LIFE CYCLE ASSESSMENT

Final Report on SBC 5400 and 7000

SBC 5400

SBC 7000

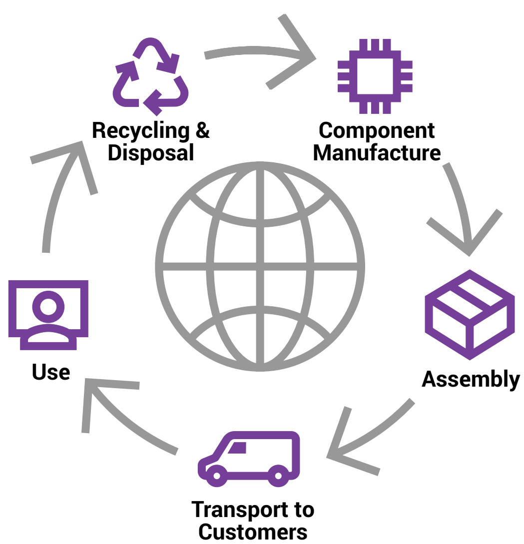
ribbon

SBC 5400

SBC 7000

1. Review Process

Ribbon is committed to reducing the environmental impacts of our products, covering all stages of the lifecycle. We use lifecycle assessment to find the most significant contributors to the environmental impact of our products and inform our sustainability strategies at the product and corporate level.



What is an LCA?

A life cycle assessment is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle. (ISO 14040:2006, sec 3.2.)

2. Executive Summary

Ribbon commissioned a lifecycle assessment of its Session Border Controller (SBC) 5400 and 7000 models in their most frequently purchased configurations.

Session Border Controllers provide robust network security, sophisticated routing and policy management plus IPv4-IPv6 interworking and built-in media transcoding. They are commonly purchased by communications service providers and large enterprises for multimedia communications.

The purpose of the study was to identify environmental hotspots which would allow future improvements, provide information on value chain carbon emissions and to meet client needs.

The study is focused solely on Global Warming Potential resulting from emissions over a 100 year timeframe (GWP 100). The system boundaries cover from cradle-to-grave which includes the impacts from raw material resource extraction through to end of life disposal and recycling. The functional unit is the same for both models, although this does not mean the two models should be compared directly. The 7000 SBC has a greater capacity than the 5400 and therefore operations at 10% loading on the 7000 are not equivalent to a 5400 at the same loading. Therefore, there is a separate Functional Unit which has the same parameters. These are one unit with a 15 year operational life in the network located in France utilising a platinum rated AC Power Supply Unit (PSU). The Functional Unit also includes the load profile in hours for the SBC.

Load	Hours per day
10%	12
20%	6
40%	6

Table 1 SBC load and hours per day.

The configuration of the SBC units can be found in table 2:

SBC Specification	5400	7000
Digital Signal Processor	Single DSP 25 card installed. 4 DSPs can be installed	Single DSP 25 card installed. 4 DSPs can be installed
Storage	480 GB SSD	960 GB SSD
Power Supply Unit Efficiency	Platinum	Platinum
Mass (g)	27,288	39,500

Table 2 SBC configuration.

Data was collected for each SBC from a Bill of Materials arid compared with measured assembly weights. The energy in use data was sourced from a simulation of the loads with a power meter attached to the SBC.

The timeframe for the study is 2023 and the geographical coverage concentrates on deployment in France, but also for sensitivity examines deployment in New York, USA.

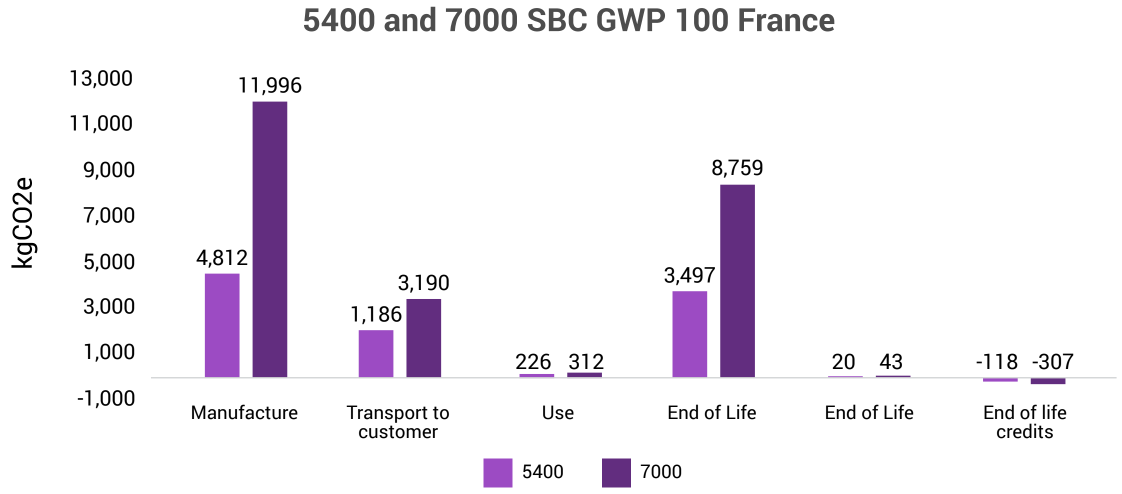


Figure 3 GWP 100 emmissions by lifecycle stage

Figure 3 shows that the use phase dominates the overall lifecycle emissions at 73% for both SBC models, even when installed in a country with low emissions per kWh of electricity. Manufacturing emissions are the next most significant source at 25% for the 5400 and 27% for the 7000. Transport emissions are relatively small, but are dominated by air travel as it is both the longest leg of the journey to the customer and the most impactful for each kilometre travelled. The recovery of metals at the end of life, particularly gold results in end of life credits, which offset some of the impacts earlier in the lifecycle.

The manufacturing impacts are dominated by the production of Printed Circuit Boards (PCBs) and active electronic components. Where possible, active components were mapped to specific Ecoinvent processes (e.g. integrated circuits, logic type), but for those where there was not a direct, logical mapping, they were placed into an active component category. The active components mapping is considered the most significant limitation of this study in terms of accuracy.

Nevertheless, this limitation is not considered significant when assessing the overall conclusions of the study as in-use energy is significantly higher than the manufacturing stage and all other lifecycle stages are a fraction of the manufacturing stage. These conclusions are reaffirmed when examining installation in New York. Despite the reduction in transport emissions due to the shorter distance between the sub-contract manufacturer and negating the need for air transport, the carbon intensity of the New York grid means that the lifetime impact of the 5400 increased from 4,812 kgCO2e to 10,730 kgCO2e. The increase was equally as large for the 7000 which increased by 125% to 27,055 kgCO2e.

