GUIDELINES: LIFE CYCLE ASSESSMENT

LCA GUIDELINES FOR CLOUD PROVIDERS

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Executive Summary

In order to understand the life cycle GHG emissions, energy, water and other environmental impacts of technology, from servers to full datacenters, analyses need to be conducted on the cradle-to-grave impacts of production, transport, use and end-of-life. A life cycle assessment (LCA) can help calculate the environmental burdens of these systems and identify opportunities for reductions. Conducting an LCA can be a complex, but this standard operating procedure (SOP) document is intended to provide tips and tricks for how to approach an LCA based on experience from the authors. This document also illustrates the similarities and differences between LCA and GHG inventory accounting and highlights how LCA can be used to inform GHG inventory work. This document is intended to provide guidance to anyone who is considering undertaking an LCA to set them up for success.

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Introduction

PURPOSE

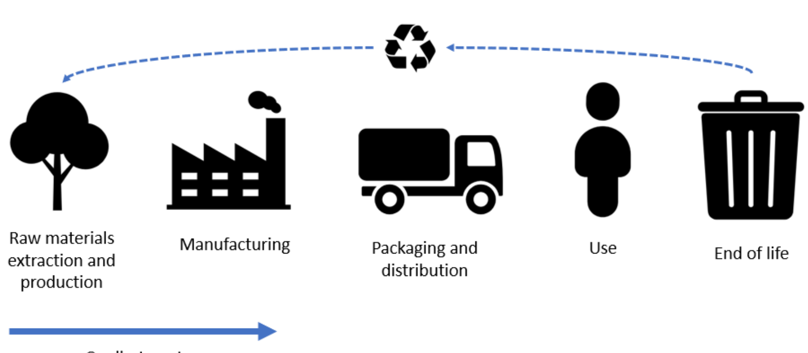
The purpose of this document is fourfold:

1. Provide a background and primer on life cycle assessment (LCA) and greenhouse gas (GHG) accounting (according to the Greenhouse Gas Protocol [GHGP]) and evaluate the similarities and differences between the two to help readers determine whether LCA will answer the questions they seek to answer scientifically.
2. Understand the fundamental questions to ask to set the analysis boundary and parameters for the LCA, collect the required data, and document the findings as a simple "starter guide," if LCA is determined to be the appropriate tool.
3. Anticipate data gaps, determine how to fill them, and understand the impact these gaps have on the analysis.
4. Ensure a harmonized approach to LCA to ensure that assessments are comparable and facilitate decision-making.

Note that this document does not cover LCA to the same level of detail as the relevant standards, but is a high-level guide to help readers decide if an LCA is an appropriate tool and identify key aspects to include in the study.

LIFE CYCLE ASSESSMENT

LCA offers a scientific framework for quantifying the environmental benefits and burdens from the production, transportation, use, and disposal of product systems. It can be used to understand the drivers of different environmental impacts, such as **GHG emissions, energy use, and water consumption**, through the life cycle to guide product design innovation and engineering and improve sustainability throughout the supply chain. The practice of LCA is guided by the International Organization for Standardization (ISO) standards 14040 and 14044, which delineate the four phases of an LCA: the goal and scope (objectives of study); life cycle inventory (LCI) (data collection); life cycle impact assessment (modeling); and interpretation. This becomes the template for performing an LCA. Step 1: Figure out what question to answer; Step 2: Collect data and fill data gaps; Step 3: Model the system, and Step 4: Interpret and analyze the results based on the original goals.



During the goal and scope phase of an LCA, the objectives of the study are described, which then determine key scope features of the study. These study features may include the function of the product system, the functional unit, the environmental impact categories to quantify, the system boundary, and the intended audience for the study. The goal and scope section discusses this in more detail.

LCAs can quantify numerous environmental impacts.[1] The impacts included in an LCA are determined by the study questions and the metrics that are meaningful to the users of the study. The system boundary can be from cradle-to-gate or from cradle-to-grave. To-gate includes from raw material extraction through final production and is selected when the product could have multiple uses, such as a chemical or an ingredient. To-grave is selected to include the use and the end-of-life (EOL) treatment of a product or system. In the case of a datacenter, a cradle-to-grave system boundary will allow the LCA results to account for the full product life cycle so that hotspots in each phase (raw material extraction, production, use, and EOL) can be identified.

