Dell Technologies

Understanding Life Cycle Assessments (LCAs), Product Carbon Footprints (PCFs), and the uses and limitations of PAIA, a streamlined LCA methodology

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Abstract

Sustainability is an integral part of our technologies. Understanding the environmental hotspots throughout a product's life cycle can improve our overall understanding of technology's environmental impacts and performance. Streamlined Life Cycle Assessment (LCA) methodologies, such as PAIA (Product Attribute to Impact Algorithm), offer their members benefits like driving performance improvements, meeting stakeholder expectations, and complying with anticipated legislative requirements. This whitepaper explores LCAs, PCFs and what streamlined LCAs such as PAIA can and cannot be used for.

Introduction

At Dell Technologies, we make sustainability a focal point of everything we do. We feel a deep responsibility to innovate for our customers and the planet, using all the levers at our disposal to make technology work for the world we need. Understanding the effects purchased products and services have on climate, habitats, natural resources, water quality and more is essential to reducing our environmental impact and is increasingly important to individuals and organizations the world over. Life Cycle Assessments (LCAs) and Product Carbon Footprints (PCFs) provide customers with specific insights into those effects and enable more informed purchasing decisions.

Information Communication Technology (ICT), such as computers, mobile phones, televisions, etc. are complex, pervasive, and growing continuously. In response to this growth, numerous standards bodies and industry consortia continue developing methodologies to evaluate ICT products' carbon impact. PAIA is one such consortia.

As part of our product carbon footprint calculation process, we use PAIA, a streamlined LCA methodology, to estimate the specific impacts throughout a product's lifecycle. This streamlined methodology focuses only on the carbon impacts or global warming potential (GWP).

What is a Life Cycle Assessment (LCA)?

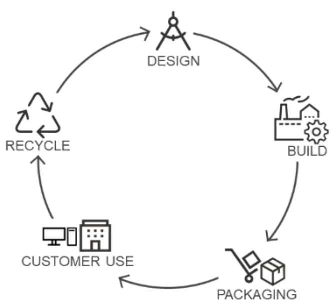

Figure 1: Life Cycle Assessment phases

A life cycle assessment (LCA) is the compilation and evaluation of a product or system's inputs, outputs and potential environmental impacts throughout its life cycle (ISO 14040: 2006, sec 3.2). LCA is an approach that covers the whole life cycle of a product or a service, usually "from cradle-to-grave," i.e., from raw material extraction to manufacturing, packaging, distribution, use and end-of-life management.

LCAs can cover a wide range of environmental impact, such as use of resources, raw materials, end of life handling, or biodiversity. They can also provide potential environmental impact profiles for many categories, such as ozone depletion, water use, and global warming potential.

Global warming potential (GWP) measures the impacts of different greenhouse gases (GHGs) over a defined period of time. Though there are several GHGs, GWP is presented as CO2 equivalent emissions (CO2e) and is one of the most widely used impact categories.

What are the main reasons for carrying out an LCA?

> "LCA is the compilation and evaluation of the inputs and outputs and the potential impacts of a product system throughout its life cycle."
>
> Definition from the
> International Standards Organization (ISO).

LCA identifies the main contributors (materials, build processing, energy usage, transportation, etc.) to key environmental impacts throughout the product's entire life cycle and establishes a benchmark against which improvements can be measured.

Understanding the environmental hotspots in the life cycle of a product can provide unique opportunities to rethink relationships with our suppliers, especially in terms of developing concepts of mutual progress and through improved information exchange and transparency.

What is a Product Carbon Footprint?

A Product Carbon Footprint (PCF) is an LCA that focuses on a **single** impact category, global warming potential, measuring the potential release of greenhouse gas (GHG) emissions over the product life cycle.

Understanding PAIA's Streamlined LCA (PCF) vs. Traditional LCA

Dell performs PCF analyses using PAIA (Product Attribute to Impact Algorithm). PAIA is a streamlined LCA tool developed by MIT's Materials System Laboratory in concert with Arizona State University and the University of California at Berkeley. PAIA aims to provide an efficient estimate of the carbon impact of a product class, including notebooks, desktops, LCD monitors, servers, network switches and storage. PAIA estimates the product's carbon footprint using limited system attributes of the product such as component dimension, screen size, system weight, and annual energy consumption.