The recommendations for improvement for the physical unit centre around addressing energy in use and subsequently major components such as the PCBs. An alternative to physical SBCs is a cloud based SBC which can be deployed in a datacentre. This would split the allocation of lifecycle impact of a server between SBC services and other uses of the server, with the expectation that environmental impact will be significantly reduced.

3. Goal of the study

Ribbon Communications commissioned the study with the following goals:

- A full Lifecycle Assessment of a Ribbon 5400 and 7000 Session Border Controller
- Identify product environmental hotspots to focus improvements in future iterations of the product.
- Support the generation of value chain emissions for the Ribbon organisation
- Generate results to respond to customer environmental data requests

The study meets the requirements of ISO 14040:2006 and 14044:2006 lifecycle assessment international standards.

The purpose of the study is not to compare the 5400 and 7000 products and to direct the purchasing of one model over another. The purpose of the single report is to meet similar requests from customers for each model and reflect that the materials, assembly location, transport and methodologies chosen have a significant degree of overlap and as a result, there is efficiency in providing a single report rather than two separate reports with repetition.

4. Scope of the study

4.1. SBC 5400 and 7000 Product Systems

The 5400 and 7000 model Session Border Controllers (SBCs) are devices placed at the edge of a communications network to control IP sessions for telecommunications service providers and large enterprises, The SBC provides robust network security, sophisticated routing and policy management.

The 5400 and 7000 series SBCs perform the same function, but the 7000 has significantly increased delivery capacity over the 5400.

Ribbon 5400 SBC

The 5400 is a 2U rackmount unit with the ability to accept up to 4 Digital Signal Processing (DSP) cards. Memory is 32 GB with a minimum of 480 GB SSD storage. A 1.8 GHz Intel Ivybridge processor is installed along with a single 1.2 GHz 3 core Network Processor. Power supply is possible via 110 V or 230 V AC or from 48 V DC from 2 x PSUs with a peak consumption of 763W. The PSUs installed are platinum-rated for efficiency.

Ribbon 7000 SBC

The 7000 is a 5U rackmount unit that can accept 4 Digital Signal Processing (DSP) cards. These cards are a different design to those used in the 5400. The 7000 system capability is approximately double that of a 5400 across most system capacity metrics when each has its maximum specification. The DSP cards are approximately 10 times the mass of the 5400 DSP cards and consequently have greater processing capabilities. In the main chassis, 2 x 1.8 GHz Intel Ivybridge processor is installed along with 2 x 1.2 Ghz 3 core Network Processors. A minimum of 960 GB SSD storage is installed. Power supply is possible via 230 V AC or 48 V DC via 2 x PSUs. The PSUs installed are platinum-rated for efficiency.

The configuration chosen for the study involves the 5400 and 7000 described above with a single DSP appropriate to each model. This is the most frequently purchased configuration.

4.2. Product Functional Unit

This study comprises of two parallel studies, so there are two functional units.

The first Functional Unit is for one 5400 SBC with a single DSP performing network communication services over a lifetime with 15 years within the network with a platinum-rated AC power supply and including all the standard ancillaries The load profile that the unit spends per day is based on recommended loads by Ribbon and those experienced in the network.

Load	Hours per day
10%	12
20%	6
40%	6

Table 3 SBC load hours per day

The functional unit for the 7000 SBC is the same as the 5400 described above, however, due to the increased capacity, the 10% load duty of the 7000 is not equivalent to the 10% load duty of the 5400 and so the systems should not be compared to one another.

4.3 System Boundaries

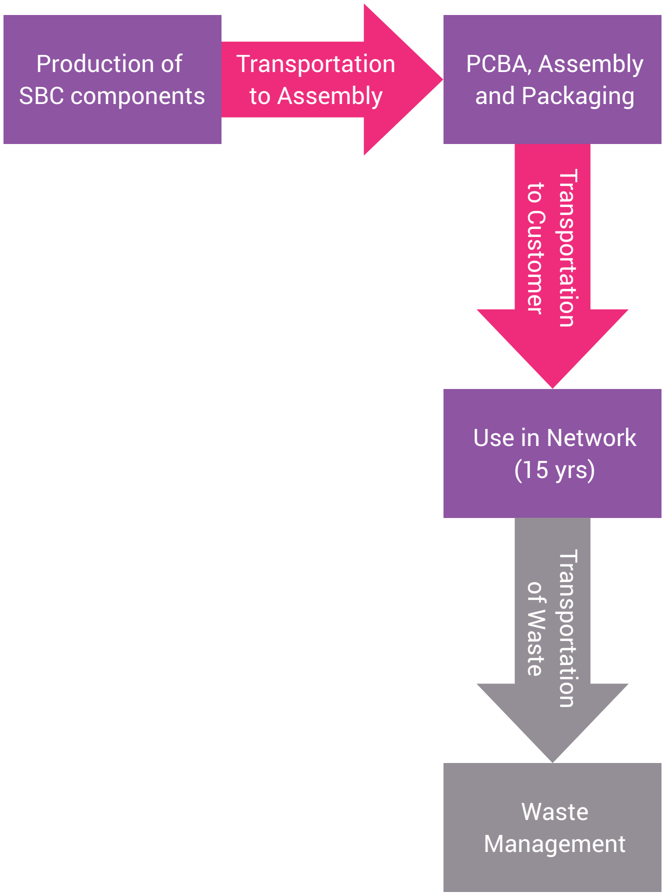


Figure 4 Study systems boundary

4.3.1. Activity boundaries

The system boundary includes, as is typical with Ecoinvent, the production of capital equipment associated with the manufacture of factories and tooling,

The system boundary excludes factors such as Ribbon employee travel, commuting, administration and impact of R&D related to activities such as physical equipment design and software creation.

Excluded during the use phase is the energy and upstream impacts of the environment in which the SBC will be installed. Primarily this relates to the provision of air conditioning and network infrastructure. Also excluded during this phase is the refurbishment or re-use of parts. Take-back and second-life provision is not a service actively provided by Ribbon. It is known that an SBC may be moved by the telecommunications provider from one area of the network to another physical location over the 15-year lifecycle, but data on the frequency and distances travelled are not known. As a consequence, this has been excluded from the use phase.

