LIFE CYCLE ASSESSMENT

Ribbon NPT 1100 and 1250

1100

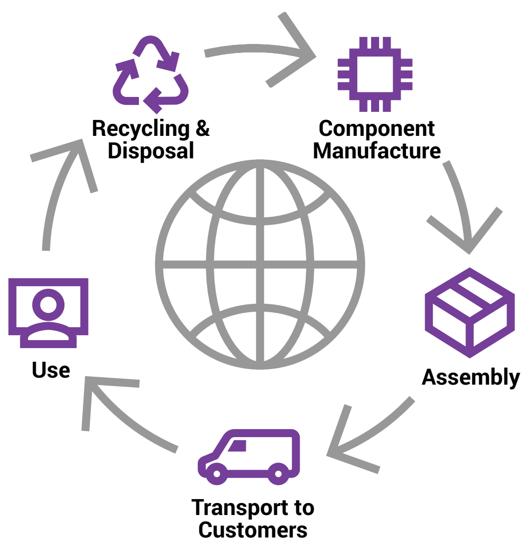
1250

1100

1250

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 Neptune (NPT) 1100 and 1250 routers in their most frequently purchased configurations.

The NPT 1100 and 1250 are routers designed to provide multi-access edge and pre-aggregation for services, applications and architectures requiring a high-availability multiservice solution. The 1100 and 1250 series perform similar function, but the 1250 has significantly increased delivery capacity on the 1100.

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 1250 has a greater capacity than the 1100. Therefore, there is a separate Functional Unit which has the same parameters. These are 1 unit with a 15 year operational life in the network located in India for the 1100 and in Germany for the 1250. The load profile for both units is static as Ribbon Product Engineers advise that as it is an optical product, load variation does not impact energy consumption. The temperature of the installed environment is advised as being the influential variable regarding energy consumption, although in a typical datacentre there is likely to be an almost net nil situation. This is on the basis that an increased environmental temperature will reduce the energy consumption of the chillers and associated cooling equipment but will increase the energy consumption of the NPT router through increased fan energy consumption.

The configuration of the NPT units can be found in Table 1:

Study parameters	1100	1250
Lifetime of the product	15 years	15 years
Use location	India	Germany
Cards	2 x 100G, 4 x 10G	2 x 300G TM and 560G switching + 19 packet cards
Memory	8 GB	8 GB
Storage	16 GB eMMC	16 GB eMMC
Power Supplies	1 + 1 redundancy	1 + 1 redundancy
Mass (packaged)	13.31 kg	24.91 kg

Table 1 NPT 1100 and 1250 configurations

Data was collected for each NPT router from a Bill of Materials (BOM) and compared with measured component weights. The energy in use data was sourced from a simulation with a power meter attached to the NPT router.

The timeframe for the study is 2024 and the geographical coverage concentrates on deployment in Mumbai, India for the 1100 and Germany for the 1250, as these represent the most popular installation location for each variant. To examine sensitivity, a variant in which deployment in New York, USA was also reviewed.

