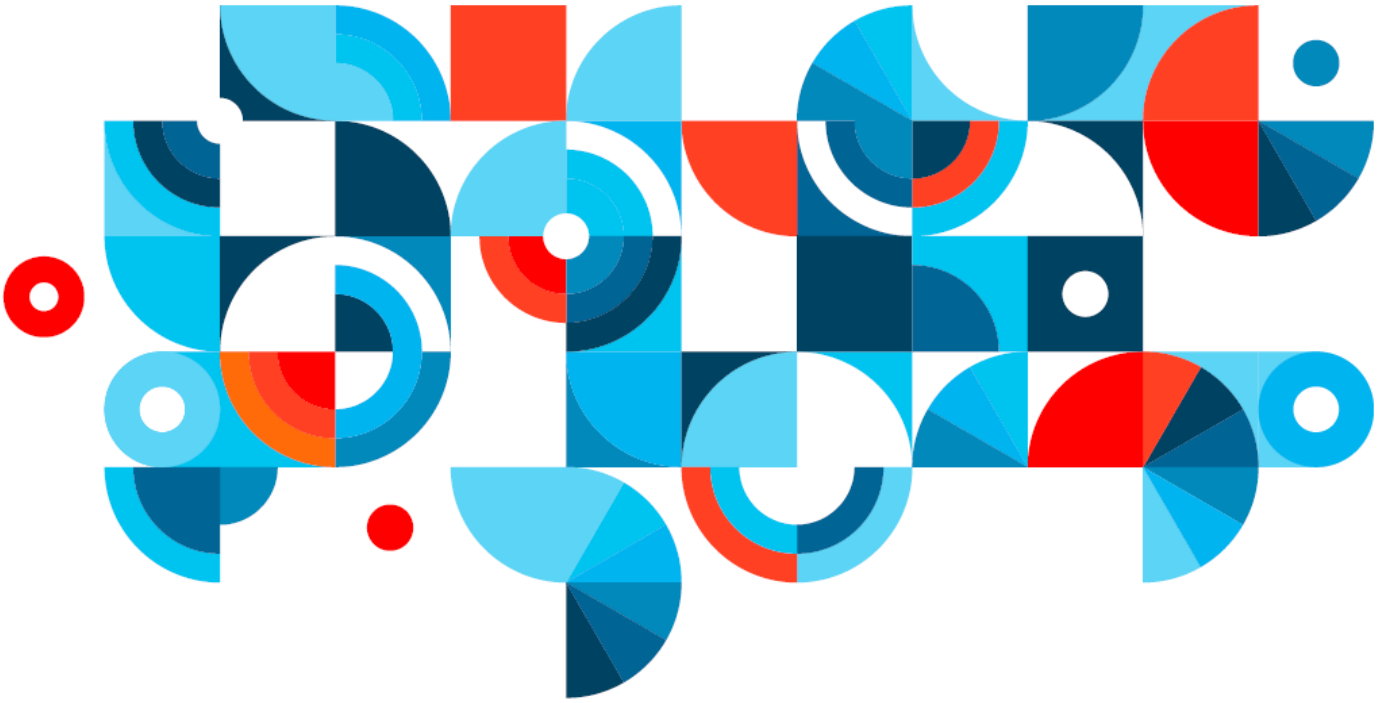
Physical **Tape**

CO_2e Report

Breakdown of the CO_2e and Other Positive Sustainability Impacts of IBM Physical Tape Products

The Product Life Cycle



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Introduction

The intent of this document is to fairly represent tape component sustainability as measured in CO_2e contribution, in no way is it expected to be completely representative of a single solution, exact micro-measurement of carbon contribution.

While all data is provided in good faith to be as accurate as represented, this document is not intended to be a legally binding representation of any of the data provided. All calculations are based on publicly available data.

This document is intended to breakdown the CO_2e and other sustainability impacts of IBM physical tape products.

The sustainability impacts are measured as a result of the lifecycle of the product at the time of the document publication.

Not all measurements are exact and may include estimations of usage during the lifecycle that do not exactly match the duty cycle of a particular use case or customer

Where available, referenced third party data is utilized in formulating the outcomes. The intent of this methodology is to provide a proof of work with as unbiased information as may be available at the time of the data collection.

Where an IBM corporate standard exists, the standard has been referenced for guidance.

This report is not intended to give total values for any complete solution architecture or customer delivery. This is due to the variability and scale of solutions.

Guidelines to Measurement and Reporting

GHG protocol methodologies as referenced in the GHG Product Life Cycle Accounting and Reporting Standard. Algorithms are derived from Product Attribute to Impact Algorithm (PAIA)

Shipping calculations are based on true reporting standards for greenhouse gas calculations from Environmental Defense Fund + Business green Freight Handbook.