4.3.2. Time Coverage

The reference period for the study is the calendar year 2023, which corresponds to the data provided for manufacture and distribution.

4.3.3. Technology coverage

The study utilises cradle-to-grave impacts based on global market production mixes unless more specific data was considered more appropriate. For example, waste management specific to Europe was chosen due to the geographical coverage.

Primary data was collected from Ribbon based on energy consumption through simulated loads, component data sourced from compliance documentation and transport routes. Primary data relating to the scope 1 and 2 emissions from the sub-contract manufacturer were also gained.

4.3.4. Geographical coverage

The geographical coverage considers the following:

- Components are sourced from the global market
- Printed Circuit Board Assembly, unit assembly and packaging takes place in Guadalajara, Mexico.
- The finished article is transport via one of two transportation providers to Ribbon's site in Texas.
- It is then moved by UPS to France via customs in the Netherlands
- The use phase assumes the item is used in France
- Recycling takes place within the EU in accordance with EU regulations.

A scenario which considers implementation in the US is also included as part of the sensitivity analysis.

4.3.5. Impact categories

The impact category chosen for the study is limited to Global Warming Potential (GWP) over a 100-year period. This is the impact category of most interest to Ribbon stakeholders.

The GWP is assessed using IPCC 2021 characterisation factors from the 6th Assessment Report (IPCC, 2021).

4.4. Allocation

4.4.1. Multi-output allocation

There only identified multi-output process in the system foreground relates to the activities of the subcontract manufacturer. The subcontract manufacturing site produces a variety of products for a number of organisations. An area is devoted to Ribbon products, but it is not separately metered for utility consumption and benefits from site-level services such as heating, ventilation and cooling. The data provided by the site allowed for the economic allocation of the scope 1 and 2 related emissions based on Ribbon revenue to overall plant revenue.

The background allocation process was chosen to be "as determined by the process" within Ecoinvent 3.10.

4.4.2. End of life allocation

Modelling utilised Ecoinvent 3.10 Cut off database. Allocation at the Point of Substitution was trialled but led to unexpected results primarily relating to the downstream impacts of paper and cardboard recycling and subsequent manufacturing of products unrelated to the foreground system.

End-of-life modelling followed the preferred order of ISO 14044 4.3.4.3 whereby the closed loop/allocation to material losses dominates for activities such as metal recycling. In this approach, credits are given to the lifecycle for the substitution of primary material, and the burdens of the approach are allocated to the lifecycle stage in which the material is lost from the technosphere. The recycling activities to recover the materials to a point whereby they are comparable to primary materials are included within the lifecycle impacts of the product.

The substitution approach was adopted for materials expected to be sent for incineration such as the wooden pallets. Credits for offset heat generated from alternative fuel sources such as natural gas boilers. This is the most commonly used and cleanest source of heat.

4.5 Cut-off criteria

The project included all available energy and material flows identified in the foreground model. The bill of materials included unit masses, areas or other physical data, which was converted to mass wherever possible. For some components, this data was not available, and so expert judgement was utilised to close the gap, ensuring the mass balance was maintained relative to measured assembly weights.

4.6 Interpretation

The interpretation of the LCI and LCIA includes the following aspects:

- Identification of significant parameters and findings
- An assessment of the completeness, sensitivity and consistency of these results
- Conclusions, limitations and recommendations

4.7 Data Quality requirements

To ensure the study allows for reproducibility and is consistent with the goal and scope of the study, data was managed in the following ways:

- Primary data is considered to be the most accurate, followed by calculated data, literature and estimated data
- Ensuring that all relevant input and outputs have been captured and validated against an overall mass and energy balance
- Ensuring that the results are not due to inconsistencies within the modelling methodologies

4.8 Software and Database

The LCA model used OpenLCA v2.1 with Ecoinvent 3.10 which provides the lifecycle inventory information for the background system.

5. Lifecycle Inventory Analysis

5.1. Data Collection Procedure

Primary data was collated from Ribbon staff in the Hardware Engineering and Logistics teams. Further primary data relating to energy inputs in the PCBA and assembly stage was gathered from the sub-contract manufacturer. A Bill of Materials (BOM) was provided in which the majority of components by number had weights assigned to them from supplier datasheets. The complete finished units were also weighed. The DSPs were weighed separately, both with and without packaging. A mass balance exercise was undertaken in which a gap between the measured complete unit mass and the sum of the component masses. The weight of some components had to be calculated as supplier datasheets were unavailable.

For energy in use, each SBC undertook a simulation resulting in 10%, 20% and 40% system loads. The SBC tested used a DC to DC PSU, which was later corrected for slight efficiency differences in the AC to DC PSU used in the Functional Unit. The test used a true RMS power meter to measure input power at the different load states. This test was varied with increasing numbers of DSPs installed to support sensitivity calculations. The energy required for cooling has been excluded from the study as the PUE status of the installed location can vary significantly between telecommunications providers.

The transportation of the completed SBC used known data on shipping routes to calculate the mileage travelled by differing transport modes. This included transport required to and from customs locations.

The sub-comtract manufacturer data collection is discussed in 4.4.1.

5.2 Product Systems

5.2.1. Product Systems

Component	5400		7000	
	Weight (g)	Comments	Weight (g)	Comments
Base chassis	15,800		22,909	
DSP	470	DSP 25	4,200	
PSU and cords	3,920		5,582	
Rackmount	2,778		2,449	
SFP	120		160	
Packaging	4,200		4,200	Estimated
TOTAL	27,288		39,500	
Component	**5400**		**7000**	
	Mass (g)	Comments	Mass (g)	Comments
Resistors	83.9		127.1	
Capacitors	59.6		114.2	
Inductors	32.7		54.1	
LEDs	2.2		45.1	
Screws, nuts, stand-off	39.0		122.5	
Sheet metal	11,825.0	Calculated from length and estimated mass per cm	15,054.0	Calculated from length and estimated mass per cm
Gasket	14.1		52.8	
Active components	117.0		384.4	
Switch	2.2		43.2	
Port/Connector	117.9		562.2	
Microprocessor	64.6		129.9	
IC - Memory type	84.6		200.5	
Diode	0.2		0.4	
Fan	1,632.0		2,734.0	
Fuse	0.0		1.2	
Heatsink	480.8		1,087.5	
Lithium coin battery	2.6		2.6	
Passive components	1.3		1.4	
SF Plug	3.8		5.1	
SPF Cage Assembly	92.5		46.6	
SDD	227.0		227.0	
Transistor	1.2		0.2	
Printed Circuit Board	780.0	Calculated from area and density	1,838.8	Calculated from area and density
TOTAL	15,664		22,835	
Mass Balance Check	136		74	
Mass Balance Allocation				
Active Components	20		20.00	
Metal Components	50		20.00	
Paper Components	66		34.23	
TOTAL	15,800		22,909	

Table 4 SBC main component breakdown

Table 4 details the components breakdown by mass and the mass balance check. The bottom-up mass shows that in the SBC 7000 there was a 74g shortfall (0.3% of chassis mass) and there was 15g in excess of the chassis mass (0.1% in excess) on the.5400 SBC.

