FederlegnoArredo/Assoimballaggi

Life-cycle analysis (LCA) of an EPAL pallet

EPAL 800 x 1200 mm pallet

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Foreword

FederlegnoArredo/Assoimballaggi has commissioned a project for a "cradle-to-grave" life cycle assessment/analysis (LCA) of the EUR/EPAL pallet (Figure 1).

One of the aims of the project is to highlight the environmental benefits of using EUR/EPAL pallets in a system based on the exchange and pooling of pallets as opposed to a system with no exchange and pooling.

The work was carried out with the collaboration of the commissioning party, who helped obtain information from a number of producers (both with and without a sawmill) and from pallet repairers.

The LCA of the EUR/EPAL pallet was carried out pursuant to the current ISO standards. Specifically, the two LCA reference standards used were: ISO 14040:2006[1] and ISO 14044:2006.[2] As required by the relevant ISO standards, the analysis was conducted over four stages: Goal and scope definition; Life cycle inventory analysis (LCI); Life cycle impact assessment (LCIA); and Life cycle interpretation.

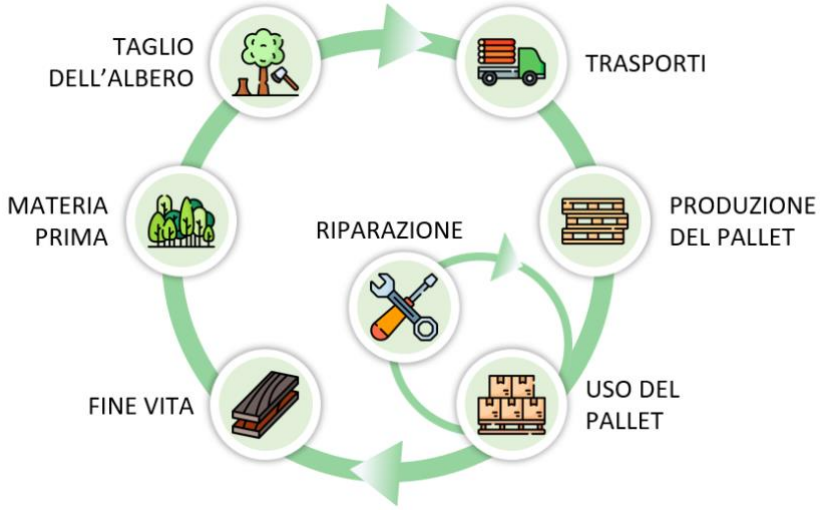

Figure 1 – Pallet life cycle

General information

Product

EPAL 800 x 1200mm pallet

Declared unit

The production of an EPAL 800 x 1200 pallet

Description

An EPAL pallet is a packaging product that is used in logistics for the transporting of various sorts of product between producers, retailers and consumers, as well as for warehouse storage and other purposes. The EPAL pallet was designed to respond to the need for a standard that both optimizes the use of space and expedites the handling of loads.

An EPAL pallet consists mainly of wooden boards that vary in length, width, height, weight and load capacity. Accordingly, the number of boards, nails and blocks used in each type of pallet varies, but the materials used are the same.

Product specifications

An EUR/EPAL pallet conforms to the EN 13698-1:2003 standard,[3] which specifies the construction criteria and therefore also the dimensions. The particular product subjected to analysis here measures 1,200 x 800 mm, usually weighs around 25 kg, and supports dynamic loads of up to 1,500 kg. Its static load capacity (i.e. the load rating for a pallet that is not moved) can reach 4,000 kg.

The main components as listed in Table 1 refer to a single 800 x 1200 mm EPAL pallet with an average weight of 25 kg. This value is to be considered indicative, for the actual weight will vary in accordance with the moisture content and the type of wood used. The nominal weight may vary from the actual weight by as much as 30% after drying.

Table 1 – Composition of an 800 x 1200 EPAL pallet

Piece	Number of pieces	Dimensions (mm)
Bottom deck board	2	1200 x 100 x 22
Top deck board	2	1200 x 145 x 22
Centre deck board	1	1200 x 145 x 22
Stringer board	3	800 x 145 x 22
Centre stringer board	1	1200 x 145 x 22
Inner deck board	2	1200 x 100 x 22
Block	6	145 x 100 x 78
Block	3	145 x 145 x 78
Wood screw with countersunk head or threaded nail	42	M 5.5 x 90
Wood screw with countersunk head or threaded nail	18	M 5.5 x 38

Technical data

The EPAL pallet subject to analysis measures 800 x 1200 mm and its main components are listed in Table 2. The total weight of the pallet can vary according to the type of wood used and the degree of humidity. Further, the standard specifies only that chipboard blocks must have a density greater than 580 kg/m^3.