In some instances, measurement of CO_2e may not be measurable within reasonable reporting levels, an uplift to the tape product is applied. In each case, an additional 5% of the total calculated attribution by product is added

Where a measurement of distance is referenced, the applied distance is an average of distance travelled and not to a specific destination. This variability has been measured at an average of +/- 8.7%.

This was deemed reasonable as destinations number in the hundreds for air shipping locations and thousands for client use destinations.

Where applicable a recycle contribution has been applied to hardware and shipping materials. This is reported as a carbon offset weight. This offset has not been applied to the data as displayed as could it be considered standard in reducing carbon impact statements

The lowest level component recognized is at the silicon-based card level. Water consumption, rare earth metals usage and waste produced during sob-component manufacturing are included in the totals. Breakdown of these components are the full responsibility of the subcomponent manufacturer. As an example of the level of consumption, the semiconductor productions represent the largest water consumer in the world at 2,200 gallons of Ultra Pure water (UPW) per 30cm wafer.

Energy calculations based on natural gas produced electricity are calculated at 40.6% efficiency.

Materials are assumed new with no attribution for recycled materials usage in the production process (metals and plastics)

- This is not a statement of the lack of usage of recycled materials. The attribution of recycled materials varies based on availability. Shortages of recycle supply at any time will not impact the data as currently derived in this report

All end measurements are reported in metric tons (mt) and should not be confused with mega ton (Mt).

Product Life Cycle Standard

Process maps are not part of this report
Generalized attributional impacts are in each phase
Vendor reported process results may be used in any phase.

Attributional impacts are included as estimates when:

- A data gap exists between primary or secondary data and it cannot be collected, only estimated
- Extrapolated data cannot be determined to fill the gap
- The data is determined to be insignificant

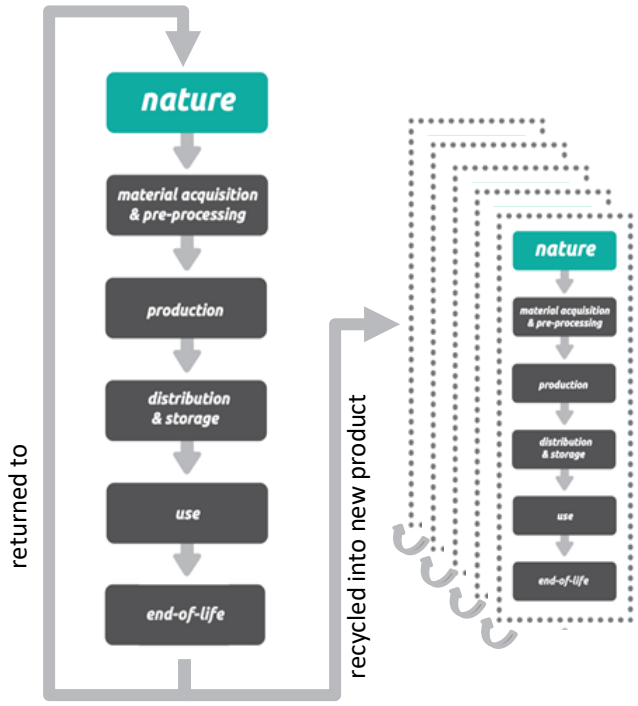


Figure 1: Visual to illustrate that we are looking at all aspects of the cycle

This process is representative of the product lifecycle as a whole.

This guidance is measurably accepted to be accurate for the hardware products presented by this document.

Recycle offsets are NOT applied to this document as the rate, cost and impact of recycling is tumultuous at this time.

Reporting Methodology

The reporting methodology is designed to break out major contributing subcomponents and to report on these components in an efficient and "worst" case scenario.

Variations in any subcomponent of greater than 5% of the total contribution between variation will be noted. (We cannot know up front that there are no such variations based on generations of tape or subcomponents.)

All calculations have a 5% gross contribution uplift as a rule of ensuring proper scale of contribution

- Where more than 1 variation of a component or subsystem exist, the highest carbon emitting process is reported
- Weights may be reported in Metric or Standard. All calculations are completed in the correctly converted form.
- No demonstration of standardized computations are included in this document.
- Where a variance of greater than 5% (+/-) in the reported value by generation, that variation has been noted.
- If no specific note is observed, the listed generations are within the previously stated variance.
- Due to the wide variance of individual end solutions, high case values are used for carbon impact. Individual solutions will have lower impact in ~99.65% of customer infrastructures.
- Any non-compliant chemical and materials are listed separately in the report slide.

Component Report: Layout

Here is how the products will be laid out.
The outcomes for contribution include shipping during manufacturing, minor gases as an uplift (due to the single component accuracy of measurement), We want to note upfront that contribution totals are based on the lifecycle of the product and tape product lifecycles are much longer than other products.

Final mile distribution is not included in the product but have been documented by region in this report as averages, of the method of shipping for each region listed.