The intended audience for the study could be internal, such as process engineers who may use the study to improve production practices, or external, like stakeholders and customers, who will receive the study as a part of support communications. The ability of an LCA to speak to internal and external audiences is relevant for a company like Microsoft, with many engineers and design decisions to make, as well as many external stakeholders involved in understanding and reducing Microsoft's overall environmental footprint.

GREENHOUSE GAS ACCOUNTING

The GHGP provides accounting and reporting standards for calculating and reporting GHG emissions. According to the GHGP, GHG emissions are classified into scopes 1, 2, and 3 (Figure 2).[2]

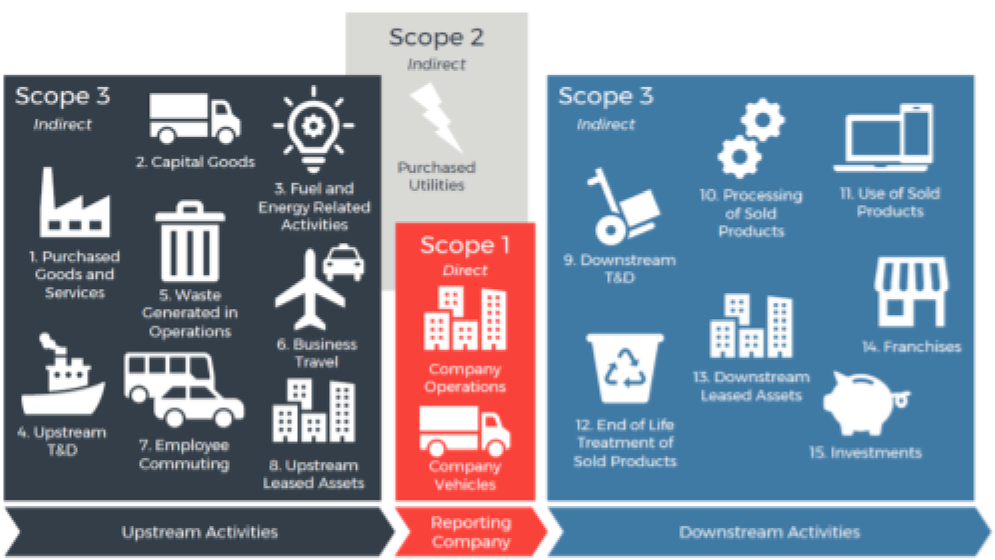


*Figure SEQ Figure * ARABIC2: Scopes 1, 2, and 3 for GHG accounting*

[1] Impacts include GHG emissions, energy use, water use and consumption, eutrophication, acidification, smog formation, ozone depletion, and resource depletion.
[2] GHGP is a joint initiative between the World Resources Institute and World Business Council for Sustainable Development.

Scope 1 GHG emissions are all direct emissions from owned operations and facilities. This includes emissions from onsite heating, cooling, and power generation (e.g., a natural gas onsite power plant), or from the combustion of gasoline and diesel from equipment. For a cloud provider, this scope could include emissions from onsite natural gas heating, or diesel combustion in company vehicles.

Scope 2 GHG emissions are associated with indirect purchased utilities such as electricity (e.g., from the grid). For cloud providers, this includes all GHG emissions from purchased electricity for use in its facilities, including the energy needed to power datacenters, and is determined using regional grid emissions factors.

Scope 3 GHG emissions are composed of 15 categories that can be further divided into upstream and downstream emissions. Upstream emissions are indirect GHG emissions related to purchased or acquired goods and services (e.g., raw materials, transportation of goods, waste generated in operations). Downstream emissions are indirect GHG emissions related to sold goods and services, which can also include emissions from products that are distributed, but not sold (i.e., without receiving payment). Some scope 3 emissions specific to cloud providers include the embodied emissions from the production of purchased goods such as servers (upstream), the GHG emissions from the energy used to power consumer electronics products (e.g., laptops and gaming consoles) (downstream), and the disposal of waste generated from datacenters (downstream).