For the 7000 SBC an allocation of the remaining mass balance was made based on the BOM components where component weights were not available. Judgement was used based on the quantity and mass of similar components to provide the allocation above.

The active component category relates to active components which do not have a direct component equivalent in the Ecoinvent database. The first order was to map components on the BOM to its direct Ecoinvent product. However, for those where this was not possible, the "active components" category was used. This typically took place where the BOM component was its own assembly often utilising multiple smaller electronic components.

Component	5400		7000	
	Mass (g)	Comments	Mass (g)	Comments
Resistors	37.6		148.7	
Capacitors	19.2		79.4	
Inductors	0.1		7.9	
LEDs	0.022		2.4	
Screws, nuts, stand-off	0.0		10.0	
Sheet metal	48.0	Calculated from length and estimated mass per cm	1,488.0	Calculated from length and estimated mass per cm
Gasket	3.0		40.3	
Active components	76.2		294.3	
Switch	0.0		0.0	
Port/Connector	0.0		33.9	
IC - Memory type	5.5		30.1	
Diode	0.0080		0.0	
Fuse			0.2	
Heatsink	25.0		541.0	
Passive components	1.9		0.0	
Transistor			0.2	
Printed Circuit Board	195.7	Calculated from area and density	1,256.4	Calculated from area and density
TOTAL	412		3,933	
Mass Balance Check	58		267	
Mass Balance Allocation				
Active Components			16.0	
Metal Components			30.0	
Paper Components	58		221.04	
TOTAL	470		4,200	

Table 5

The DSP BOM had a greater proportion of components that did not have a mass against them , although analysis should that in the case of the DSP for the 5400 these all related to instruction manuals, diagrams and packaging. Judgement was used to generate an approximate mass based on the number of active electronic and metal components with the remaining value being allocated to paper components. For the 7000 DSP, there were a small number of active electronic components and metal components that did not have a unit mass. It was noted that the most frequent items without a mass were paper based components as with the 5400 DSP.

The 5400 unit only had one line item against the PSU, therefore no further details can be given. The PSU is bought as a complete unt from the manufacturer with an LCA for this component unavailable. It was not possible to undertake a tear-down of the PSU unit. For the 7000 unit a breakdown of PSU housing components was provided in addition to the PSU unit.

Component	7000	
	Mass (g)	Comments
Resistors	0.3	
Screws, nuts, stand-off	4.0	
Sheet metal	418.0	
Port/Connector	19.2	
Power Cord	726.0	
PSU	3,814.0	
Printed Circuit Board	29.3	
TOTAL	5,011	
Mass Balance Check	571	
Mass Balance Allocation		
Active Components		
Metal Components		
Paper Components	571.00	
TOTAL	5,582	

Table 6 PSU breakdown

Component	5400		7000	
	Mass (g)	Comments	Mass (g)	Comments
Screws, nuts, stand-off	190.0		304.7	
Sheet metal	2,430.0		1,986.0	
Paper components	158.0		158.0	
TOTAL	2,778		2,449	
Mass Balance Check	-		-	

Table 7 Rackmount breakdown

The BOM had a mass against all components except for the paper components. Therefore, the remaining mass has been allocated fully to this category.

The rackmount values balanced perfectly.

The packaging breakdown can be found in table 8. Packaging details for the 5400 was presented in a different format to the 7000 so items such as instruction manuals and boxes for the DSP are found in the component tables above.

Component	5400		7000	
	Mass (g)	Comments	Mass (g)	Comments
Cardboard	2,200.0		2,200.0	
Packaging foam	1,500.0		1,500.0	
Instruction manuals	400.0		400.0	
Protective Bag	100.0		100.0	Email communication re similarity to 5400
TOTAL	4,200		4,200	

Table 8 Packaging breakdown

5.2.2. Component manufacturing

Component manufacturing for the majority of components is managed by the sub-contract manufacturer and is assumed to be sourced from the global market.

The components of which Ribbon are aware of the production location are detailed below. The chassis and DSP sheetmetal is formed in the USA The PSU for the 5400 and 7000 are manufactured in the Philippines and China respectively. Lifecycle assessment data relating to the SSD could not be found from the manufacturer. A literature review was conducted as Ecoinvent's standard storage 21 medium is a magnetic style HDD. It is well known that the production impacts of an SSD is significantly greater than a HDD and thus the use of the standard Ecoinvent data would be inappropriate. Tannu and Nair 1 undertook an LCA literature review of SSDs from suppliers such as HP, Dell, Apple and others showed there was a linear relationship between capacity and embodied carbon emissions. This study uses Tannu and Nair's finding that the embodied carbon emissions of an SSD is 0.16 kgC02e per GB. The boundary for these studies does not comment on capital equipment related emissions and so has been manuall added to the Tannu and Nair figures.

Energy data was collected from the sub-contract manufacturer and allocated on an economic basis as discussed in section 4.4.1. To ensure consistent boundaries the following was added to the PCBA and assembly process:

- Silver solder paste at the default rate per m2 of PCB in Ecoinvent
- Emissions relating to the capital equipment production and the sub contract factory. This data used the Ecoinvent desktop computer emissions as a proxy for input flows.

The sub-contract manufacturer is based in Mexico.

5.2.3. Transport

Transport to a customer location in Paris, France was included as the primary variant. For sensitivity, an alternative use location of New York was chosen.

For the customer in Paris, this involved:

- Transport by truck from Mexico to the Ribbon headquarters and then onto the UPS location in Memphis
- Air transport from Memphis to Paris.
- Transport by truck from Paris to Schipol for EU Customs and return back to Paris

For the variant in New York, the first leg of the journey is the same with an additional truck leg from Memphis to New York.

5.2.4. Use

The use load profile used for the modelling matches those typically seen when deployed and the level recommended by Ribbon's sales team. Data was collected as described in section 5.1.

