Environmental Analysis of Six Pallet Configurations

Prepared for AIRDEX
By Environmental Packaging International (EPI)
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1. Executive Summary

This report summarizes the findings of an environmental analysis comparing six different pallet configurations, as shown below:

1. AIRDEX's AIRpallet™
2. Corrugated pallet
3. GMA Wood pallet
4. Aluminum pallet
5. HDPE pallet
6. China-sourced pressed wood chips pallet

The analysis includes a comparative packaging assessment (in terms of environmental impacts based on life-cycle metrics and packaging attributes) using the latest PIQET update (the Packaging Impact Quick Evaluation Tool 4.0, initially developed by the Sustainable Packaging Alliance Pty Ltd., and currently under the ownership of Life Cycle Strategies Pty. Ltd.), as well an "Other observations" section that includes a brief discussion of potential packaging waste fees for five markets: Austria (local Waste Recovery Organization – WRO – of focus: ARA), Belgium (WRO: Val-I-Pac), Czech Republic (WRO: Eko-Kom), Finland (WRO: RINKI Ltd), and Sweden (WRO: FTI), as well as other general EPI observations not captured in the analysis above.

The purpose of this report is to inform the packaging design and selection process and to support AIRDEX and its customers in evaluating the various environmental attributes of different packaging systems. None of the statements contained herein constitute endorsement of any packaging material or system, nor are they intended to be used as marketing claims as specified in the FTC Environmental Marketing Claims Guidance. It should be noted that PIQET is a design-phase guidance tool. Under the license terms of PIQET, the data generated from PIQET should only be used to assist in making packaging design decisions; it cannot be used to make marketing claims or to advertise products.

The major findings include:

Environmental Impacts - Comparative Packaging Impact Evaluation:

Seven life cycle impacts were calculated by using the PIQET tool. For six of these metrics, the AirPallet™ outperforms all other pallet configurations analyzed, when **one** air shipment is assumed to be performed from China to the US once the pallet is produced. A brief discussion of why the fiber-based pallets perform better in one of the metrics (Water Use) is included in section 4 below. Please note that some of environmental comparative advantages (for instance in greenhouse gas emissions reduction) would increase with each air shipment included, given the dramatically lighter weight of the AirPallet™ in comparison with the other systems included in this analysis.

Other observations:

Generally, the packaging fees that would be paid for the AirPallet™ in many of the countries that have charges on transport packaging would be in the lower range, or, potentially, the lowest among the analyzed systems. The most important reasons for this performance are the significantly low weight of the pallet, as well as the process of reusing this package. In many countries, pallets that are accepted as "reusable" (if they meet established criteria) either pay just a "one-time" fee, or are completely exempt from fee payment. Note that some countries do not charge packaging fees on business to business packaging, on tertiary (transport) packaging, or on packaging that meets the "reusable" definition set by the local authorities, which may only be required to incur an one-time fee. Please check appropriate rules and regulations for details. EPI has also included comments in reference to possible corporate concerns regarding the usage of EPS as packaging material.

2. Basis for Comparison and Analysis Assumptions

EPI analyzed six different pallet configurations, with an identical product capacity assumed for each of these systems. In order to avoid unnecessary complexities, the only packaging assumed was the pallet itself. All other primary and secondary packaging was assumed to be identical, and therefore not relevant to the ***comparative*** analysis, and excluded from it. While an initial analysis was performed on each pallet system carrying an identical amount of product, namely 66 boxes of 4kg each, it was noted that the weight of the product was overpowering the results in some of the transportation phases. Therefore, in order to ensure that the only comparative impacts analyzed are the ones of the pallets themselves, for the final analysis it was assumed that the pallets were carrying the same, but negligible, product weight. In this way, the comparative impacts of the pallets, when transported by air, for example, are a lot more visible. The packaging components comprising the 6 systems are displayed in Table 1 below.

Also, in terms of the streamlined LCA analysis in PIQET, the following additional assumptions were made for each of the pallets:

1. All analyses were performed for 1 (one) pallet unit placed on market annually. This number is only relevant for the absolute impact levels (such as "amount of GHG emitted during the life cycled phases analyzed"), but the relative impacts would remain the same at any number of units.
2. The consumption location was assumed to be 100% "away from home", since none of the pallets would reach a household as the final consumer (relevant only for end-of-life).
3. Transport routes and distances were configured based on client input. Where road transportation was used as the mode of transport, the same type of truck was used (although the location might have been different), respectively "Rigid 15t truck, average".
4. For the final leg of transportation, "Transport to retailer", the same type of transportation (air – international) was used for all pallets, and an average distance of 10,000 km was assumed. Adding this step ensured that the environmental benefits of using the AirPallet™ include its applications for air shipment of merchandise.
5. In terms of the "Waste management" at the end-of-life, a number of assumptions were made, based on client data, and PIQET defaults were overwritten. In cases in which information was available about take-back systems, only about 10% of the systems were assumed to end up in landfills. For systems made of materials such as Aluminum and Corrugated, the existing recycling data was used for these materials.

6. Please note that PIQET 4.0, while substantially improving conversion choices, still has some limited options, most notable for fiber materials. While the closest conversion types were chosen for each pallet, for the corrugated version, the only conversion process available was "board folding".

In terms of the packaging fees in this report, they were calculated for the weight of 1,000 pallet units – (fees are generally calculated per weight of package placed on market). 1,000 units were used in order for the fee magnitude to be easier to read.

Table 1 - Packaging Systems

Packaging System	Component	Material Type	Weight (g)
Airdex AIRpallet™	Pallet	EPS Composite (53.5% HIPS, 46.5% PS - General Purpose)	3,400.00
China Pallet	Pallet	Wood	14,969.00
Corrugated US Pallet	Pallet	Corrugate	7,700.00
GMA Wood Pallet	Pallet	Treated Wood	18,143.00
Aluminum Pallet	Pallet	Aluminum	18,134.00
HDPE Pallet	Pallet	HDPE	24,494.00

3. Environmental Impacts – Packaging Impact Quick Evaluation Tool 4.0

EPI has conducted a Packaging Impact Quick Evaluation Tool (PIQET) analysis for the given packaging systems by examining: a) eight environmental impact assessment indicators, and b) two packaging-specific indicators.