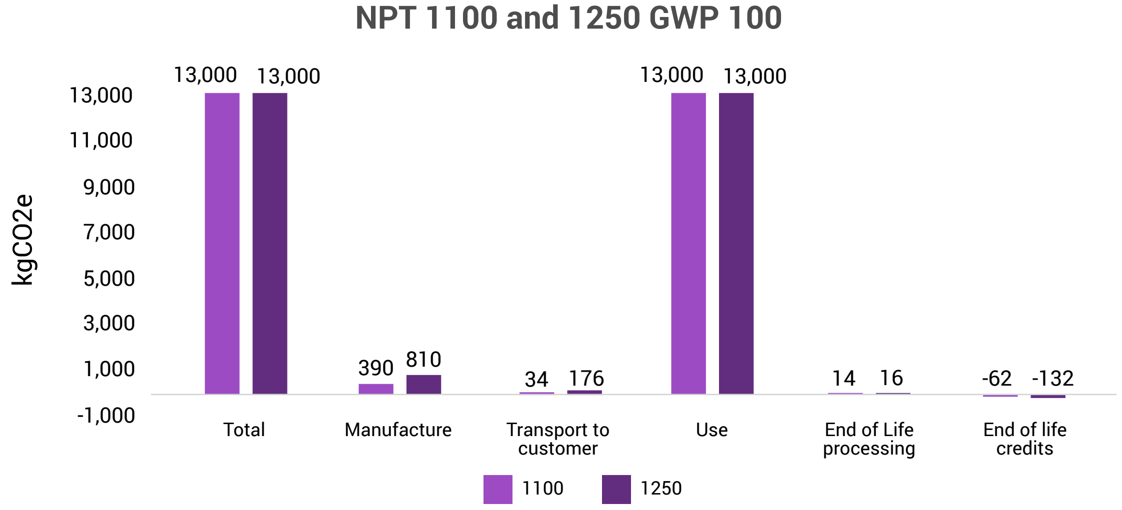


Figure 3 GWP 100 emmissions by lifecycle stage

Figure 3 shows that the use phase dominates the overall lifecycle emissions at 98% for the 1100 and 94% for the 1250. Manufacturing emissions are the next most significant source at 2% for the 1100 and 6% for the 1250. 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 per km 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). However, the mass of the PCB and sheet metal which are the two heaviest components on the BOM could not be directly determined and so were derived through the chassis mass minus component mass. The component masses were predominantly gathered using the Bill of Materials specification and searches via Artificial Intelligence with manual sample checks for 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 increase in transport emissions due to the increased distance between the sub-contract manufacturer and the installation location, the carbon intensity of the New York grid means that the lifetime impact of the 1100 decreased from 21,328 kgCO2e to 3,700 kgCO2e. The decrease was more muted for the 1250 which decreased by 33% to 9,481 kgCO2e.

The recommendations for improvement for the physical unit centre around addressing energy in use and subsequently major components such as the PCBs. As cooling dominates the energy consumption, design choices to improve cooling performance while reducing fan energy consumption is the most impactful way to reduce the overall lifetime impact.

3. Goal of the study

Ribbon Communications commissioned the study with the following goals:

- A full Lifecycle Assessment of a Ribbon NPT 1100 and 1250 multi-access edge and pre-aggregation routers
- 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 1100 and 1250 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. NPT 1100 and 1250 Product Systems

The NPT 1100 and 1250 are routers designed to provide multi-access edge and pre-aggregation for services, applications and architectures requiring a high-availability multiservice solution. The 1100 and 1250 series perform similar function, but the 1250 has significantly increased delivery capacity on the 1100.

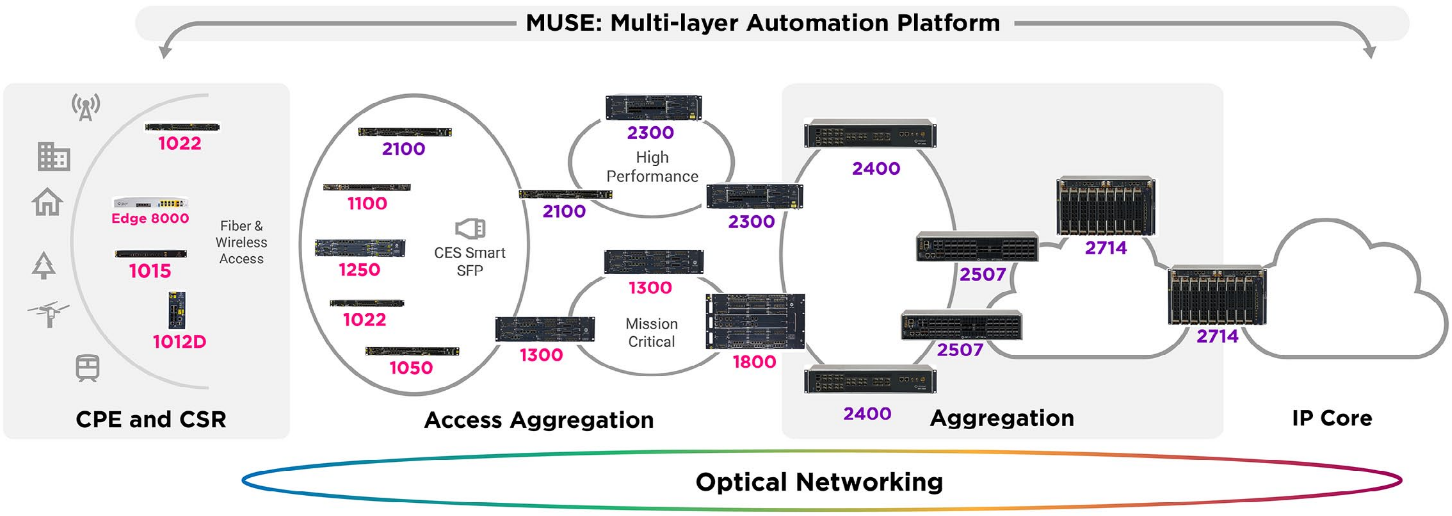


Figure 2 NPT 1100 and 1250 position within the network

Figure 2 demonstrates the position within the network architecture supporting 5G xHaul, broadband backhaul, business services, and TDM migration all from a single converged platform.

