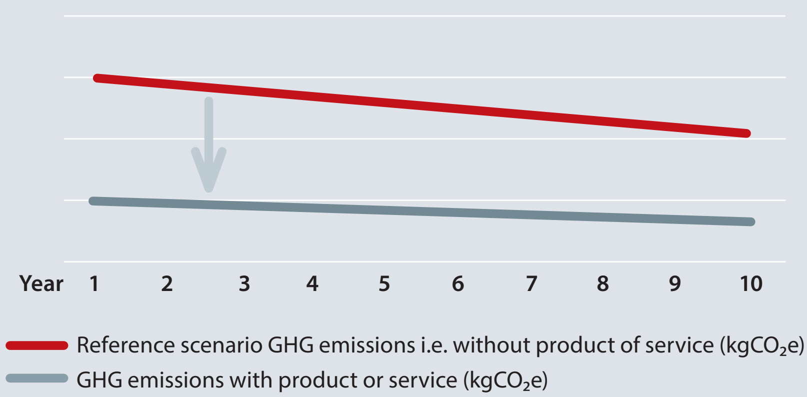

Figure 3: *Display of how avoided emissions are calculated by always comparing to a reference scenario. Avoided emissions are the difference between the energy consumed in the refence scenario, minus the estimated energy consumed in the new scenario with a solution.*

When making any assumptions regarding the reference scenario, conservative estimates are applied to avoid overestimation of the AE. In practice this means that when establishing the reference scenario, one shall consider what is the most relevant alternative for the specific application to be comparing to, while at the same time ensuring that the performance of this alternative is not underestimated. Since the AE will most likely be overestimated if an unrealistically poor performing reference scenario is chosen, the reference scenario shall be kept conservative when unknown. To illustrate this, consider the following example: An AC drive in a fan system is being replaced by a more efficient AC drive. If the performance of the old AC drive is underestimated, the AE compared to the more efficient AC drive will be overestimated. Therefore, a more average or well performing AC drive shall be chosen for the reference scenario to ensure that the calculated AE represent a realistic, or conservative, scenario.

The WBCSD differentiates between five different reference scenarios (Figure 4) based on the specific application:

1. **New demand**
2. **Improvement – regulation** imposed
3. **Improvement – non-regulation** imposed
4. **Replacement – regulation** imposed
5. **Replacement – non-regulation** imposed

