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Quantifying Data Center Scope 3 GHG Emissions to Prioritize Reduction Efforts

White Paper 99

Version 1

Energy Management Research Center

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Executive summary

More data centers are transitioning to renewable energy sources. As this happens, Scope 3 becomes a data center's largest contributor to greenhouse gas (GHG) emissions. This category of emissions is also the least reported and understood. Quantifying Scope 3 emissions is one of the most important issues the industry is facing. In this paper, we use a single hypothetical data center to demonstrate how to quantify Scope 3 emissions and identify the largest emission sources. We provide a calculator that estimates a data center's lifecycle carbon footprint and other assessment tools. Finally, we describe best practices for reducing emissions. This paper and the "Data Center Lifecycle CO2e Calculator" TradeOff Tool mark the first comprehensive attempt to quantify the details driving Scope 3 in an enterprise data center.

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Introduction

This paper is meant for any company that uses IT resources, including companies in the data center business (e.g., colocation and cloud providers) and enterprise companies that depend on cloud-based IT resources. As the data center industry transitions to renewable energy, the focus of carbon emissions turns to Scope 3, the indirect emissions from a data center's value chain. However, quantifying and reporting on Scope 3 presents a significant challenge for data center operators. **This is mainly due to a lack of three resources: reliable supplier data, quantitative tools, and an accounting and reporting methodology**. WP53, *Recommended Inventory for Data Center Scope 3 GHG Emissions Reporting*, proposes nine GHG emissions source categories and their data center-specific subcategories to develop the inventory for Scope 3 accounting and reporting.

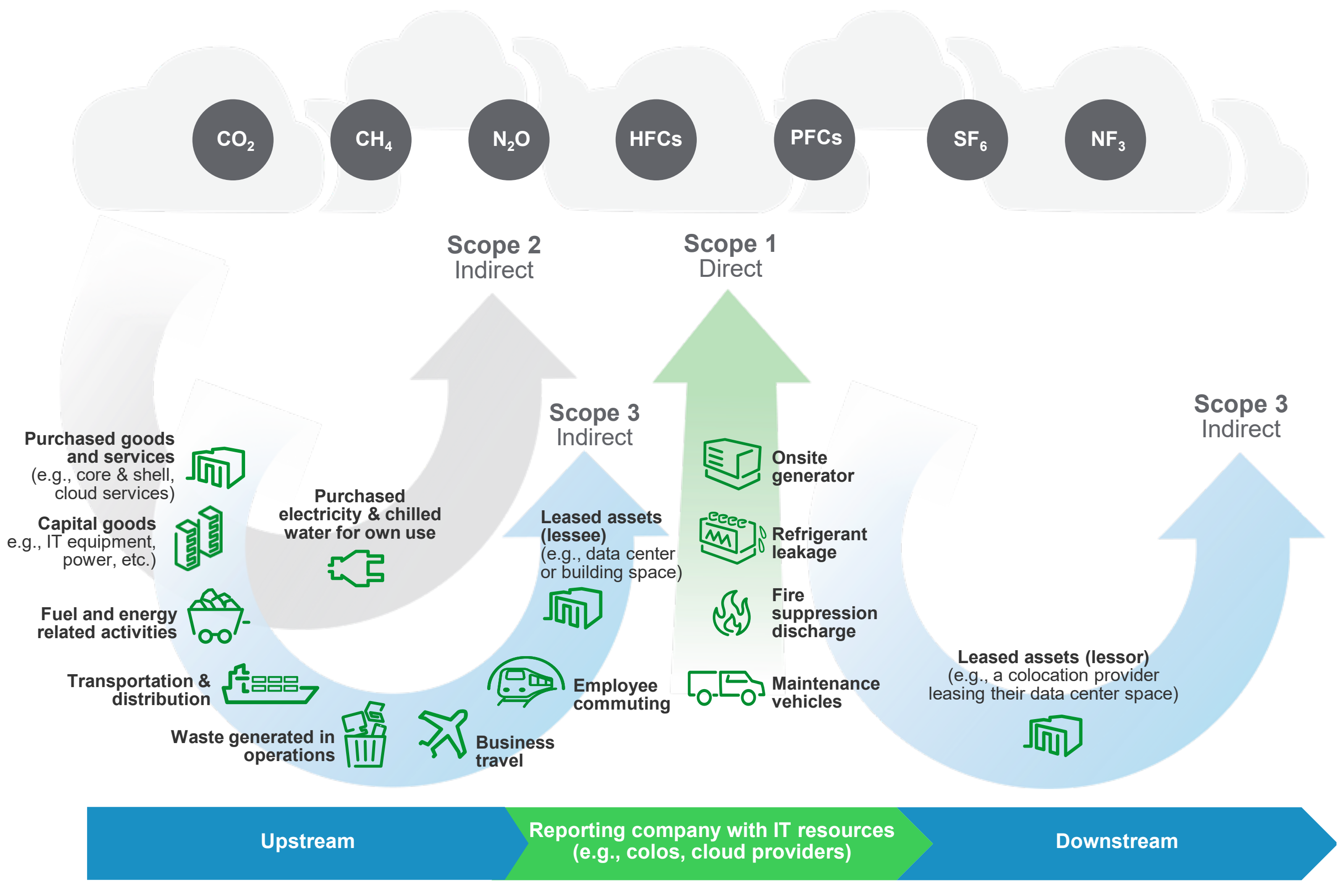
Without understanding Scope 3 emissions, it's hard for data center operators to prioritize their carbon-reduction efforts as they need answers to questions like:

- What is the total carbon footprint (Scope 1, 2, and 3) of my data center?
- Does my data center emit more carbon from Scope 2 energy use or embodied carbon of material/equipment from Scope 3 supply chain?
- How much embodied carbon is in my data center?
- Of everything in my data center, what causes(ed) the most emissions?
- Where can I find the data/tools to quantify my embodied carbon?

To answer these questions, it is important to quantify the carbon from all emissions sources including direct emissions from the reporting company and indirect emissions from upstream and downstream activities as shown in Figure 1.

Figure 1

GHG Protocol scopes and emissions across the data center value chain
Source: Adapted from Corporate Value Chain (Scope 3) Accounting and Reporting Standard



In order to prioritize a data center's emissions-reduction efforts, Scope 3 emissions should be as familiar as cost and energy efficiency (PUE). **We believe understanding Scope 3 emissions is the next frontier for data center industry key performance indicators (KPIs)**.

This white paper provides an in-depth look at the Scope 3 emissions of a single hypothetical data center, to identify the key drivers of carbon. Using a data center lifecycle carbon model, we estimate the Scope 1, 2, and 3 emissions to demonstrate how the total carbon emissions and composition change over time. We then break out Scope 3 emissions from different perspectives including GHG source category[1], lifecycle phase[2], subsystem, etc. to identify the key drivers of carbon from the value chain. We also provide useful tools to help data center operators assess their carbon footprint. Finally, we propose best practices for reducing Scope 3 emissions. **A key conclusion is that suppliers must provide data center operators with Scope 3 emissions data, related to the products used in their data centers**.

Quantifying data center Scope 3 emissions

In this section, we model a hypothetical 1-megawatt data center to estimate its total carbon footprint (Scope 1, 2, and 3), with a focus on Scope 3 emissions. This hypothetical data center is treated as an on-premise data center to isolate the quantification of its carbon footprint. Out of scope for this paper are colocation & cloud data centers and cloud services, which must allocate carbon between data center operators and tenants or cloud users. Consequently, GHG Categories 8 (Upstream leased assets) and 9 (Downstream leased assets) are excluded from the estimated Scope 3 emissions. **Though we break out the footprint by Scope, GHG source category, lifecycle phase, and data center subsystem, these breakouts may look very different for your data center**. These emissions vary significantly depending on many factors including data center size, redundancy level, location, electricity emission factor, core & shell construction, IT equipment configuration, energy efficiency, equipment lifespan & replacement frequency, value chain activities, etc. **Note that while there is uncertainty in the model's data, our intent is to provide a sense for the magnitude and proportion of the emissions**.

Main assumptions & methodology

- 1MW data center capacity, Tier 3, 50% loaded, based on a reference design[3].
- 6kW/rack average power density
- 1.34 average annual PUE (N+1 power and chilled water cooling)
- 0.511 t CO_2e/MWh average electricity emission factor for U.S.[4]
- IT servers and networking gear are 50% physically populated[5]
- Allocation of IT power to IT equipment
    - Servers integrated with storage - 94%
    - Networking gear - 6%
- Carbon intensity for servers[6] is 5 t CO_2e per kW of IT capacity. Networking gear is the same as the servers.

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[1] Scope 3 GHG category includes purchased goods and services, capital goods, fuel- and energy-related activities, etc. White Paper 53, *Recommended Inventory for Data Center Scope 3 GHG Reporting*, provides definitions and applications for each source category.

[2] Five lifecycle phases include - manufacturing, transportation, installation, use, and end of life (EoL).

[3] For more information on reference designs, see White Paper 147, *Data Center Projects: Advantages of Using a Reference Design*.

[4] Tends to decrease year over year, however we keep it constant to isolate the impact of other factors.

[5]Assumes % of IT equipment installed is the same as the IT load ratio to account for embodied carbon.

[6]The carbon intensity for servers varies widely depending on server configuration. For example, heavily-configured higher-U servers will have a carbon intensity value much higher than this value. We assumed a value between least and moderately configured.

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The **cumulative** carbon footprint of the data center was calculated at year 1, 5, 10, 15, and 20 to assess emissions trends and composition between Scope 1, 2, and 3, and other perspectives. Although data centers report their emissions on an annual basis (not cumulative), presenting the cumulative carbon footprint at various years helps with trending and benchmarking. See **Appendix** for a full list of detailed assumptions & methodology.