Figure 3 Ribbon NPT 1100

The NPT 1100 is a 1U rackmount unit with a Qumran-AX chipset, 8 GB of DRAM and 16 GB eMMC storage. Traffic interfaces include 2 x 100G, 8 x 25G or 22 x 10G and 30 GE ports resulting in a switch capacity of up to 300 Gbps. Power supply is possible via 110 V or 230 V AC or from 4) V DC from 2 x PSUs with 1 + 1 redundancy and a typical power consumption of 110W in the chosen configuration.

Figure 4 Ribbon NPT 1250

The provides 560Gbit interface switching, 300 Gbit/s processing capacity and 100G interfaces in a 2 RU form factor. It provides an extensive set of interfaces for multiple access technologies such as Ethernet, MPLS, PON and legacy TDM(CES), and has the capacity to be used for pre-aggregation or a large access edge deployment. With a full set IP/MPLS, transport capabilities, the NPT 1250 can efficiently aggregate and route the services over the network, meeting their service performance needs (SLAs) on a service by service basis. Full redundancy and support for segment routing and MPLS-TP make the NPT 1250 a perfect fit for operators delivering business and mission critical services. A significant difference to the 1100 is the addition of the removable network packet switches which contains a significant proportion of the 1250's integrated circuits, heat sinks and PCB area. The core chassis has an 8 core PPC CPU, 8 GB DRAM and 16 GB eMMC.

The configuration chosen for the study is outlined in Table 2. The configuration chosen was defined by the Ribbon product team based on sales data from the previous 12 months.

Study parameters	1100	1250
Lifetime of the product	15 years	15 years
Use location	India	Germany
Cards	2 x 100G, 4 x 10G	2 x 300G TM and 560G switching + 19 packet cards
Memory	8 GB	8 GB
Storage	16 GB eMMC	16 GB eMMC
Power Supplies	1 + 1 redundancy	1 + 1 redundancy
Mass (packaged)	13.31 kg	24.91 kg

Table 2 NPT configuration

4.2. Product Functional Unit

TThis study comprises of 2 parallel studies, so there are 2 functional units.

The first Functional Unit is for 1 x 1100 NPT performing network communication services over a lifetime with 15 years within the network in India. The load profile is advised to be static and independent on network traffic. Variation in electricity consumption is due to differences in the temperature of the operating environment.

The functional unit for the 1250 NPT is the same as the 1100 but with the installation location in Germany.

4.3. System Boundaries

4.3.1. Activity boundaries

The system boundary is defined in Figure 5.