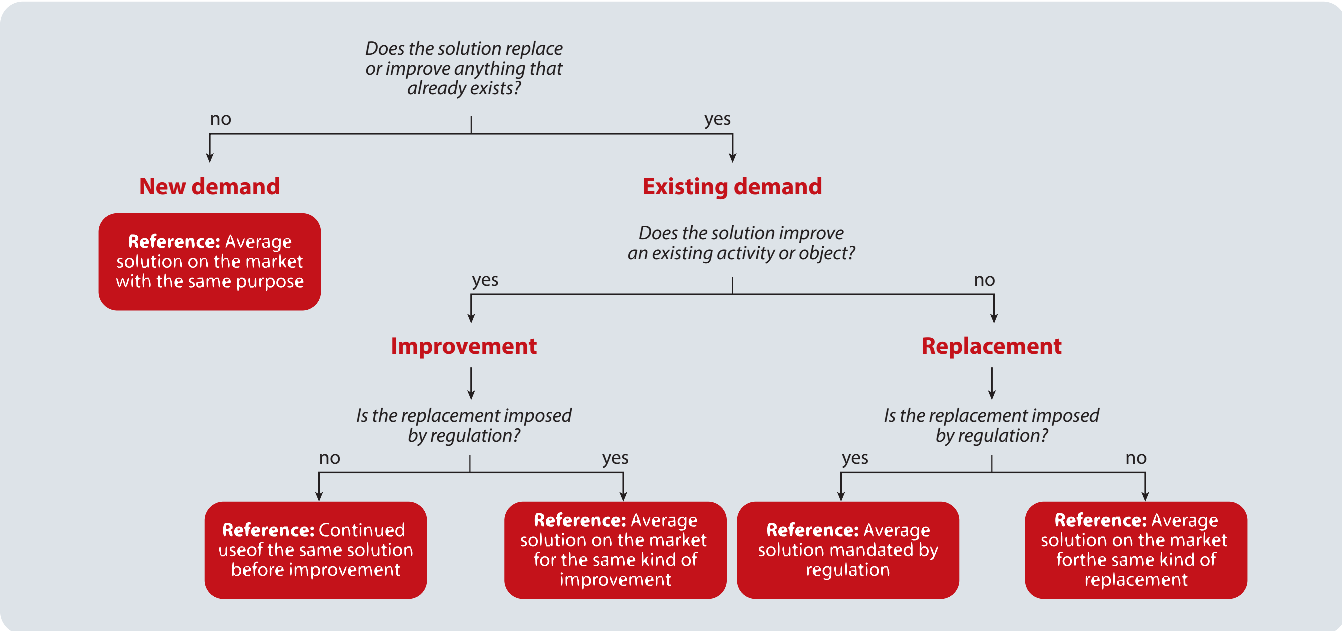

Figure 4: *The decision tree that determines which reference scenario to use, taken from the WBCSD's Avoided Emissions framework* [8].

This methodology further refines these scenarios to better fit the specific products and industries of AC drive manufacturers. The following definitions are defined for the three scenario groups:

- **New demand:** A completely new system has been built, and the AC drive has been included from the start
- **Improvement:** An already operating system gets improved through the addition of a (more efficient) AC drive
- **Replacement:** An already operating system gets an AC drive replacement to fulfil the same functionality with the same efficiency

[8] World Business Council for Sustainable Development (2023, p23). Guidance on Avoided Emissions: Helping Business Drive Innovations and Scale Solutions Toward Net Zero. https://www.wbcsd.org/resources/guidance-on-avoided-emissions-helping-business-drive-innovations-and-scale-solutions-towards-net-zero/

Approach

The following data is needed for each reference scenario:

- **New demand:** The new AC drive should be compared to the market average product performance of the same product type, where market average is defined as the average reference of the product in a given market (in case of AC drive manufacturers this is the market average efficiency of an AC drive within the relevant industry)
- **Improvement:** In case of no regulation, the AC drive should be compared to the continued use of the previous system (in case of AC drive manufacturers this is either the continued use of the old, less efficient AC drive, or the continued use of the system without an AC drive). For the reference scenario it is then assumed that the previous system would have remained in place and running for the set time period (the lifetime of the AC drive solution) without a replacement taking place in this time (for example the potential replacement of the previous system with the same performing solution at the end of its life). It is possible that the previous system would have needed a replacement at the end of life, but this replacement is not included in the reference scenario as it is case-specific. Aside from this, in assuming no replacement, the reference scenario is conservative. If the additional emissions from a replacement were included, the reference scenario's emissions would be higher, and the claimed AE as well as a result. Thus, by not including a replacement, the AE are less likely to be overestimated. In case of regulation-imposed improvements, the AC drive should be compared to the definition of the minimum requirements as defined in the regulation (e.g. a minimum efficiency of an AC drive as specified in the regulation)
- **Replacement:** In case of a replacement no AE are claimed as the assumption is that the new AC drive will not change the functioning or performance of the system

At Danfoss Drives, interviews and surveys are used to assess the split of sales between the different reference scenarios. The survey shall be answered by internal experts who provide data for a specific type of application and thus individual industries within their expertise. Potential limitations, including the number of experts consulted, are described in detail in the section 'Limitations' later in this paper. The survey shall contain questions about the efficiency of AC drives, as well as usage in terms of reference scenarios (such as percentage split between the different reference scenarios). To ensure input for each application type, multiple experts shall be contacted per application type to ensure input for the different industries. For each application at least one participant is necessary to cover the industry questions, although it should be noted that the more experts providing input, the more accurate the data would be. The average market efficiency of an AC drive could be taken from external sources, but so far, no average efficiency has been established in the AC drive industry.