The Packaging Impact Quick Evaluation Tool (PIQET) is a streamlined LCI-based tool intended for comparative analysis during the packaging design phase. It was developed with the input and support of industry partners and funding from the Australian Government, initially as a tool to enable brand owners to perform and present credible analyses needed for their Australia's National Packaging Covenant (NPC)[1] reporting. Its methodology was developed with the goal of converting complex life

[1] Australia's National Packaging Covenant (NPC) signatories are required to develop and submit an Action Plan detailing how they propose to implement their Covenant commitments regarding the impacts of the packaging placed on the market. Brand owners that do not participate in the voluntary Australia Packaging Covenant and that have a turnover of at least $5 million AUD per year are regulated under the National Environmental Protection (Used Packaging Materials) Measure. The legislation requires that brand owners that are not Covenant signatories must take back and reuse a percentage of their packaging product.

cycle assessments (LCA), environmental data and packaging waste management and recycling data into a quick turnaround, easy-to-use business tool that allows companies to evaluate packaging from raw material extraction, packaging manufacture, filling and product/packaging distribution through to packaging disposal, re-use and material reclamation. In time, PIQET has become a tool used by many consumer goods companies in the design phase of their packaging, because streamlined LCA tools provide accessible (and fairly quick) life cycle information for environmental assessments.

The environmental indictors analyzed provide a comparative snapshot that can be used during the design phase of the packaging. The Environmental Impact Assessment Indicators included in this analysis are shown below; indicators are calculated for all processes considered (for example, total solid waste generated by the production, conversion, and end of life processes):

- Global Warming (kg CO2 eq)[2] – effects from emission of global warming gases
- Cumulative Energy Demand (MJ LHV)[3] – fossil, renewable, nuclear
- Minerals and Fuel (MJ surplus – currently $ surplus cost, see note below)
- Photochemical Oxidation (kg C2H2 eq)
- Eutrophication (kg PO4 3- eq – fresh water impact only; PIQET 4.0 separates this metric in fresh water, terrestrial and marine impacts)
- Water Use (kL H20)[4] – for all processes included, except hydro generation of energy
- Land Use (HA)
- Solid Waste (kg)

After performing the analysis, EPI has decided to not include the ”Land use” metric in the final presentation of results, because of the nature of materials analyzed. In PIQET, some of the background datasets do not account for land use (these include most plastic datasets). Therefore, this indicator truly is relevant when packaging materials are sourced from agriculture or forestry, not for materials such as foam, metal, or resins other than PHA and PLA. *However*, note that all fiber-based materials (such as the wooden and the corrugate pallets) would have a much larger impact in the “Land use” indicator, if calculated.

PIQET 4.0, while working with updated data sources, has kept the option of analyzing the same life cycle metrics as the previous version, while offering additional metrics as well, based on certain EU-based goals and data. For this comparison, we chose to use the legacy metrics, which are most relevant. However, one notable exemption is the “Fossil Fuel” metric. While initially the new developers have switched to a new metric “Fossil Fuel Depletion”, measured differently, and with heavy impacts on metal parts of packages (and less on resins), they have currently reverted to a metric that is less controversial, and much more similar to the previous one (which was measured in MJ surplus; currently, the metric is measured in $ surplus cost and is called “Resource Damage – mineral, fossil”; additional details about this metric will emerge in the next few months).

The results are presented as annual impacts, based on packaging characteristics, number of units sold (assumed to be 1 unit in this case, as noted above), as well as the target market. Note that PIQET currently has data sets for the USA, Western Europe, United Kingdom, Australia, China, Japan, New Zealand, and Brazil. For this analysis, the market where the systems become waste has been assumed

[2] Conversion conform to IPPC fourth assessment
[3] Based on first CML impact assessment method
[4] Based on first CML impact assessment method

to be the US for all analyzed pallets. Material sourcing countries have been assigned, based on client data, to be US, China, or New Zealand.

The Packaging Specific Indicators presented in this analysis are:

- Packaging to Product Ratio; this is the one indicator in the analysis for which an amount of 264 kg of product were assumed to be placed on each of the pallets.
- Packaging to Landfill or Packaging to Recycle.