Findings

It's important to note that these findings are meant to serve as an educational tool. We demonstrate the findings using five steps. **Figure 2** illustrates the progression of our analysis starting with the data center's total carbon footprint and ending with embodied[7] carbon for facility infrastructure and its subsystems.

Figure 2

Progression of carbon analysis

Step 1 Total carbon emissions (Scope 1, 2, and 3)

Step 2 Scope 3 emissions by removing Scope 1 and 2

Step 3 Embodied carbon by removing Scope 3 GHG Categories 3, 6, and 7[8]

Step 4 Facility infrastructure embodied carbon by removing IT

Step 5 Subsystem embodied carbon (e.g., power)

The following sections describe each step along with charts and findings[9]. **We defer proposed actions for Scope 3 to the section titled, "Prioritizing Scope 3 emissions-reduction efforts".** For a quick summary of findings and proposed actions, skip ahead to **Tables 2** & **3**.

Step 1: Total carbon emissions profile over time

This step compares the total cumulative carbon footprint between Scope 1, 2, and 3 at different years throughout the data center's life to identify which Scopes are major drivers of carbon. We also compare the total cumulative carbon footprint at year 15 for three geographies including the United States, France, and Singapore to illustrate how electricity carbon emission factors[10] impact the results in this section. See **Appendix** for more information on carbon emission factors.

Figures 3 (a) and **(b)** show the total cumulative carbon footprint broken out by scope as a value and percentage respectively over time.

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[7] According to Carbon Leadership Forum (CLF), "embodied carbon refers to GHG emissions arising from the manufacturing, transportation, installation, and disposal of building materials." This definition is focused on buildings but is also applicable to data centers. The carbon due to maintenance and repair during the use phase also belongs to embodied carbon.

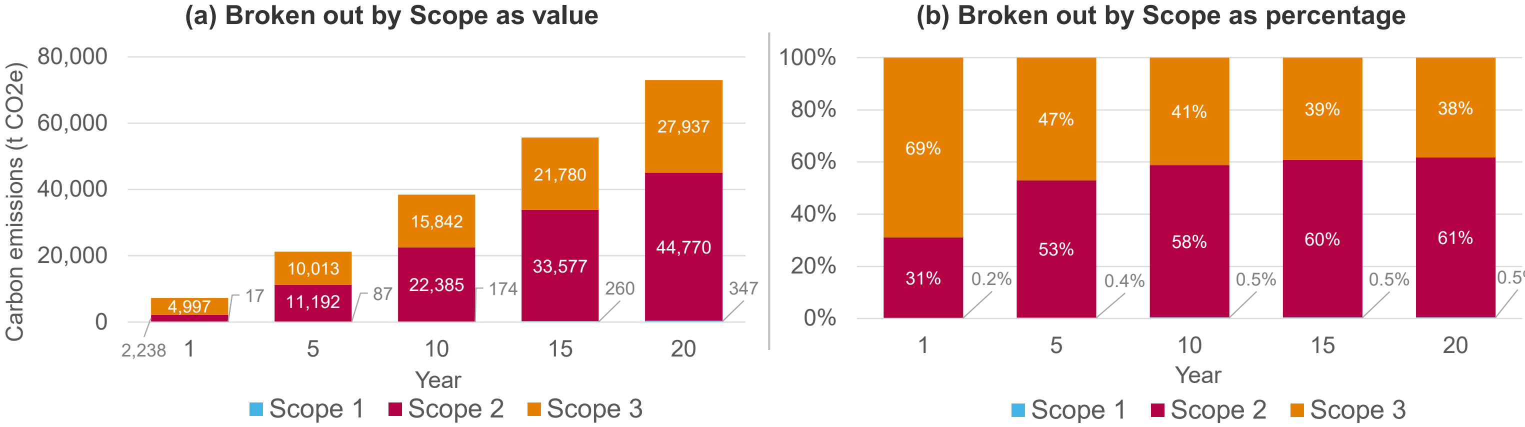
[8] Category 3 represents upstream emissions of purchased and consumed fuels and energy that are not included in Scope 1 or Scope 2. Category 6 represents emissions from employee transportation for business-related activities. Category 7 represents emissions from the transportation of employees between their homes and their worksites. For more information on these three categories, see White Paper 53, *Recommended Inventory for Data Center Scope 3 GHG Reporting*.

[9] Note that individual percentages in some charts may not sum to 100% due to rounding.

[10] The electricity carbon emission factor (t CO_2e/MWh) for the United States, France, and Singapore is 0.511, 0.090, and 0.686 respectively. All other variables remained constant for this scenario.

Figure 3 (a) and (b)

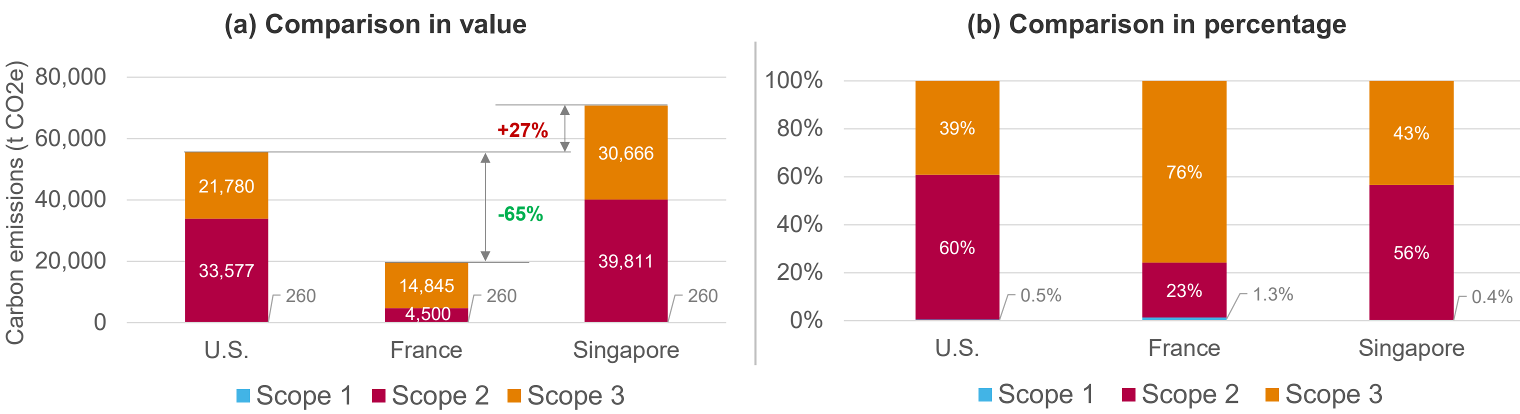
Cumulative total carbon footprint profile over time



Figures 4 (a) and (b) show the cumulative total carbon footprint comparisons between the United States, France, and Singapore at year 15 (typical data center lifespan); broken out by scope as a value and percentage respectively. Note: there is a wide variation in emission factor from one utility grid to the next in these countries.

Figure 4 (a) and (b)

Cumulative total carbon footprint comparisons between the United States vs. France vs. Singapore at year 15



Findings

- **Scope 3** represents the majority (69%) of the data center's total carbon footprint at year 1 mostly due to IT, power, and cooling equipment. Core & shell (physical building) represents 6.6% of total Scope 3 emissions **before power is turned on** (i.e., start of year 1 - embodied carbon only). This is why it's important to only install the IT and supporting equipment when you need it. This percentage decreases as Scope 2 increases cumulatively over the years, although periodic equipment replacement, with embodied carbon, maintains Scope 3 as a significant percentage.
- **Purchased electricity has a Scope 3 component**. Each electricity source has pre-combustion, combustion, and transmission & distribution (T&D) emissions. Pre-combustion and T&D are normally allocated to Scope 3 emissions while combustion is allocated to Scope 2 emissions for electricity consumers. **If the emission factors were not broken out in different scopes and instead as a single factor fully allocated to Scope 2, the Scope 3 values in Figure 4a would be identical.** See **Appendix** for more information.

- Scope 1 represents a very small percentage (0.2%-0.5%) of the total carbon footprint. The emissions come from two main sources including diesel genset operation (77%) and chiller refrigerant leakage (23%). See Appendix for proposed actions to reduce Scope 1 emissions.
- Scope 2 represents 31%-53% for years 1 through 5. However, as more electricity is consumed every year, this percentage increases to around 60% in later years. The regional graphs show the impact of electricity sources with different carbon intensity. For example, France, with a high percentage of nuclear, has a low Scope 2 component. See Appendix for proposed actions to reduce Scope 2 emissions.