To be able to annually calculate the overall AE for Danfoss Drives, data shall be collected for the different reference scenarios as outlined below.

First, the percentage split between the reference scenarios (New Demand, Improvement, Replacement) is determined for each application type.

Another factor that could potentially impact the split between the different scenarios is the size of the AC drive. However, based on collected data no indication was found that this is currently the case for any application type. If this were to change, and a correlation would be found between AC drive's size and split between the reference scenarios, additional data should be collected to determine what the split would be in cases of different sized AC drives. In the calculations, an extra filter for AC drive's size would then be added to implement this data accordingly.

In case of an improvement scenario, two possible scenarios are identified in which the AC drive serves as an improvement:

- The customer installs an AC drive in an installation previously running direct-on-line without a VSD installed
- The customer upgrades the AC drive in an existing installation to a higher-efficiency AC drive

What has to be determined is thus what percentage systems already had an AC drive and what percentage of systems did not have an AC drive installed. To determine the split between these two improvement scenarios, ideally data would be gathered directly from the source, in this case the use location. In case this type of data is not available, industry experts for each application are asked for a split.

The market average product performance for the same product type (that is, the average efficiency of an AC drive on the market) is collected and used in both the New Demand and Improvement scenarios. For each application type, estimates are collected of what the average industry efficiency of an AC drive is on a global scale as well as for the AC drive manufacturer's products only.

To determine the proportion of installations that are regulation-imposed, it is important to create an overview of which regulations are in place or coming up which would force end-users to include an AC drive. If no relevant regulations are found, the market average is taken as a reference scenario. This is assumed to be a conservative approach as the regulations are expected to set a minimum efficiency that is lower than the market average.

When calculating AE for a specific case, the product-related emissions (production and end-of-life) are also included to ensure that these additional emissions are added to the new scenario before comparing it to the reference scenario, where no additional product-related emissions are added. Since this methodology covers the calculation of AE on a company level, these product-related emissions are covered in Danfoss' Scope 1, 2 & 3 value chain emissions. To calculate the "clean" AE, the relevant emissions from the different Scopes (raw material, production energy, end-of-life) are subtracted from the AE. To ensure that the AE are correctly understood by various stakeholders, the AE should always be disclosed together with Scope 1, 2 & 3 emissions, to keep them in perspective of the overall emissions picture. In general, Danfoss takes an attributional approach to LCA, which is also the case for this methodology.

Savings Factor

Once all the data is in place for each application type for the different reference scenarios, as well as the applications' market average product performance, a savings factor for each application type is calculated. The savings factor is calculated based on the various inputs for each reference scenario per application type. The savings factor represents the average savings that can be claimed for a specific application type. It thus represents the average savings based on the split in reference scenarios and the related savings for each, thereby removing the need to calculate the savings per reference scenario individually for each application.
The formula used to calculate the savings factor for each respective application is illustrated below (Figure 5). The formula considers an efficiency improvement factor for each reference scenario. It should be noted that the reference scenario of 'Replacement' is not included in the formula as it is assumed that the AE associated with 'Replacement' are 0.

