Environmental impact of using EUR-size wooden and plastic pallets

measured by generated carbon footprint and solid waste.

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Abstract

The paper addresses environmental impact of using pallets and compares the performance of plastic and wooden pallets regarding to carbon footprint and waste, they produce.
Common wisdom has it, that wooden pallets are environmentally friendly. Plastic pallets, due to the material they are being made of, are regarded to be a potential source of pollution in land, air, and water. We have gathered, evaluated, extracted and/or calculated data showing how much CO_2, and solid waste is generated due to specific wooden and plastic pallet operations. The Life Cycle Assessment method has been used, with primary data extracted from our own studies and experience or taken from reputable sources we quote in our work.

Keywords

circular economy, carbon footprint, waste, pallets.

Presenters Profile

Msc Krzysztof Witos, economist, logistician, inventor (holding patent for a plastic pallet system), entrepreneur, and researcher interested in resource management and network efficiency, PhD student in Warsaw School of Economics. Participating in research and development projects, e.g., "Local government level support instruments for SMEs, based on the model of multi-level regional management (REGIOGMINA)", “Conditions enhancing creation and development of the so-called "smart society”. Involved in issues related to reverse logistics, waste management, recycling, reusing, and remaking. Follows and readily quotes professors Kaplan’s statement “if you can’t measure, you can’t manage”.

Professor Zbigniew Grzymała and Doctor Agnieszka Wójcik - Czerniawska are employees of the Warsaw School of Economics. As employees of the Department of Economics and Finance for Local Government, they deal with the issues of sustainable development in a very broad sense.

1. Introduction

Pallets are common assets in the range of logistic tools, applied to maintain efficiency in storage and transportation of goods. They are used across all industries, and all means of transportation. Pallets made of wood have prevailed in the market. They are standardized, easy to manufacture, common to use and swap, and - until recently - relatively cheap. Timber has been regarded as environmentally friendly material obtained from seemingly inexhaustible source: trees growing without any limitations in our forests. Common wisdom has it, that wooden pallets withdrawn from operations, can be burned, or can rot without adversely affecting nature.

Plastic (and metal) pallets have also been used for quite some decades by now, though on smaller scale than their wooden counterparts. They vary in construction and performance characteristics. Generally, they have been regarded as more durable and simultaneously more expensive than wooden ones. Manufacturing plastic pallets requires relatively high investment in molding machines and high material costs of oil and/or gas-derived plastic granulate. Public opinion is not in favor of plastics, accusing it to be the source of pollution in land, air, and water. Pictures of plastic items floating on ocean surface, or black smoke coming from plastic incineration, we can find in the media are all too common, not to be addressed, unless we agree that sustained development, and the need to care for environment are just empty phrases.

We have come across common judgements of plastic goods adversely affecting our environment, based on opinions with often limited if any data to back them. We, instead, wanted to check and present data, refraining from expressing our opinion, let alone a firm judgement, ready to accept critics and corrections to the method we applied and results we have achieved. Should the results stand the critics and appear generally correct, we would be glad to proceed and participate in implementing advantages of plastic pallets, reflected by the outcome of our research.

Our intention has been to gather, check, extract and/or calculate data showing how much CO_2, and solid waste is generated due to specific wooden and plastic pallet production and operations. We have been relaying on our personal experience and research, as well as literature available. We accept that others' experiences may be different; all are welcomed to test our model with their own scenarios and compare results.

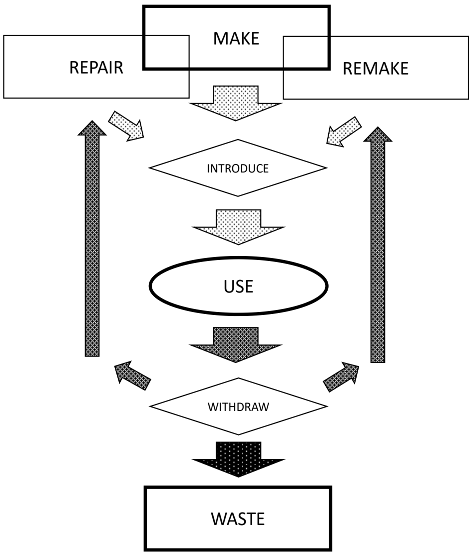
2. Methods

Pallets are “made to work” - facilitate storing and transporting of goods. Our goal is to provide a transparent account of the environmental impact of making, using, and wasting different pallets, along their lifetime, in relation to the work they have done. Sourcing raw materials, manufacturing elements, assembling pallets, working with them, and finally disposing of them, requires energy, and generates emissions and waste. Ultimately, we want to compare total CO_2 emissions and solid waste generated by pallets, against the number of trips completed with their use.