Product description>

Component/Assembly 1> <QTY>…..<future: RA>
Component /Assembly +n> <QTY…..<future: RA>
Transportation Contribution
Weight
Recycle Offset
Energy usage <kWh>
Life Cycle <years average>

<Metric Outcomes>

- *In all cases shipping as part of production is included in the final outcomes.*
- *Minor gaseous contributions are contained within each process measurement and not broken out.*
- *Contribution totals are based on the stated life cycle in years, not an individual usage calculation.*
- *All stated values subject to variability in sourcing, scale and delivery.*
- *End-of-Life stage assumes local recycling and e-waste disposal. Associated fees are regional and not included due to scope and variation.*
- *Final Mile distribution not included in product contribution (see Final mile page for uplift by product and Geo)*

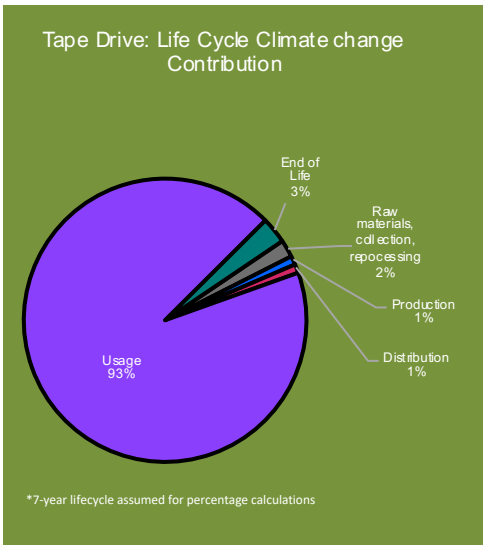
High Level Inputs and Outcomes

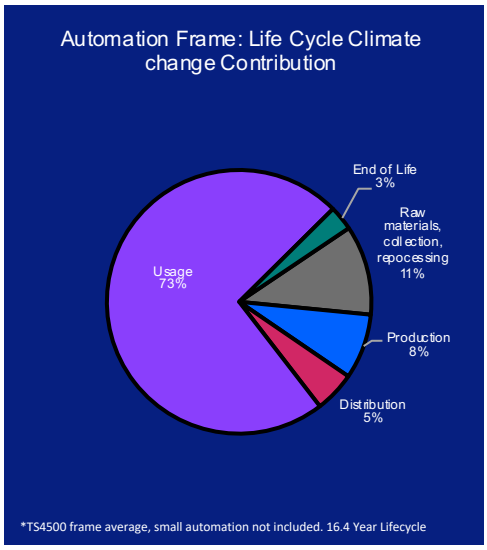
The IBM Tape study for sustainability assumes raw materials extraction. Contributions to sustainability through usage of recycle products are not applied to the CO_2e variance.

This method is utilized as a result of continuously variable percentages of available recycled material. All end values are measured against solid, liquid or gaseous metric measurements, and reported back via the standard CO_2e metric Ton contribution.

Tape is heavily driven by usage contribution. This is disproportional for 2 reasons, 1) Low carbon impact of tape products, 2) Extremely long life of tape products.

Hazardous and restricted materials may change with regulatory requirements and this is reflected in the general statements within the document.





System Boundaries

- Raw material extraction
- Material manufacturing
- Supplier transportation
- Product assembly and distribution
- Packaging
- Data center usage
- End of life burdens
- Recycling burdens
    - Benefits from recycling virgin materials savings are not included
- Manufacturing systems infrastructure not included

Hazardous/Restricted Materials Statements

- Contain no bromine or chlorine above 900 parts per million (ppm) or listed phthalates at the homogeneous material level
- No JIG/IEC 62474 restricted chemicals over allowed limits
- No ozone depleting chemicals, and no REACH substances of very high concern (SVHC) over 1000 ppm at the article level

Component Report:
LTO Full High Tape Drives

Sustainability boundary of measurement is the raw drive without media present.

This contribution contains all materials and processes related to the production, manufacturing, and shipping for the tape drive components.

As noted, drive generation contributions are below a reasonably expected threshold as a change value that is not representable in the overall boundary measurement.

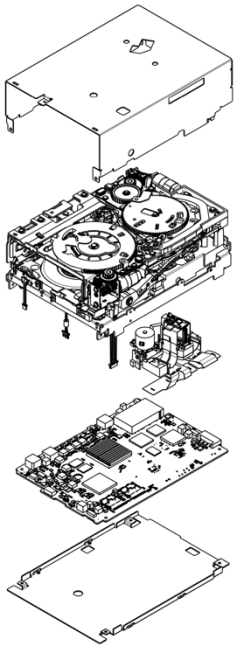
Full high tape drives are installed as an enterprise level interface to write and read tape media. Tape drives receive power from larger sub-systems. On average, Tape drives are deployed in a 1:175 ratio with tape media.