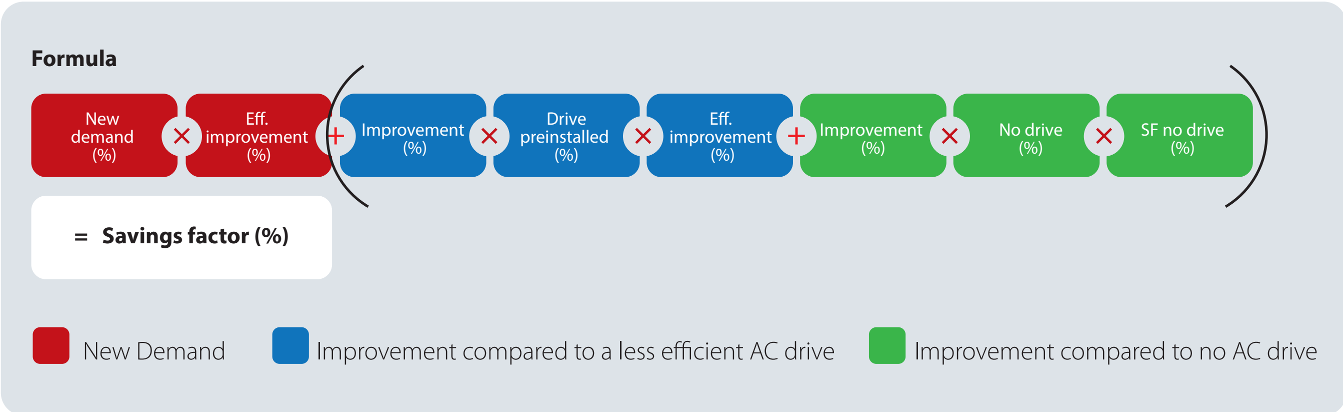

Figure 5: *The formula to calculate the individual savings factor for each application.*

The first box of each color (New Demand (%) and Improvement (%)) contains the percentage splits for the specific application among these reference scenarios. The Eff. Improvement (%) for both New Demand and Improvement is the improvement in efficiency of the new AC drive compared to the market average. If in the future regulations come into effect specifying minimum AC drive efficiencies, an additional part must be added to the formula covering the efficiency improvement compared to this minimum efficiency. Drive pre-installed (%) contains the percentage which represents the cases in which an AC drive is assumed to be pre-installed, and thus where the new AC drive must be compared to the market average rather than to no AC drive. In contrast, No drive (%) contains the percentage of cases in which no AC drive was installed prior and where the new AC drive is thus compared to direct-on-line. The SF no drive (%) therefore represents the average improvement gained through installment of an AC drive compared to no AC drive.

Example of calculation

Below is an illustrative example for the HVAC application, demonstrating the calculation of the savings factor. Figure 6 shows the decision tree with the various data points and reference scenario split.