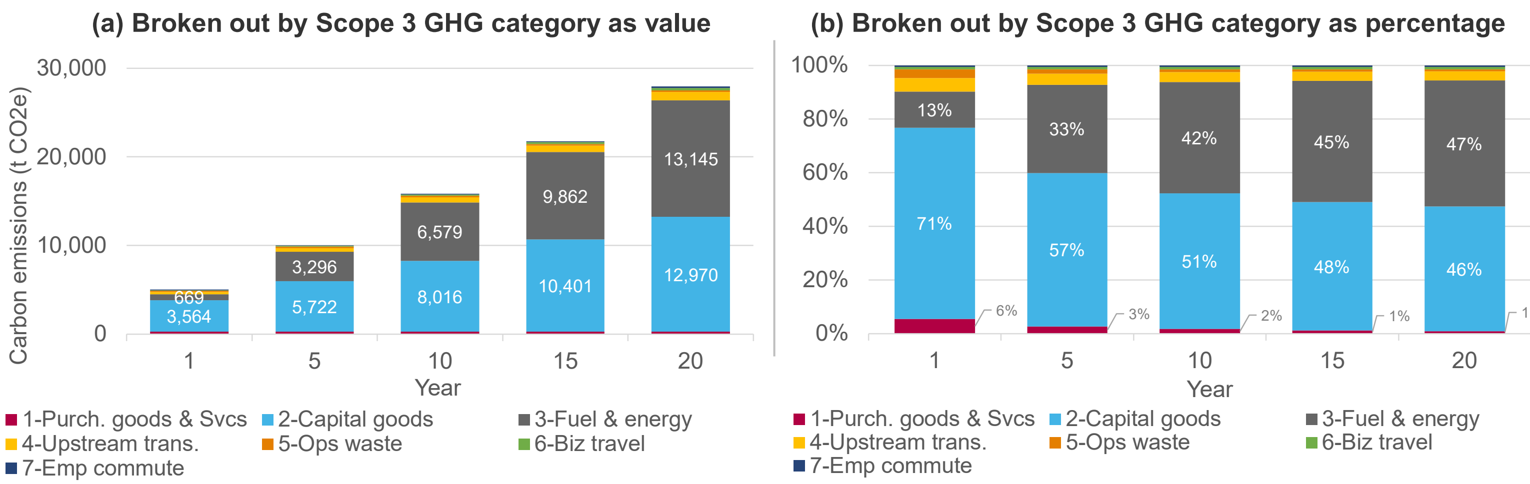
Step 2: Scope 3 emissions profile over time

According to GHG Protocol and White Paper 53, a data center's Scope 3 emissions can be allocated into seven GHG source categories. Step 2 breaks out the cumulative Scope 3 emissions by these seven categories to identify the drivers of carbon.

Figures 5 (a) and (b) show the cumulative Scope 3 emissions profile broken out by Scope 3 GHG category as a value and percentage respectively over time.

Figure 5 (a) and (b)

Cumulative Scope 3 emissions profile over time



Findings

- The cumulative Scope 3 emissions increase year over year due to periodic equipment replacement, continuous energy consumption (emissions from electricity's upstream and downstream activities), business travel, etc.
- Capital goods and fuel- and energy-related activities are two major contributors (over 84%) to Scope 3 carbon. Note that we categorize all equipment, such as IT and power, as capital goods. We categorized core & shell as purchased goods & services.
- Purchased goods & services (core & shell) represents a small percentage of Scope 3 emissions. This percentage decreases year over year as other categories increase because this is never replaced for the life of the data center.

Step 3: Embodied carbon profile for IT vs. facility infrastructure[11]

In the previous step we learned capital goods (part of embodied carbon) are a significant contributor to Scope 3 emissions. In this step we focus solely on embodied carbon, which is Scope 3 without Categories 3, 6, and 7 as illustrated in Table 1.

[11] Facility infrastructure means physical infrastructure including core & shell (physical building), power, cooling, IT rack, and rack PDU. IT hardware is not part of facility infrastructure.

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Table 1

Embodied carbon is part of Scope 3 carbon

(Excludes Category 3, 6, & 7)

Scope 3 - GHG source category	Scope 3 carbon	Embodied carbon
1- Purchased goods & services	✓	✓
2 - Capital goods	✓	✓
3 - Fuel & energy-related activities	✓	
4 - Upstream transportation & distribution	✓	✓
5 - Waste in operations	✓	✓
6 - Business travel	✓	
7 - Employee commuting	✓	

To identify the major drivers of embodied carbon, we looked at the cumulative embodied carbon by lifecycle phases – manufacturing, distribution, installation, use (maintenance only), and EoL. We found that the **manufacturing represents about 90% of embodied carbon**. IT and facility infrastructure are typically owned and operated by different departments in a data center organization. Therefore, we break out the embodied carbon by IT and facility infrastructure to demonstrate their relative contribution.

Figures 6 (a) and **(b)** show the cumulative embodied carbon profile broken out by IT and facility infrastructure as a value and percentage respectively over time.

Figure 6 (a) and (b)

*Cumulative **embodied** carbon profile for IT vs. facility infrastructure over time*

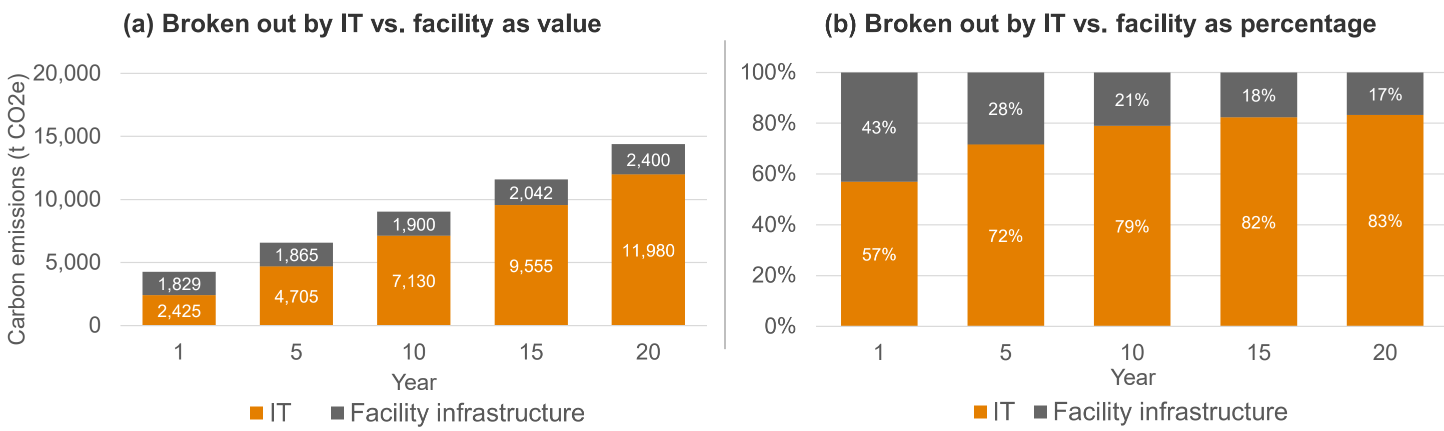
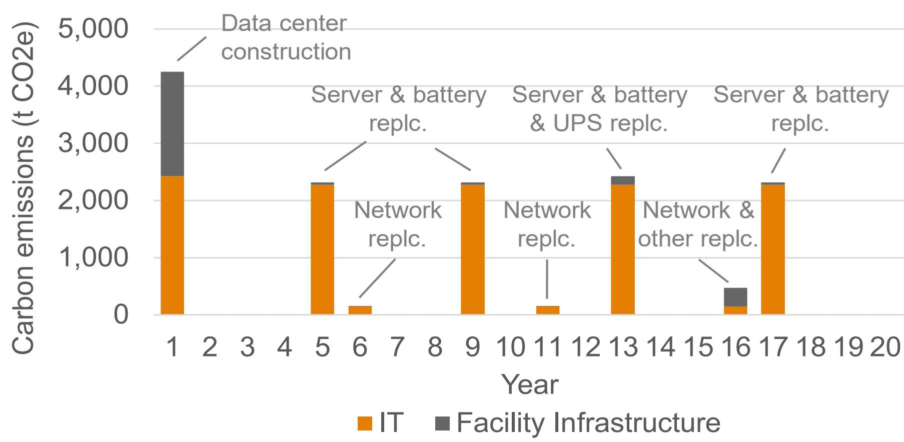


Figure 7 shows the **yearly** embodied carbon profile broken out by IT and facility infrastructure over time.

Figure 7 (a) and (b)

***Yearly** embodied carbon profile for IT vs. facility infrastructure over time*



Findings

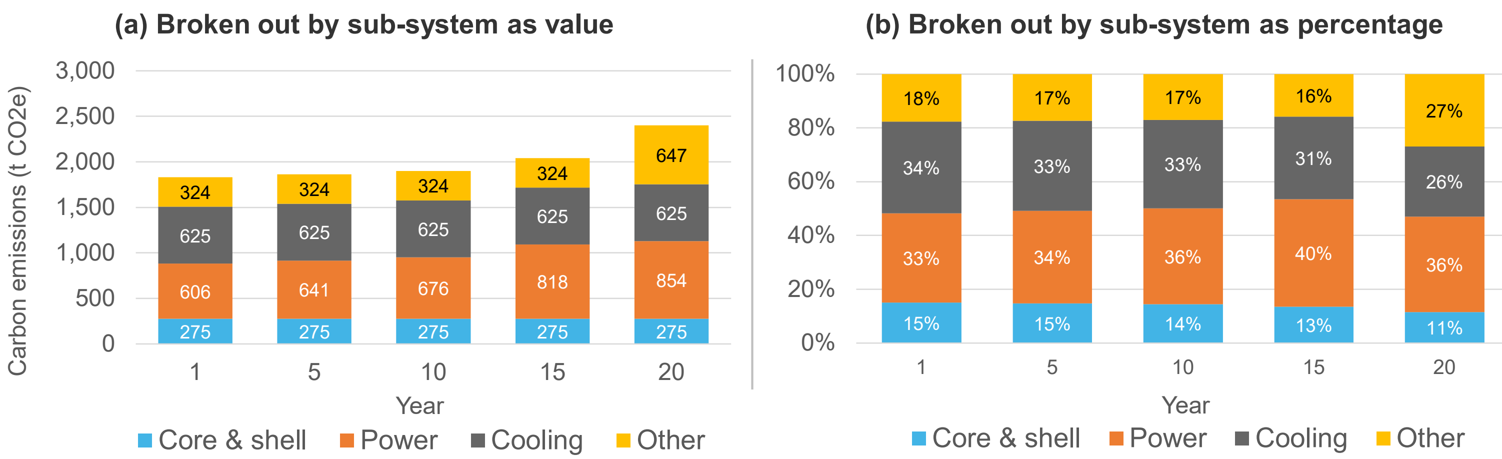
- **The cumulative embodied carbon** increases periodically due to periodic equipment replacement.
- **IT** represents 57% at year 1. However, since server replacements occur every four years, IT increases to over 70% starting at year 5. There are two main reasons for this: 1. IT has a much higher replacement frequency than facility infrastructure due to its shorter lifespan, and 2. IT has a higher carbon intensity, due to electronic components.
- **Facility infrastructure** represents 43% at year 1. This percentage decreases as IT increases cumulatively every four years, despite periodic equipment replacements such as VRLA batteries, etc.
- **The yearly embodied carbon** appears as peaks over the years due to data center construction (at year 1) and periodic equipment replacement. For carbon reporting, data center operators report these values in addition to Scope 2 (carbon from energy use) and Scope 3 GHG Categories 3, 6, and 7 on an annual basis.