Table 2 – Composition of an 800 x 1200 EPAL pallet

Type	Amount	UM
Wooden boards	0.033	m^3
Chipboard wood blocks	0.012	m^3
Steel nails	0.340	kg

Market

The EPAL 800 x 1200 pallet that was examined in this analysis is representative of the type produced in Italy. Data was collected from different manufacturers, most of them in northern Italy, who can be subdivided as follows:

- two manufacturers with a sawmill,
- four manufacturers without a sawmill,
- two pallet repair firms.

Service life

Based on information provided by industry experts, the following premises were assumed:

- Useful life: 5 years.
- Rotations: 25 journeys over 5 years of useful life.
- Repairs: 5 during the period of useful life

LCA: Calculation rules

Functional/Declared Unit

The declared unit (DU) of the analysis is an EPAL pallet measuring 1200 x 800 mm.

The initial grounds for opting to use a declared unit are that some uncertainty exists both in respect of the distances travelled by an EPAL pallet during its life and in respect of the type of vehicle used for transportation. With regard to the latter, the data presented here do not refer to the transport/shipment of goods during the useful life of the unit. Transportation will be subject to a sensitivity analysis in the extended report.

A careful analysis of the literature has shown that Europe has no specific product category rules (PCR) for pallets, and certainly not for exchange pallets. In some cases, the PCR for generic packaging have been used instead. To date, only one specific set of PCR has been developed for wooden pallets - though not for exchange pallets - and they refer to the USA (https://www.shopulstandards.com/).[4] The PCR for wooden pallets form the basis for the environmental product declaration (EPD)[5] used in the USA (https://www.fpl.fs.usda.gov/documnts/fplrp/fpl_rp707.pdf).[6,7] For the purposes of the PCR used in the USA, a functional unit has been defined with reference to the number of pallets needed to transport a certain quantity of goods (42.4 tons).

Data quality

The quality of the data used can be deemed generally acceptable. All the major processes are represented through good quality data that conform to ISO 14044[2] and ISO 14025[5] standards. The quantitative data relating to raw materials, the provenance of supply, and the processes for the transformation of the raw materials by the Italian producers interviewed for the study are derived from company reports for 2020.

In general, the background data are of high quality. Almost all the data refer to Europe, and those relating to energy use are country-specific. Most of the datasets are only a couple of years old, and diverse production technologies are well represented. In compliance with the requirements of the EN 15804:2012+A2:2019 standard,[8] manufacturer-specific data were used for processes that can be directly affected by the producer's manufacturing/processing facility. For upstream processes, secondary data were used. The source of the secondary data is the Ecoinvent 3.8 database (https://ecoinvent.org/). The cut-off model was used for the

quantification of environmental credits and impacts relating to recycled content and recyclable material. The modelling of the whole process was carried out using SimaPro 9.5.0.1 software (https://simapro.com/).

Allocation

All the environmental impacts associated with forestry are allocated to the use of logs, and none to forestry waste products (branches and tops). Pursuant to the EN 15804:2012+A2:2019 standard,[8] the environmental impact of outputs resulting from downstream processing (e.g. at the sawmill) that are sold as separate co-products is determined on the basis of mass allocation.

Economic allocation is used to measure the impact of sawmill activities. Economic allocation considers the revenues derived from the sale of wooden boards and sawdust and is applied to all sawmill activities. Of the total environmental impact of sawmill activities, 93% is allocated to sawn lumber and the remaining 7% to sawdust sold for the making of wood pellets. Bark is sometimes used to produce fertilizer, but not by the Italian producers included in the scope of the analysis, for which reason it was excluded from the economic allocation.