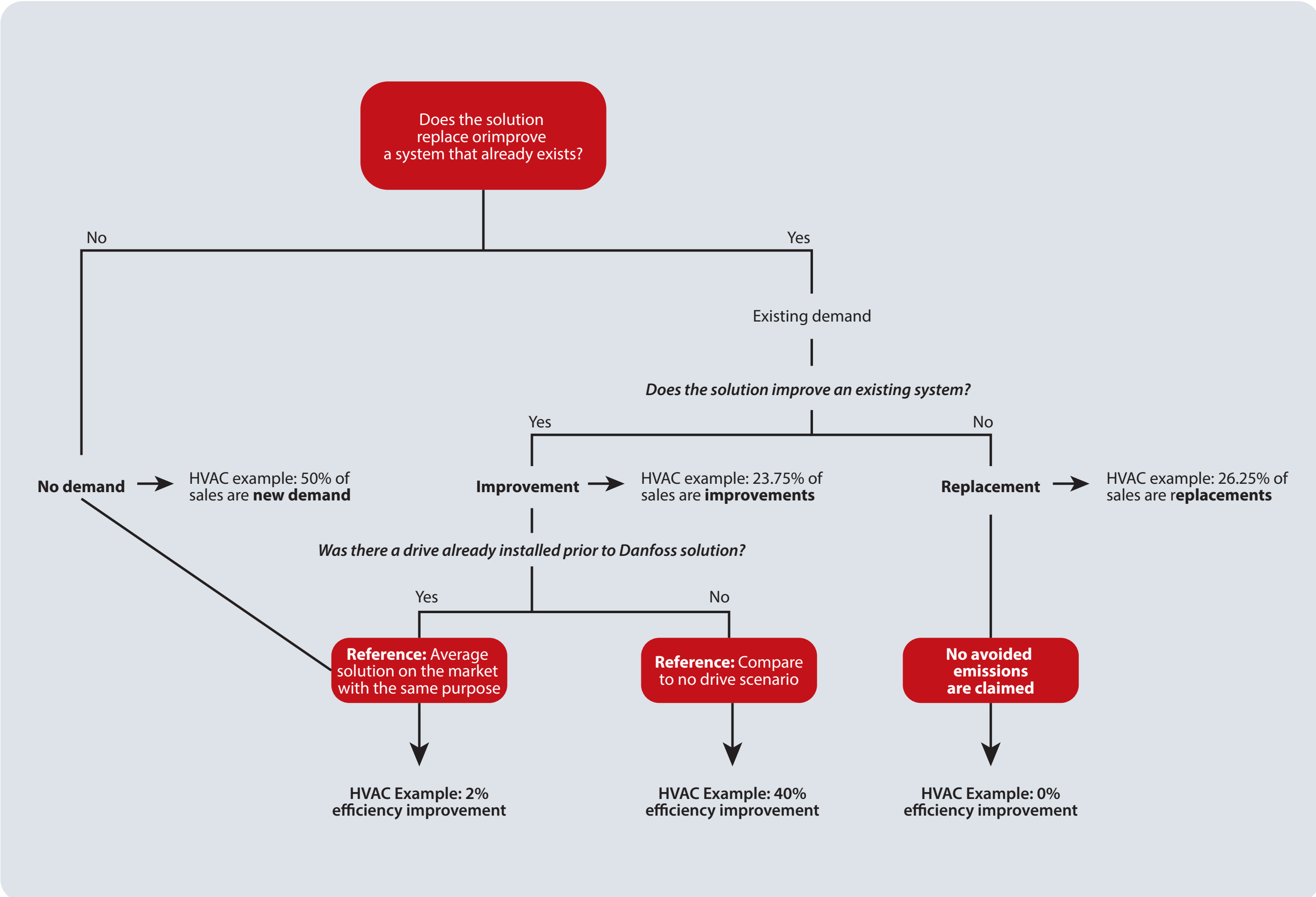

Figure 6: *A HVAC example of the various points of data for the applications reference scenario and associated efficiency improvements, represented visually through a decision tree .*

Assuming the following data gathered for HVAC:

- **Reference Scenario in HVAC:**
  - New Demand: 50%
  - Improvement: 23.75%
  - Replacement: 26.25%
- **Efficiency:**
  - Market average efficiency of an AC drive: 95%
  - Efficiency of the new AC drive: 97%
  - Efficiency improvement of utilizing the new AC drive compared to the market average: 97%-95% = 2%
- **Average rate of no AC drive being installed prior:** 25%
- **Average rate of an AC drive being installed prior:** 75%
- **New AC drive energy savings when no prior AC drive was installed:** 40%

Following the collection of all the relevant data, the savings factor is calculated, as can been seen in Figure 7.

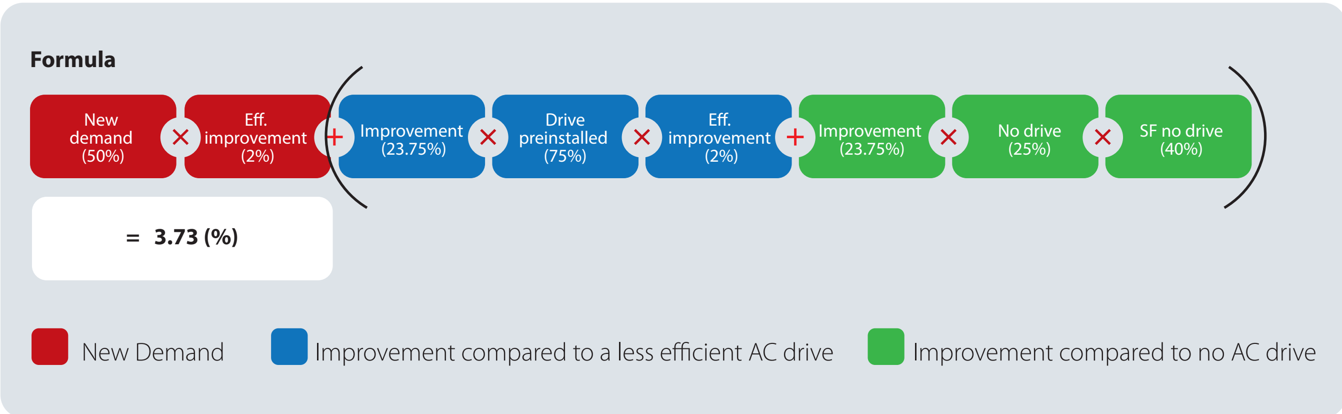

Figure 7: *The savings factor formula with exemplified data from the HVAC application in 2024.*