Step 4: Embodied carbon profile for facility infrastructure over time

In this section we focus solely on facility infrastructure and break it out by subsystem including core & shell, power, cooling, and other[12]. **Figures 8 (a)** and **(b)** show the cumulative facility infrastructure embodied carbon profile broken out by subsystem as a value and percentage respectively over time.

Figure 8 (a) and (b)

Cumulative facility infrastructure ***embodied*** *carbon profile over time*



Findings

- **Power** and **cooling systems** are two major drivers of facility infrastructure embodied carbon, together representing over 60%. Power increases faster than cooling due to VRLA batteries replacement frequency.
- **Core & shell (physical building)** represents a small percentage (15%) of facility infrastructure at year 1 and stays low as it has a long life compared to other equipment.
- **Other** represents around 20%. The top three contributors in this subsystem are **network cabling, raised floor,** and **IT rack,** which combined represent 85% of this category. The percentages vary mainly by the power density. The higher the design density, the lower the emissions from these three subsystems. For example, increasing the rack power density from 6kW/rack to

[12] Other includes IT racks, primary auxiliary, critical auxiliary, fire protection, raised floor/dropped ceiling, lighting, network cabling, management, and security.

8kW/rack decreases these emissions by 25% at year 15. Increasing from 6 kW/rack to 10kW/rack decreases these emissions by 41% at year 15.

Step 5: Subsystem embodied carbon profile

We break out the subsystems including core & shell, power, and cooling to identify the drivers of carbon for each subsystem. The following sections describe the findings of each subsystem in detail.

Cumulative core & shell embodied carbon broken out by material

With a 50-year lifespan, the core & shell embodied carbon remains constant from year 1 through 30. As such, in lieu of an annual bar chart with identical bars, we illustrate the embodied carbon breakout with a pie chart.

Figure 9 shows the cumulative core & shell embodied carbon broken out by material including concrete, finishes & flooring, etc.

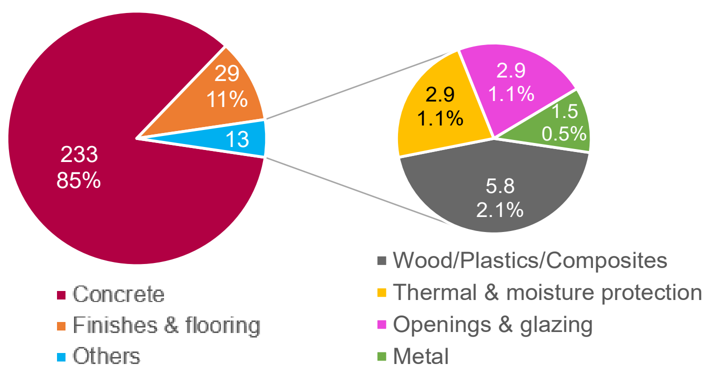


Figure 9

*Cumulative core & shell **embodied** carbon broken out by material*

Findings

- **Concrete** represents the majority (85%) of the carbon while **finishes & flooring** represent the second large portion (11%).

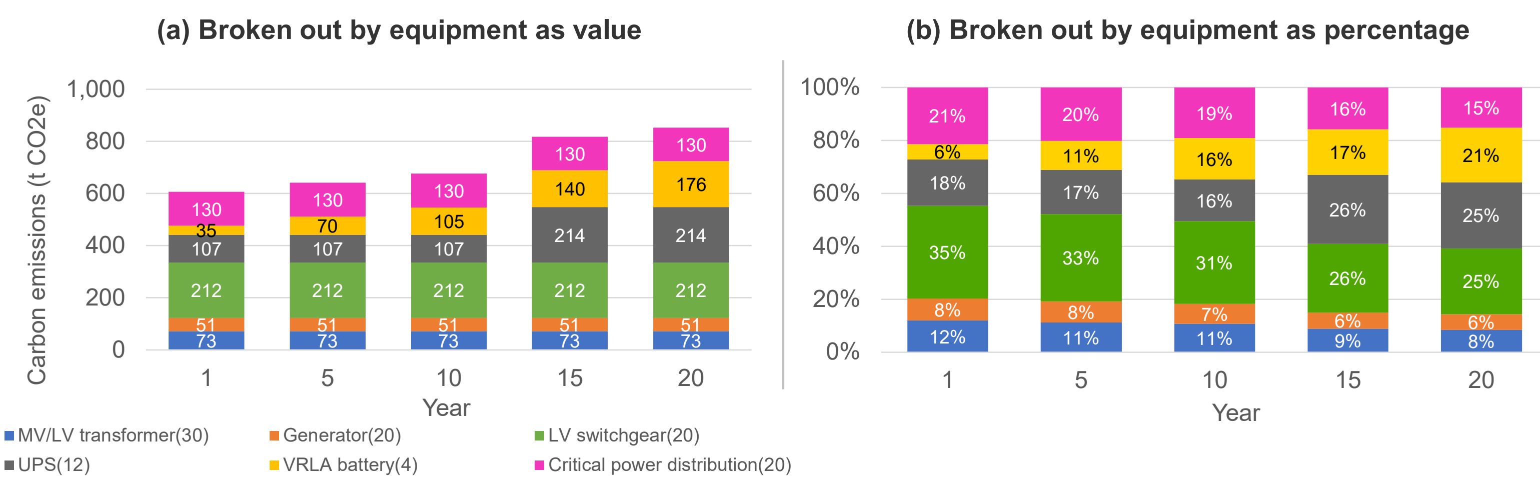
Cumulative power system embodied carbon broken out by equipment

We broke out the power system by the major equipment types with varying lifespans.

Figure 10 (a) and (b) shows the cumulative power system embodied carbon broken out by equipment as a value and percentage respectively over time.

Figure 10 (a) and (b)

*The cumulative power system **embodied** carbon profile over time*



Note the numbers in legend are the assumed lifespans.

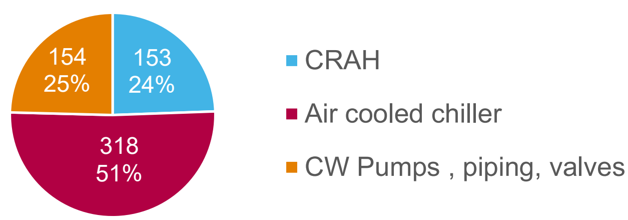
Findings

- **LV switchgear**[13] has the highest percentage (~ 30%) of embodied carbon. This percentage decreases over the years due to less replacement frequency (20-year lifespan).
- **VRLA battery** represents a small percentage (6%) for years 1 through 3. This increases up to 21% in later years due to its 4-year replacement frequency.
- **UPS** represents 16%-18% of the carbon for years 1 through 10. This increases to around 25% after the first replacement (12-year lifespan).
- **Critical power distribution**[14] represents around 20% of the carbon. 60% of this is from busway, 14% from tap off units, and 21% from rack PDUs.
- **Generator** and **MV/LV transformer** represent 20% at year 1 and decreases to 12% at year 30, due to long lifespans.

Cumulative cooling system embodied carbon broken out by equipment
With a 20-year lifespan, the cooling system embodied carbon remains constant from year 1 through 20. As such, in lieu of an annual bar chart, we illustrate the embodied carbon breakout with a pie chart. **Figure 11** shows the cumulative cooling system embodied carbon broken out by equipment.

Figure 11

Cumulative cooling system embodied carbon broken out by equipment



Findings

- **Air cooled chiller** represents 51% of carbon due to the integrated condenser.
- **CRAH** and **chilled water pumps, piping, and valves** represent a similar percentage (25%) for this hypothetical data center.

Key takeaways from the Scope 3 emissions analysis

- At year 15, the cumulative emissions from IT equipment embodied carbon was 9,991 t CO_2e. In contrast, Category 3 (fuel- and energy-related activities) was 9,862 t CO_2e. Depending on your grid carbon intensity, the largest Scope 3 component may swing between IT equipment embodied carbon and fuel & energy related activities Scope 3 GHG Category 3.
- If we focus solely on facility infrastructure *embodied carbon* at year 15, **Table 2** shows the top 10 contributors, which represent 95.5% of the total.

[13] LV switchgear includes switchgear, breakers, all conductor/wiring and EMT conduit upstream of PDU.

[14] Critical power distribution includes panelboard, busway and tap off units, power management modules, and all conductor/wiring & EMT conduit below PDU.