System boundaries

System boundaries include the cradle-to-grave approach: pallet production (A1-A3), distribution (A4), use and repair (B1-B2), and end of life (C1-C4). The abbreviated terminology derives from the EN 15804:2012+A2:2019 standard[8], and is now regularly used by many sectors other than construction, for which it was originally developed. The details of the system boundaries are given in Figure 2, which also shows the abbreviations used to refer the different phases of the life of a pallet. The description of each phase is given in

Table 3. Of the pallet producers in Italy, an estimated 20% possess in-house sawmills and 80% do not.

Cut-off/exclusion criteria

The general rules for the exclusion of inputs and outputs follow the requirements of the EN 15804+A2, 6.3.5 standard, which specifies that the total of disregarded input flows per module must not exceed 5% of energy and mass consumption or, for unit processes, 1% of energy and mass consumption. In particular, the packaging used for the transport of raw materials and semi-finished products was excluded, while, in line with the 'polluter-pays' principle, waste treatment was included in every stage or process unit of the product's life cycle.

Impact analysis method

For the assessment of impacts, the characterization method laid out in the EN 15804:2012+A2:2019[8] standard was used. It includes 13 main environmental impact categories, to which others may be added. The main impact categories are as follows:

- Total GWP: Total global warming potential;
- Fossil-GWP: Fossil-fuel global warming potential;
- Biogenic GWP: Biogenic global warming potential;
- GWP-LULUC: Global warming potential from land use and land use change;
- ODP: Ozone depletion potential (loss of stratospheric ozone);
- AP: Acidification potential;
- Freshwater EP: Freshwater eutrophication potential - the fraction of nutrients reaching the terminal freshwater compartment;

- Marine EP: Marine eutrophication potential - the fraction of nutrients reaching the terminal saltwater compartment;
- Terrestrial EP: Terrestrial eutrophication potential;
- POCP: Photochemical ozone creation potential;
- ADP-M&M: Abiotic depletion potential of non-fossil resources (minerals and metals);
- ADP-fossils: Abiotic depletion potential of fossil resources;
- WDP: Water deprivation potential, water consumption weighted with reference to the potential for deprivation.

Additional categories include:

- PM: Particulate matter emissions;
- IRP: Ionizing radiation potential;
- HTP-c: Human toxicity potential - carcinogenic effects;
- HTP-nc: Human toxicity potential - non-carcinogenic effects;
- ETP-fw: Ecotoxicity potential in fresh water;
- Impacts related to land use/soil quality.

The reference standard also requires the mandatory reporting of resource consumption for construction materials and products.