Our model is based upon LCA[1] approach. We have cumulated the energy needed to source materials and the energy to assemble/mold a Ready to Use (R2U) object – the pallet. All energy in the **MAKE** process has been treated as electrical energy and denominated in kWh. Generating electricity produces carbon dioxide: 0,7733 kg CO_2 / 1 kWh (data for Poland). The CO_2 emissions of the **USE** phase are function of pallet weight, distance driven and fuel (diesel oil) consumption. **WASTE** is seen in two dimensions: CO_2 emissions deriving from material decomposition, and solid waste, both in kg.; they make up for the whole waste.

2.1. Model

Graph 2.1



The **MAKE** phase yields a Ready to Use pallet (R2U). A pallet will be assigned the R2U status, following one of the processes: manufacturing from original/virgin materials or elements, repairing - using both new and/or recovered elements, and remanufacturing - using materials from previously used, recycled items.

Each of these processes may require different inputs and result in specific waste generated volumes.

When R2U state is observed, action: INTRODUCE is executed, and pallets are made available for the Use phase.

The **USE** phase embraces all activities that pallets have been made for. Pallet life cycle and their "productivity" vary, depending, among others, upon the way they are being used. For the Reference Service Life (RSL), a synthetic measure of pallet productivity, durability, and longevity, we have adopted the average number of trips (issues) executed within pallet's lifetime. The USE phase CO_2 emissions volumes are a function of pallet weight, distance driven and fuel (diesel oil) consumption. Different conditions and pallet type could produce different RSL levels. A pallet that cannot be used due to technical reasons is regarded as defected - DFC. When DFC state occurs, action WITHDRAW is executed. DFC pallets, withdrawn from use are redirected to repair, or to remanufacture, or to waste.

The **WASTE** phase embrace: recycling - resulting with materials that would be applied in industries other than pallet manufacturing, incineration – burning for heat and/or energy production, landfilling – using time and space for wasted product/material to biodegrade.

[1] Life cycle assessment or LCA (also known as life cycle analysis) is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave)- http//:www.wikipedia.org; [access: 01/07/2021]

2.2. Scope

2.2.1. Pallet choice

Pallets, we find in the market, vary substantially. Materials used, the construction concept, load capacity, current condition, etc. determine if and where we can use them safely. Many of them are used only once. Some are earmarked for light weights only. We limit our interest to returnable pallets, used in the **FMCG and Retail Goods** industries. These require relatively high weight capacity, and robust pallets, that can stand multiple handling operations with different goods bestowed on the way from a Manufacturer to a Sales Point, which may be hundreds of kilometers away, along the supply chain system. Saving precious warehouse space, palletized goods are stored in high racks. Low quality, low capacity, and one-way pallets are out of scope of our study.

2.2.2. Pallet circulation

Palletized goods are sent from Manufacturer to Distribution Centre and ultimately delivered to Sales Point. It is common for Manufacturer and Distribution Centre to keep goods in high storage racks, demanding adequate capacity and quality from pallets used. Various types of vehicles are used for transport and distribution; however, our model is based on commonly used transport unit: a truck tractor and 13,6 m trailer, that can carry 33 pallets with approximately 24.000 kg load, stowed 2,60 m high. This type of vehicle offers favorable ratio of fuel consumption to carried load weight. We assume this transport unit consumes, as per 100 km, 21 liters of fuel - empty, plus 0,4 liters - for every ton of load carried. Considering the maximum authorized vehicle weight[2], we assume an average single pallet load as 800 kg, carried from a Manufacturer's location to a Distribution Centre - a 100 km drive, and from a Distribution Centre, further to a Sales Point - another 100 km. One full working cycle consists of a pallet loaded and carried 200 km, then empty returned same 200 km back. While real life scenarios may vary, the proportions of energy (fuel) consumption for transportation of wooden and plastic pallets, remain. Using discrete measure of 100 km may be helpful to make individual calculations. We assume that burning 1 liter of diesel fuel generates 2,64 kg CO_2 emissions[3]. Apart from the transport itself, no other activities e.g., using forklift /crane, generating emission, have been taken into consideration in the model.