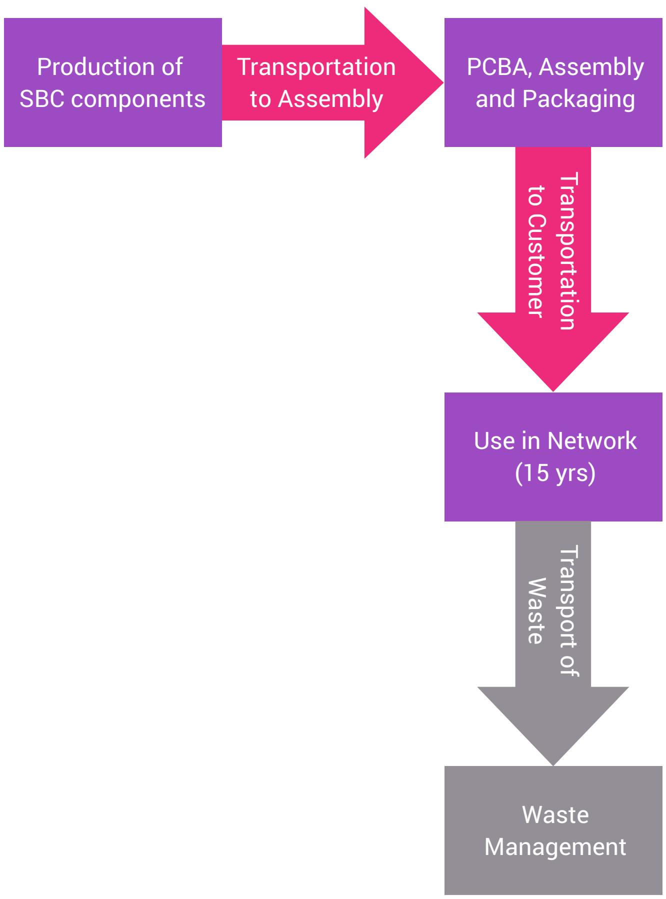


Figure 5 Study systems boundary

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 NPT unit 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 possible that an NPT 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 2024, 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 for the 1200.

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 Ecoinvent provider which best represents Shenzhen, China
- The components are transported via a combination of truck and container ship from Shenzhen to Thailand for assembly.
- Printed Circuit Board Assembly, unit assembly and packaging takes place in Bangkok, Thailand.
- The finished article is transport via a combination of truck and airplane to Mumbai, India for the 1100 and to Frankfurt, Germany for the 1250.
- The use phase assumes the item is used in India for the 1100 and Germany for the 1250.
- Recycling takes place within the EU in accordance with EU regulations in Germany and WEEE recycling also takes place in India.

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. There is no 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.

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 v2.5 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.

The complete finished units were weighed, with a gross and net weight of each major component to represent the packaged and unpackaged weight. A Bill of Materials (BOM) was provided. Wherever possible, the PLM system was interrogated for item weight, but this was rarely successful as this is not data typically required. The Ribbon team were able to provide the mass of each heat sink used in each configuration. Artificial Intelligence based queries were run on major components such as integrated circuits, memory chips, resistor, transistor, inductors, switches and ports based on the BOM specification which were then combined with the BOM quantity. For the 1250, the above exercise was repeated not just for the main chassis but also the MCIPS300FBH central packet switch. A mass balance exercise was undertaken in which a gap between the measured complete unit mass and the sum of the component masses. Reviewing the BOM for items which had not been allocated a mass the most notable either by size, expected contribution to the overall impact or by volume were the printed circuit boards, sheet metal for the case and mechanical parts such as screws, nuts and stand-offs. Expert judgement was used to estimate that the remaining mass was allocated to be 20% PCB and 80% mechanical parts.

The energy in use was based on measured data in the Ribbon laboratory. An average power demand for the 1100 of 101 W and 268 W for the 1250 was used.

The transportation of the completed NPT UNIT used known data on shipping routes to calculate the mileage travelled by differing transport modes

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

5.2 Product Systems

5.2.1. Product Systems

Component	1100		1250	
	Weight (g)	Comments	Weight (g)	Comments
Base chassis	5,110	incl. fan and PSU as per spec	5,400	incl. fan and PSU as per spec
Common and Packet Cards	540	Optical cards	3,950	Optical and common cards
Panel blank & accessories	5,480		10,480	
Packaging	2,440		5,080	
TOTAL	**13,570**		**24,910**	

Table 3 Product system components

The main components of the 1100 and 1250 NPT considered in the study are listed above. The following tables provide more detail into the main components.

Component	1100		1250	
	Mass (g)	Comments	Mass (g)	Comments
Bead	1.38		0.10	
Capacitors	10.20		1.39	
Diode	0.86		1.28	
Fan	370.00		784.29	
Fuse	0.25		0.11	
Heatsink	399.70		18.40	
IC - Memory type	4.63		0.33	
Inductors	116.21		15.40	
Labels	2.00		2.00	
LEDs	17.75		7.50	
Lightpipe	4.75		0.25	
Microprocessor	12.43		3.29	
Port/ Connector	458.42		0.46	
Printed Circuit Board	632.23	Estimated	714.92	Estimated
PSU	540.00		960.00	
Resistors	1.69		0.47	
Screws, nuts, stand-off and sheet metal	2528.93	Estimated	2859.67	Estimated
Switch	8.00		-	
Thermal Pad	0.49		0.00	
Transformer	-		30.00	
Transisitor	0.10		0.14	
TOTAL	**5,110**		**5,400**	
Mass Balance Check	**-**		**-**	

Table 4 Chassis components

Table 4 details the components breakdown by mass and the mass balance check, although a difference in mass would not be expected given the calculation approach.