SIMILARITIES AND DIFFERENCES BETWEEN LCA AND GHG ACCOUNTING

An important similarity between LCA and GHG accounting is that both processes can be used to quantify the GHG emissions from a cloud provider's activities. There are some notable differences between the two, however. LCA quantifies many different environmental impacts, not just GHG emissions. Furthermore, GHG accounting and LCA parse GHG emissions into different categories based on where the emissions occur in the life cycle. The scope 1 direct GHG emissions most often fall into the use phase of a product or service in an LCA, but not always. For example, at a datacenter, scope 1 GHG emissions would arise from the onsite fuel combustion that generates either heat or electricity.[3] Scope 2 GHG emissions would arise from the purchased electricity used to power the datacenter. In LCA, the use phase GHG emissions would encompass all GHG emissions such as purchased electricity or onsite electricity generation, and other emissions produced when operating the datacenter. In the case of scope 3, GHG emissions from the production of inputs to the datacenter, such as servers, would be included in the upstream category 1 emissions for GHG accounting. In LCA, these GHG emissions, often called "embodied GHG emissions," fall into the production life cycle phase, which accounts for the raw materials used to make the servers (e.g., Printed Circuit Board, semiconductors) and heat and energy used to manufacture the servers. In the scope 3 downstream categories, the EOL of sold products (category 12) would align with the EOL

[3] This also could include emissions from backup diesel generators in use or during monthly testing.

phase in LCA. It is possible to use GHG emissions calculated using an LCA to report scope 1, 2, and 3 GHG emissions—it simply requires some recategorization from life cycle phases into scopes and categories.

Figure 3 illustrates some of these sources of scope 1, 2, and 3 emissions from a datacenter. In this figure, the first column of datacenter hardware manufacturing would be considered upstream production in LCA, the second column would be use phase, and the third column would be EOL. This is relevant to stakeholders interested in using the results of an LCA for scope 1, 2, and 3 reporting to understand how the two methodologies differ and that the results of an LCA may need to be parsed differently in order to fit the GHGP methods of accounting.[4]