Confini del sistema

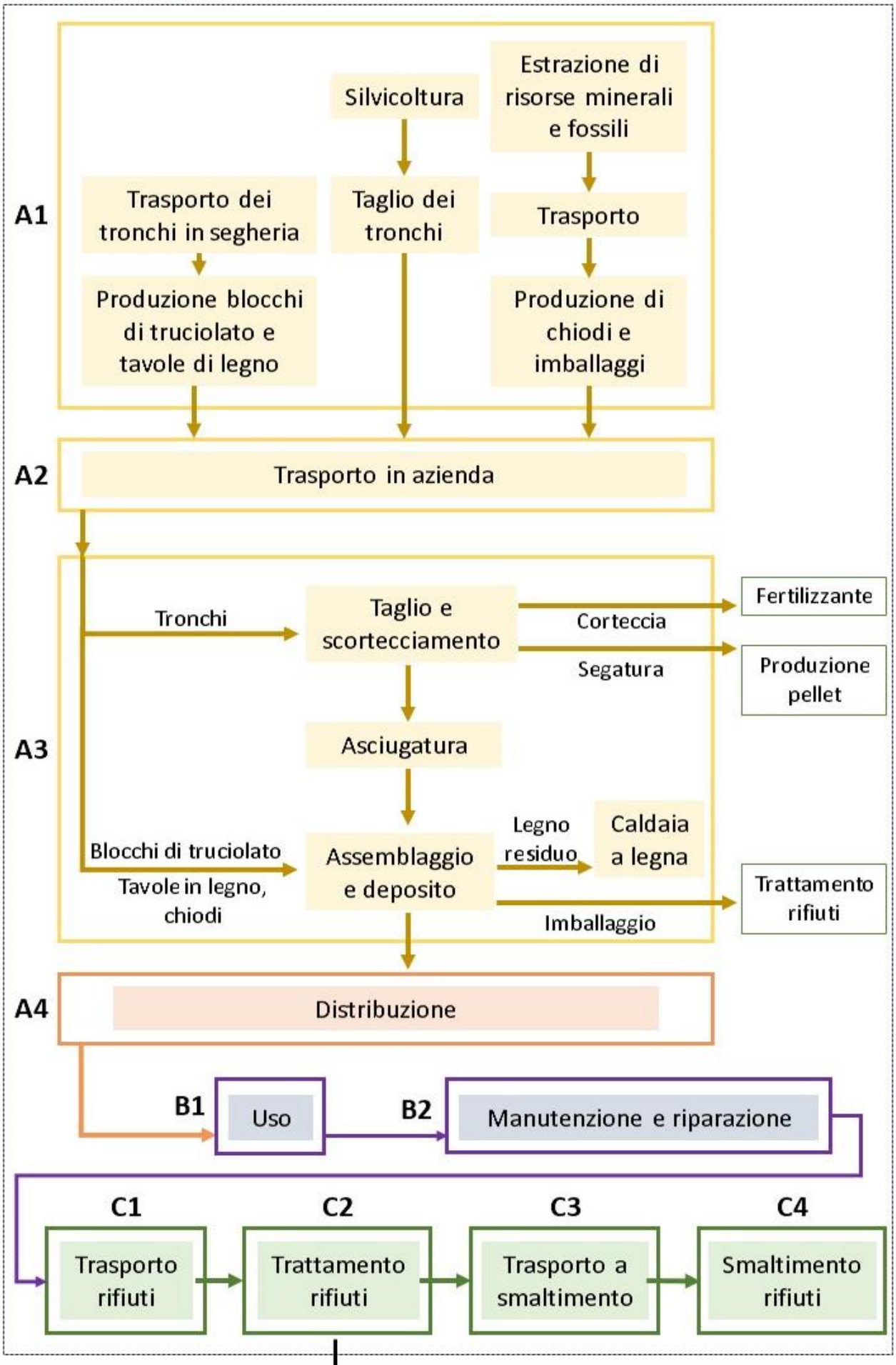

Figure 2 – System boundaries of the EPAL pallet

Table 3 – Description of the life stages of the pallet

Life cycle stage	Module	Notes
Production of raw materials and semi-finished products	A1	Planks, steel nails and chipboard blocks
Transportation of materials from the final processing site to the pallet manufacturer	A2	Road transport using EURO 6 vehicles
Pallet production	A3	Producers with in-house sawmill (20%) and producers without in-house sawmill (80%)
Distribution	A4	Road transport of the pallet from producer to consumer
Use	B1	Use of pallet for transport of goods or for warehouse storage of goods
Maintenance and repair	B2	Repairers
End of life of pallet	C1	Transport of the pallet at end of life to the collection centre
	C2	Treatment of the pallet at the end of its life, for example disassembly and separation of pieces, transportation to a materials recycling centre
	C3	Transport to disposal facility (incinerator, landfill, composting plant)
	C4	Incineration, landfill, composting
Benefits and environmental impacts deriving from subsequent life	D	Avoided production of thermal and/or electrical energy, recycling of ferrous material (nails), recycling of wood

LCA: Scenarios and additional technical information

The following describes scenarios relating to the different modules used in the LCA.

Transportation scenarios

The transportation of raw materials and semi-finished products (A2) is effected by road vehicles, and forms part of the primary data provided by the companies interviewed. The A4 module refers to the transport between the EPAL pallet manufacturing plant and a specific customer. This type of data is variable and depends on the specifics of the case. For this reason, an average distance of 100 km was chosen as being representative of the sort of distance typical for Italy.

The same variability also applies to the modelling of end-of-life transportation, for which an average distance of 50 km from final user to the disposal centre was used. Module C1 refers to waste collection as well as transportation for recycling and energy recovery.

Based on the opinion of industry experts, the useful life stage of the pallet can be assumed to be 5 years, inclusive of, on average, one repair per year and 25 journeys over its entire life. It is difficult, however, to determine the distance covered in the various journeys or, therefore, the total distance covered during its service life.