Base (Aluminum)	1
Sheet Metal Assembly	2
Misc. Motors	1
Media Motors	2
Silicon Card Assembly (8 Layer, Including All Connectors)	1
Head Assembly	1
Plastic Assemblies	8
Fibre Channel Interface (Integrated for SAS)	2

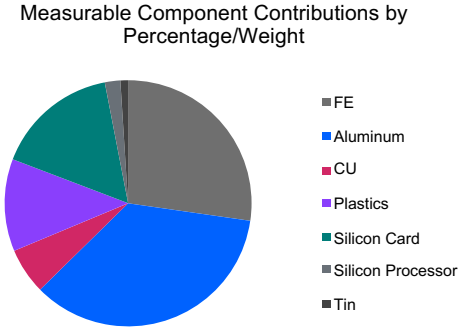
Weight	2.9kg
Recycle Offset	3.2kg
Energy Usage (Average)	.031 kWh
Life Cycle	6.85Yrs

Production	41.3kg
MFG Distribution	.4kg
Operational Energy	836.4kg
Cooling Energy	347.1kg
End-of-Life	4.94kg

1.4
metric tons
CO_2e



Note: Variation in drive generations are below the threshold of change value to overall contribution to carbon impact. The represented values may be considered accurate, (no more than), for all available and serviceable generations.



Component Report:
LTO Half High Tape Drives

Sustainability boundary of measurement is the raw drive without media present.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the tape drive components.

As noted, drive generation contributions are below a reasonably expected threshold as a change value that is not representable in the overall boundary measurement.

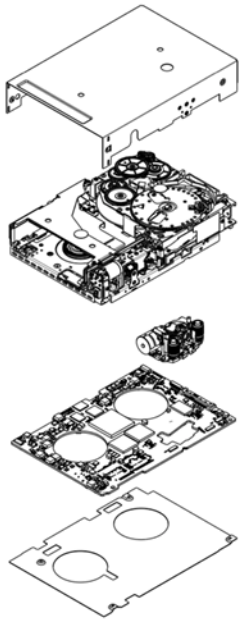
Half high tape drives are installed as an enterprise level interface to write and read tape media. Tape drives receive power from larger sub-systems. On average, tape drives are deployed in a 1:20 ratio with tape media.

Sheet Metal Assembly	3
Misc Motors	2
Media Motors	2
Silicon Card Assembly (8 Layer, Including All Connectors)	1
Head Assembly	1
Plastic Assemblies	7
Fibre Channel Interface (Integrated for SAS)	2

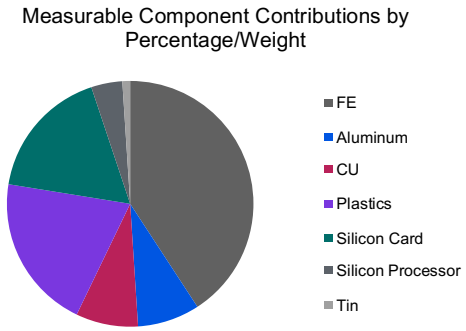
Weight	2.9kg
Recycle Offset	3.2kg
Energy Usage (Average)	.028 kWh
Life Cycle	5.85Yrs

Production	31.76kg
MFG Distribution	.2kg
Operational Energy	549.4kg
Cooling Energy	217.9kg
End-of-Life	3.32kg

.9
metric tons
CO_2e



Note: Variation in drive generations are below the threshold of change value to overall contribution to carbon impact. The represented values may be considered accurate, (no more than), for all available and serviceable generations.



Component Report: TS1100 Tape Drives

Sustainability boundary of measurement is the raw drive without media present.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the tape drive components.

As noted, drive generation contributions are below a reasonably expected threshold as a change value that is not representable in the overall boundary measurement.

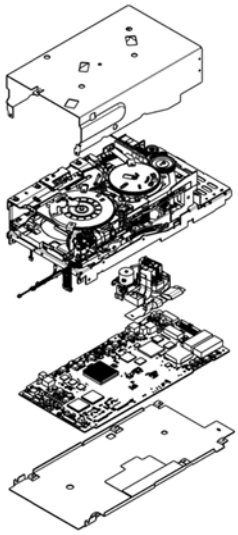
TS1100 tape drives are installed as enterprise level interface to write and read tape media. Tape drives receive power from larger sub-systems. On average, tape drives are deployed in a 1:135 ratio with tape media.

Base (Aluminum)	1
Sheet Metal Assembly	2
Misc. Motors	1
Media Motors	2
Silicon Card Assembly (8 Layer, Including All Connectors)	1
Head Assembly	1
Fibre Channel Interface	2

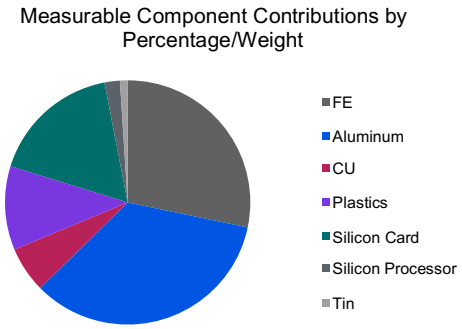
Weight	4.7kg
Recycle Offset	5.1kg
Energy Usage (Average)	.055 kWh
Life Cycle	8.78Yrs

Production	73.82kg
MFG Distribution	.5kg
Operational Energy	1731.7kg
Cooling Energy	703.2kg
End-of-Life	7.97kg

2.8 metric tons CO_2e



Note: Variation in drive generations are below the threshold of change value to overall contribution to carbon impact. The represented values may be considered accurate, (no more than), for all available and serviceable generations.