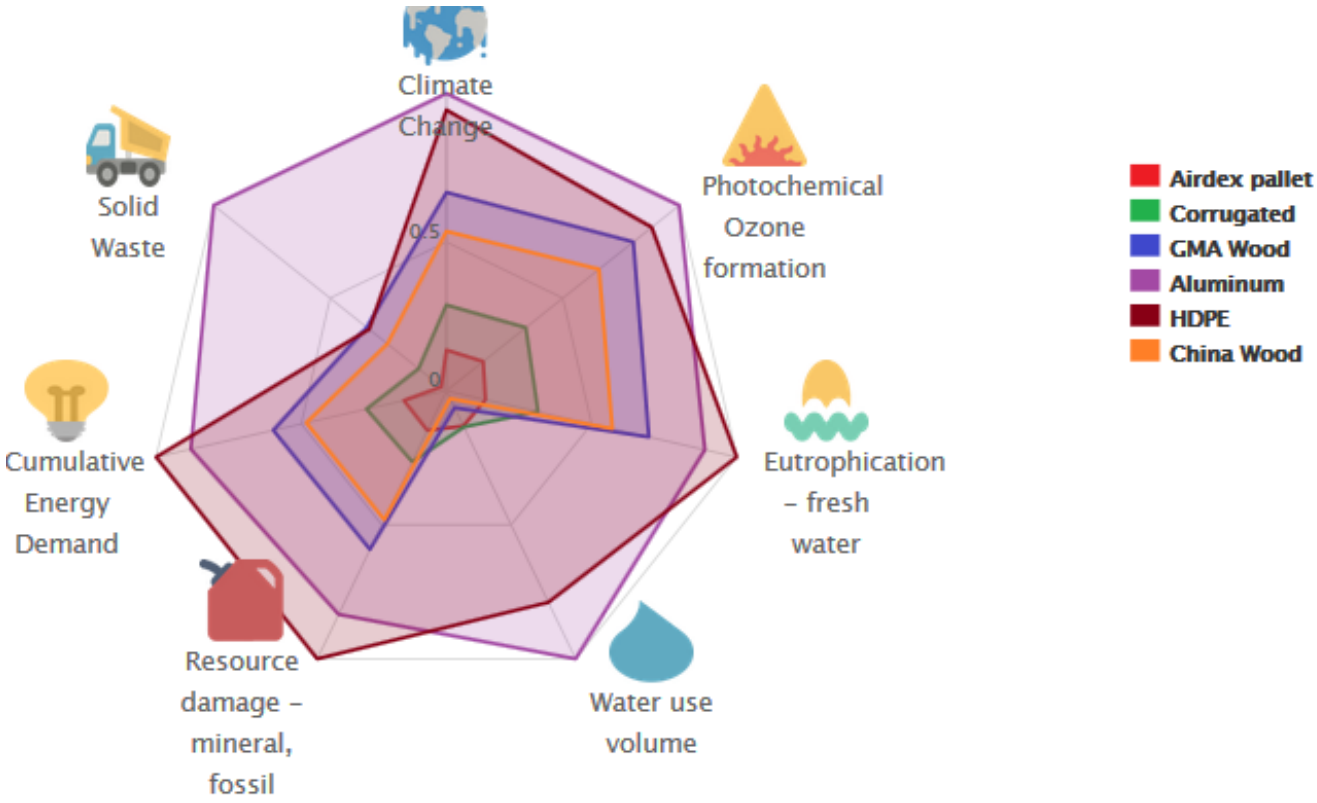
These indicators are calculated in PIQET based on a methodology that is consistent with the Global Protocol on Packaging Sustainability (GPPS) metric calculations.

PIQET Analysis Results

PIQET 4.0 performs ***"at-a-glance" relative impacts*** comparisons for a maximum of six packages at a time. The following combined graph shows all the analyzed impacts (metrics) for the AirPallet™, as compared to other sets of pallets (the complete comparison of percentage changes in impacts as compared to the AirPallet™ levels is presented below the diagram).

In the spider diagram below, the closer the shaded area is to the center, the lesser are the environmental impacts.

Graph 1: AirPallet™ vs All Other Analyzed Systems



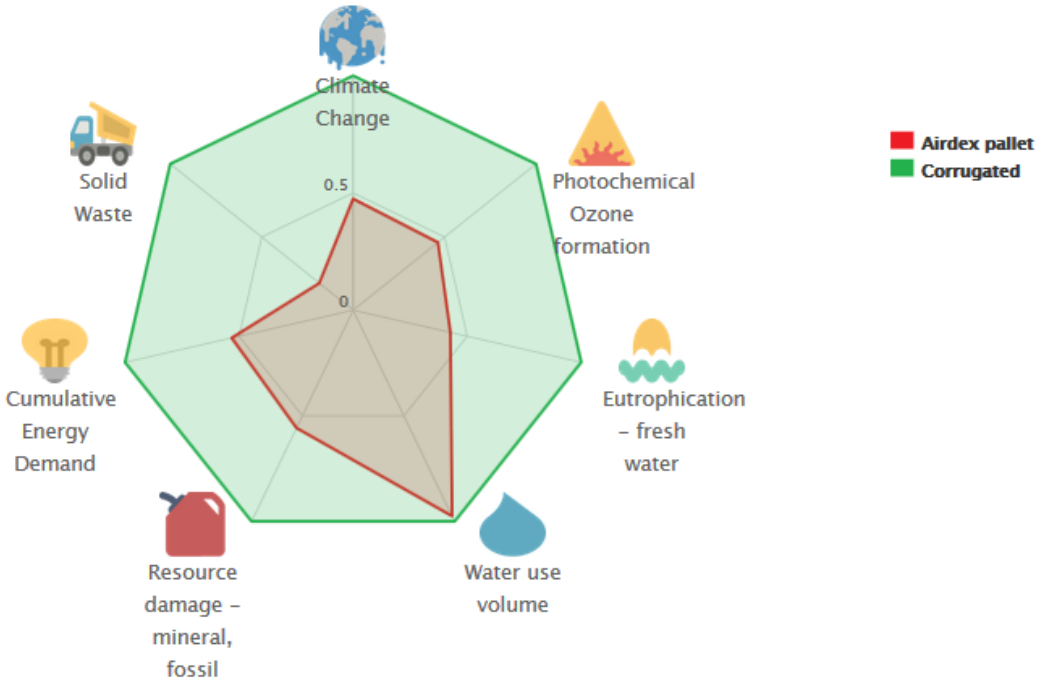
As it can be noted in the graph above, the AirPallet™ outperforms most of the other pallet systems in all categories. The one exception is water use, where the wooden pallets slightly outperform AirPallet™. Without the air shipment step, the differences would be less dramatic, and the resin pallet would show a higher comparative impact in the "Mineral and Fuels" consumption (being a fossil-fuel based material). But since the AirPallet™ is so much lighter than the other structures, these comparative impacts are overwhelmingly smaller when analyzing the pallet's applications (shipment by air) – and the comparative disadvantages in initial life cycle phases become comparative advantages, which increase with the number of shipments performed (this analysis only assumes one shipment). As expected, the Water Use impact is lower for the wooden systems (versus most resins), as this indicator is not impacted by the air or truck shipments (and depends solely on previous life cycle phases), however, the magnitude of the difference is much smaller than the magnitude of comparative advantage in the other metrics. Please see Table 3 below for details.