		5400		7000	
Load	Hours per day	SBC Power (W)	DSC Power (W)	SBC Power (W)	DSC Power (W)
10%	12	301.5	4.9	530.3	224.7
20%	6	306.1	5.0	535.6	227.0
40%	6	310.8	5.0	538.7	228.3
Energy consumed (kWh)		39,252	638	70,180	29,737

Table 9 Energy Consumption

The energy consumption was derived by the hour per load state multiplied by the power demand for that load and scaled to 15 years in the network. The DSP power demand was interpreted from the additional power draw of a double DSP configuration undertaking the same load tests as a single DSP configuration.

5.2.5. End of Life

The end of life modelling assumes that as the equipment is in a corporate environment the materials will be separated and individually recycled. Ribbon are not responsible for the end of life disposal and so the true fate of the SBC materials is not known. However, to use municipal waste recycling rates was considered inappropriate given the purchasers of the SBC are typically organisations with their own sustainability strategies and goals. In the European Union, electronic and electrical equipment must be sent for recycling.

The model assumes that the SBC will travel 200 km to a point where it will be dismantled into the main components such as the steel chassis, fan, PCB and from that point will be transported onwards to specific recycling processes. The location of the recyclers who deal with the specific materials is not known but is assumed to take place in Europe. Ecoinvent markets for recycling activities are utilised as they include transport within the process.

6. Results

The results of the study are an approximation of the impacts that would occur if all the processes described abo were to occur. When using datasets such as Ecoinvent, despite the best efforts for completeness, some fraction of the environmental burden will be unaccounted for in the product system.

6.1 Overall Results

The overall impact across the major lifecycles stages can be seen in Figure 4

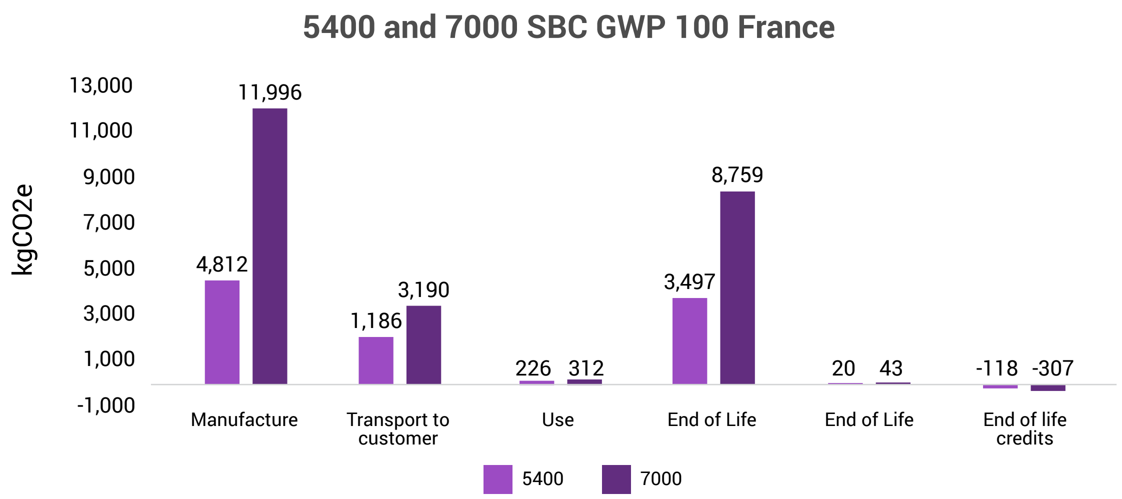
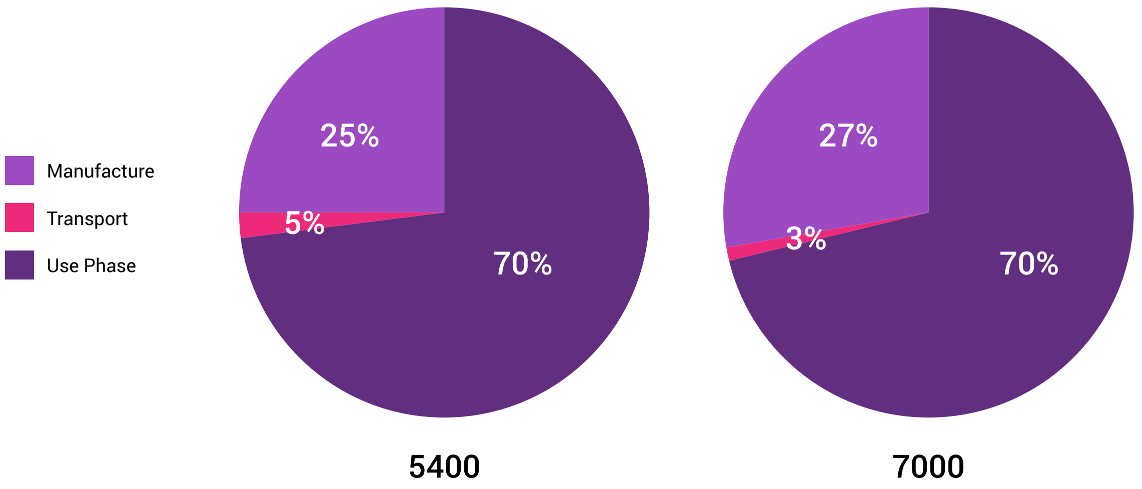


Figure 5 GWP 100 emmissions by lifecycle stage

Figure 5 shows that the most significant lifecycle impacts occur during the use phase for both the 5400 and 7000 SBC. The use phase is responsible for 73% of the lifetime impacts for both units. The second highest lifecycle impact area is the manufacture which comprises 25% and 27% of the 5400 and 7000 lifecycle impact respectively. Transport to the customer is 5% and 3% respectively for the 5400 and 7000.