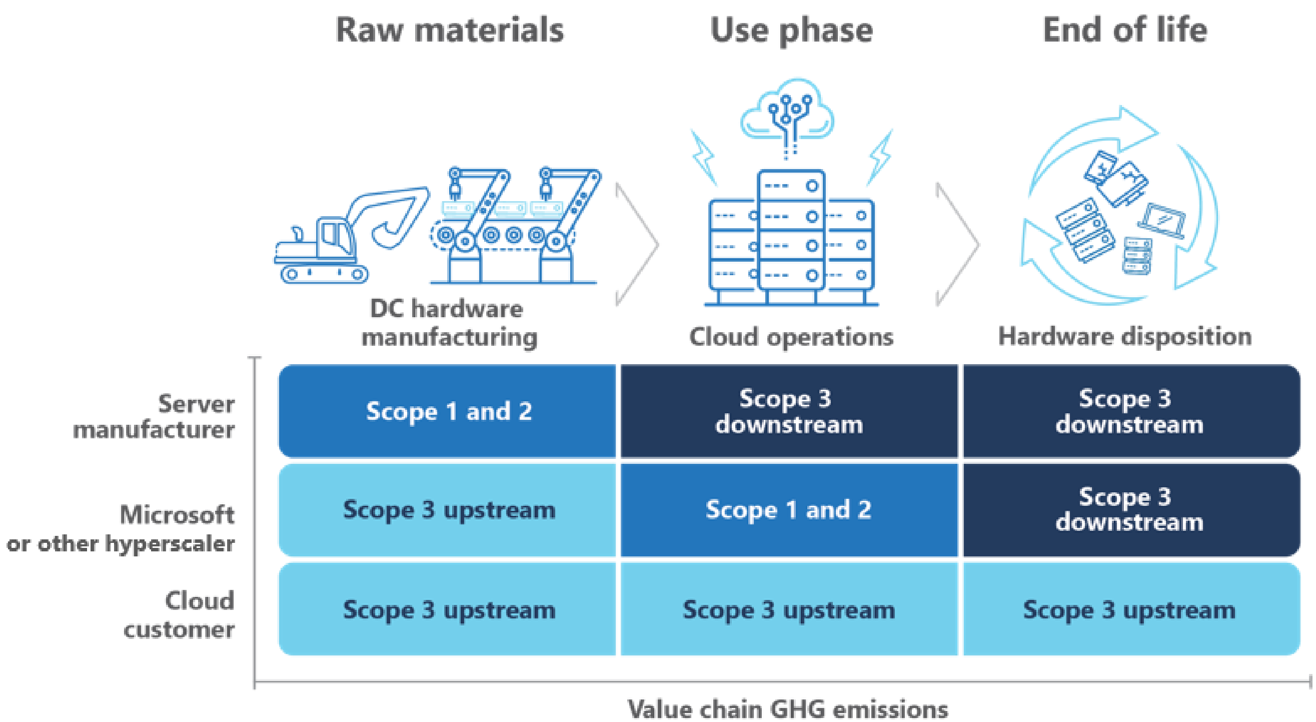


Figure 3: Scope 1, 2, and 3 sources of emissions for a cloud ecosystem.

Key takeaways:

1. *LCAs can quantify GHG emissions and other environmental impacts (such as energy and water consumption) from the production, use, transport, and EOL of products and systems.*

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[4] In GHG inventory accounting (according to the GHG Protocol), the purchase of renewable energy equal to the amount of electricity consumed by the datacenters reduces the GHG emissions from direct energy use by the datacenters to zero using market-based accounting. Note that in LCA methodology, according to ISO standards 14040 and 14044, market-based accounting for GHG emissions is not followed. Further, the GHG emissions associated with the production and EOL of materials (e.g., building, servers, equipment) are not affected by renewable energy purchasing.

2. *GHG accounting (per the GHGP) is used to quantify GHG emissions into scopes 1 (direct onsite), 2 (purchased electricity), and 3 (upstream and downstream) GHG emissions for accounting and reporting GHG emissions.*

3. *LCA and GHG accounting are similar in that they both can be used to quantify GHG emissions but differ in that LCA can also quantify other environmental impacts. The categories in which GHG emissions are designated may also vary between the two methods. Understanding these differences will help determine if an LCA or a GHG inventory is needed.*

1 Goal and Scope

At the start of an LCA, it is important to identify several aspects of the study, including the study's objectives and how the system boundary and functional unit are defined to achieve those objectives. In LCA, this is called setting the goal and scope of the study. Figure 4 and Table 1 below summarizes these key questions, provides a generic example of comparing an electric hand dryer to paper towels to help think through the process, and then provides a more specific example from the datacenter/server LCA.[5]