End of life (C2)

Waste treatment modelling is based on the results of the **Rilegno Report 2023** (https://www.rilegno.org/report-2023/). The report states that of the total number of pallets placed on the market per year, 62.74% are recycled. Recycled wood packaging that is not regenerated has three possible destinations: it may be recycled as new raw material, designated for composting, or used for energy recovery. Regeneration is effected by repairers who make the pallet available for use again. Based on the findings of the report mentioned above and on the assumption that each pallet reaches its end of its life without being disposed of in the environment, the percentages are as shown in Table 4.

Table 4 – Pallet end of life scenario

Type	%	Notes
Recycled into raw material	92.43	Recycling provides secondary raw material for the production of wood panels
Composting	3.05	Soil production
Energy recovery	4.52	Incineration enables the production of thermal energy, as well as of electricity when carried out in cogeneration plants

Benefits and impacts beyond system boundaries (D):

The benefits and impacts beyond system boundaries are calculated from the net flows sent for incineration and recycling. The energy recovered from incineration replaces the heat generated by boilers that use the most common fuel type: natural gas. The model refers to a small boiler. Electricity cogeneration was not considered because it does not apply to the Italian situation.

Wood sent for recycling mainly replaces the raw material for the production of chipboard panels. Nails are recycled as scrap iron for the production of new steel.

Table 5 – Benefits deriving from the recycling of end-of-life EPAL pallets

Type	UM	Amount
Substitution of virgin wood chips for the production of panels	kg	27.5
Substitution of ferrous raw material for steel production	kg	0.340
Substitution of thermal energy	MJ	67.6

LCA: Results

The following section lists the environmental impacts calculated according to EN 15804:2012+A2:2019[8] specifications for the main indicators (Table 6), as well as several additional indicators. The results are presented per declared unit (DU), and, for simplicity's sake, scientific notation is used: i.e. 9.0 E-03 = 9.0*10-3 = 0.009.

Table 6 – Impact analysis per DU, main indicators

Indicator	Unit of measure	A1-A3	A4	B1-B2	C1-C4	D
GWP-total	kg CO_2 eq	-2.15E +01	1.89E-01	4.72E+00	1.83E +01	-9.27E +01
GWP-biogenic	kg CO_2 eq	-3.16E+01	5.91E-05	-1.37E+00	1.71E+01	4.98E+01
GWP-fossil	kg CO_2 eq	1.00E+01	1.89E-01	6.07E+00	1.14E+00	-1.42E+02
GWP-LULUC	kg CO_2 eq	3. 36E-02	3.83E -06	1.55E-02	5.29E-04	-7.73E-02
ODP	kg CFC11 eq	2.54E-07	4.23E-09	1.32E-07	2.30E-08	-6.37E-06
AP	mol H^+ eq	3.42E-02	2.44E-04	2.53E-02	8.51E-03	-8.67E-02
EP-fresh water	kg CO_2 eq	5.80E-04	1.54E-07	3.72E-04	2.41E-05	-1.16E-03
Marine EP	kg CO_2 eq	1.03E-02	5.99E-05	7.30E-03	2.71E-03	-2.97E-02
EP-terrestrial	mol N eq	1.14E-01	5.80E-04	8.03E-02	3.79E-02	-3.22E-01
POCP	kg NMVOC eq	5.56E-02	4.58E-04	3.53E-02	8.60E-03	-2.45E-01
ADP-minerals and metals	kg Sb eq	4.85E-06	6.72E-09	1.22E-05	7.46E-08	-1.10E-06
ADP-fossil	MJ	1.56E+02	2.60E+00	8.40E+01	1.72E+01	-2.04E+03
WDP	m^3 depriv.	2.80E+00	2.38E-03	1.43E+00	-3.03E-03	-1.30E+00

The reference standard[8] requires a compulsory declaration of the global warming potential (GWP) of the main components: fossil, biogenic and the land use/land use change.

Additional environmental impact indicators

The additional impact indicators need to be treated with caution because the characterization methods have not yet been solidly established at an international level and the results are susceptible to considerable uncertainty (Table 7).