[2] European COUNCIL DIRECTIVE 96/53/EC

[3] Polska Agencja Rozwoju Przedsiębiorczości, https://www.parp.gov.pl/storage/grants/documents/103/Wytyczne-dotyczce-konwersji---emisje-gazw-cieplarnianych_20200225.pdf

2.2.3. Data

Data, concerning the energy needed for production of materials, have been estimated using Inventory of Carbon & Energy (ICE) Version 2.0[4] - for lumber and steel wire (nails), Eco-profiles of the European Plastic Industry[5] - for polypropylene.

The emissions due to electric energy production and diesel oil combustion were adopted from PARP (Poland) conversion tables[6].

Data, concerning manufacturing of plastic pallets studied, road transport fuel consumption, used in the model, are based on hands on experience. Data concerning Reference Service Life of pallets are mainly based on experience; we have chosen high values for wooden, and low values for plastic pallets.

3. Pallets surveyed

We surveyed two specific 1200 x 800 mm pallet models: wooden – EPAL EUR-1, and plastic – AGP-S. Both models can be used for storing loads in high racks and fulfil foodstuff transport requirements: wooden pallet - for a limited time, and plastic pallet - for life. Other differences, existing between the two models, are not directly relevant for the study.

3.1. Wooden Pallets

3.1.1. MAKE

EPAL[7] EUR-1 wooden pallets are made of wooden boards and blocks, joint with steel nails. The weight of the EPAL EUR-1 pallet is stated at approximately 25 kg[8]. We assume the material input at 25 kg of kiln dried softwood lumber (e.g., pine) and 0,38 kg of steel nails per pallet. Each material carries energy, and emissions deriving from processes prior to arriving at the pallet assembly point: wood 7MJ/kg, nails 30 MJ/kg. We assume the energy input of 0,7 kWh for the assembly process[9] and 4 kWh for heat treatment per pallet, which is to initially protect

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[4] Hammond, G.P; Jones, C.I. (2011) *Embodied energy and carbon in construction materials*. Geoff Hammond & Craig Jones Sustainable Energy Research Team (SERT) Department of Mechanical Engineering University of Bath, UK (2011)

[5] Eco-profiles of the European Plastic Industry, Polypropylene (PP), 11, (2005)

[6] Polska Agencja Rozwoju Przedsiębiorczości, https://www.parp.gov.pl/storage/grants/documents/103/Wytyczne-dotyczce-konwersji---emisje-gazw-cieplarnianych_20200225.pdf

[7] EPAL - THE EUROPEAN PALLET ASSOCIATION - founded in 1991, EPAL has focused on developing and safeguarding l open pooling system for load carriers (wooden pallets) worldwide.

[8] The EN-13698 presents the weight of wooden elements at 21,9 kg, however e.g., EPAL, CHEP, IPP, that manufacture and use compatible pallets, state 25 kg as an approximate weight in their product descriptions. Our experience confirms 25 kg to be correct for pallets “out of the manufacturing process”, due to low moisture level. Otherwise, they may weight substantially more.

[9] Deviatkin, I; Hortanainen, M. (2020) Carbon Footprint of an EUR-sized wooden and plastic pallet. E3S Web of Conferences 158, 03001 (2020)

it against pests and fungi, according to International Phytosanitary Measure IPSM-15[10]. We do not take eventual paint, anti-pest chemical agents, clips, inhouse transport, nor transport to the first user, etc., in our model, into account.