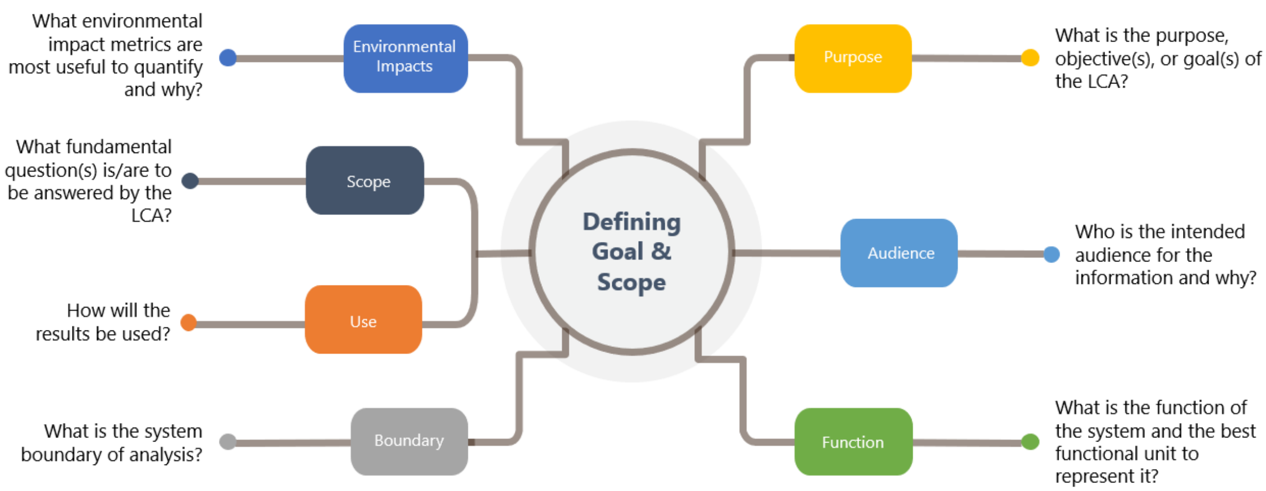

Figure 4: Fundamental questions that help define LCA goal and scope

[5] One important part of most LCAs is that of allocation, which was not part of the datacenter analysis. Allocation is when the burdens of a system must be apportioned between multiple co-products of production when multiple products from the same system, e.g., crude oil refining results in dozens of products, exist. If there are multiple co-products of a system, a method of either subdividing the impacts of production or allocating the burdens between multiple products must be considered.

Table 1: LCA Goal and scope questions and sample answers

Question	Hand Drying Example	Datacenter/server Example
What environmental impact metrics are most useful to quantify and why? (e.g., GHG emissions, blue water consumption[6], energy, acidification, eutrophication, ozone depletion, smog formation, and many others)	Environmental impacts to quantify could be impacts likely to be of interest to consumers, such as GHG emissions and water consumption.	The environmental impacts quantified are GHG emissions, primary energy use, and blue water consumption because these are the metrics important to a cloud provider's stakeholders for reporting and understanding datacenter environmental impacts.
What is the purpose, objective(s), or goal(s) of the LCA? (e.g., make comparative or noncomparative analysis, support an external claim, or drive design decision-making and process improvements)	To compare the environmental impacts of an electric hand dryer to that of a paper towel dispenser and determine which method of hand drying reduces environmental impacts.	To calculate the different or delta in environmental impacts between an existing server and a newer model.
What fundamental question(s) will be answered by the LCA? (e.g., comparative environmental impacts between two systems, total footprint of one system/product)	Which method of hand drying reduces environmental impacts, an electric hand dryer or paper towels?	1. What are the total environmental impact savings across water, energy, and GHG emissions from a current server design and one being designed? 2. What are the primary drivers of water, energy, and GHG emissions from the new server design and how can they be reduced through process engineering and design?
Who is the intended audience for the information and why? (e.g., internal stakeholders to drive decision-making, external clients/customers to support marketing claims and regulatory submissions, or both)	The intended audience is external to make marketing claims of enhanced environmental benefits of one method of hand drying over the other.	The intended audience is both internal, to inform process engineering and design, and external, to communicate the environmental impact reductions from a new technology and or server design.

[6] Blue water consumption is the net water (withdrawals – returns) including water embodied in products and production i.e., water required to make the products that go into a system not just cooling water

How will the results be used? (e.g., to inform design decisions, to communicate externally)[7]	The results will be used to communicate about the environmental benefits of one method of hand drying over the other to potential customers, such as building owners and consumers.	The results will be used to communicate about the environmental benefits of a new server design and to inform design decision about future platform architectures & server designs.
What is the system boundary of analysis? (e.g., from cradle-to-gate, cradle-to-grave, gate-to-gate)	The system boundary of analysis is from cradle-to-grave, which includes: 1. Extraction of raw materials, including metals, electronics, paint, and adhesives, to make both dryer types. 2. Production of the electric hand dryer and the paper towel holder. 3. Use phase energy to power the electric hand dryer and the paper towels used to dry hands. 4. EOL treatment of all materials from recycling and reuse to incineration and landfilling, including the electric hand dryer itself at EOL and all of the paper towels used over the lifetime of the paper towel holder.	The system boundary of analysis is from cradle-to-grave, which includes: 1. Extraction of raw materials to make the building, servers, racks, network gear, and building support equipment (e.g., air handling units, dry coolers, generators, and electrical infrastructure). 2. Production of servers, racks, equipment, and the building. 3. Use phase energy to power the datacenters and GHG emissions from use phase. Water for cooling where applicable. 4. EOL treatment of all materials from recycling and reuse to incineration and landfilling.

[7] The answer to this question will determine the level of accuracy and precision required for the input data. For example, if external comparative assertions or marketing claims will be made about comparisons between two systems, then a greater level of accuracy and detail in input data may be required than in the case of informing directional design decisions for a product or systems engineering team.