Component Report:
TS2900 Tape Automation

Sustainability boundary of measurement is the basic library with tape drive contribution included.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components and the tape drive base contribution.

Small automation device used to store and orchestrate media delivery to a single tape drive. This is a self-contained infrastructure.

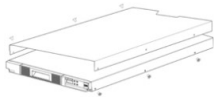
Motor	2
Silicon Card	3
Sheet Metal Assembly	2
'Plastic' Media Cells	1
Accessor Assembly	1
LED Display	1
Power Supply	1

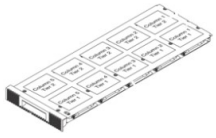
Weight	13kg
Recycle Offset	14kg
Energy Usage	.11kWh
Life Cycle	7Yrs

Production	250.55kg
MFG Distribution	108.4kg
Operational Energy*	3013.3kg
Cooling Energy	163.0kg
End-of-Life `	29.97kg

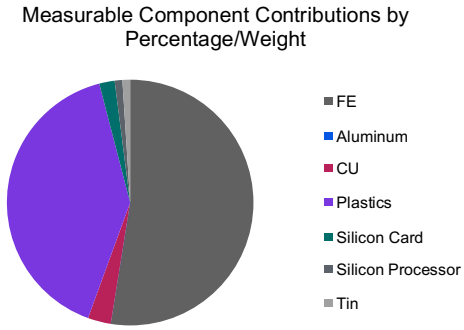
*Includes LTO-8 Half-High Tape Drive

3.9 metric tons CO_2e





Note: Variation in drive generations are below the threshold of change value to overall contribution to carbon impact. The represented values may be considered accurate, (no more than), for all available and serviceable generations.



Component Report:
TS4300 Tape Automation L3A

Sustainability boundary of measurement is the basic library with no tape drives. Components to hold tape drives are included for worst case scenario contribution.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components

Entry level automation device used to store and orchestrate media delivery to a single tape drive. Expandable infrastructure starting with L3A base with 40 media slots.

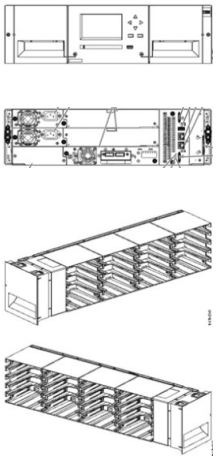
Motor	2
Silicon Card	3
Sheet Metal assembly	2
'Plastic' Media cells	1
Accessor Assembly	1
Tape Drive Mount Assembly	3*
LED Display	1
Power Supply	1

*based on highest count for this assembly: actuals will vary for each individual installation

Weight	20.1kg
Recycle Offset	24kg
Energy Usage	.3kWh
Life Cycle	8.4Yrs

Production	752.79kg
MFG Distribution	.5kg
Operational Energy	9861.8kg
Cooling Energy	273.8kg
End-of-Life	86.81kg

12.1 metric tons CO_2e



Component Report:
TS4300 Tape Automation E3A

Sustainability boundary of measurement is the basic library with no tape drives. Components to hold tape drives are included for worst case scenario contribution.

No power supplies are assumed in this expansion. This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components.

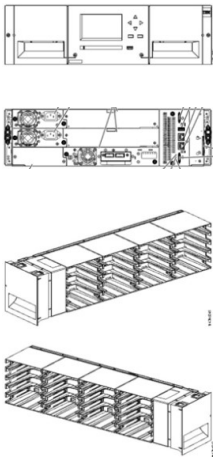
Expansion module to the entry level automation device used to store and orchestrate media delivery to multiple tape drives. Adds up to 3 tape drives and 40 media slots.

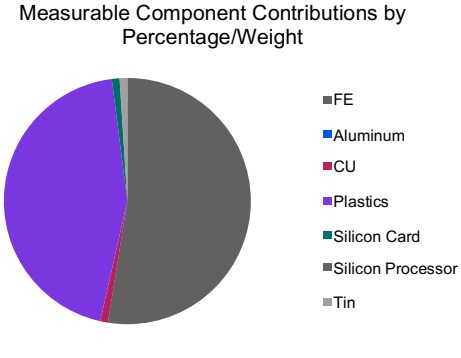
Motors	2
Silicon Card	3
Sheet Metal Assembly	2
'Plastic' Media Cells	1
Accessor Assembly	1
Tape Drive Mount Assembly	3*
Power Supply	1*

*based on highest count for this assembly: actuals will vary for each individual installation

Weight	13.2kg
Recycle Offset	15.0kg
Energy Usage	0kWh
Life Cycle	8.4Yrs
Production	560.27kg
MFG Distribution	.4kg
Operational Energy	11kg
Cooling Energy	11kg
End-of-Life	65.43kg

.7
metric tons
CO_2e





Component Report:
TS4500 Tape Automation L25/55

Sustainability boundary of measurement is the basic library with no tape drives. Components to hold tape drives are included for worst case scenario contribution.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components.