3.1.2. USE

EUR-1 type wooden pallets are commonly used in Europe[11] being sold with the goods, exchanged within the so called "open" pool systems (white pallets), or close pool systems (color pallets)[12]. Reference Service Life (RSL) – number of work cycles before withdrawal from usage – vary case by case. Calculations based on pallet stock count, number of trips covered, and numbered of pallets acquired to substitute for those withdrawn from operations, at a given time, show that a wooden pallet, used intensively in FMCG and Retail Goods distribution sector, e.g., within supermarket networks, lasts 5 - 8 trips. These findings correspond to some data found in literature. The fuel used and CO_2 emission per EUR-1 EPAL pallet, due to transport for the distance of 100 km has been calculated respectively: 0,045354 l. and 0,119733 kg CO_2.

3.1.2.1. Repair

It is commonly understood that wooden pallets can be repaired, increasing RSL value, before final withdrawal. Deviatkin [13], assumed 20 trips in total and 2 repairs per wooden pallet before final withdrawal, at the end-of-life. This might be true in some cases but cannot be considered as average for the market. According to EPAL, in 2020, for over 600 million pallets that had been in use, 97,5 million new pallets had been introduced, and 26,2 million repaired pallets reintroduced into the system[14]. No more than 5 % of the total number of pallets in the EPAL system were subject to repair. Should we count for 10 pallet trips before the need of first repair, and additional 5 trips afterwards (no "space" left for the second repair to occur) the RSL of an average wooden pallet would be up by 0,25 trip. **Remake process does not apply.**

The question could be asked whether it is possible to increase the number of wooden pallets repaired and by how much. As simple as the pallet construction may look like, it should be assembled with a high degree of precision and consistency, using strictly defined materials, of size and quality. The holes in boards and blocks of disassembled pallets remain. You would not hammer nails into or close to these holes, understanding that the pallet might be used at high racks with a load of close to 1000 kilograms on the top.

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[10] IPSM-15 https://www.ippc.int/en/core-activities/standards-setting/explanatory-documents-international-standards-phytosanitary-measures/
[11] EPAL alone claims over 600 million pallets in use https://www.epal-pallets.org/eu-en/news/news/details/article/production-of-epal-pallets-at-a-high-level-in-2019-again.
[12] CHEP, IPP, etc. pallet providers on rental basis
[13] Deviatkin, I; Hortanainen, M. (2020) *Carbon Footprint of an EUR-sized wooden and plastic pallet.* E3S Web of Conferences 158, 03001 (2020)
[14] EPAL-PALLETS, https://www.epal-pallets.org/eu-en/news/news/details/article/epal-pallet-production-increases-despite-covid-19-pandemic

Taking above into consideration, we assume wooden pallet RSL for 10 trips in our model before being withdrawn from service. We disregard repairs.

3.1.3. WASTE

Should we assume that the number of pallets used in trade as constant, all new pallets introduced compensate for the pallets withdrawn permanently form operations. In case of EPAL it can be therefore approximately 100 million pallets withdrawn from the system in 2020. There are three methods of dealing with withdrawn wooden pallets:

3.1.3.1. incinerate – that some claim to be a welcomed process of "recovering energy" [15],
3.1.3.2. mulch and use as live-stock bedding or soil fertilizer,
3.1.3.3. landfill.

All these scenarios lead to CO_2 emission due to energy applied for "forced" process of dismantling, segregating, mulching, and transporting of wasted pallets, and "natural" process of wood decomposition resulting with biogenic carbon. Wood decomposition varies in time: burning takes minutes, decomposition of mulched wood can last months, decomposition of wooden elements left to rot, may last years. Whatever scenario we chose, 1 kg of wood upon complete decomposition will release 1,65 – 1,80 kg CO_2[16] . Disregarding energy costs and carbon emissions of different methods of pallet disassembling and waste treatment, we take into our model the amount of 1,7 kg CO_2 emission per every kg of wasted pallet wood - biogenic carbon, and weight of nails - solid waste.

3.2. Plastic Pallets

3.2.1. MAKE

AGP-S plastic pallets are made of polypropylene (PP). Prime Energy Demand for PP is estimated at 73 MJ/kg[17]. Each pallet weights 11,7 kg; weights and dimensions are consistent. AGP-S pallets are rackable and nestable. The pallet production line has been based upon YIZUMI UN 2300 DP molding machine, consuming 2,5 kWh of energy per single pallet manufacturing process. Polypropylene PP is fully recyclable and reusable in consecutive injection cycles, maintaining strength and durability of the products made[18].