The PAIA tool conforms with IEC 62921 requirements and uses data from participating companies and secondary emission factors from third-party sources (such as Ecoinvent). PAIA's statistical analysis generates an estimate of the carbon impact at a component level together with the standard deviation (margin of uncertainty). This enables the PCF to be estimated with relative accuracy and without the need to calculate it from scratch. The outputs are, therefore, based on hardware characteristics and may not capture the specifics of the production process and related innovations in materials use. The results of the PCF analysis reflect our understanding at the time of publishing and are not directly comparable with those conducted by other parties or at other times due to differing assumptions.

The difference between using PAIA's streamlined LCA tool vs. conducting a full LCA is related to the input data and comprehensiveness in calculation of the lifecycle impacts. Rather than building a fully robust model for every single intricate system from scratch (full LCA), PAIA's streamlined calculation tool allows users to estimate PCFs using limited input data that describes the main attributes of the modeled system and pairs that data with a generic background model of that system. Since full LCAs can be a lengthy, resource-intensive process, the streamlined LCA methodology was created to support quick and less resource-intensive estimations.

Another difference between PAIA's streamlined LCA tool and a full LCA can be seen in the results; PAIA's streamlined LCA tool provides potential impacts in terms of a single impact category, Global Warming Potential, expressed as CO2 equivalents (CO2e describes all greenhouse gases in a common unit of carbon dioxide equivalence). In contrast, a full LCA might include additional impact categories such as water use, abiotic resource depletion, or acidification potential. Additionally, a typical product carbon footprint would be expressed as a single CO2e figure, but PAIA's results will provide a single figure and a +/- range to show the standard deviation or margin of uncertainty.

For this product, the estimate has a mean of 348 kg of CO2e and a standard deviation (margin of uncertainty) of 67 kg of CO2e. Therefore, 348 kg of CO2e is what we refer to as the Product's Carbon Footprint (PCF).

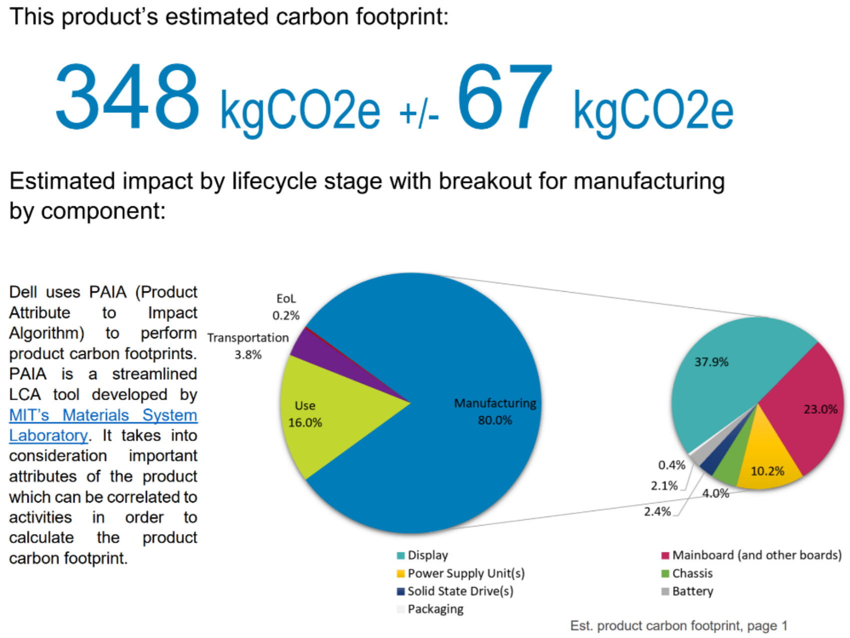

Figure 2: PCF estimate of a Latitude 5510

Why do we use PAIA Methodology for Product Carbon Footprint Analysis?

ICT products typically have many components and long, complex value chains scattered geographically. As a result, assessments can be costly and time-consuming to produce. Additionally, product portfolios tend to evolve rapidly, so in-depth studies may quickly become outdated. PAIA's streamlined LCA methodology offers a comprehensive and timely platform for performing a quantitative evaluation of the carbon footprint of ICT products.