Enterprise level automation device used to store and orchestrate media delivery to multiple tape drives. Expandable infrastructure starting with Lx5 base.

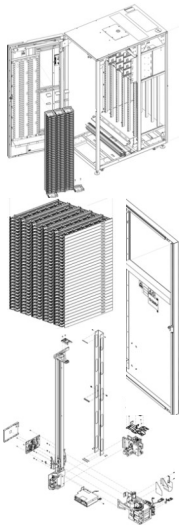
Motor	4
Silicon Card	6
Sheet Metal Assembly	6*
Structural Steel	8*
'Plastic' Media Cells	1
Accessor Assembly	1
Tape Drive Mount Assembly	12*
LED Display (Large)	1
Computing Interface (In Form of Mini-pc)	1
Power Supply	1

*based on highest count for this assembly: actuals will vary for each individual installation

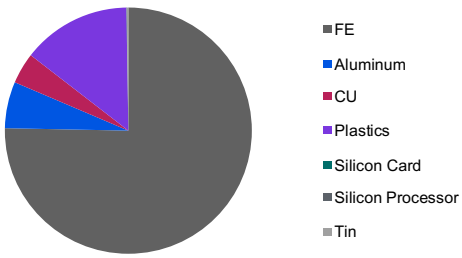
Weight	410kg
Recycle Offset	535kg
Energy Usage	.365kWh
Life Cycle	16.4Yrs

Production	11049.71kg
MFG Distribution	6.3kg
Drive mounts	295.8kg
Operational Energy	26425.8kg
Cooling Energy	6437.9kg
End-of-Life	1154.07kg

50.0
metric tons
CO_2e



Measurable Component Contributions by Percentage/Weight



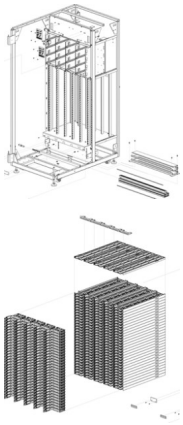
Component Report:
TS4500 Tape Automation D25/55

Sustainability boundary of measurement is the basic library with no tape drives. Components to hold tape drives are included for worst case scenario contribution.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components.

Performance expansion frame for enterprise level automation device used to store and orchestrate media delivery to multiple tape drives. Expands drives and media.

14.4 metric tons CO_2e

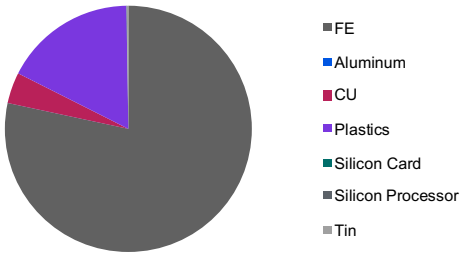


Silicon Card	4
Sheet Metal Assembly	6*
Structural Steel	8*
'Plastic' Media Cells	1
Tape Drive Mount Assembly	16*
Communications Distribution Assembly	1
Power Supply	1

*based on highest count for this assembly: actuals will vary for each individual installation

Weight	416kg
Recycle Offset	422kg
Energy Usage	.078kWh
Life Cycle	16.4Yrs
Production	7250.9kg
MFG Distribution	6.3kg
Drive Mounts	394.5kg
Operational Energy	4171.7kg
Cooling Energy	595.7kg
End-of-Life	648.04kg

Measurable Component Contributions by Percentage/Weight



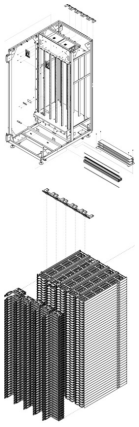
Component Report:
TS4500 Tape Automation S25/55

Sustainability boundary of measurement is the basic.

This contribution contains all materials and processes related to the production, manufacturing, and shipments for the automation components.

10.5 metric tons CO_2e

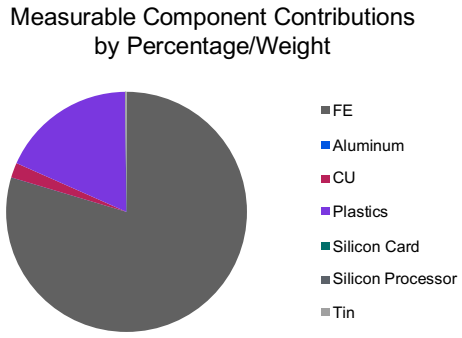
Capacity expansion frame for enterprise level automation device used to store and orchestrate media delivery to multiple tape drives. Expands media only.