Table 7 – Impact analysis per DU, additional indicators

Indicator	Unit of measure	A1-A3	A4	B1-B2	C1-C4	D
PM	disease inc.	1.03E-06	1.49E-08	5.22E-07	9.79E-08	-2.26E-07
IRP	kBq U-235 eq	1.96E-01	4.14E-04	1.25E-01	5.52E-02	-5.03E-01
HTP-c	CTUh	4.37E-08	1.29E-11	3.35E-08	4.10E-10	-8.28E-09
HTP-nc	CTUh	9.17E-08	1.71E-09	8.16E-08	1.64E-08	-1.09E-07

Resource use

The data for resource use are taken from the product system inventory and include the following indicators:

- PERE: Renewable primary energy excluding renewable primary energy resources used as raw materials
- PERM: Renewable primary energy resources used as raw materials
- PERT: Total use of renewable primary energy resources

- PENRE: Non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
- PERNM: Non-renewable primary energy resources used as raw materials
- PENRT: Total use of non-renewable primary energy resources
- SM: Secondary materials
- RSF: Renewable secondary fuels
- NRSF: Non-renewable secondary fuels
- W: Freshwater net use

Table 8 – Use of resources per DU

Indicator	Unit of measure	A1-A3	A4	B1-B2	C1-C4	D
PERE	MJ	515.58	0.01	238.31	1.32	-576.04
PERM	MJ	511.06	0.00	233.98	0.15	-564.74
PERT	MJ	1026.64	0.01	472.28	1.47	-1140.78
PENRE	MJ	159.47	2.53	93.44	15.91	-2112.76
PENRM	MJ	0.00	0.00	0.00	0.00	0.00
PENRT	MJ	159.47	2.53	93.44	15.91	-2112.76
SM	kg	0	0	0	0	0
RSF	MJ	0	0	0	0	0
NRSF	MJ	0	0	0	0	0
W	m^3	8,68E-02	1,09E-04	4,96E-02	5,00E-03	-7,19E-02

End of life – waste

Pursuant to the EN 15804 standard,[8] waste at the end of life was calculated for each life stage. Waste is divided into the following three categories:

- Hazardous waste (HW)
- Non-hazardous waste (NHW)
- Radioactive waste (RW)

Table 9 – Production of waste per DU

Indicator	Unit of measure	A1-A3	A4	B1-B2	C1-C4	D
HW extension	kg	7.89E-04	1.72E-05	4.48E-04	8.52E-05	-8.73E-03
NHW	kg	3.70E-01	1.28E-04	9.07E-01	1.46E-02	-1.28E-01
RW	kg	1.56E-04	2.23E-07	9.49E-05	4.12E-05	-3.85E-04

End of life – output flows

Finally, the EN 15804 standard[8] requires an explicit declaration to be made of the output flows at the end of life for each phase of the cycle.

These output flows are divided into:

- CR – Components for Reuse
- MR – Materials for Recycling
- MER – Materials for Energy Recycling
- EEE – Exported Electrical Energy
- EET – Exported Thermal Energy

In the production phase, part of the sawdust and wood waste is reused in the sawmill, which thus operates a closed-loop recycling process. The excess sawdust is sold for the production of wood pellets. In this second case, the sawdust sold was accounted for by means of economic allocation and was therefore removed from the product system. For this reason, no recycled materials (MR) result from stages A1-A3, as may be seen in Table 10.

Table 10 – Output flows at end of life of DU

Indicator	Unit of measure	A1-A3	A4	B1-B2	C1-C4	D
CR	kg	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	27.80	0.00
MER	kg	0.04	0.00	1.09	1.35	0.00
EEE	MJ	0.00	0.00	0.00	0.00	0.00
ETE	MJ	0.00	0.00	0.00	0.00	0.00

Information concerning biogenic carbon at the production stage

Being mainly made of wood, an EPAL pallet has a high biogenic carbon content. It is sold without any packaging, in which respect it has zero biogenic carbon content. One kilogram of carbon is equivalent to 44/12 kg of CO_2.

Table 11 – Biogenic carbon content

Biogenic carbon content	Value	Unit of measure
EPAL 800 x 1200 pallet	14.7	kg
Packaging	0	kg

Conclusions

Thanks to the use of natural materials (wood) and the recycling chain, an EPAL 800 x 1200 pallet has a very low environmental impact over its life.

- Its lifetime carbon footprint is very small.
- Other environmental impact indicators are likewise low.
- It has a high circularity index thanks to the supply chain run by Rilegno in Italy and thanks to the fact that it is made up of easily recyclable materials (wood and steel).
- Accounting also for recycling and the energy recovery at the end of its life, an EPAL pallet even qualifies as "carbon negative" in that it allows significant savings of CO_2- equivalent emissions.

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