Each AGP-S pallet is identified with unique code, beneficial when pallets are in the use and ultimately, when they are withdrawn from operations, preventing uncontrollable landfill which happens all to often in case of unidentified objects no more needed.

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[15] Carrano, A.L; Thorn, B.K; Woltag, H. (2014) *Characterizing the Carbon Footprint of Wood Pallet Logistics*. Forest Products Journal 64(7):232-241

[16] Carbon storage using Tibber, https://www.accoya.com/app/uploads/2020/04/Carbon-Storage-Using-Timber-Products.pdf

[17] Eco-profiles of the European Plastic Industry, Polypropylene (PP), page 11, 2005.

[18] Kloziński, A; Jakubowska, P. (2009) *Chosen Properties of Multiple Recycled PP/PS Blend* Mechanika, Wydawnictwo Politechniki Krakowskiej, 2009.

3.2.2. USE

Plastic pallets in general are noticeably more durable and long-lasting then their wooden counterparts[19]. They can be cleaned and disinfected, yet another advantage. AGP-S pallets maintain these features alike. Basing on tests and proven record, we assume AGP-S pallet RSL at 80 trips in our model. The fuel used and CO_2 emission per AGP-S pallet, due to transport for the distance of 100 km has been calculated respectively: 0,030255 l. diesel and 0,079872kg CO_2.

3.2.2.1. Remake

We assume that due to adopted model of operations, and EU "plastic tax"[20] regulations, the risk of intentional landfill is minimalized, and 100 % of initial material used for constructing pallets is returned by the users, back for remanufacturing.

After withdrawal from service, pallets and their parts are fragmented with Hammerman HR 1000 crusher using 1 kWh energy per pallet. To compensate for potential quality loss up to 20% of virgin material is added to the batch of recycled plastic. As the recycled plastic comes only from original AGP pallets, process efficiency and product quality are maintained. Remaking a pallet ultimately requires 3,5 kWh energy and 2,34 kg of virgin PP. **Repair process does not apply.**

3.2.3. WASTE

Unlike wooden pallets, 100% of the material from withdrawn plastic pallets can be reused in consecutive remanufacturing processes. Polypropylene is virtually non-biodegradable, does not easily come in chemical reaction with the environment, should not and needs not to be landfilled or incinerated. In our model, excessive 20% of recycled material is used for manufacturing items other than AGP-S pallets.

4. Results

4.1. Life Cycle Inventory

According to our study a single EUR-1 wooden pallet production process, "from cradle to gate", generates 43,67 kg CO_2, while AGP-S plastic pallet manufacturing is responsible for

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[19] It's not uncommon for a plastic pallet to serve 100-200 trips before withdrawal.
[20] COUNCIL DECISION (EU, Euratom) 2020/2053 of 14 December 2020 *on the system of own resources of the European Union* and repealing Decision 2014/335/EU, Euratom

186,33 kg CO_2. Should we use each pallet one-time, plastic pallet would add to **environmental burden over four times** as much as wooden counterpart.

Tab. 4.1

measure unit	MATERIALS	PED (MJ/kg)	kWh	kg CO2/ measure unit	
kg	softwood lumber kiln dried (pine)	7			
kg	steel nails (HDG steel)	30			
kg	polypropylene PP	73,37			
	PROCESSES				
1 pallet	wooden pallet assembly		0,70		
1 pallet	wooden pallet heat treatment (IPSM-15)		4,00		
kg	wood decomposition			1,6	
1 pallet	plastic pallet injection molding		2,50		
1 pallet	plastic pallet recycling (crushing, washing)		1,00		
	ENERGY				
1 MJ	MJ/kWh		0,2778		
1 kWh	emission due to electrical power production (PL mix)			0,7733	
1 liter	diesel fuel			2,64	
	MAKE	**WOODEN PALLET**		**PALSTIC PALLET**	
	MATERIALS				
kg	wood	25		-	
kg	nails	0,38		-	
kg	plastic PP	-		11,7	
	ENERGY				
kWh	assembly/pallet	0,70			
kWh	heat treatment/pallet	4,00			
kWh	injection molding/pallet			2,50	
kWh	CUMULATIVE ENERGY Ready to Use	56,4778		240,9525	**PP/WOOD**
kg	CUMULATIVE kg CO2 Ready to Use	43,6743		186,3286	**426,63%**

Source: own research

4.1.1. Replacing withdrawn pallets

Remaking and replacing plastic pallet generate 39,59 kg CO_2. Our assumption is that wooden pallet replacement is always done with a new item. Wooden pallet replacement generates slightly higher carbon footprint than its plastic counterpart.