6.2 Component manufacturing and Assembly Impacts

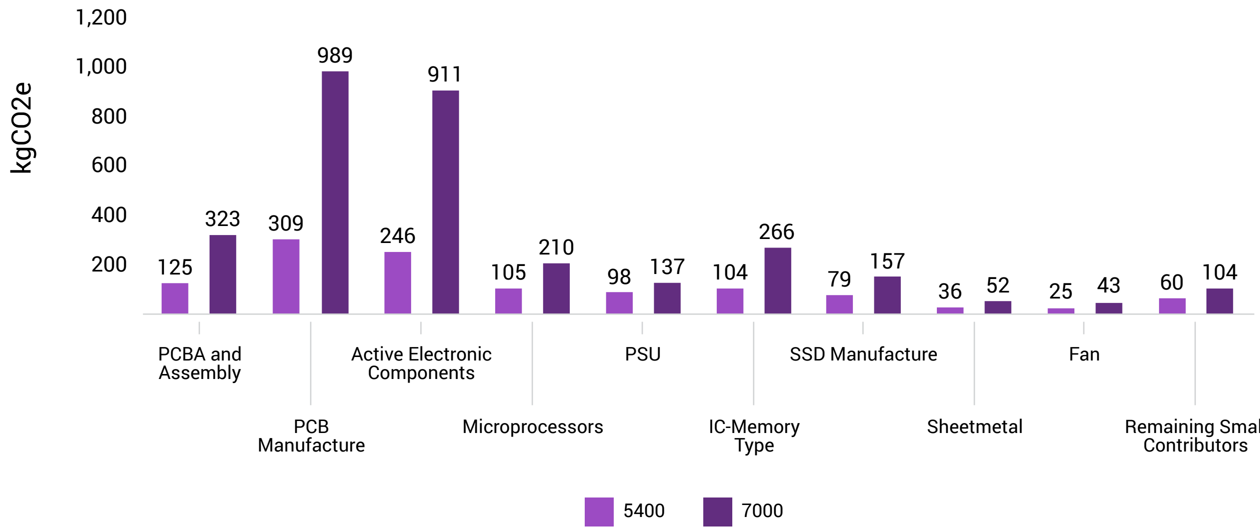


Figure 6 Manufacturing and assembly impact breakdown (GWP 100 emissions from manufacture)

The manufacturing and assembly stage has a contribution of 1186 and 3190 kgCO2e. Figure 6 shows the breakdown of the contributors to the manufacturing and assembly impact.

Printed Circuit Board manufacture is the most significant individual contributor to the lifecycle impact, closely followed by active electronic components such as transistors, MOSFETS, clock oscillators and DC to DC converters. These two categories contribute 47% and 60% to the manufacturing and assembly impacts. The assembly stage which includes PCB assembly, assembly of the SBC and placing in packaging comprises 11 and 10% of the 5400 and 7000 impact respectively.

Although the microprocessors only represent 0.2 - 0.3% of the overall SBC mass, the impact is significantly outsized at 2% of the overall impact or 9% of the manufacturing and assembly stage for the 5400. For the 7000 the microprocessors are also 2% of the overall impact and 7% of the manufacturing and assembly stage. This can be traced to the high energy consumption of microprocessor production, which typically takes place in countries with high emissions per kWh of electricity.

Conversely, sheetmetal which is the component with the highest mass represents only 3% of the 5400 assembly and manufacturing lifecycle stage, with the value being slightly lower at 2% for the 7000.

The SSD, with its impact calculated not from mass, but from journal data represents less than 1.6% of the overall impact for both versions.

6.3 Transport Impacts

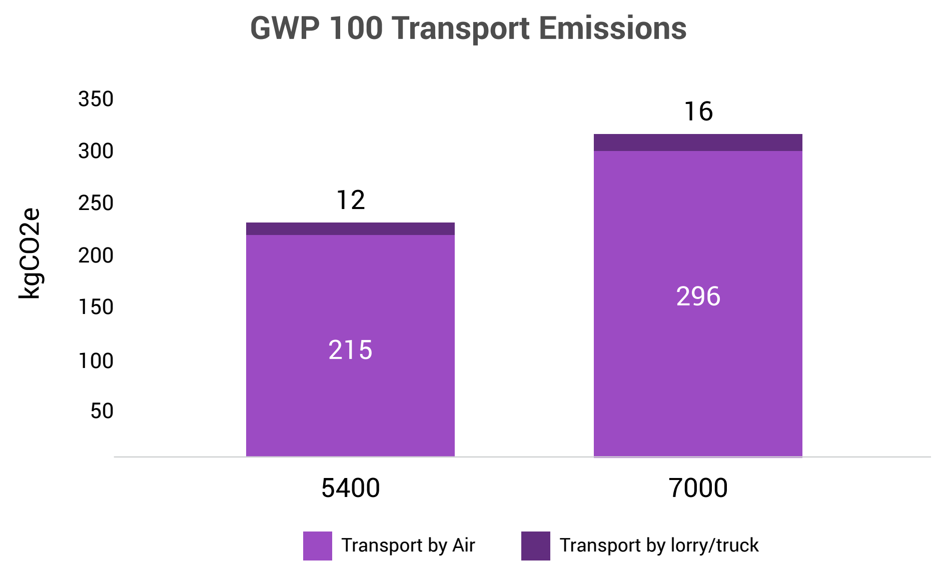


Figure 7 Transport Impact

Figure 7 shows the total impact and breakdown of impact by travel mode. The graph demonstrates that transport by air from the USA to France is the dominant transport impact. Air travel is both longer in terms of miles travelled than the distance travelled by lorry/truck and significantly more impactful per mile travelled.

An alternative where the SBCs are operated in New York showed that the transport impact would be reduce to 18 kgC02e for the 5400 and 24.5 kgC02e for the 7000. Therefore, the transport impact via use in New York compared to in Paris is reduced by 92%.