What is streamlined LCA Intended for? In general, LCA and PCF can be used to: • Provide a reasonable estimate of the range of carbon impact of a product. • Identify the major drivers of impact, or carbon intensive hotspots in the lifecycle of the product, thus identifying where reduction strategies should be focused. • Estimate changes in the environmental impact of a process or product over time. • Spark conversations related to sustainability with suppliers or to innovate new processes/materials uses.		**What streamlined LCA cannot be used for?** In general, LCA and PCF cannot be used to: • Compare results of ICT products head-to-head (i.e. laptop A against laptop B) in terms of carbon impact. • Compare products between other manufacturers. • Aggregate individual LCA/PCF studies to derive a figure for the total carbon impact of ICT and use this figure as a benchmark for reduction targets.

Understanding the Limitations of Streamlined LCA Methodologies.

Streamlined LCA methodologies, such as PAIA, provide many benefits, such as driving performance improvements, meeting stakeholder expectations, and complying with anticipated legislative requirements. However, it is important to understand the limitations if it is to be used effectively.

Generally, comparisons of results obtained through PAIA or via other methods aligned to ISO 14040 is not recommended and should be treated with caution.

Uncertainty

In practice, we cannot compare similar products based on streamlined LCA due to the uncertainty and lack of consistency of LCA and PCF results. Concerns like measurement inaccuracies, allocation inconsistencies, outdated data sources, human bias, and error contribute to data uncertainty. Since these pervasive challenges persist, so do uncertainty and variability. ICT products, in particular, are prone to uncertainty due to the high evolution speed within the technology itself and its manufacturing processes. The issue with rapidly evolving areas of technology is the inability to compare like for like over time because the original product has ceased to exist.

Data

Databases are used as an efficient approach to sourcing data where the collection of primary data offers limited timeliness. Numerous assumptions are made during the analysis that require practitioners to understand all the assumptions, like the age of the data, etc. While databases are improving, this level of nuance may not be possible for every single data point. Comparing PCFs or LCAs is not recommended due to the different levels of granularity, data quality, system boundaries, assumptions, calculation methodologies, and many other factors that could influence the outcome of the assessment.

The way we use data

There is a strong desire to compare LCA and PCF results. However, the lack of context is particularly problematic when making such comparisons. If company A publishes LCA or PCF data for a laptop, and company B does the same for its competing device, the immediate temptation is to compare those results. However, comparing those results without knowing all the assumptions, data sources, databases and tools can be problematic.

Any comparison carries inherent risk unless the modeling methodology and approach are exactly the same (i.e., using common primary data/collected data, normalized factors, and tools). Where standardized methods are used, differences in results can be due to different assumptions/normalized factors built into the calculation. The scope for calculation can also vary. Some calculators (such as PAIA) provide a lifecycle perspective (including emissions linked with manufacturing and end-of-life activities). Others focus purely on emissions linked to the energy consumed during the product's use.

We do not recommend comparing results between products made by different manufacturers (although comparisons within a single manufacturer's portfolio are possible). There is potential for significant deviations in results due to different primary data, tools, or modeling used to generate the calculation. Variances are also formulated within the calculations to allow for flexibility when estimating impact.

LCA is not an exact science. Any differences in results might not represent the actual situation.

Understanding the Limitations of PAIA

For full detailed accounting of PAIA's Intended Uses and Limitations please refer to the accompanying guidance document titled 'Intended Uses & Limitations of the PAIA Model'.

Assumptions made in the PCF modeling of Dell hardware

Lifetime

The lifetime and durability of a product are essential attributes to consider when calculating the total PCF. The lifetime of products varies across platforms, which requires some careful consideration as, in practice, it would not be reasonable to apply the same lifetime if products are known to deteriorate at different rates.

The table below outlines the product lifetime (in years) across Dell clients and servers used in PCF modeling. These lifetimes are consistent with general business customer use models and Dell's 2030 goals.

Table 1: Product Lifetime (years)

Clients/Servers	Product Lifetime (Years)
Displays	**5***
Notebooks	**4**
Desktops	**4**
All-in-One	**4**
Servers	**4**
Thin Client	**2**
Tablet	**2**
Networking Switch	**3**

**The assumption for a display's lifetime has been updated to 5 years in 2023.*

Transport

The transportation from assembly to customer includes the emissions generated during air, ocean and land transportation of finished or semi-finished Dell products between Dell facilities and between Dell facilities to customers.