Please note that certain characteristics of the wooden pallets that may have an additional impact on the final results (such as details about wood treatment and conversion processes which may increase or decrease "water use", for instance) were not available in PIQET, which is a streamlined LCA tool.

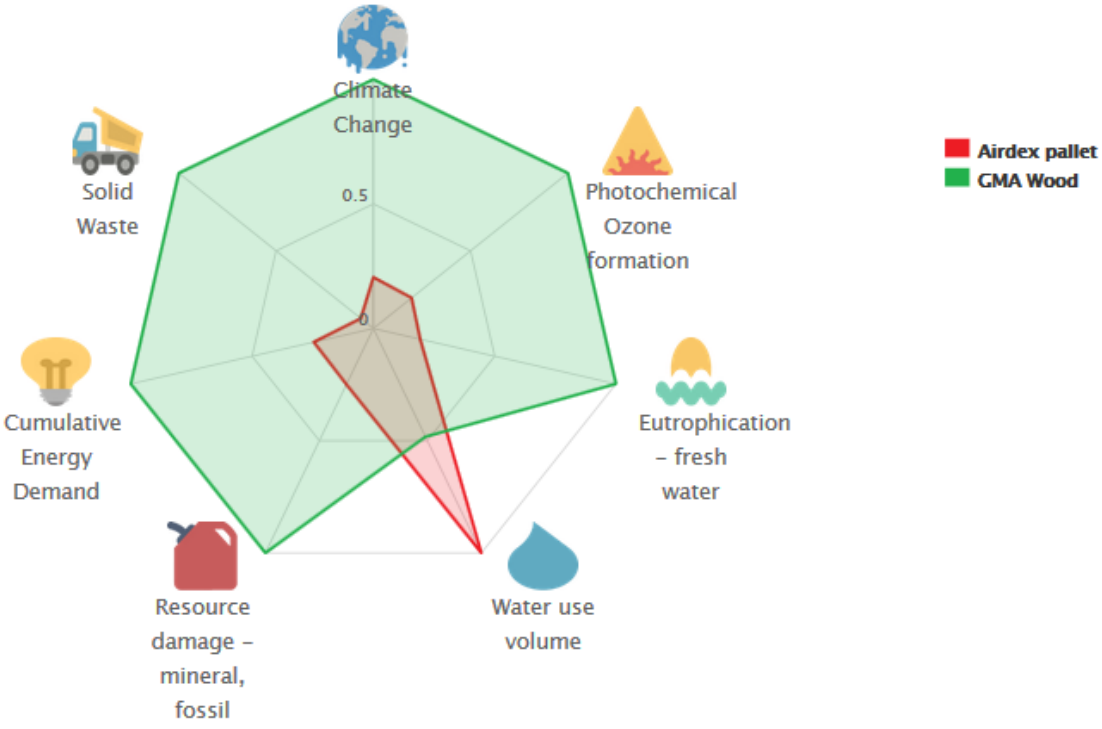
While the corrugated pallet is one of the lighter systems in the analysis (although still a bit more than double the weight of the AirPallet™), the AIRDEX pallet still outperforms its impacts in most of the metrics. As expected, the "Water Use" metric is similar for both systems, since the advantages of shipping merchandise on the AirPallet™, by air, are not impacting this metric. As clearly seen in the diagram, the environmental impacts of the AirPallet™ are dramatically lower when compared against the Aluminum and HDPE pallets. Both the materials analyzed, as well as the much higher weight of the metal and HDPE pallets impact these results.

The diagrams below show the performance of the AirPallet™, as compared to each of the analyzed alternatives:

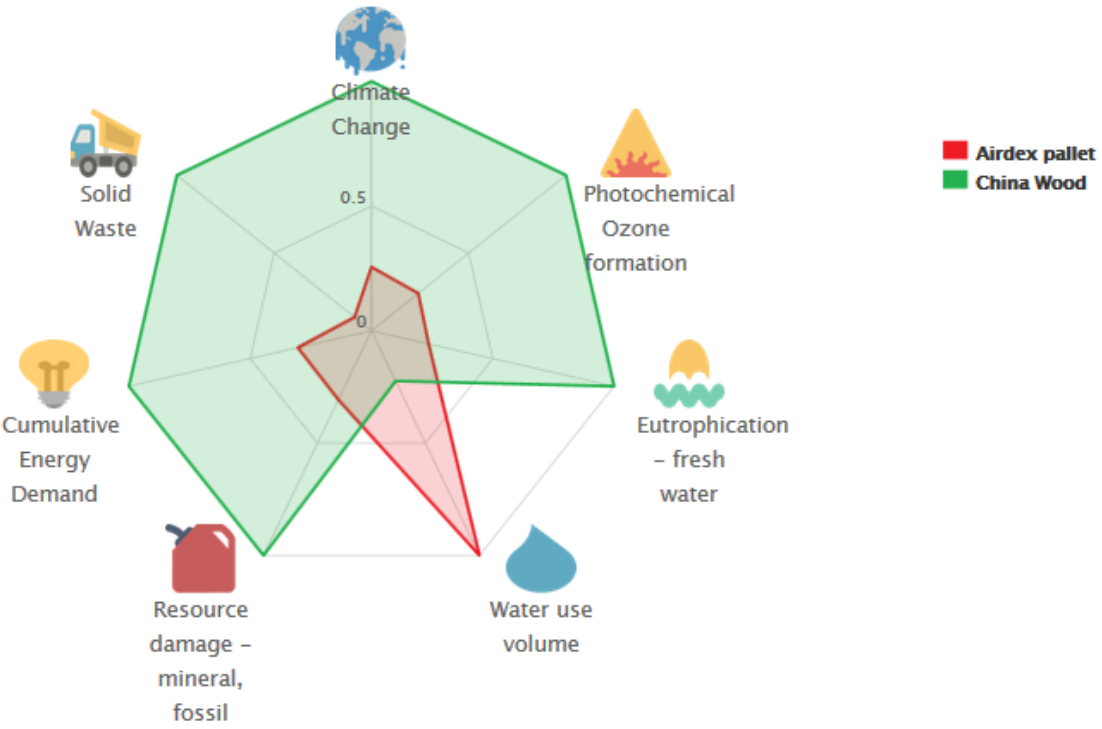
Graph 1a: AirPallet™ vs Corrugated Pallet