6.4 Use Phase Impacts

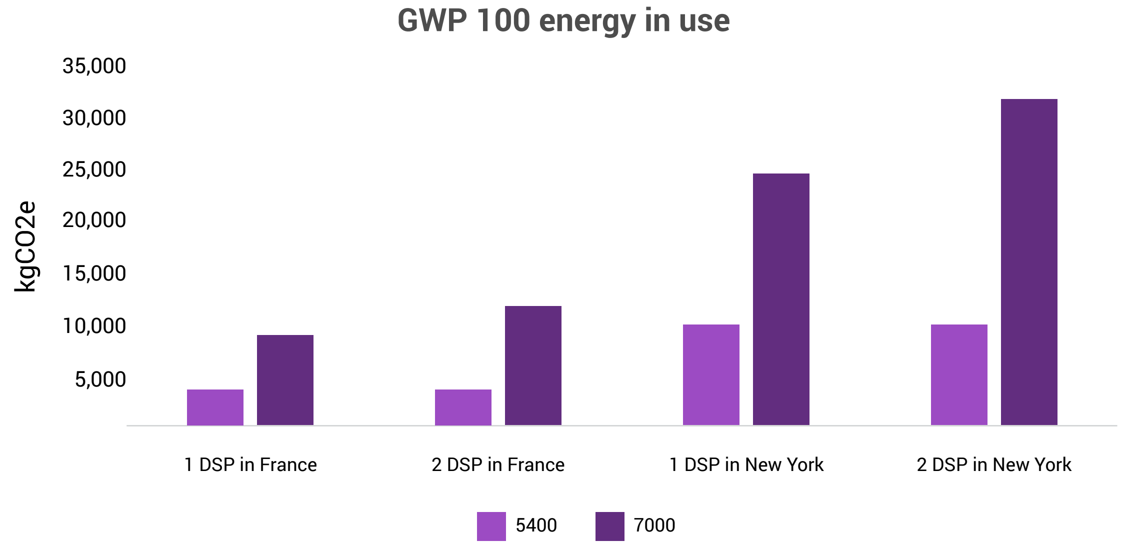


Figure 8 Impact from different use locations and DPS arrangements

Figure 8 shows that the 7000 SBC impact is approximately 2.5 times greater with a single DSP than the 5400. The gap widens to 3.2 times when there are 2 DSPs installed. This fits with Figure 5 which shows that the marginal energy increase of an additional DSP is much greater for the 7000 than the 5400.

Figure 8 also shows how the local electricity grid determines the overall impact of the SBC unit. The electricity supply in France is very low carbon due to widescale use of nuclear and hydroelectricity. Conversely, electricity grids which are reliant on fossil fuels result in significantly elevated in-life impacts.

6.5 End of Life Impacts

Recycling of the 5400 and 7000 SBCs result in a recycling impact credit of 97.4 kgCO2e and 264.6 kgCO2e respectively. This equates to a lifecycle impact reduction of approximately 2% in each case.

Recycling credits are given where there is an avoidance of primary production as a result of recycling as long as the recycled material can be used instead of primary materials.

In the case of the metals, both used in the chassis and electronic components recovery can be undertaken. In this study there has been no assumption of material losses beyond those in the standard Ecoinvent processes. Ribbon does not have access to detailed end of life treatment statistics. However, the Spring Environmental team has visited within the UK facilities that undertake the first stage recovery of network equipment similar to that described on behalf of telecommunications providers. Maximising recovery of all the materials is a core to the business model. Once the SBC has been through the first process in which the main constituents are separated by hand, the populated PCBs are shredded and undergo further processes to recover valuable metals such as gold, silver and copper.

The only material which is assumed not to be recycled was the wood which forms the shipping pallet. This was assumed to be incinerated, producing useful heat energy and so offsetting heating energy input from fossil fuels. In reality at Ribbon pallets are reused and reused until they become damaged, only at this point is it incinerated for electricity generation.

Material	5400	7000
Aluminum	-9.5	-30.7
Steel	-14.3	-34.6
PCB	0.2	0.1
Paper and Cardboard	0.1	0.1
Fan	0.5	0.9
Copper	-12.5	-27.4
Gold	-40.6	-144.4
Silver	-2.9	-10.6
Wood	-13.2	-13.2
Polystyrene	-5.7	-5.7
Polyethylene Film	-0.1	-0.1
Transport to Disassembly	0.6	1.0
TOTAL	-97.4	-264.6

Table 9

Table 9 shows that the majority of the recycling credits for both SBCs are due to the recovery of gold. Gold is a very high impact metal, and so the recovery of approximately 95 grams in the case of the 7000 SBC results in a recycling credit of 144.4 kgC02e. Further credits primarily come from the recovery of the aluminium in the heatsinks and steel in the chassis, DSP casing and rackmounts.

As the packaging weights are assumed to be the same for the 7000 as the 5400's weighed values this results in the same results for many of the constituents such as the polystyrene, polyethylene film and shipping pallet.

The major deviation expected form this model would be that the plastics are incinerated rather than sent for recycling. In that event. a credit would still be present as other fossil fuels would be offset for heating purposes but, the impact would increase by 6.7 kgCO2e. The sensitivity modelling for this used typical municipal waste disposal methods in Ecoinvent which are based on specific technology use within France. However, it is considered that the waste disposal options taken by the telecommunications provider will result in higher recycling rates than the general public.

7. Interpretation

7.1 Conclusions of the study

The data in section 6 shows that the general data trends are generally the same between the 5400 and 7000 SBC units. The major difference is in the scale of resource use, whether that be energy and or physical inputs. Nevertheless, direct comparisons are not recommended due to the different operating capacities of the machines. The functional unit is not conceived deliberately, to compare the units directly and to reach conclusions regarding the relative performance.

The main conclusions of the study are:

- Approximately 73% of the lifetime impacts occur in the use phase. The location of installation will have the most significant bearing on the overall lifecycle impacts of each of the SBC units. The installation in New York would increase lifetime impacts by approximately 125%, even when the reduced transport emissions are taken into account.
- The manufacturing and assembly stage is responsible for approximately 25% of the lifetime emissions. The highest impacts for manufacturing and assembly come from the manufacture of PCBs. The manufacture of PCBs is known to be an energy and resource intensive process due to the need for process baths which are held are high temperatures and the process of adding and removing of materials to leave the desired wiring pathways. PCBs represent 26% for the 5400 and 31% of the manufacturing stage impact.
- The active electronic component group represents 0.4% in the 5400 and 1% in the 7000 of the overall mass, but the impact is significantly higher at 5.1% and 7.6% of the environmental impact respectively. This is typical of electronic components where the energy input is significant. Logic type integrated circuits are the biggest contributor to the active component footprint as these are understood to be a constituent of larger installed componerits on the BOO. Where it was possible to separate out individual components this was done so. It is possible that the active component impact is over-stated, but this would require analysis at a level below that of the current BOM.

  Similar to the active component group, the microprocessors comprise a tiny fraction of the SBC mass but contribute approximately 2% to the lifetime environmental impact for the reasons explained above.
- While the sheetmetal used in the chassis, DSP and rackmount is the largest single item by mass, the production of the sheetmetal is a relatively small contributor to the overall footprint at 0.7% and 0.4% for the 5400 and 7000 respectively. The treatment at end of life also assumes that this is fully recovered and so there is a further credit meaning that the full lifecycle emissions for the sheetmetal are lower still at only 18 kgCO2e for the 7000, which includes transport from the production site in the USA to Mexico.
- The number of DSPs influences the environmental impact of the lifetime of each unit through the requirement for additional input resources through all the lifecycle stages. For the 7000, an additional DSP will increase the lifetime impact by 3162 kgCO2e, of which 76% is through the additional energy demand. The manufacturing and assembly stage comprises 25%, of which the printed circuit board and active components comprise 23%.
- A 5400 DSP increases the environmental impact by 216 kgCO2e, with 79% of the impact resulting from the manufacturing process. The energy increase with the DSP25 is very small and so accounts for 26% of the overall impact. Transport and recycling collectively have a credit impact of just under 5%.
- At the end of life, the recovery of gold is the most significant activity when considering the carbon emission metrics. Gold recovery provides a credit worth approximately 1% of the SBCs lifetime impact, with the recovery of all the remaining materials having the same credit impact as the gold alone.