Table 2

*Top 10 contributors to facility infrastructure **embodied** carbon at year 15*

No.	Material / Equipment	Percentage
1	Other (Top 3 - Network cabling/raised floor/IT rack)	15.8% (5.7% / 4.1% / 3.6%)
2	Air cooled chiller	15.6%
3	Core & shell - concrete	11.4%
4	UPS	10.5%
5	LV switchgear	10.4%
6	CRAH	7.5%
7	CH pumps, piping, valves	7.5%
8	VRLA battery	6.9%
9	Critical power distribution	6.3%
10	MV/LV transformer	3.6%
	TOTAL	95.5%

To summarize the 5-step carbon analysis, Table 3 lists the main findings and our proposed actions to reduce carbon. We provide detailed explanations for the proposed actions in the section, "Prioritizing Scope 3 emissions-reduction efforts".

Table 3

Summary of findings with proposed actions from this study

Step	Carbon focus	Findings	Proposed actions
1	Total carbon	• Scope 3 represents 38-69% • Electricity has a Scope 3 component	• Use more renewable/clean energy
2	Scope 3 emissions	• Capital goods represents 46-71% • Fuel- and energy-related activities represents 13-47% • Core & shell represents a small percentage	• Purchase low carbon capital goods • Use more renewable/clean energy
3	Embodied carbon	• Manufacturing represents ~ 90% • IT represents 57-83% • Facility infrastructure represents 17-43%	• Extend server lifespans • Design and operate for high utilization from IT to the facility • Optimize IT demand
4	Facility infrastructure embodied carbon	• Power system represents ~ 30% • Cooling system represents ~ 30% • Core & shell represents 8-15%	• Purchase efficient and low carbon products • Reuse existing building for data centers instead of new construction
5	Sub-system embodied carbon	• Concrete represents 85% • LV switchgear represents ~ 30% • VRLA battery represents 6-21% • Air-cooled chiller represents ~50%	• Evaluate modular and prefabricated construction methods • Purchase efficient and low carbon products

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The role of data center utilization and IT demand

For our analysis, we used a hypothetical 1 megawatt data center that was 50% loaded. We intentionally kept this fixed over time to show trends more clearly in embodied carbon. But the analysis does not show the effect data center utilization has on embodied carbon. The more you can load an existing data center, you can avoid or delay data center expansion, which will lower your overall Scope 3 emissions. Although this is a straightforward concept, the data center industry does not always perform well in this area. The financial business incentives to get the most out of assets might be enough to optimize this aspect of carbon emissions but reporting on Scope 3 will add another dimension of transparency and force further improvements. Utilization problems can occur in the following areas:

- Low server utilization or "zombie" servers
- Low data center facility loading
- Stranded data center capacity and uneven use of capacities (i.e. run out of space before running out of power & cooling, or vice versa)

The lowest carbon data center is the one you don't have to build. In other words, optimizing IT demand to avoid over-building also plays an important role in data center carbon reduction. In the next section, we will cover strategies to improve utilization and IT demand.

Prioritizing Scope 3 emission-reduction efforts

In this section, we explain in detail the proposed actions listed in **Table 3** to reduce Scope 3 emissions. While all these actions are important, they are not in priority order because the priority would likely change by altering variables like electricity emission factor, IT load %, and IT server intensity. The proposed actions are:

- Use more renewable/clean[15] energy
- Extend server lifespans
- Purchase efficient and low carbon products
- Reuse existing building for data centers instead of new construction
- Evaluate modular and prefabricated construction methods
- Design and operate for high utilization from IT to the facility
- Optimize IT demand

We discuss each approach in the following sections.

Use more renewable/clean energy

Using more renewable/clean energy reduces Scope 3 GHG Category 3 - fuel & energy-related activities. This is a significant lever in reducing a data center's carbon footprint. The reality is that apart from those facilities with easy access to hydroelectric, solar, and wind sources, it is rare for renewable energy to power data centers directly. There are organizations that help data centers increase their renewable energy mix such as Neo Network. Note that while buying renewable energy certificate (RECs) or power purchase agreement (PPAs) do lower utility emissions, they do not directly lower actual emissions associated with the data center. PPAs and offsets such as RECs result in what is commonly called market-based emission factors.

[15]We use the term "clean" to describe energy sources like nuclear because they are not renewable.

Extend server lifespans

IT represents the majority of a data center's cumulative embodied carbon (58%-85%) over a data center's lifetime. There are two main reasons for this. First, servers have a large number of electronic components high in embodied carbon. Second, servers have a high replacement frequency. For example, there are three server replacements over a 15-year typical data center lifetime, assuming the servers have a 4-year lifespan. We performed a sensitivity analysis to assess how different server lifespans impact Scope 3 emissions (as show in Figure 12). **If we extend the server's lifespan an extra year, we reduce the cumulative data center embodied carbon by about 16%**.

While extending the server lifespans may lower embodied carbon, the decision is not as straightforward as it appears. Server replacement must be weighed against performance and energy efficiency gains of newer IT equipment. Consider these two cases:

- Replace old servers with new higher-performance servers (i.e., they are 50% more productive per watt). This means you need fewer servers to do the same job as the original servers, but you still incur embodied carbon that year.
- Keep the existing servers for two more years to avoid the embodied carbon of new servers. However, you incur higher energy-related carbon emissions.

The optimal solution is the one with the lowest total carbon footprint (embodied carbon AND energy-related carbon).

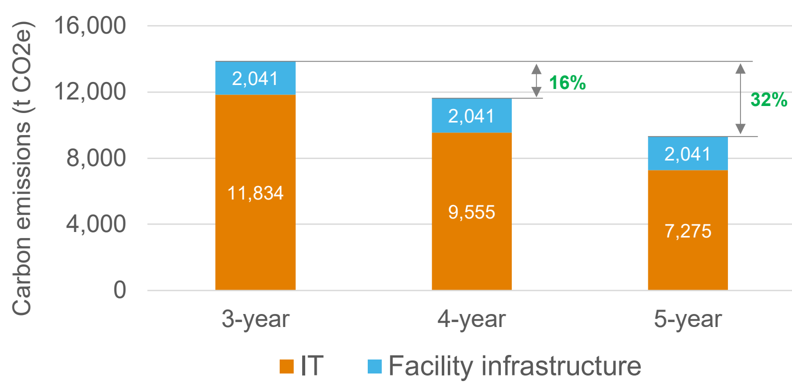


Figure 12

Sensitivity analysis of server lifespan impact on cumulative ***embodied*** *carbon at year 15*

According to 2022 Uptime Institute's survey, the percentage of respondents who said they kept their servers in operation for five years or longer increased to 52%. The reasons include semiconductor shortages (beginning in 2020) and a slowdown in server power efficiency gains. **We believe this percentage would increase if operators considered the impact to their data center's embodied carbon**. Infrastructure such as power supply units (PSUs), power cabling, and network cabling have longer lifespans than servers, so "disaggregated" architectures like OCP and Open 19 allow this hardware to continue operating long after the servers are refreshed, reducing Scope 3 emissions. The standard form factor of server "bricks" also allows for easier re-use of the sheet metal and connectors.

Purchase efficient and low carbon products

We estimate that capital goods (GHG – source Category 2) represents 72% of cumulative Scope 3 emissions at year 1 of a data center's life. This is 50% of total emissions (Scope 1, 2, and 3), which highlights the importance of this practice. Products should be low in embodied carbon, energy-efficient, and have good circular economy properties like durability and recyclability. **Specifying products based**

on embodied carbon is critical to minimizing your data center's carbon footprint. Besides price, quality, and features, specifiers should assess a product or service's carbon footprint by referring to their Environmental Product Declaration (EPD) document. The EPD document also provides the recyclability potential as a percentage of the product material and several other compulsory indicators such as mineral resources depletion, soil and water acidification, water eutrophication, ozone layer depletion, etc. See **Appendix** for more information on this topic. Below are two examples of facility infrastructure equipment choices that can reduce Scope 3 emissions.

Evaluate alternatives to VRLA batteries
The embodied carbon of VRLA batteries for UPS applications can represent 6-21% of Scope 3 emissions from all power equipment throughout a data center's life. This is because the VRLA battery's short lifespan (4-5 years) leads to high replacement frequency over the data center's lifetime. There is a growing demand to replace traditional VRLA batteries with lithium-ion batteries due to benefits such as smaller size and longer life expectancy (over 10 years). **Lithium-ion and other long-life technologies give new opportunities to reduce Scope 3 of energy storage technologies**. Schneider Electric conducted a quantitative life cycle assessment (LCA) comparing the sustainability impact of VRLA to Li-ion batteries. We found that the carbon footprint of li-ion was slightly lower than VRLA, and we anticipate this to improve further in the future as li-ion and other technologies improve. For more information on this topic, see White Paper 71, *Understanding the Total Sustainability Impact of Li-ion UPS Batteries*.

As a result, in order to minimize the carbon emissions from capital goods, **we recommend data center operators select vendors that have committed to reduce the embodied carbon of their product portfolio (ask for their roadmap) and also have committed to provide validated carbon reporting**. White Paper 70, *Guidance to Help Determine a Commercial Product's Sustainability*, provides more information on how to select environmentally sustainable products to reduce an organization's environmental footprint.

Reuse existing building instead of new construction

Carbon emissions from constructing a building (core & shell) and use of material such as steel, cement, and glass, represent 11% of all annual global GHG emissions, according to IEA. Unlike commercial and residential buildings, data centers are energy intensive and include a significant amount of equipment such as IT, power, and cooling systems. Our study shows the embodied carbon of core & shell represents around 5% of the total carbon footprint of a data center at year 1 (15% of Scope 3 emissions). We recommend the following two approaches to reduce core & shell embodied carbon.