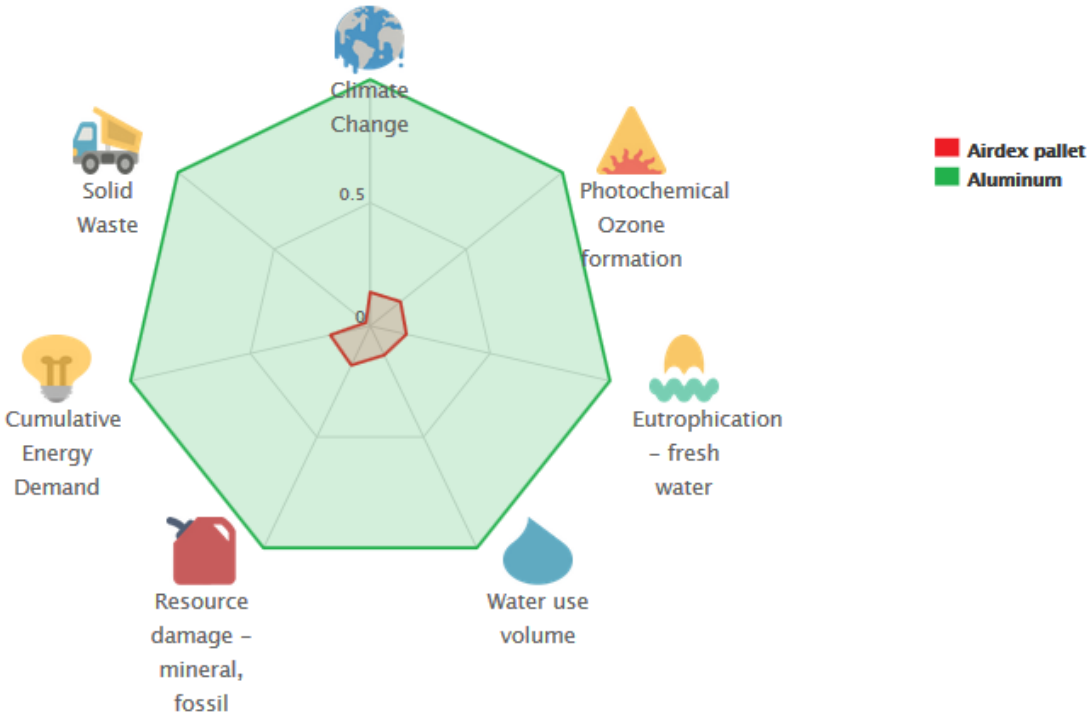
Graph 1b: AirPallet™ vs the GMA Wood Pallet



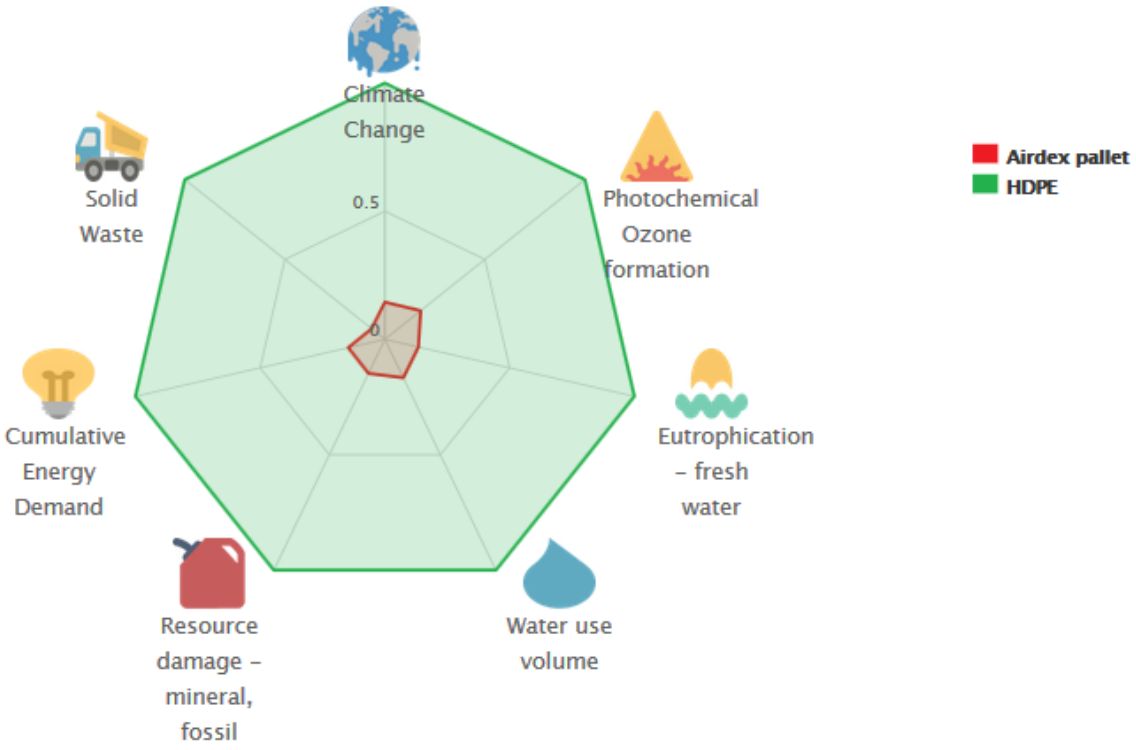
Graph 1c: AirPallet™ vs the China Wood Pallet



Graph 1d: AirPallet™ vs the Aluminum Pallet



Graph 1e: AirPallet™ vs the HDPE Pallet



The Table 2 below summarizes the scale (in %) of the impact comparisons presented in the graphs above. The table shows the **environmental impact increase** (or reduction, for the negative values) when comparing the listed pallets' performance to that of the reference scenario (the AirPallet™).