The breakdown of card components was calculated below. The 1100 cards are bought as complete assemblies and data was not forthcoming from suppliers. The breakdown of materials was estimated using artificial intelligence following interrogation with returned unit weights around the same as the quoted weight from the Ribbon product team. The MCIPS300FBH central packet switch had its own BOM and had its component weights estimated using the same methodology as the main chassis above.

Component	1100		1250	
	Mass (g)	Comments	Mass (g)	Comments
Aluminium	10.00			
Cardboard box	30.00			
Passive electronic components	4.90			
Integrated Circuit	0.10		14.77	
Printed Circuit Board	5.00		91.85	Estimated
Sheet Metal			183.70	
IC - Memory type			5.04	
Capacitors			7.25	
Resistors			1.05	
Inductors			21.00	
Diode			0.23	
Transistors			0.04	
LED			3.50	
Light pipe			0.25	
Heat Sink			366.00	
Connectors			0.33	
Fuse			0.02	
Bead			1.13	
Transformer			12.00	
Ports			91.85	
Card scalar	**10.8**		**4.94**	
TOTAL	**540**		**3,950**	
Mass Balance Check	-		-	

Table 5 MCIPS300FBH

The card scalar value represents the scaler used to take the individual card breakdown and mass to the total card mass used within the configuration. This does lead to uncertainty but the lack of forthcoming data from card suppliers meant this approximation was the most practical solution.

The packaging breakdown can be found in Table 6. As mentioned previously, the packaged and unpackaged weight was provided which derives the total. The breakdown has then been estimated based on items founds in the bill of materials.

Component	1100		1250	
	Mass (g)	Comments	Mass (g)	Comments
Cardboard	2420.00		5,060.00	
Protective bag	20.00	Estimated	20.00	Estimated
TOTAL	**2,440.00**		**5,080.00**	

Table 6 Packaging breakdown

A list of accessories was provided each NPT unit, with the breakdown as shown in Table 7.

Component	1100		1250	
	Mass (g)	Comments	Mass (g)	Comments
ESD equipment	40.00		40.00	
Cable ties	100.00		100.00	
Cable assembly	3000.00		8000.00	
Optical patch cord	1600.00		1600.00	
Circuit Breaker	200.00		200	
Panel Blank	40.00		40.00	
Ground cable	500.00		500.00	
TOTAL	**5,480.00**		**10,480.00**	

Table 7 Accessories by mass

5.2.2. Component manufacturing

Component manufacturing for the majority of components is managed by the sub-contract manufacturer and is understood to be sourced from China, specifically the Shenzhen area.

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. The area was derived from the estimated mass using a standard density factor and PCB thickness data from the SBC LCA study.
- 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 Thailand.

5.2.3. Transport

Transport to a customer location in Mumbai, India was included as the primary variant for the 1100. For sensitivity, an alternative use location of New York was chosen. For the 1250, the primary installed location was Frankfurt, Germany, with New York as the alternative location.

The transport involved a leg by truck from the sub-contract factory to the Bangkok Suvarnabhumi airport to the relevant airport for the 1100 and 1250. There was an equivalent leg by truck to the chosen end point.

For the variant in New York, the first leg of the journey is the same with a longer flight from Bangkok Suvarnabhumi to JFK airport.

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.

Unit	Power (W)	kWh
1100	101	13,271
1250	268	35,215

Table 8 Energy consumption

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 NPT materials is not known. However, to use municipal waste recycling rates was considered inappropriate given the purchasers of the NPT 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 NPT 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 for the 1250 and within India for the 1100. Ecoinvent markets for recycling activities are utilised as they include transport within the process.

The exact quantities of all the recoverable materials, in particular the metals used in electronic equipment manufacture such as gold and silver, are not known but were estimated using data on direct consumption based on the components and use of silver solder paste.

6. Results

The results of the study are an approximation of the impacts that would occur if all the processes described above 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 lifecycle stages can be seen in Figure 6.