Reusing existing buildings instead of new construction
This is an effective way for data center operators to minimize this environmental impact. Research from Serverfarm shows that "Modernization of data centers, which reuses existing buildings while expanding capacity, can deliver embodied carbon savings of 88% when compared with the material carbon cost of new projects."

Digitizing the design and construction phases with software
Construction management software such as RIB software provides opportunities to evaluate and improve sustainability in a digital version before deploying the building in the physical world. Through accurate modeling managing the construction process, low carbon products can be selected, and construction waste can be reduced, improving overall Scope 3 emissions of the building.

Evaluate modular and prefabricated construction methods

Prefabricated modular data center systems are pre-engineered and are pre-assembled, integrated, and tested in a factory environment to shorten deployment timeframe and improve predictability of performance and cost (See Figure 13). For more information on prefabricated solutions, see White Paper 165, *Types of Prefabricated Modular Data Centers*. These solutions allow data center owners or operators to: 1. deploy resources as needed; 2. scale as demand grows; and 3. reduce construction waste.

Figure 13

Example of a prefabricated modular power system

Scaling facility infrastructure. It's common to design and build a data center with more capacity than required on day 1. This penalizes the data center's carbon footprint if the subsystems are all installed on day 1 but aren't used. Things like racks, UPS, batteries, cooling units, and chillers, could be added later in the data center's life as the load increases. This means that this equipment will run longer into the life of the data center, requiring fewer equipment replacements.

Although we haven't performed a quantified environmental analysis between modular prefabricated solutions vs. 100% stick-built construction, we're optimistic implementing prefabricated solutions will have lower embodied carbon. More information is available here.

Design and operate for high utilization from IT to the facility

Monitor and improve server utilization

IT optimization tools, a function of data center infrastructure management (DCIM), monitor server utilization and power consumption at a rack and individual server level. These tools help reduce overall IT energy consumption by avoiding overprovisioning and underutilization. The server utilization can be improved through virtualization, load balancing, and autoscaling.

Design for higher facility utilization

Common problems during the design phase are over-designing redundancy and oversizing electrical and cooling systems (i.e., safety margin). Today, not all IT applications require the same level of availability. This enables different availability strategies like different levels of rack redundancy or even geographic redundancy, saving on embodied carbon. Additionally, modern facility equipment is designed to run at 100% load with substantial overload ratings. Understanding this during the design phase also improves facility utilization.

Design for higher rack power density

Higher rack power density results in fewer racks, less data center space, less networking cable, smaller core & shell, smaller raised floor, and smaller dropped ceiling. For example, increasing the density of our hypothetical data center from 6 kW/rack to 8 kW/rack decreases the total carbon footprint by 0.5% and the total Scope 3 footprint by 0.7%. While this is not a big lever, it does directly decrease CapEx as discussed in White Paper 155, *Calculating Space and Power Density Requirements for Data Centers*.

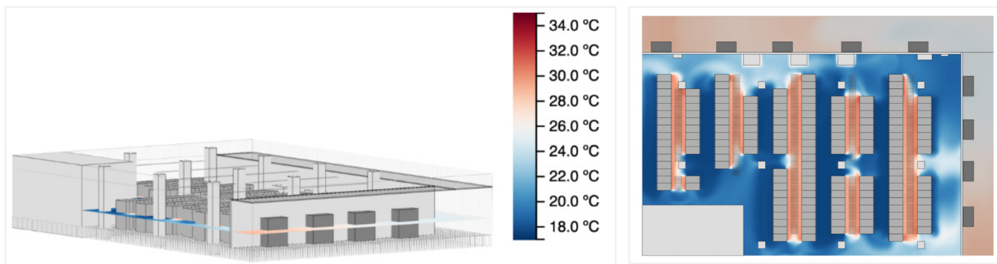
Reduce stranded capacity

Digital design tools (i.e., ETAP, computational fluid dynamics (CFD), EcoStruxure IT Advisor) simulate systems to reduce stranded electrical and cooling system capacity. It might be that only minor investments are needed to free stranded capacity and use it for new IT loads. Figure 14 shows an example where CFD is used to optimize the performance of a cooling system. An effective tool not only identifies and highlights stranded capacity, but also helps data center operators avoid creating it in the first place. For more information on this topic, see White Paper 150, *Power and Cooling Capacity Management for Data Centers*. White Paper 118, *Virtualization: Optimized Power, Cooling, and Management Maximizes Benefits*, provides more information on how to optimize facility infrastructure when virtualization is used.

Figure 14

Example of a data center with CFD analysis to free stranded capacity

(Schneider Electric EcoStruxure IT Advisor CFD shown)



Optimize IT demand

Optimize your IT for higher productivity with the same assets. For example, write / purchase code that is more efficient so you can serve up more queries per watt of power consumption. Furthermore, as the lowest carbon data center is the one you don't have to build, data center operators need to improve their IT demand forecast. This is never easy, but design practices can limit over-building. For example, modular design (i.e., modular UPS) and prefabricated subsystems optimize data center demand planning and construction. Build only what you need.

Note that the industry is at the beginning stages of this journey and these seven areas of improvement are the "tip of the iceberg". As Scope 3 embodied carbon reporting becomes more accurate, we expect to learn about more carbon-reducing opportunities, allowing for continued systematic improvement.

Additional resources

Schneider Electric has developed a TradeOff Tool "*Data Center Lifecycle CO_2e Calculator*", to help you estimate and learn about your data center's total carbon footprint. The results show breakouts based on different inputs, as shown in Figure 12.

Using the calculator in Figure 15 will help to prioritize your data center's carbon-reduction efforts. To improve the accuracy of your carbon accounting and reporting, use the tools provided in Table 4. GHG Protocol also provides some useful methodologies and tools in its document titled, *Technical Guidance for Calculating Scope 3 Emissions*.

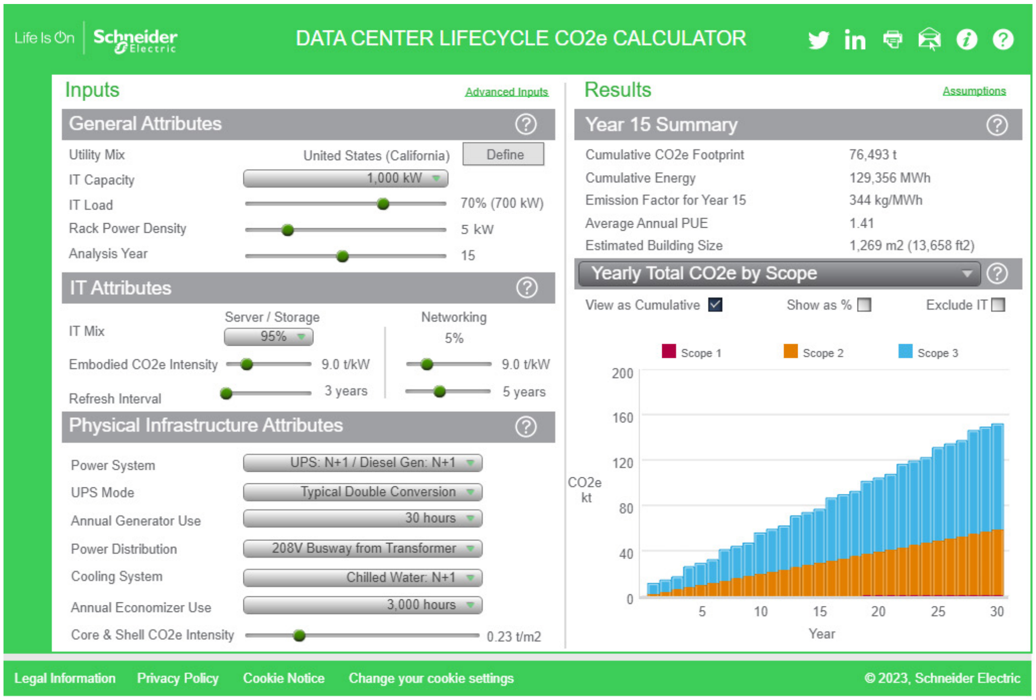


Figure 15

Data Center Lifecycle CO_2e Calculator

Table 4

Useful tools for Scope 3 emissions assessment

No.	GHG Scope 3 source category	Useful tools
1	Purchased goods & services	• Calculation Tools from GHG Protocol • CDP Supply Chain Responses of Tier 1 Suppliers • UK's Carbon Footprint – Indirect Emissions from the Supply Chain • Product Environmental Profile (PEP) - Ecopassport
2	Capital goods	• CDP Supply Chain Responses of Tier 1 Suppliers • ISO 14040 Environmental Management – Life Cycle Assessment – Principles and Framework • Embodied Carbon in Construction Calculator (EC3)
3	Fuel- and energy-related activities	• Per capita electricity generation by source, 2021 • Electricity Maps (carbon intensity) • Emissions Factors 2021 – IEA • Emissions & Generation Resources Integrated Database (eGRID) - EPA • Energy and climate change: evidence and analysis
4	Upstream transportation and distribution	• CDP supply chain responses of Tier 1 Suppliers • UK's carbon footprint – Indirect emissions from the supply chain
5	Waste generated in operations	• Waste Reduction Model (WARM) - EPA
6	Business travel	• GHG Emission Factors Hub • GHG Emissions from Transport or Mobile Sources • Greenhouse Gas Reporting: Conversion Factors • Greenhouse Gas Inventory Guidance – Indirect Emissions from Events and Conferences
7	Employee commuting	• The EPA Automotive Trends Report • Federal Transit Administration

Conclusion

Scope 3 emissions are by far the most challenging to report for data center operators. However, as we have shown, Scope 3 is major source of emissions today and will become an even larger percentage of emissions in the future. Although report on Scope 3 sustainability is not a mandatory requirement yet, it is beneficial for data center operators to understand the major drivers Scope 3 emissions for data centers in detail. This paper and the "*Data Center Lifecycle CO_2e Calculator*" TradeOff Tool mark the first comprehensive attempt to quantify the details driving Scope 3 in an enterprise data center. We have introduced a quantification model to estimate the Scope 3 emissions of a hypothetical 1MW data center.