Silicon Card	2
Sheet Metal Assembly	6*
Structural Steel	8*
'Plastic' Media Cells	1

*based on highest count for this assembly: actuals will vary for each individual installation

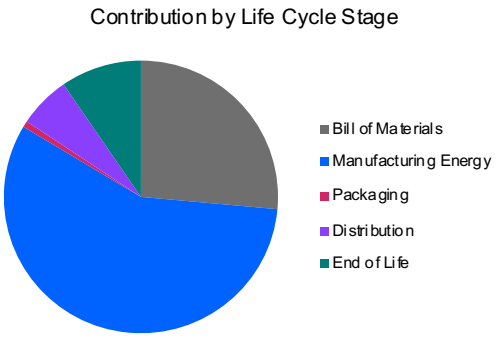
Weight	304kg
Recycle Offset	399kg
Energy Usage	.011kWh
Life Cycle	16.4Yrs
Production	7892.91kg
MFG Distribution	6.3kg
Operational Energy	706.0kg
Cooling Energy	290.2kg
End-of-Life	609.68kg



Tape Media
Third Party Assessment

All data represented herein can be verified in the media sustainability report from Brad Johns Consulting.

Sponsored by Fuji Film and IBM the intent is to fairly report tape sustainability at the media level.



LTO

Raw Materials	2.12kg-CO_2
MFG Process	4.58kg-CO_2
Operational Energy	0kg-CO_2
Cooling Energy*	.01kg-CO_2
End-of-Life	.76kg-CO_2

*Cooling energy is based on media averages per install of a library set across the total cooling of the automation device

.007 metric tons CO_2e

3592

Raw Materials	2.20kg-CO_2
MFG Process	4.63kg-CO_2
Operational Energy	0kg-CO_2
Cooling Energy*	.01kg-CO_2
End-of-Life	.78kg-CO_2

*Cooling energy is based on media averages per install of a library set across the total cooling of the automation device

.008 metric tons CO_2e

Related "Last Mile" Shipping – CO_2e in Metric Tons

All configuration weights are at highest weight without media.
All distances used in calculations are average distances for the region.
Specific destination will vary for air and ground distances, with little impact on the outcome of the CO_2e production.

Product	Region									
	NA		EU		MEA		ASEAN		LA	
	Air	Ground	Air	Ground	Air	Ground	Air	Ground	Air	Ground
LTO Drive	.012	.0002	.048	.0002	.067	.0002	.058	.0002	.012	.0002
TS1100 Drive	.021	.0003	.093	.0003	.113	.0003	.107	.0003	.021	.0003
TS4300 L3	.0519	.001	.207	.0007	.286	.0008	.248	.0008	.129	.001
TS4300 E3	.0518	.001	.207	.0007	.286	.0008	.248	.0008	.129	.001
TS4500 L	.755	.015	3.01	.010	4.16	.011	3.62	.011	1.87	.012
TS4500 D	.774	.015	3.02	.010	4.18	.011	3.64	.011	1.89	.012
TS4500 S	.755	.015	3.01	.010	4.16	.011	3.62	.011	1.87	.012

TS4500 Tape Automation
8-Year Total Solution Example

The solution example is for illustrative purposes with 125.5 PB.

Data Rate	75TB/HR
Access Points	60
Uncompressed Capacity	**125.5PB**
Space	148.2 Sq Ft 13.76m^2
"Final Mile"	Europe

~422 metric tons CO_2e for 8 years

1 L Frame	41.5 $mtCO_2e$
3 D Frames	41.7 $mtCO_2e$
4 S Frames	44.5 $mtCO_2e$
60 Tape drives	197.7$mtCO_2e$
6275 Cartridges	95.9 $mtCO_2e$

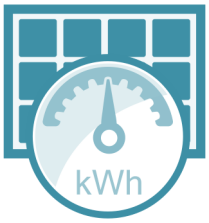
.42 metric tons CO_2e per PB per year

Low Power Consumption

Power Consumption KPIs
Note: Power consumption computed at **maximum** drive configuration for each frame.

kWh/Ft2 (Watts per square foot)
TS4500

L Frame	110	Watts
D Frames	105	Watts
S Frame	1	Watt



kWh/Ft3 (Watts per cubic foot)
TS4500

L Frame	18	Watts
D Frames	18	Watts
S Frame	1	Watt

kWh/TB (Watts per terabyte)
TS4500

L Frame	.1	Watts
D Frames	.1	Watts
S Frame	.0005	Watt

Sustainability Comparison: HDD and Tape

As we previously learned in the Fuji film presentation, tape solutions reduce CO_2 emissions by 87%.
That number is influenced by 3 major data center performance indexes (KPIs):

97% lower energy consumption
95% lower heat dissipation resulting in lower data center heat management

The future is even more positive for tape with the 17x higher technology demonstration. With no increase in CO_2 lifecycle emissions to meet the 580TB capacity, CO_2e per TB will plummet in comparison to future HDDs. Why is this number significant?
Meeting carbon neutrality must start with reducing the creation of CO_2e emissions (Reducing Consumption). Of course, that is a challenge when measured against the global growth of digital data. IDC estimates retained data to be 8.7ZB in 2020.
It is also estimated that between 40% and 80% of data is rarely or never accessed. Using the complete sustainability lifecycle from brad johns consulting, Moving just cold data, not including replication of data, to tape, reduces the 10-year CO_2e emissions by over 11 million tons, when compared to the full life cycle of HDDs.