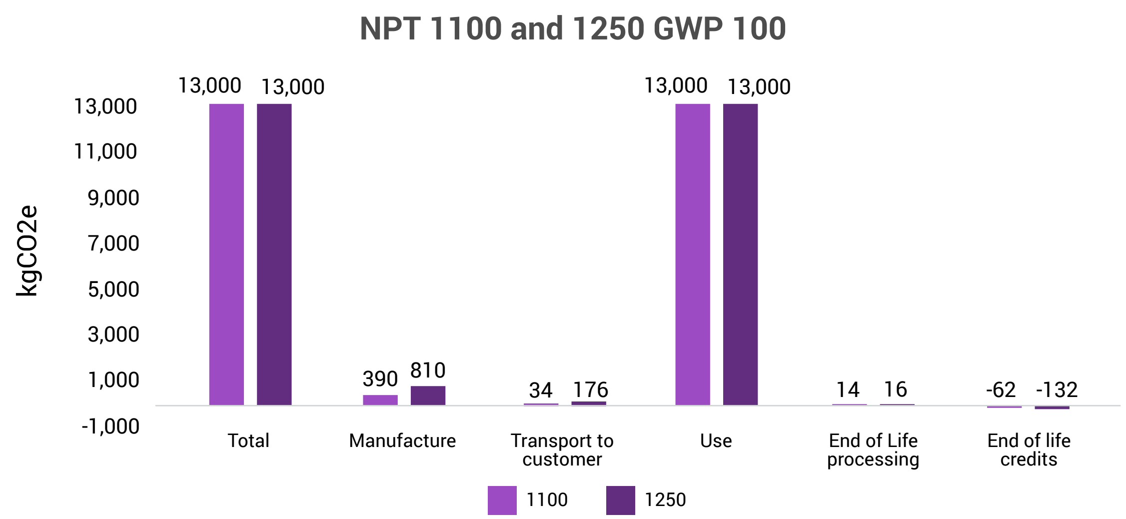


Figure 6 NPT 1100 and 1250 GWP 100 by lifecycle stage. 1100 installed in India, 1250 in Germany.

Figure 6 shows that the most significant lifecycle impacts occur during the use phase for both the 1100 and 1250. The use phase is responsible for 98% of the lifetime impacts for the 1100 and 94% for the 1250. The second highest lifecycle impact area is the manufacture which comprises just under 2% and 6% of the 1100 and 1250 lifecycle impact respectively. Transport to the customer is 0.2% and just over 1% respectively for the 1100 and 1250.