The TradeOff Tool breaks down data center emissions by Scopes and also by IT attributes and physical infrastructure attributes. Then it allows the user to drill down into the attributes to get details for the specific domains the data center operator identifies as areas of priority. Scope 3 varies in the lifecycle for IT and physical infrastructure attributes; therefore the tool also provides a breakdown by year to provide detailed expectations for the intimal deployment and subsequent years. The data center operator can use this for initial understating of the drivers as well as areas to target for reduction and the timing.

Once the data center operator estimates the carbon footprint with the TradeOff Tool, he or she can form the foundation for other sustainability focused efforts. The calculator will enable them to start using carbon as part of the procurement process for example. They will also be in a position to reduce the top contributors to embodied carbon with digital tools.

Our analysis provided some key insights:

- Depending on the carbon intensity of purchased electricity, Scope 3 emissions can be the largest contributor to total carbon footprint.
- Capital goods is the largest driver of embodied carbon.
- The composition of Scope 1, 2, and 3 varies throughout the lifetime of a data center. Scope 1 emissions represent a small percentage (0.2-0.5%) of the total carbon footprint while Scope 2 emissions represent 31-61%. Scope 3 emissions represent 38-69% of total carbon footprint. However, as the data center uses more renewable energy, Scope 2 emissions could represent a much smaller percentage.
- The total cumulative carbon footprint of a data center increases year over year due to continuous fuel (diesel) combustion, energy consumption, and value chain activities.

According to these insights, we recommend actions to reduce Scope 3 emissions. **Data center operators should integrate sustainability into their evaluation criteria when selecting data center equipment suppliers and service providers to minimize Scope 3 value chain carbon footprint.** Vendors need to commit to reducing the embodied carbon of their product portfolio. Finally, data center equipment suppliers must make Type III Environmental Product Disclosure (EPD) documents freely available and easily understandable for their products.

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About the authors

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Resources

Recommended Inventory for Data Center Scope 3 GHG Emissions Reporting
White Paper 53

Why Data Centers Must Prioritize Environmental Sustainability: Four Key Drivers
White Paper 64

Data Center Projects: Advantages of Using a Reference Design
White Paper 147

The Reality of Replacing Diesel Generators with Natural Gas, Energy Storage, Fuel Cells & Other Options
White Paper 14

Guidance to Help Determine a Commercial Product's Sustainability
White Paper 70

Understanding the Total Sustainability Impact of Li-ion UPS Batteries
White Paper 71

Types of Prefabricated Modular Data Centers
White Paper 165

Calculating Space and Power Density Requirements for Data Centers
White Paper 155

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Data Center Lifecycle CO2e Calculator
TradeOff Tool 33

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Contact us

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If you are a customer and have questions specific to your data center project:

Contact your Schneider Electric representative at
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Appendix

Detailed assumptions

Facility infrastructure attributes

- 0.23 t CO_2e/m^2 carbon intensity for core & shell[16]
- Medium voltage switchgear is not included[17]
- 28.7 operation hours per year for diesel genset[18]
- 70 gallons/MWh diesel genset fuel consumption rate
- 0.973 t CO_2e/MWh diesel genset emission factor
- 72 hours of diesel fuel storage for genset
- Emissions from genset transportation is not considered
- 5 minutes UPS battery runtime
- Chilled water system with air-cooled packaged chiller
- 5000 annual hours of economization
- 0.5% R-134a refrigerant leakage rate for chillers

Others

- Power purchase agreement (PPA) usage is not considered
- Direct emissions include fuel combustion from backup diesel genset and refrigerant leakage. Onsite vehicles are not considered.
- Discharge of fire protection system due to fire is not considered
- There is no "carbon credit" when equipment is sent to its second-life usage or recycled at end-of-life, such as IT servers and batteries.
- Emissions from business travel is 1% of the sum of GHG categories 1 through 5 while emissions from employee commuting is 0.5%[19].
- No upstream and downstream leased assets
- Typical lifespans
    - Building shell - 50 years
    - Data center - 15 years
    - Server - 4 years
    - Networking gear - 5 years
    - MV/LV transformer - 30 years
    - Genset - 20 years
    - LV switchgear - 20 years
    - UPS - 12 years
    - VRLA battery - 4 years
    - Critical power distribution - 20 years
    - Air cooled chiller - 20 years
    - CRAH - 20 years

[16]Standard stick-built construction, https://www.serverfarmllc.com/2020/04/modernization-vs-new-build-data-centers/

[17]MV switchgear is typically owned by the electric grid operators for this data center capacity.

[18]Assumes 24 hours for maintenance and 4.7 hours of power outage per year, per WP14, *The Reality of Replacing Diesel Generators with Natural Gas, Energy Storage, Fuel Cells & Other Options*.

[19]Carbon emissions from business travel and employee commuting normally represent a small percentage of Scope 3 emissions. For more information on categories, see WP53, *Recommended Inventory for Data Center Scope 3 GHG Emissions Reporting*.

- Pumps, metal piping, valves - 20 years
- Other[20] - 15 years

Additional analysis methodology

1. The core & shell was categorized as purchased goods (Scope 3 - GHG category 1), while all other equipment was categorized as capital goods (Scope 3 - GHG category 2). For more information on the definitions of GHG categories, see White Paper 53, *Recommended Inventory for Data Center Scope 3 GHG Emissions Reporting*.
2. Replacement frequencies for equipment such as servers, batteries, and UPSs were determined according to their typical lifespans.
3. Use product environmental profile (PEP)[21] documents to get the primary[22] embodied carbon data for most equipment. See the last subsection for more information on PEP. If PEP documentation did not exist, we estimated the embodied carbon by referencing a similar model or obtaining material disclosure forms from suppliers.
4. All the emissions are quantified in tonnes of CO_2 equivalent (t CO_2e).

Table A1 provides detailed design parameters of the data center used in our analysis.

[20] Other includes IT racks, primary auxiliary, critical auxiliary, fire protection, raised floor/dropped ceiling, lighting, management & security. Primary auxiliary devices are non-IT loads that are powered by primary utility (primary power bus). Examples include, HVAC controls, actuators, space heaters in maintenance hallways, kiosks, flat screen TVs, electronics chargers for wireless phones and two-way radios, etc. Critical auxiliary devices are non-IT loads that are powered by a UPS (critical power bus). Examples include, control, data center alarm systems, BMS servers, fire control systems, and physical security systems.

[21] PEP is one kind of Type III Environmental Product Disclosure (EPD) document. In a PEP document, a life cycle assessment (LCA) is used to quantify the carbon footprint of equipment in five stages: manufacturing, distribution, installation, operation, and end of life according to ISO 14025 standard.

[22] Primary data from equipment suppliers can provide a more accurate representation of a company's specific value chain activities compared with secondary data (industry-average data). See Table 7.5 Advantages and disadvantages of primary data and secondary data in *Corporate Value Chain (Scope 3) Accounting and Reporting Standard* for more information.

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Table A1

Design parameters of the hypothetical data center analyzed

Parameters		Value	Unit
Overview	Target availability	Tier 3	Tier
	Annualized PUE	1.34	Unitless
	Data center IT capacity	1000	kW
	IT & facility floor space	12,895	ft^2
	Average density	6	kW/rack
Facility power	Total amps (main bus)	3,200	A
	Input voltage (main bus)	480	V
	Switchboard kAIC	65	kA
	Power path	Dual	
	Generator redundancy	N+1	
	IT space UPS capacity	1,200	kW
	IT space UPS redundancy	N+1	
	IT space UPS runtime @ rated load	5	minutes
	IT space UPS output voltage	480	V
	Facility cooling UPS capacity	54/60	kW/kVA
	Facility cooling UPS redundancy	N+1	
	Facility cooling UPS runtime @ rated load	5	minutes
Facility cooling	Total cooling capacity	1,400	kW
	Input voltage	480	V
	Heat rejection medium	Chilled water	
	Mechanical redundancy	N+1	
	Outdoor heat exchange	Air-cooled, packaged chiller	
	Coolant supply temperature	59	°F
	Coolant return temperature	69	°F
	Storage tank size	5,000	gallons
	Ride-through time	5	minutes
	Economizer type	Water-side	
IT space	IT load	500	kW
	Input voltage	480	V
	Supply voltage to IT	240	V
	Average density	6	kW/rack
	Number of racks	168	racks
	IT floor space	6,388	ft^2
	Single or dual cord	Dual	
	Heat rejection medium	Chilled water	
	CRAC/CRAH type	Room-based CRAH	
	CRAC/CRAH redundancy	N+1	
	Containment type	Hot aisle	

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Electricity carbon accounting and allocation throughout supply chain

Electricity used by a data center is normally from a combination of different sources including utility, diesel genset, and PPAs. Utility normally has different energy sources such as coal, natural gas, nuclear, oil and renewables. Each energy source has different emissions (evaluated in t CO_2e/MWh) from different stages of its supply chain including pre-combustion, combustion, transmission & distribution (T&D) (as shown in **Table A2**).