Tab 4.1.1

	REMAKE/REPLACE	WOODEN PALLET		PALSTIC PALLET	
	virgin added to recycled			20,00%	
kg	plastic - PP			2,34	
kWh	energy		3,50		
	REPLACE	56,4778		51,1905	**PP/WOOD**
		43,6743		39,5856	**90,64%**

Source: own research

Polypropylene recycling process seems not to adversely affect it's mechanical characteristics. Khademi, F. et al[21] conclude "…using a higher percentage of recycled material will not have a significant effect on the mechanical properties of polypropylene. This finding is the main contribution of this research because of its potential benefit to plastic industries and to the

[21] Khademi, F; Ma, Y; Ayranci, C; Choi, K; Duke, K. (2016) *Effects of Recycling on the Mechanical Behavior of Polypropylene at Room Temperature Through Statistical Analysis Method* POLYM. ENG. SCI., 00:000–000, 2016. VC 2016 Society of Plastics Engineers

environment. That means, to reduce costs, more recycled material can therefore be used without a significant reduction in material performance….”.

4.1.2. Reference Service Life and CO_2 emissions in transport

Due to the weight difference in favor of plastic pallet, it generates some 30 % less CO_2 emissions than wooden pallet. Regarding the design the material used, AGP-S plastic pallet can cover 8 times more trips – RSL = 80 trips, than wooden pallet – RSL = 10 trips.

Tab 4.1.2

	FEATURES			
trips	RSL - Reference Service Life (trips to withdrawal)	**10**	**80**	
liters	diesel fuel used to transport a pallet/ 100 km	0,0454	0,0303	**PP/WOOD**
kg	kg CO2 emission per pallet/100 km	0,1197	0,0799	**66,71%**

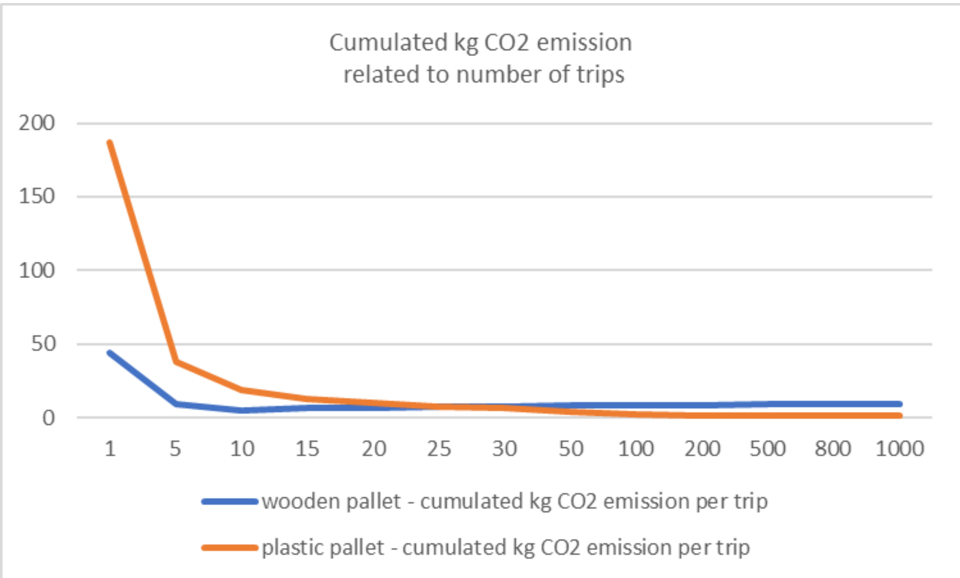
Source: own research

4.2. Life Cycle Assessment

4.2.1. Functional Unit: 1000 trips/1 pallet

Calculating the use of a single wooden and single plastic pallet in a process to cover 1000 trips, replacing any of them, when Reference Service Life is completed, shows the need to replace wooden pallets 99 times, and plastic pallet 12 times. CO_2 emission in transport alone is 30% lower, when using plastic pallets. Cumulating emissions due to transport and replacements, plastic pallets generate 80 % less carbon footprint, than when wooden pallets are used.