A minimum of 64% reduction, that is a grand start to outperforming carbon neutrality goals.

Reference information
A study by Brad Johns Consulting LLC (released in October 2020), compared HDD and Tape solutions in a hypothetical example. In this example, an HDD solution's energy requirements that included 10 TB HDD's, JBOD storage drawers, controllers, and servers was compared to tape storage solution that included an enterprise tape library, LTO8 tape drives, media, disk cache, servers, and SAN connectivity. This was compared over a ten-year energy consumption of 10 PB of cold data growing at 35% per year. In this hypothetical example, it was shown that the tape solution used dramatically less energy consumption and heat dissipation. Assuming a natural gas plant generated the power needs, the HDD system would have produced 3,013 tons of carbon dioxide versus 383 tons for the tape system. Storing the inactive data on tape storage produced over 87% less carbon dioxide.

```
97% lower energy consumption
95% lower heat dissipation
17 times higher demonstrated density
```

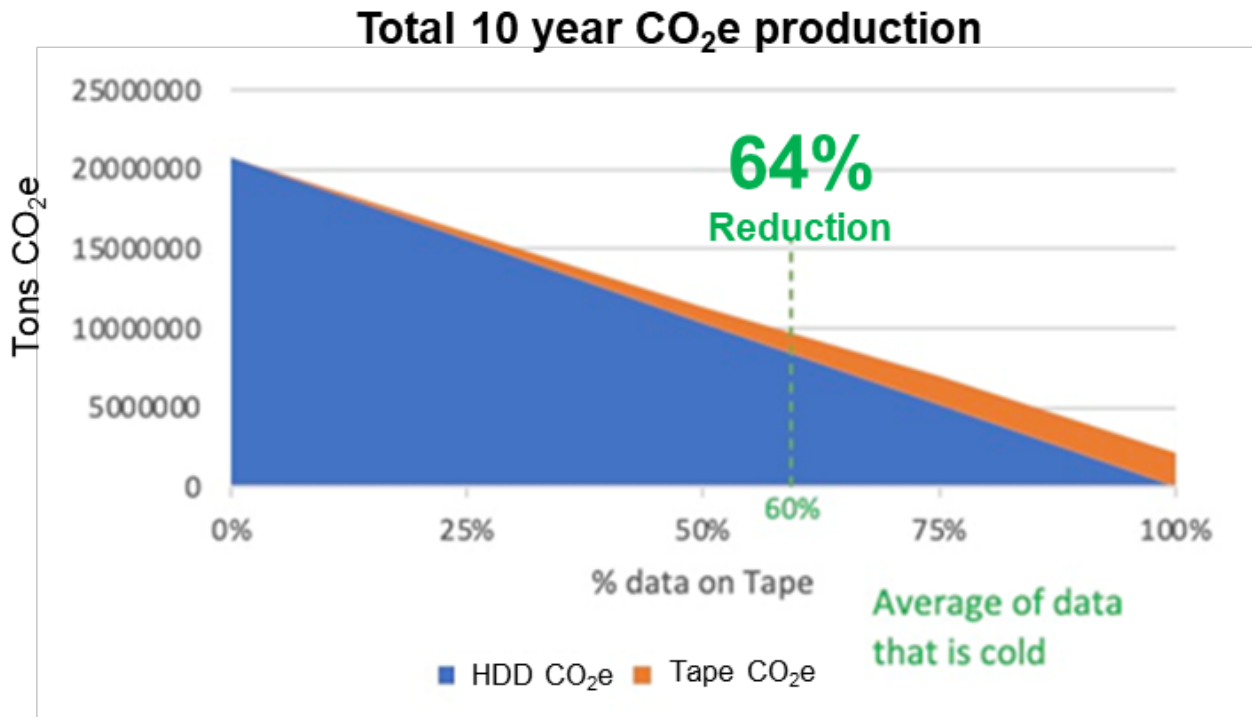
>87%
Reduction in CO_2 production*

*When comparing the same capacity and durations Brad Johns Consulting LLC – Reducing Data Center Energy Consumption and Emissions with Modern Tape Storage

What if: Global Data Analysis

8.7ZB of data retained globally
60% of data is rarely or never accessed

Tiered data storage is the most efficient reducer of CO_2 emissions



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