Table A2

Emission factors per MWh of electricity generated

Utility generation mix	Pre-combustion (t CO_2e/MWh)	Combustion (t CO_2e/MWh)	T&D (t CO_2e/MWh)
Coal	0.043	0.962	0.060
Natural gas	0.185	0.468	0.039
Nuclear	0.023	N/A	0.001
Oil	0.101	0.757	0.051
Renewables	0	N/A	N/A

These emissions should be allocated to different Scopes (1, 2, and 3) for electricity consumers. For example, pre-combustion and T&D are normally allocated to Scope 3 emissions while combustion is allocated to Scope 2 emissions. The study in this paper uses the GHG Protocol methodology shown in **Figure A1** to allocate the electricity supply chain emissions.

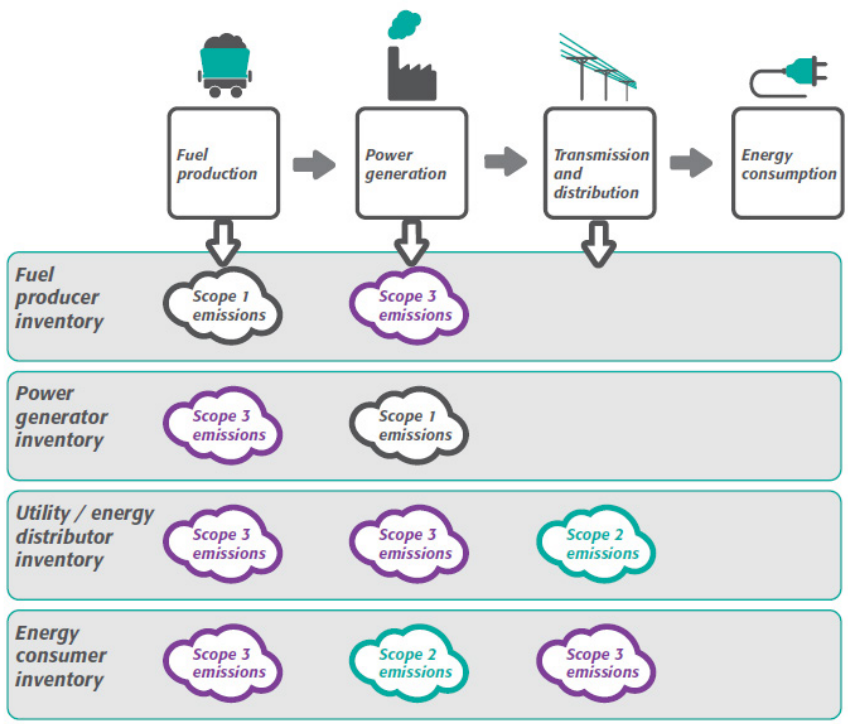

Figure A1

Electricity emissions accounting and allocation throughout the supply chain

Source: GHG Protocol Scope 2 Guidance, pg. 97

Table A3 assigns the emission factors from **Table A2** to the relevant Scope for each energy source. Because pre-combustion and T&D are both Scope 3, they are added together under Scope 3. Notice how coal has the highest Scope 2 emissions while natural gas has the highest Scope 3 emissions. Accounting for these separately makes a material difference in Scope 2 and 3 reporting. We believe most data center operators have reported their Scope 2 emissions using an emission factor that combines both Scope 2 and 3. However, we hope this paper provides the insight needed for operators to ask their utility providers to break out their emission factor by Scope 2 and 3. Doing so will help organizations bring transparency to the total carbon footprint of their fuel- and energy-related activities. More importantly, this will help organizations make energy procurement improvements to reduce this Scope 3 impact. Even if the utility is unable to provide separate emission factors, they can provide the percentage energy source mix for your location. Using these percentages in the *Data Center Lifecycle CO_2e Calculator* will provide the emission factor for each Scope.

Table A3 provides the Scope 1, 2, and 3 emission factors for each electricity generation source. Using the emission factors in Table A3, Table A4 shows the electricity source mix and the resultant "rolled up" emission factors for three geographies including the United States, France, and Singapore.

Table A3

Emission factors of utility energy sources

Utility generation source	Scope 1 (t CO_2e/MWh)	Scope 2 (t CO_2e/MWh)	Scope 3 (t CO_2e/MWh)
Coal	0	0.962	0.103
Natural gas	0	0.468	0.224
Nuclear	0	0	0.025
Oil	0	0.757	0.152
Renewables	0	0	0

Table A4

Electricity carbon emission factors based on source mix

Source: Per capita electricity generation by source, 2021

Utility generation mix	U.S.	France	Singapore
Coal	22%	1%	0%
Natural gas	39%	6%	95%
Nuclear	19%	69%	0%
Oil	0%	2%	3%
Renewables	20%	22%	2%
Emission factor[23] (t CO_2e/MWh)	0.511	0.090	0.686

Proposed actions to reduce Scope 1 and 2 emissions

Scope 1 reduction - Although it represents a small percentage, strategies to reduce diesel generator emissions are being reviewed by many large data center operators. In July 2020, *Microsoft announced its goal* to eliminate their dependency on diesel fuel for backup power in their data centers by 2030. Actions to reduce Scope 1 may include:

- Replace diesel gensets with more sustainable alternatives such as nature gas gensets, fuel cells, etc.24.
- Select cooling systems with less refrigerant and lower global warming potential (GWP).

Scope 2 reduction - Use more renewable energy through onsite generation or buying RECs or PPAs.

[23] These emission factors combine pre-combustion (Scope 3), combustion (Scope 2), and T&D (Scope 3) emissions.

[24] White Paper 14, *The Reality of Replacing Diesel Generators with Nature Gas, Energy Storage, Fuel Cells & Other Options*, provides a in depth look at these alternatives.

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Product environmental profile (PEP)

The embodied carbon of capital goods represents the majority of a data center's Scope 3 emissions; therefore, data center equipment suppliers should freely provide Type III Environmental Product Disclosure (EPD) documents for their equipment. PEP is one kind of EPD document. In essence, it's a summary of a full life cycle assessment (LCA)[25] for a given product range. It provides key data that quantifies the environmental impact of the reference product. Figure A2 (a) and (b) show an example of a PEP document for a three phase UPS. While the ISO standards provide the basis for EPDs, they don't eliminate manufacturer mistakes or ensure valid comparisons. Therefore, end users must be vigilant when comparing PEPs for two or more products, especially if they're from different manufacturers. White Paper 70, *Guide to Assess a Commercial Product's Sustainability*, discusses the major errors people make when comparing the carbon footprint of two or more products.

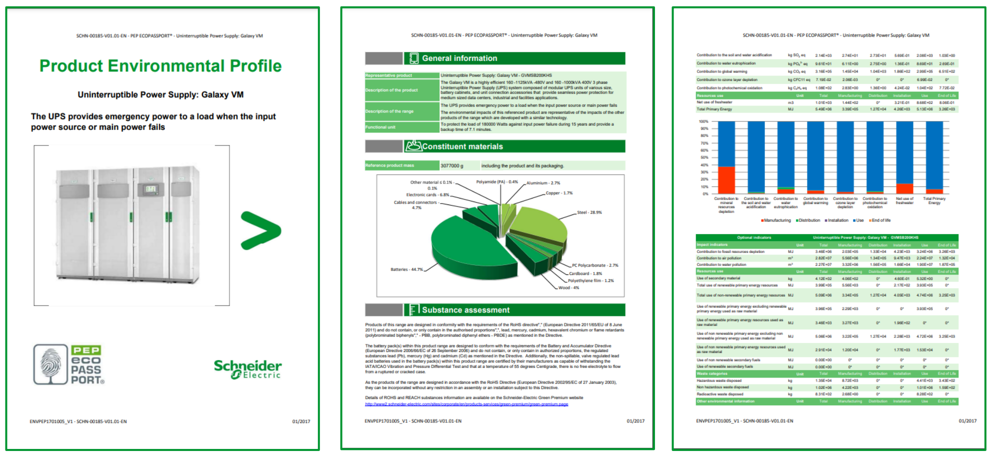

Figure A2 (a)

An example of PEP document for a UPS

(Schneider Electric Galaxy VM shown)

Figure A2 (b)

Zoom in of carbon footprint of the UPS

Compulsory indicators	Uninterruptible Power Supply: Galaxy VM - GVMSB200KHS						
Impact indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of Life
Contribution to mineral resources depletion	kg Sb eq	2.08E+01	7.80E+00	0*	0*	1.30E+01	0*
Contribution to the soil and water acidification	kg SO_2 eq	2.14E+03	2.74E+01	2.73E+01	5.69E-01	2.08E+03	1.03E+00
Contribution to water eutrophication	kg PO_4^{3-} eq	9.61E+01	6.11E+00	2.75E+00	1.36E-01	8.69E+01	2.69E-01
Contribution to global warming	kg CO_2 eq	3.16E+05	1.45E+04	1.04E+03	1.86E+02	2.99E+05	6.51E+02
Contribution to ozone layer depletion	kg CFC11 eq	7.19E-02	2.06E-03	0*	0*	6.99E-02	0*
Contribution to photochemical oxidation	kg C_2H_4 eq	1.08E+02	2.83E+00	1.36E+00	4.24E-02	1.04E+02	7.72E-02
Resources use	Unit	Total	Manufacturing	Distribution	Installation	Use	End of Life
Net use of freshwater	m3	1.01E+03	1.44E+02	0*	3.21E-01	8.68E+02	8.06E-01
Total Primary Energy	MJ	5.49E+06	3.39E+05	1.27E+04	4.26E+03	5.13E+06	3.26E+03

[25]According to ISO 14040: 2006, "LCA is the compilation and evaluation of the inputs and outputs and the potential impacts of a product system throughout its life cycle."