Table 2: Relative Performance Snapshot

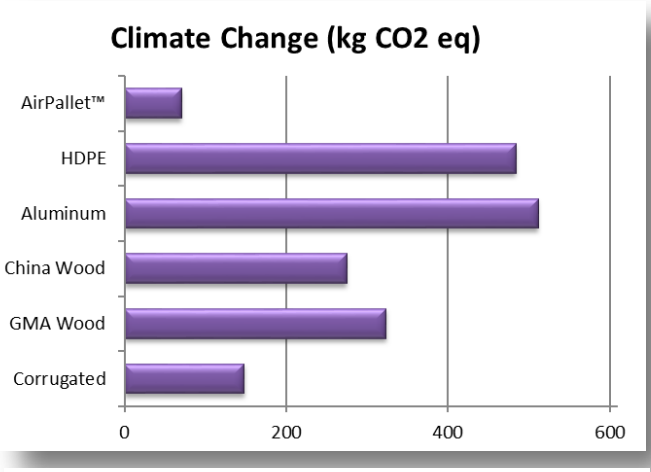
	Climate Change	Cumulative Energy Demand	Minerals & Fuel	Photochemical Oxidation	Eutrophication	Water Use	Solid Waste
Corrugated vs AirPallet™	+111%	+87.9%	+79.3%	+115%	+134%	+2.6%	+441%
GMA Wood vs AirPallet™	+387%	+307%	+301%	+408%	+418%	-51.8%	+1,449%
Aluminum vs AirPallet™	+629%	+501%	+465%	+533%	+562%	+661%	+4,424%
HDPE vs AirPallet™	+589%	+583%	+577%	+459%	+644%	+500%	+1,403%
China Wood vs AirPallet™	+291%	+229%	+226%	+316%	+324%	-77.6%	+1,084%

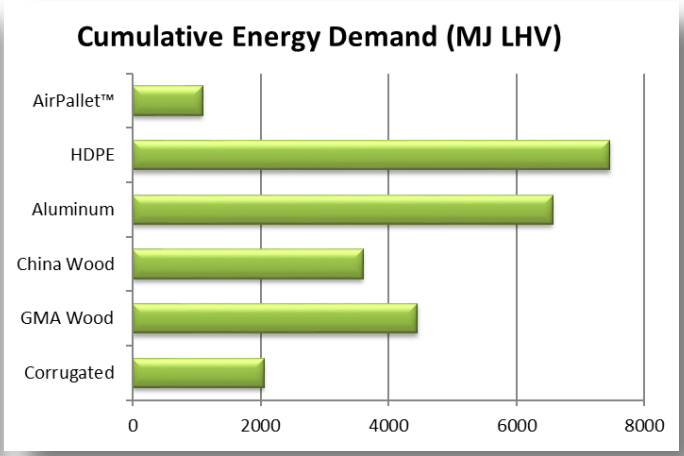
The values for the ***Life Cycle Impacts*** are presented in Table. The comparison graphs are shown below. A lower environmental Impact represents a better result.

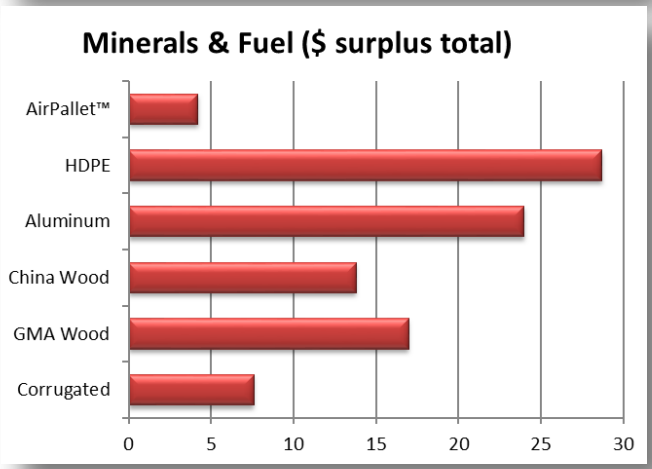
Table 3: Life cycle impacts - per annum - per 1 unit

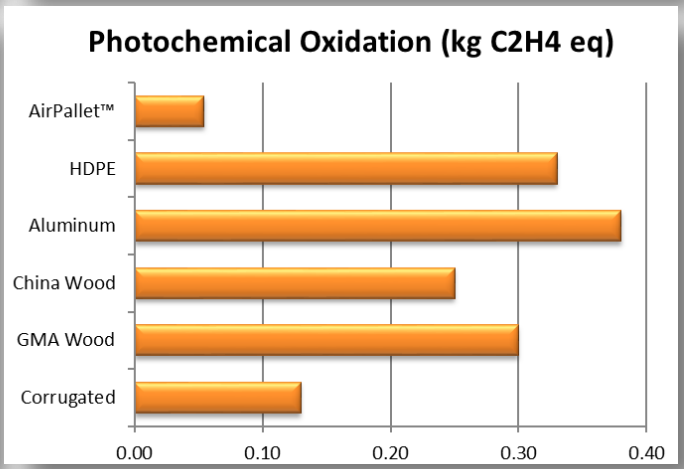
Pallet Configuration Name	Climate Change (kg CO2 eq)	Cumulative Energy Demand (MJ LHV)	Minerals & Fuel ($ surplus total)	Photochemical Oxidation (kg C2H4 eq)	Eutrophication (kg PO4 3- eq)	Water Use (kL H2O)	Solid Waste (kg)
Corrugated	148.000	2054.000	7.600	0.130	0.130	0.620	3.500
GMA Wood	323.665	4449.000	17.000	0.300	0.280	0.290	10.100
China Wood	275.000	3601.000	13.800	0.250	0.230	0.140	7.500
Aluminum	512.000	6569.000	24.000	0.380	0.360	4.600	29.500
HDPE	484.000	7461.000	28.700	0.330	0.400	3.700	9.800
AirPallet™	70.300	1093.000	4.200	0.054	0.059	0.610	0.650