The result of this analysis shows that the environmental hotspots to inform future physical designs and software development should focus on measures to reduce energy consumption in-life. The output of the electricity consumed by the SBCs primarily is heat, which typically will be managed through being installed in an airconditioned environment. Therefore, there is a consequential impact that reducing primary electricity consumption in the SBC will have further downstream energy reductions. The design of the SBC shows that the electricity consumption at 10% load is over 97% of the consumption for 40% loading, indicating that acquiescent consumption is the most significant area to focus improvements. This is bolstered by the fact that half of the day is spent running at 10% load resulting in the high acquiescent power demand combined with the majority of operating hours being at low load combine to be the most significant hotspot for attention.

The next two focus areas are sourcing low impact active electronic components, including the microprocessors and the PCBs. A 5% reduction in emissions from each of these areas would reduce the lifetime emissions by 1%. A limitation of the study is that the "Active component" process in Ecoivnet is dominated by the proportion of logic type integrated circuits allocated to this process. In the event that the proportion of logic type integrated circuits in the Ecoinvent process is greater than that of the components allocated to this category, then the impact of production will be increased. However, within the BOM many of the components allocated to this category were individual small assemblies where the composition of active components within them was not known.

A typical SBC is understood to be moved around within the telecommunication provider's network over the course of the 15-year lifecycle, which limits the potential for re-use. SSDs and PSUs would not typically be considered for re-use after this timeframe.

The Ribbon SBC product portfolio includes a software edition of the SBC which can be run as a virtual machine within a client datacentre. Given the virtual machine has the capability to be adapt relative to demand, thus allowing the server to undertake other work during periods of low SBC workload. This appears to be the single most effective way to reduce the environmental impact of SBC service provision, resulting in vastly reduced physical resource use during manufacturing and energy during transportation and in-life.

7.2. Data and Model quality assessment

7.2.1. Completeness

Each foreground process was checked for completeness via mass balance activity mentioned above and consistency of the boundaries. During the process of the study omissions were identified, such as the capital equipment employed at the sub-contract manufacturer which were updated in the final version. Information on the amount of solder paste used during PCB assembly was not available and so was estimated using industry benchmarks.

The PUE of any cooling associated in the datacentre is the only known and deliberate omission as there is significant variation between different datacentres and is not a statistic freely available to Ribbon in typical deployment locations.

Mass balance checks were undertaken wherever possible and where estimates were required to match the bottom up component mass to the measured assembly mass, the allocation to the various materials was documented.

Reproducibility has been attempted through transparently communicating the input material types and weights and highlighting any shortfalls and documenting the modelling choices, particularly regarding end of life.

7.2.2. Consistency

The study aims to be compliant with ISO 14040/44 only and therefore does not need to deal with any inconsistencies between differing LCA standards.

The section above with regards to completeness comment on the efforts to ensure that all processes consistently operated using the same boundary conditions.

The study conclusions are considered consistent with the attributional approach to developing an LCA as the scope was not to directly make comparative assertions and therefore affect decision making between one product and another.

The temporal and spatial boundaries have been reviewed to ensure consistency with the production and use locations at the resolution allowed by the Ecoinvent database. The data provided by Ribbon was related to production in 2023, matching the process dates within Ecoinvent.

There are no value choices required as only one impact category has been chosen, therefore, value choices comparing one impact category with another are negated.

7.2.3. Precision

The foreground data is calculated from primary measured data in all of the lifecycle stages, with the exception of the end of life. The source of the data involved measured masses or mass from datasheets combined with the Bill of Materials. Where the mass was not available for individual components, it was interpreted from assembly weights. Data checks were performed which led during the process of the LCA activity to updated weights used in the final study.

The background data is sourced from Ecoinvent v.3.10 where each process has documented uncertainty.

Areas for improvement primarily relate to the weight of 7000 packaging being known and ensuring that all active components have a mass associated with them where the mass balance exercise demonstrated a shortfall between the overall mass and the sum of the component weights.

Overall, the precision is considered to be good.

7.2.4. Sensitivity

The sensitivity of the results and conclusions were examined with regards to the main and expected variables that an SBC will be subject. Primarily this relates to the installation location which determines transport and energy-in-use emissions. A variation in the end-of-life treatment for the packaging materials was also investigated.

The location significantly affects the overall lifetime impact of the SBC while the end of life treatment for the packaging materials was largely inconsequential.

The SBC load is based on measured loads in the market and the recommendations made to clients to ensure consistent and trouble-free service provision. The marginal increase in electricity consumption from increased load means that higher loading of individual units are not considered to materially affect the conclusions.

8. Glossary of terms

DSP - Digital Signal Processor. Modules which can be added to the SBC chassis to add processing capabilities.

HDD - Hard Disc Drive. A solid magnetic disc based storage medium used on computing and server equipment

GB - Gigabyte, which is one billion bytes of digital information.

PSU - Power Supply Unit. Unit which in the case of the study converts Alternating Current electricity supply to Direct Current as used by electronic devices

SBC - Session Border Controller. Equipment which provides robust network security, sophisticated routing and policy management plus IPv4- IPv6 interworking and built-in media transcoding.

SSD - Solid State Drive. A semiconductor based storage device, which typically uses NAND flash memory. Typically, provide faster response and increased reliability over HDDs but at increased cost.

9. References

[1]Tannu S. and Nair P.J. 2023. The Dirty Secret of SSDs: Embodied Carbon. Energy Informatics Review Vol 3 Issue 3. https://arxiv.org/pdf/2207.10793 Accessed 29/2/2024

IPCC. 2021 Sixth Assessment Report (AR6). https://www.ipcc.ch/report/ar6/wgl/

ISO. 2006. ISO 14040: Environmental Management - Life cycle assessment - Principles and framework

ISO. 2006 ISO 14044: Environmental Management - Life cycle assessment - Requirements and guidelines

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