What is the function of the system and the best functional unit to represent it? (e.g., one unit of product, one unit of measure, such as kg, liter, terabyte of data)	The function of the two systems is the same, to dry hands. Therefore, the functional unit for purposes of comparison is a set number of pairs of hands dried (e.g., 100 pairs or 1,000 pairs of hands).	The function of the datacenter system is to provision virtual machines (VMs) for use by cloud customers. Therefore, the most appropriate functional unit is one VM and results will be reported as GHG emissions, energy use and water consumption per VM. While this example is specific to datacenters, for a product like Xbox or Surface, this could be per one device.[8]

Key takeaways:

1. *In LCA, setting the goal and scope is the first step in the process as it determines the fundamental question to be answered by the LCA and sets up how the question will be answered.*
2. *It is important to select a functional unit that will facilitate answering the fundamental question of the LCA, especially if that question is comparing the environmental impacts of two systems with the same function. What this functional unit should be is not always obvious.*
3. *It is in the goal and scope part of the LCA that key aspects like the system boundaries, environmental impacts to quantify, and target audience are set, and this will guide how the rest of the assessment is done.*

2 Data Collection

Data collection, or the LCI phase in LCA, can often be the most time-consuming stage. While collecting data to build the LCA model, data gaps may be encountered. Often, assumptions can be made to fill these gaps and sensitivity analysis can be performed on these assumptions to test if variations in accuracy will affect the final results. The types of data to be collected depend on the question to be answered by the LCA, the system boundary of analysis, and the availability of data. For example, if the networking equipment would be essentially the same when used with two difference types of servers, and the goal of the study is to calculate the differences in impacts between two types of servers, then data on the production of the networking equipment is not needed. Identifying irrelevant datapoints can be a valuable time-saver.[9]

[8] This can become a complicated decision, in the case of comparing the GHG emissions of two different software applications or frameworks/algorithms that perform the same function in different ways.
[9] In some cases, it will be possible to build upon the work of previous LCAs to prevent redundancy by reusing data from completed LCAs.

A high-level example of an assumption made in the comparative datacenter LCA is for building materials, Revit[10] models can be used. If data is not readily available scaling factors can be used to address different generations and designs of the data center. Furthermore, for the equipment used to run the datacenter (e.g., air handling units and adiabatic cooler or dry coolers), many environmental product declarations (EPDs) are available on different types of equipment used in buildings. However, industries are still catching up with the demand for product EPDs.[11] For instance, if there is no available data on the adiabatic coolers, one can use a proxy with information about how air handling units and radiators are produced. More granular assumptions can be made in the modeling of the servers, where specific components like solid state drives (SSDs) and dual in-line memory modules (DIMMs) used in a server design does not have background data available on their production from the databases where LCI data is sourced.[12] Therefore, proxy datasets can be identified from these databases and from published LCAs.

A challenge commonly faced in LCA is determining the best sources of data within an organization and ensuring engagement from different teams to provide data. A datacenter or server LCA is a prime example of this as it required data from many different teams outside of the team that may have requested the LCA to be conducted. It is important to identify appropriate data sources within different teams and clearly communicate what the request is and why it is important from within the organization. Permissions and specialized nondisclosure agreements may need to be obtained or confidential file-sharing folders may need to be set up to enable data sharing. Table 2 below illustrates an example of teams that could be involved in sourcing different data for a datacenter LCA.

Table 2: Data types and sources

Data Type	Data Source Examples
Power Usage effectiveness (PUE), VMs/core, cores/server, server power	Various teams across datacenter infrastructure and management, server & product design, research
Building information including materials and construction Datacenter support equipment (e.g., air handling units)	Datacenter design, engineering & sustainability teams
Servers (compute, storage, AI), racks, switches, etc..	Equipment manufacturers and internal server design team
EOL of materials	Supply Chain Sustainability team

[10] Revit is a 3D building modeling software that enables the quantification of building materials for whole building LCA using a plugin called Tally.
[11] An EPD is a declaration that quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. EPDs follow LCA methodology according to ISO standards 14040 and 14025.
[12] For example, GaBi and ecoinvent.