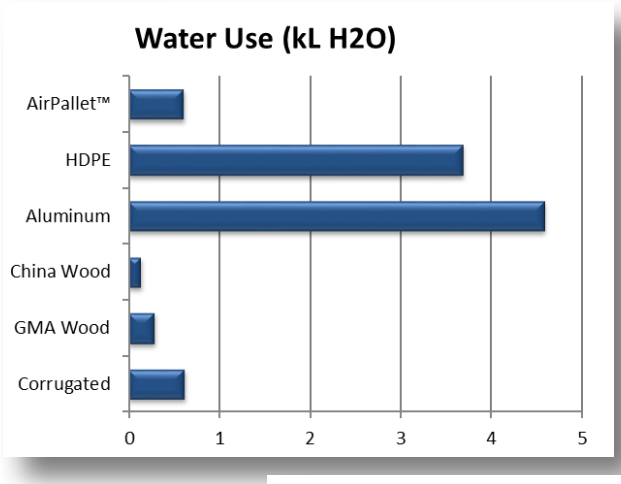
Impact Assessment Indicators – Comparative Graphs

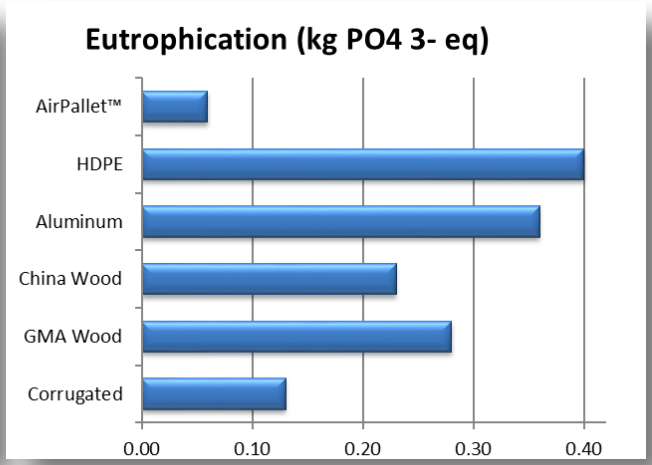


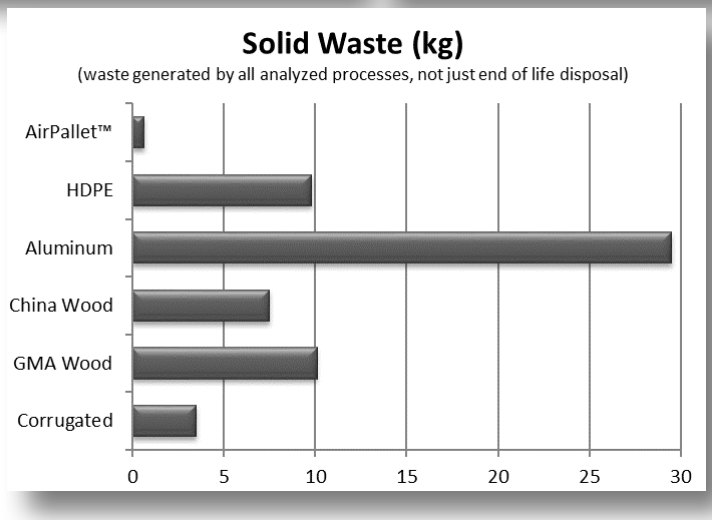








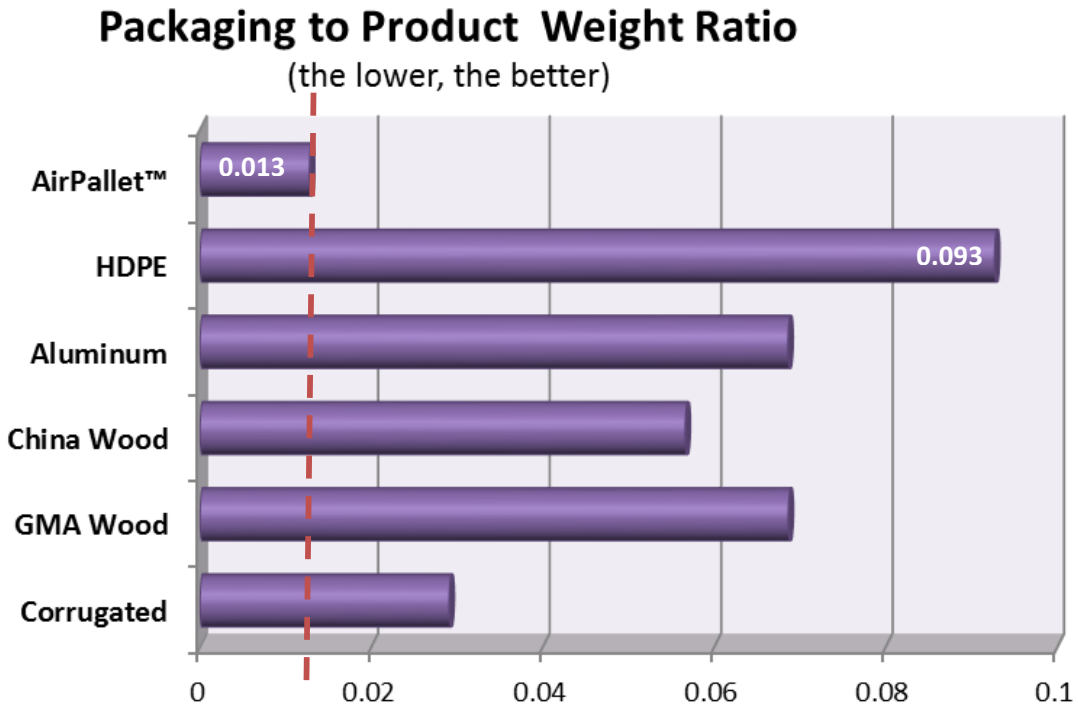




As shown above, and noted in the "at a glance comparison", especially when including the impact of air shipment, the AirPallet™ is dramatically outperforming other systems in all metrics except for Water Use (not impacted by shipping by air). In other words, producing and using (shipping merchandise by air) the AirPallet™, has the least impact of all analyzed systems on the climate change indicator (effects resulting from the emission of six greenhouse gases – above calculated in equivalent CO_2 emissions), on the Cumulative Energy Demand, on photochemical oxidation (measurement of the increased potential of photochemical smog events due to the chemical reaction between sunlight and specific gases released into the atmosphere), on eutrophication (mainly the release of phosphorus and nitrogen into fresh water systems, causing related toxic effects), and the generation of solid waste by all the life cycle phases included. Also, because of the very light weight compared to the other pallets, the "Mineral and Fuels" metric becomes another indicator where the AirPallet™ does much better than the other systems, although in previous lifecycle phases it uses more fossil fuels.

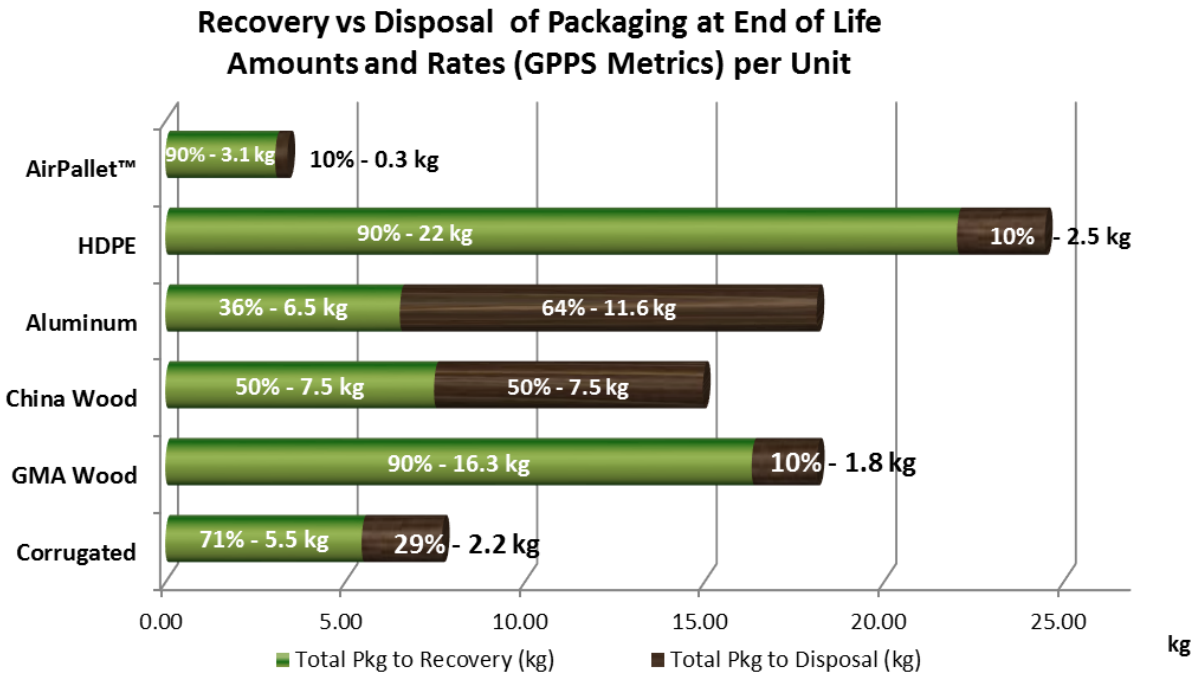
As noted above, for the Water Use indicator, the AirPallet™ performs closely to the fiber-based systems, since this metric is not influenced by the transportation phase. The conversion and sourcing processes used for EPS are more water-intensive.