Table 2 outlines the transportation breakdown for the average EU customer (Rail is not used for in-country deliveries and has been excluded in the modeling) (2).

This breakdown is used in the modeling of Dell clients and servers.

Table 2: Transportation breakdown for the average EU customer

To Country of Use			In Country of Use		
Air	**Ship**	**Rail**	**Air**	**Truck**	**Rail**
20 %	70 %	10 %	10%	90 %	0 %

Manufacturing

The manufacturing stage of the product's life cycle considers the emissions generated during the extraction, production, and transport of raw materials, the manufacture of components and subassemblies (including the product packaging) and product assembly.

The manufacturing location of key components such as batteries, HDDs, SSDs, chassis, cables etc. and assembly at an ODM level generally is China. Only desktops, workstations, servers, and storage are assembled in Europe.

Use

For most commercial client products, the energy the product consumes in the use phase is calculated in using the latest US EPA's Energy Star Typical Energy Consumption (TEC) methodology and the power consumption of Monitors comply with Energy Related Products (ErP) Directive 2009/125/EC*. Servers are modeled based on typical i.e., 'highest selling configuration'. TEC is then determined by running the Dell Enterprise Infrastructure Planning Tool (EIPT).

The average TEC value is considered for PCF modelling. The calculated energy consumption is combined with average emission factors for the designated country of use to calculate emissions. The use location is based on the EU.

End of Life (EoL)

It is assumed that a designated portion of the product is recycled at the end of use. It is also assumed that a balance of the product waste materials is disposed of by landfill. Emissions generated in the separation, mechanical destruction and transportation to EoL facilities are included in this calculation.

Table 3 outlines past and current EoL fractions.

Table 3: EoL Fractions

	Old Assumption		New Assumption		Comment
	Fraction Recycled (remainder to landfill)	**Fraction Shredded (Remainder to manual)**	**Fraction Recycled (remainder to landfill)**	**Fraction Shredded (Remainder to manual)**	
Displays	0.75	0.77	**0.7**	**0.5**	Displays have less recyclability compared to desktops & notebooks. Shredded dust from LCA cannot be recovered so we reduced the fraction shredded recycled.
Notebooks	0.8	0.77	**0.75**	**0.6**	In between displays & desktops (the screen is snipped off and undergoes process like displays, which is why we lowered to 60% for the fraction shredded.
Desktops	0.8	0.77	**0.8**	**0.7**	Baseline – simple modular construction of case & PCB's.
AIO	0.7989	0.5	**0.75**	**0.55**	Between displays & notebooks (motherboard & LCD in AIO).
Thin Clients	0.77	0.5	**0.8**	**0.7**	Little complex material used in these, much smaller, greater opportunity for recycling, which is why we increased the fractions for both recycled & shredded.
Servers	0.8	0.77	**0.9**	**0.85**	Servers have high recyclability. Metals & plastics are highly recoverable, which is why we increased the fractions for both recycled & shredded.

Conclusion

Overall, streamlined LCA methodologies such as PAIA are valuable for identifying which parts of a product life cycle have the most significant carbon impact so that organizations can concentrate on delivering the greatest improvements in related areas. It is also a useful tool for companies to explore the impact of changes to materials or processes on the product's global warming impact. As with any other tool, streamlined LCA tools should be used for the purpose for which they are designed: for identifying the most carbon-intensive points in a lifecycle.

As outlined above, there are several limitations to a streamlined LCA methodology. Without strict adherence to model products based on the same assumptions and databases, the margin of uncertainty is likely too significant to use LCA and PCF results to compare products meaningfully.

Streamlined LCA-based methodologies such as PAIA are not designed or equipped to provide all the answers on the carbon impact of ICT products. Moreover, while they may not supply us with all the answers we seek, they provide essential insights in certain areas and, if allowed to evolve and develop, will play a pivotal role in improving our overall understanding of ICT products' environmental impacts and performance.

As sustainability impact reporting continues to evolve through continuous improvement, we at Dell are actively engaging in efforts (as Dell and as part of broader industry consortiums) to enhance methodologies and drive accuracy and standardization in PCFs and LCAs. **Please refer to our PCF FAQs for additional topic related Q&A.**

Click here for Dell Product Carbon Footprint Datasheets

Click here to learn more about PAIA

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