Another consideration in obtaining data is access to unit process information, datasets, and databases that require licenses, such as commercial databases. While one can expect a reasonable level of detail and visibility into background data from these commercial databases, some information may be obscured due to intellectual property and market competitiveness concerns. For example, background data on semiconductor manufacturing is generally composed of an average of at least three manufacturers and rolled into a “black box” dataset so that information about the amount of energy or input materials cannot be determined, as this could be used to estimate the costs of production and drive down purchasing prices. Some datasets may also be based upon generic or industry-average assumptions, and the availability of complete LCI data lags in the marketplace. It may not be possible to obtain all the details about how a background dataset was modeled.

Key takeaways:

1. *Data will likely need to be collected from many different sources, such as different teams within the company and different databases combined with LCA publications and EPDs. Some data may be based on industry averages with limited transparency due to intellectual property or market competitiveness concerns.*
2. *Where data gaps exist, assumptions can be made based on guidance and experience, as long as all assumptions are well documented in the LCA report and other supporting documentation.*
3. *Data collection is often the most time-consuming stage of an LCA. Ensuring engagement by relevant teams leading up to this phase is crucial to moving the project forward.*

3 Modeling

The life cycle impact assessment phase is where all of the collected data is brought together in a model built in a tool like Excel or an LCA-specific software.[13] In creating such models, it is important to define a base case scenario upon which comparisons can be made. In the comparative server example, only one version of a given server configuration could be modeled as a point of comparison to the newer model. Other types of parameters could involve varying the use phase energy of the server or the lifespan of the device. With these parameters in mind, the baseline model can be built, and then different parameters can be varied to test their effect on the environmental impact results.

The results from the LCA can also be parsed in different ways to identify hotspots in the life cycle phases and materials used to create and run the datacenter. For example, the energy used to run the datacenter is often the

[13] For example, GaBi or SimaPro

primary driver of GHG emissions and water consumption (based on the water required to generate grid electricity) from datacenters. Within materials production, hotspots can be identified among the various parts needed to build a datacenter (e.g., the building, equipment, racks, and servers). In a general datacenter LCA it could be demonstrated that the building materials are not a significant driver of GHG emissions, energy or water consumption, but the servers are. Going one step deeper, within the servers, the SSDs and DIMMs are identified as the key contributors to production impacts. This information can be considered when choosing which areas to focus on for design improvements. For example, instead of building footprint reduction, time and resources could be directed to server design, to reduce the number of DIMMs, or to electronic suppliers, to engage with them on how to minimize the footprints of their products.

Finally, this data can be used to identify areas for sensitivity analysis based on any assumptions made in the data collection phase. If building materials are not a significant driver of environmental impacts; further sensitivity analysis on the assumption made about datacenter size or materials may not be as impactful as a sensitivity analysis that examines, and tests assumptions made about the server components as they were larger drivers of environmental impacts. With this information, best- and worst-case scenarios can be designed to ensure that the results of the LCA encompass the full range of possible environmental impacts and differences between current and new server designs.

Key takeaways:

1. *The base case scenario is informed by the fundamental question(s) the LCA was set to answer in the goal and scope phase. Understanding what the base case scenario is will inform what information needs to be collected.*
2. *One of the applications of the LCA results is to identify hot spots in the raw materials, use phase and EOL of the system to target for environmental impact reductions.*
3. *The sensitivity analyses and/or scenario modeling can be used to explore the best- and worst-case scenarios of a product or system which are valuable for informing and setting engineering design principles. Sensitivity analyses can also be used to test the effects of assumptions made in data collection on the final results of the study.*

4 Reporting format for ISO

Within LCA, several different reporting options exist. If the results of the LCA are only to be communicated internally, then they can be documented in slides and/or a report for posterity and to facilitate communication with other teams outside the one that commissioned the LCA. If results of an LCA, particularly a comparative LCA, are to be communicated externally, then ISO standards require that the LCA be documented in an ISO-conformant LCA report, and that that report undergo critical review by a panel of three independent experts in LCA and the subject matter (e.g., datacenters). This method of reporting and critical review provides a level of confidence in the results that they can withstand external scrutiny when communicated through different reporting methods (e.g., CDP (formerly the Carbon Disclosure Project) responses and annual sustainability reports). We strongly recommend that all -conducted LCAs be ISO-conformant to ensure alignment of methodologies and internal consistency. Additionally, it is recommended that documentation is completed within Excel and PowerPoint, or similar productivity applications, to facilitate transparent communication and effective understanding of data sources and assumptions.