The ***Packaging Specific Indicators*** below show the fact that the AirPallet™ has the best packaging to product weight ratio out of all the analyzed systems – and this is in the case when it is assumed that it holds the same amount of product (264 kg in the graph below), yet the total weight of the pallet is much lower. This difference can become even more dramatic in the case when, because of the light weight of the pallet, additional product weight can be added, and still be acceptable as total weight for air transportation.



In terms of ***end of life recovery versus disposal***, (the Recovery Rate includes incineration with energy recovery, composting and recycling, while the Disposal Rate includes incineration without energy recovery, as well as landfilling), the results of the analysis are presented in the graph below. As noted, some of the waste versus recovery data was based on client input, while some was default PIQET info.

Note that the graph below is showing both the percentage of the pallet weight that would be landfilled (vs recovered), but also the actual amount (weight) of material that would end up in landfill. As a consequence, for the heavier systems that are assumed to be recovered at the same high rate as the AirPallet™ (only 10% landfill), the amount disposed of in landfill is, of course, larger. For example, 10% of the AirPallet™ would mean 0.3 kg of landfilled material, while 10% of the HDPE pallet would imply that about 2.5 kg of material would end up in the landfill. Similarly, about 1.8 kg of the wood material from one GMA pallet would be landfilled.


Recovery vs Disposal of Packaging at End of Life
Amounts and Rates (GPPS Metrics) per Unit
AirPallet™
HDPE
Aluminum
China Wood
GMA Wood
Corrugated
90% - 3.1 kg
10% - 0.3 kg
90% - 22 kg
10% - 2.5 kg
36% - 6.5 kg
64% - 11.6 kg
50% - 7.5 kg
50% - 7.5 kg
90% - 16.3 kg
10% - 1.8 kg
71% - 5.5 kg
29% - 2.2 kg
0.00
5.00
10.00
15.00
20.00
25.00
kg
Total Pkg to Recovery (kg)
Total Pkg to Disposal (kg)