6.2. Component Manufacturing and Assembly Impacts

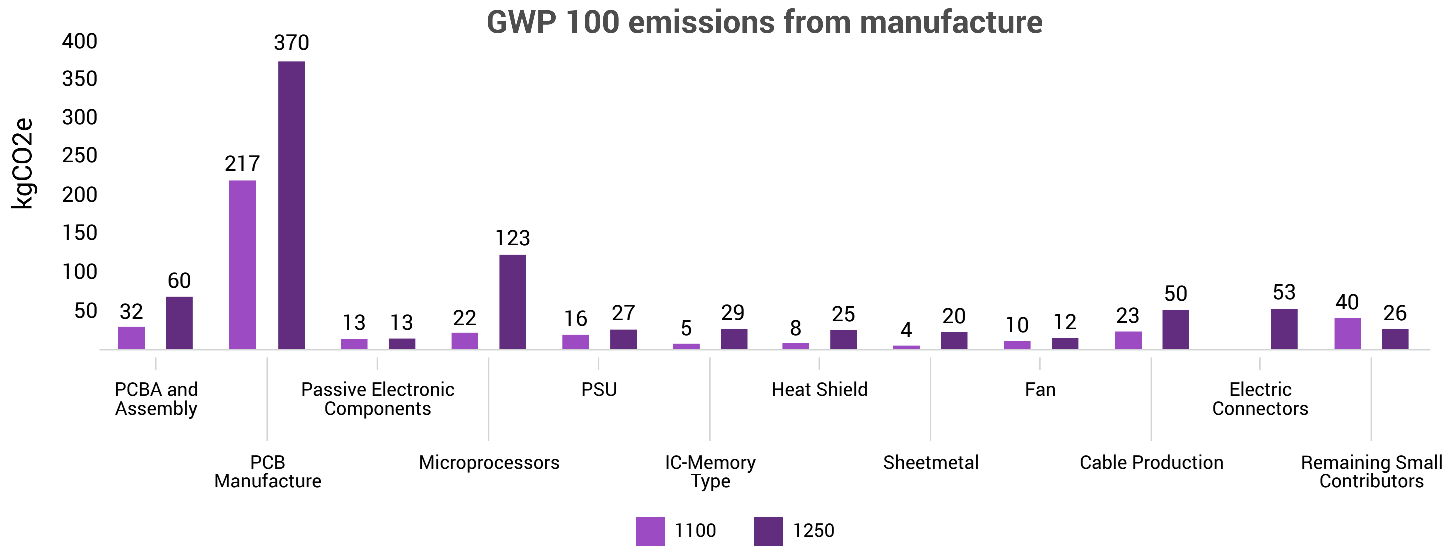


Figure 7 Manufacturing and assembly impact breakdown

The manufacturing and assembly stage has a contribution of 217 and 317 kgCO2e. Figure 7 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, followed by microprocessor integrated circuits. The number of microprocessors on the 1250 Central packet switch increases the impact relative to the 1100. These two categories contribute 61% to the manufacturing and assembly impacts of both units. The assembly stage which includes PCB assembly, assembly of the NPT and placing in packaging comprises 8% and 7% of the 1100 and 1250 impact respectively.

By mass, the microprocessor units are estimated to comprise 0.2% and 0.4% of the overall main chassis and card weight, however their environmental impact id disproportionately high. This can be traced to the high energy consumption of microprocessor production, which also takes place in countries with high emissions per kWh of electricity.

Conversely, sheetmetal which is the component with the highest mass represents only 1% of the 1100 assembly and manufacturing lifecycle stage, with the value being slightly higher at 3% for the 1250.

6.3 Transport Impacts

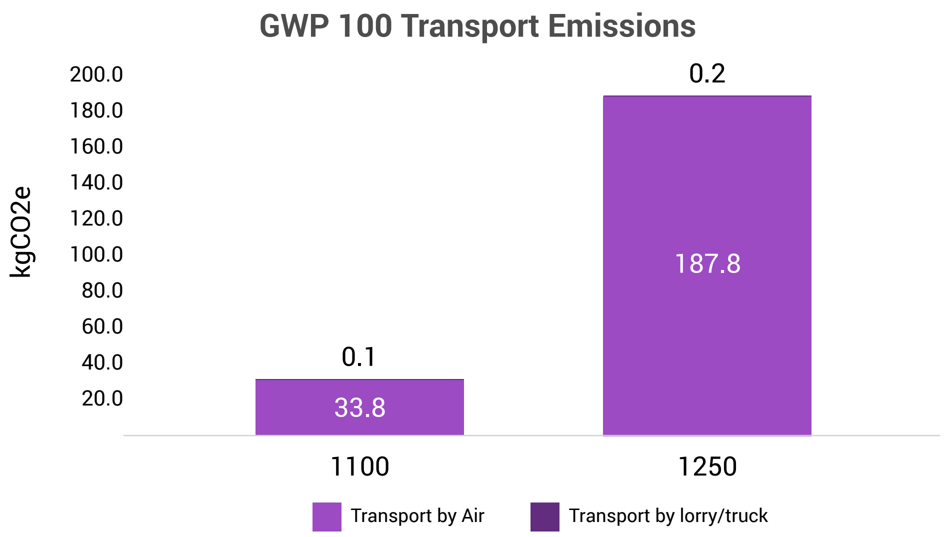


Figure 8 Transport impact

Figure 8 shows the total impact and breakdown of impact by travel mode. The graph demonstrates that transport by air from Thailand to the use destination 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 NPT units are operated in New York showed that the transport impact would increase to 156 kgCO2e for the 1100 and to 291 kgCO2e for the 1250. This is driven primarily by the increased distance from the sub-contract manufacturer to the use location when compared with India and Germany.