››› Use phase parameters

In accordance with the WBCSD guidelines, the last category to be specified to ensure proper compliance is the applied product solution. To define the new AC drive solution, various parameters are set. These include the use phase parameters, such as lifetime and active hours per year, as well as other, solution-specific, parameters. In case of AC drives the solution-specific parameter is the AC drive's efficiency. However, since this data is collected per application and is included in the respective savings factor for each application, it is not included in this category of parameters.
One should aim, as a minimum, to have data for the relevant products concerning the average performance, lifetime, annual operating hours, number of units sold, as well as the power consumption during use, for example:

- Different lifetime scenarios can be applied, for example if different AC drive sizes have a different reference service life (RSL). If all products in scope are assumed to have the same RSL, this lifetime can be used throughout all calculations. It is important that the RSL used, matches the RSL used in Scope 3.11 (Use of Sold Products) calculations.
- The annual operating hours can be set depending on the product series, or other criteria. These hours shall also be in line with the hours used in Scope 3.11.
- For AE calculations, the number of units sold is extracted annually.
- The power consumption during use in case of an AC drive is coming from the losses of the AC drive, which is thus determined by its efficiency: the lower the efficiency, the higher the losses and the higher the power consumption. This parameter is therefore factored into the savings factor described in the previous chapter.

When making any assumptions regarding solutions, one shall apply conservative estimates to not overestimate the avoided emissions calculated.

››› Calculating avoided emissions

Following the gathering of data concerning the applications' respective savings factors, geographical splits, as well as the selection of appropriate use phase parameters, the next step is to calculate the total avoided emissions.

The calculation is made using the following formulas:

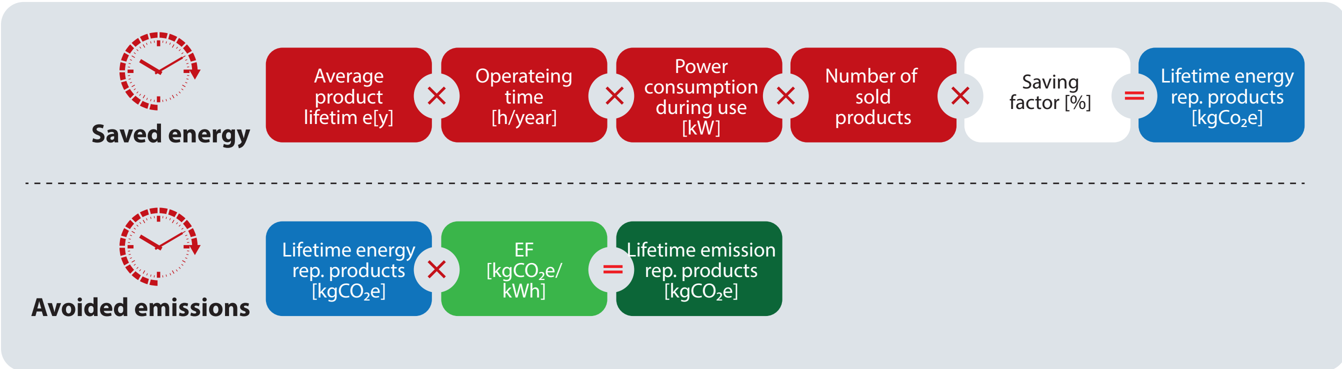

Figure 8: *Illustration of the formula utilized to calculate the avoided emissions of Danfoss Drives.*