The process for completing an ISO-conformant LCA report with critical review is as follows:

1. Identify the critical review panel chair who will aid in selecting the other two panel members.
2. Draft the goal and scope document (the first two chapters of the ISO-conformant LCA, per the ISO standards).
3. Engage the panel chair to review the goal and scope document.
4. Address comments on the goal and scope document.
5. Prepare the full ISO-conformant report with the following sections:
    a. Goal
    b. Scope
    c. LCI
    d. Life cycle impact assessment
    e. Interpretation
        i. Significant findings
        ii. Data quality assessment
        iii. Limitations
        iv. Recommendations
    f. References
    g. Supporting information
6. Engage the panel for the first round of critical review.
7. Respond to and address comments from the panel's first review.
8. Engage the panel for the second round of critical review.
9. Respond to and address comments from the panel's second review.
    a. If accepted, the panel then issues the critical review statement.
    b. If not accepted, then the report undergoes further revisions until it can be accepted.

10. If external claims are made on the basis of the comparative ISO-conformant LCA report, then the report could be made publicly available either through the company's website or by direct request.

Other methods of communication of the LCA could include white papers, blog posts, or even a published paper in a scientific journal. However, having the ISO-conformant LCA with critical review supporting these other forms of messaging can be very helpful in streamlining high-level communications, as these communications can always refer to the details in the report. The typical outcomes from LCA work include an ISO-conformant report (with or without critical review), a tool, and slide presentation.

Key takeaways:

1. *Reporting is an important step to both document what was done in the LCA and ensure transparency when discussing the process and results both internally and externally.*
2. *If the results of a comparative LCA are to be disclosed externally, then according to the ISO standards on LCA, the LCA report must undergo critical review by a panel of three independent experts.*
3. *Other deliverables from an LCA can include slide presentations and tools for future calculations, but the ISO-conformant report will serve as complete documentation to support these additional deliverables.*

5 Conclusion

LCA is a powerful tool for calculating the environmental impacts, like GHG emissions, energy and water, from the production, transportation, use and EOL of a product or system. There are many key questions to consider when undertaking an LCA which we have outlined herein and provided examples to help guide the reader through the process. Inevitably, novel and unanticipated questions will arise in any LCA, so we anticipate an ongoing and evolving discussion.

6 Glossary

LIST OF ABBREVIATIONS

AFR – Annualized Failure Rate

DIMM – dual in-line memory module

EOL – end of life

EPD – environmental product declaration

GHG – greenhouse gas

GHGP – Greenhouse Gas Protocol

GWP – global warming potential

ISO – International Organization for Standardization

LCA – life cycle assessment

LCI – life cycle inventory

LCIA – life cycle impact assessment

SDD – solid state drive

VM – Virtual Machine

DEFINITIONS

Critical review – the process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment

Functional Unit – a quantified performance of a product system for use as a reference unit

Impact category – class representing environmental issues of concern to which life cycle inventory analysis results may be assigned

Impact category indicator (or metric) – quantifiable representation of an impact category

Life cycle assessment – a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

Sensitivity analysis – systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study

System boundary – set of criteria specifying which unit processes are part of a product system

Unit process – a set of interrelated or interacting activities that transforms inputs into outputs

7 References

RESOURCES FOR MORE INFORMATION

1 ISO standards

a. 14040 Environmental management—Life cycle assessment—Principles and framework
b. 14044 Environmental management—Life cycle assessment—Requirements and guidelines
c. 14046 Environmental management—Water footprint—Principles, requirements and guidelines
d. 14064
    i. Greenhouse gases—Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals
    ii. Greenhouse gases—Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements
    iii. Greenhouse gases—Part 3: Specification with guidance for the verification and validation of greenhouse gas statements

2 The GHGP

a. Corporate standard

b. GHGP for cities

c. Mitigation goal standard

d. Corporate value chain (scope 3) standard

e. Policy and action standard

f. Product standard

g. Project protocol

10 License

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