6.4. Use Phase Impacts

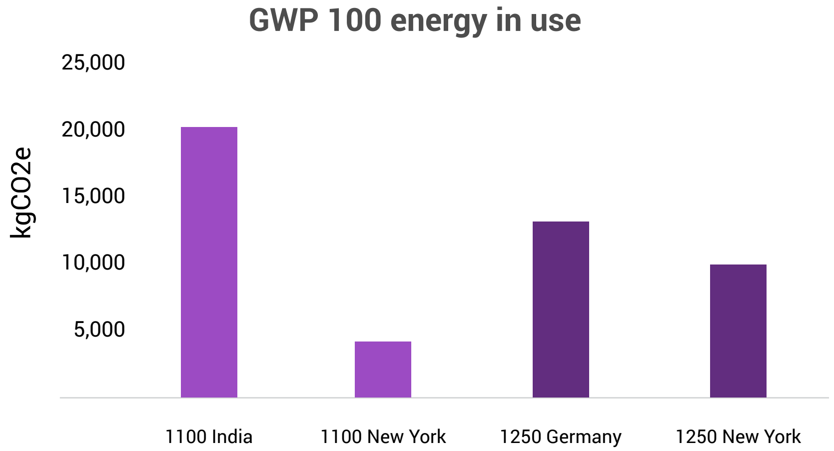


Figure 9 Impact from different use locations

Figure 9 shows that the 1100 and 1250 lifetime impact can be significantly reduced when installed in a location with a lower carbon intensity. This is seen most clearly in the 1100 examples, where installing in India results in a higher lifetime carbon footprint than either of the 1250 variants, even though the 1250 power demand is 165% greater than the 1100. This is because the Indian electricity grid serving the Mumbai area is one of the most carbon intensive in the world. The carbon intensity of the New York grid by contrast is one of the lowest due to the high proliferation of nuclear supply.

6.5. End of Life Impacts

Recycling of the 1100 and 1250 result in a recycling impact credit of 62 kgCO2e and 132 kgCO2e respectively. This equates to a lifecycle impact reduction of less than 1% 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 NPT 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 majority of the recycling credits for both NPTs are due to the recovery of gold. Gold is a very high impact metal, and so the recovery of approximately 1.8 grams in the case of the 1100 results in a recycling credit of 25.8 kgCO2e. Further credits primarily come from the recovery of the aluminium in the heatsinks and copper. The values are higher for the 1250 due to the greater weight of PCB and electronic components than the 1100.

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 1100 and 1250 NPT 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 98% of the lifetime impacts occur in the use phase for the 1100 and 94% for the 1250. The location of installation will have the most significant bearing on the overall lifecycle impacts of each of the NPT units. The installation in New York would reduce lifetime impacts by approximately 82% in the case of the 1100 and by 33% for the 1250, even when the increased transport emissions are taken into account.

- The manufacturing and assembly stage is responsible for approximately 2% to 5% of the lifetime emissions respectively for the 1100 and 1250.

- 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 56% for the 1100 and 46% of the 1250's manufacturing stage impact.

- The microprocessors comprise a tiny fraction of the mass but contribute approximately 2% to the lifetime environmental impact for the reasons explained above.

- While the sheet metal used in the chassis is the largest single item by mass, the production of the sheet metal is a relatively small contributor to the overall footprint at 4% and 3% for the 1100 and 1250 respectively.

- 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 0.1% of the lifetime impact.

The result of this analysis shows that the environmental hotspots to inform future physical designs and development should focus on measures to reduce energy consumption in-life. The output of the electricity consumed by the NPT units is primarily heat, which typically will be managed through being installed in an air-conditioned environment. Therefore, there is a consequential impact that reducing primary electricity consumption in the NPT will have further downstream energy reductions. The fixed consumption is understood to only vary as a result of the environmental temperature. Therefore, a warmer environment which has a lower air conditioning consumption would result in increased fan consumption and vice versa. Based on data from Patterson, Michael. (2008)1 And Seaton I. (2019)2 a calculation that shows cooling demand from the unit fans and the datacentre cooling technology will result in an overall power demand increase of around 0-2W (2%) per degree. However, if the increased cooling energy requirement of the datacentre is ignored, then increasing the environmental temperature will increase the unit electricity consumption by approximately 3%.

The next focus areas is the sourcing of PCBs. A 5% reduction in emissions from each of these areas would reduce the lifetime emissions by less than 0.1%.

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 was 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 and 2024, 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 either 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 BOM. Where the mass was not available for individual components, it was interpreted from specifications and informed by using artificial intelligence to find data on the component mass. Sample data checks on the accuracy of the artificial intelligence derived information were undertaken with no discernible discrepancy that would affect the overall outcome of this 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 1100 and 1250 sheet metal and PCB weights which were derived using the process described in 5.2.1.

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 NPT router 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 regarding incineration of the cardboard and polyethylene bag.

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

The marginal decrease in electricity consumption from changes in the datacentre operating temperatures are not considered to materially affect the conclusions given the dominance of impact from the use phase.

8. Glossary of terms

BOM – Bill of Materials. Schedule of components that makes up a large assembly.

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

NPT – Neptune optical router of which the 1100 and 1250 variants are the subject of this study.

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.

9. References

[1]Patterson, Michael. (2008). The effect of data center temperature on energy efficiency. 1167 - 1174. 10.1109/ITHERM.2008.4544393

[2]Seaton I. (2019). Data Center Cooling Algorithms: Allowable Temperature Envelope. Accessed 01/07/2025

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