The calculation of AE is conducted for each application respectively. The 'saving factor' part of the formula is calculated per application, based on the data as outlined in the 'Reference Scenario' section of this paper. The 'average product lifetime', 'operating time', 'number of sold products' as well as 'power consumption during use', are all parameters outlined in the 'Use Phase Parameters' section of this paper. The EF is determined for each application as a weighted average of their geographical location split, as described in the 'Geography' section of this paper. To account for future grid decarbonization, the EF that is applied for each product is determined based on the year of sale and the RSL of the product. If for example a product was sold in Northern Europe in 2022 with a RSL of 10 years, the EF that is used, would be calculated as follows:

$$EF = (EF_{2022} + EF_{2023} + EF_{2024} + EF_{2025} \ldots)/10$$

Since the energy use is assumed to be constant throughout the product's RSL, an average EF can be determined using this formula.

››› Dynamic rebound effects

The methodology described in this paper relies on various types of data and input, ranging from sales data to average market performance of AC drives. Since each AC drive ends up in a different system, certain parameters can vary case-by-case. However, since this methodology describes an approach to calculating AE at company level, the data available does not always account for these case-specific differences. This can lead to rebound effects, which will be discussed in this chapter.

A first potential rebound effect that should be pointed out, is the possibility that the system being replaced has not reached its end-of-life. This means that through implementing the current system early, the remaining time of the RSL of the previous system is "going to waste". It can be assumed that in such a situation, the reason for replacing the previous system early is the improved efficiency of the AC drive, which should save more energy for the user. In the methodology, the current assumption underlying the AE calculations is that the AC drive-controlled system is being compared to the previous system running for the RSL of the AC drive. So, from a use-phase perspective, the difference in impact is included. However, the additional impact caused by producing a new AC drive and "wasting" the remainder of the RSL of the previous system, are not. The first is however covered by Scope 1,2 and 3 emissions and as explained prior, it is therefore important that when AE are being shared, the other scopes are also disclosed at the same time. The issue of the remaining lifetime of the previous system, however, remains a rebound effect to be aware of.

Second, when an AC drive is being installed into a system, it is possible that additional equipment is also needed or that the user does not install the AC drive optimally. Both factors would cause additional emissions compared to the optimal scenario. Since these are parameters that differ case-by-case, they are not reflected directly in the company-level AE. This rebound effect should therefore be considered when calculating AE. It is known however, that AC drives, on average, have a positive impact on the system's overall lifetime.

Third, if a previous system is being replaced by an AC drive-controlled system, this could influence the energy source. Since this methodology uses grid factors, and thus assumes electricity as the energy source, it is unlikely that a different fuel will have lower emissions and thus lead to less AE, but it should nevertheless be pointed out as a factor to be aware of.

Finally, AE only covers CO_2 emissions even though many other environmental impacts exist and can be assessed. Since the field of AE is a rather new one, with a lack of official regulations and guidance, its scope could change in the future. In that case, the methodology should be updated to also reflect the calculation of other environmental impacts. Currently, this methodology only covers AE, but it should be noted that other environmental impacts are related as well.

››› Recalculation policy

The methodology outlined in this paper aims to ensure calculation of AE as accurately as possible. However, due to the topic of AE being rather novel, various parts of the methodology rely, at least partly, on assumptions. As stated in the paper, these assumptions should always remain conservative as to not overestimate the AE. Due to the reliance on assumptions for specific parts of the methodology it is important to specify when and how the methodology and subsequent AE calculations should be revisited and recalculated.

A first trigger for recalculation is a change to the EFs, for example when the IEA updates their numbers. This would not influence the methodology described in this paper, but it would affect the results. For the annual reporting of AE this should not be of importance, as the grid factors for prior years are often verified. The forecasts, however, can be subject to change. If an AE goal has been set, this would be affected by such a change. It is therefore recommended to set an AE goal together with an energy savings goal (in MWh) so that the absolute savings can be tracked regardless of potential changes to EF.

Secondly, if in the future new regulations come into effect, for example specifying a minimum AC drive efficiency or agreeing on the market average performance of an AC drive this data must be used instead of the current assumptions. In such a case, the methodology will have to be updated accordingly and subsequently the AE calculated. As explained in the paper, the current assumptions for both factors are conservative and are therefore expected to cover any potential change that could occur later on. The methodology should thus not lead to overestimated AE. In this case, the AE from that point forward will follow the newest input available, for example if an organization introduce new standards, but the old AE can be kept the same as they would be underestimated. If the AE turn out to be overestimated following changes to input, this should be corrected in any case. It is therefore recommended to, in general, mention that the reported AE are based on the best available information to date and that, if new information influences the results, it is specified what was changed in the process.

Since the AE should be reported annually, this methodology should also be checked for validity at the same time, thereby keeping an annual checkup of the approach in place. If any changes are required, a verifier should be involved to validate these changes to in- or outputs.

››› Limitations

Potential limitations have been explored that could affect accuracy and robustness in calculating AE of AC drives. It should be noted that these limitations mainly influence the quality of the calculated AE results, rather than the methodology itself. The calculations described in this paper are based on the best available data. In some cases, it has been recognized that the accuracy of this data should ideally be improved to increase the robustness of the results, however currently the accuracy of the data on these points cannot be improved or is not available. Therefore, the current calculations are based on best available data and assumptions.
Here an overview of potential limitations and suggestions for improvements:

- **Market Average Scenario**
  - Currently, the assumptions concerning the market average performance of an AC drive rely on the expertise of internal experts who provide trusted insights into AC drive performances. However, there is a critical need for a default market average derived from broader industry consensus. Establishing an industry-wide agreement concerning the average performance of an AC drive will enhance the robustness and credibility of avoided emissions calculations. Collaborating with industry bodies and stakeholders through for example CEMEP or local trade organizations, to define these benchmarks is essential for standardizing the industry approach for calculations.

- **Influence of Internal Expertise**
  - The collected data inputs are predominantly based on the knowledge and experience of internal experts. Incorporating data from external studies, industry agreements, external experts, and third-party analyses will provide a more comprehensive dataset. This broader data integration would improve the accuracy and reliability of the calculations by reducing potential biases and additional perspectives.

- **Survey Coverage**
  - The accuracy of the AE calculations is directly influenced by the scope and depth of the survey coverage. Expanding the survey efforts to include more participants with diverse expertise will enhance the granularity and precision of the data. By increasing the volume and diversity of survey responses, a more representative understanding of the market averages and scenarios across various applications can be achieved.

- **Use Scenario Uncertainty**
  - The operational profiles which are used within the AE calculations are presently aligned with the UoSP (Use of Sold Products) scenarios, which may not fully represent the actual use cases encountered in the industry. To improve alignment and relevance, it would be optimal to synchronize the use scenarios with industry-aligned profiles. This requires collaboration with industry partners to develop and adopt standardized operational profiles to help ensure aligned use phase parameters.

- **Emissions factor Uncertainty**
  - The main limitation of this methodology regarding the EFs is that it assumes an equal uptake for renewable throughout the EU.
  - A second limitation lies in assuming that grid losses and upstream EFs are stable.

››› Verification

The Danfoss AE methodology described in this document has been third-party verified by FORCE Technology Denmark (2024). This methodology document is abridged to exclude confidential information. The verification report confirms that the Danfoss Drives AE methodology is in general found to be thorough and in support of the general principles of climate accounting – to the extent that this is possible with the available data and industry knowledge (transparency, relevance, completeness, accuracy, consistency).
The third-party verification is based on relevant requirements of:

- World Business Council for Sustainable Development (WBCSD) Guidance on Avoided Emissions: Helping Business Drive Innovations and Scale Solutions Toward Net Zero (WBCSD, 2023)[9]
- GHG Protocol corporate and Corporate Value Chain (Scope 3) Accounting and Reporting Standard
- ISO 14040:2006 "Environmental management – Life cycle assessment – Principles and framework"
- ISO 14044:2006 "Environmental management – Life cycle assessment – Requirements and guidelines"

[9]Any requirements in the WBCSD guideline which are not related to the calculation of avoided emissions are not in scope

››› References

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