Graph. 4.2.1.



Source: own research

Tab 4.2.1

	SCENARIO				
trips	FU - Functional Unit	**1 000**		trips total number	1 000
pallets	**PC - Pool Count ("pool pallets")**	**1**		periods	1
km	trip distance (from loading to loading)	**400**		standard trip distance	100
		WOODEN PALLET		**PALSTIC PALLET**	
	POOL'S PRIME ENERGY NEED AND CO2 EMISSION				
1 kWh	energy	56,48		240,95	**PP/WOOD**
1 kg	CO2	43,67		186,33	**426,63%**
	FEATURES				
trips	RSL - Reference Service Life (trips to withdrawal)	**10**		**80**	
liters	diesel fuel used to transport a pallet/ 100 km	0,0454		0,0303	**PP/WOOD**
kg	kg CO2 emission per pallet/100 km	0,1197		0,0799	**66,71%**
	USE				
	TRANSPORT				
liters	Transport - diesel fuel consumption	181,41		121,02	**PP/WOOD**
kg	Transport - kg CO2 emission	478,93		319,49	**66,71%**
	POOL MAINTENANCE - REPLENISHMENT				
life	RSL's per "pool pallet"	100		12,5	
pallets	number of pallets withdrawn	99		**12**	
pallets	numbers of pallets repaired	0	**0,00%**	0	
pallets	number of pallets remade	0		12	**100,00%**
pallets	number of pallets replaced with new pallets	99,00		0,00	
pallets	number of pallets wasted	99,00		0,00	
kg					
	REMAKE				
1 kWh	energy			588,69	
kg	CO2 emission			455,23	
	REPLACE				
1 kWh	energy	5 591,30			
kg	CO2 emission	4 323,75			
	SUBTOTAL				**PP/WOOD**
kg	CO2 emission	4 846,36		961,05	**19,83%**
	WASTE				
kg	wood	2 475,00			
kg	CO2 wood decomposition	3 960,00			
kg	plastic recycled to be used in other products or industries			26,91	
	CO2 plastic decomposition				
kg	nails	37,62			
kg	CO2 nails decomposition				
	TOTAL				**PP/WOOD**
kg	CO2 emission	8 806,36		961,05	**10,91%**

Source: own research

Adding CO_2 emissions due to wood decomposition on the top, we find plastic pallet operations generating 10% carbon impact comparing scenario when wooden pallet is used. As for solid waste, 37,62 kg of nails fall into wooden pallet account, and 26,91 kg of Polypropylene PP recycled is to debit plastic pallet account. Both can be reused, however recovering, and reusing nails seems to be more problematic, than reusing plastic scrap.

4.3. Functional Unit: 15.000.000 trips / 500.000 pallets – 1 year

Real life scenarios require a significant number of pallets allowing to serve wide streem of supplies, starting from "day one". Creating a pool of half a millon plastic pallets generates, naturaly, far more CO_2 emissions, than the respective pool of wooden pallets. However comparing the total emission of CO_2 already at the end of the "year one"shows, that using plastic pallet should lead to limiting CO_2 emissions by 13% in comparison to wooden pallets. No solid waste, while replacing wooden pallets would find us with 380 tons of nails to be recycled, provided they are not scaterd around.

Tab. 4.3.

	SCENARIO				
trips	FU - Functional Unit	**15 000 000**		trips total number	15 000 000
pallets	**PC - Pool Count ("pool pallets")**	**500 000**		periods	1
km	trip distance (from loading to loading)	**400**		standard trip distance	100
		WOODEN PALLET		**PALSTIC PALLET**	
	POOL'S PRIME ENERGY NEED AND CO2 EMISSION				
1 kWh	energy	28 238 888,89		120 476 250,00	**PP/WOOD**
1 kg	CO2	21 837 132,78		93 164 284,13	**426,63%**
	FEATURES				
trips	RSL - Reference Service Life (trips to withdrawal)	**10**		**80**	
liters	diesel fuel used to transport a pallet/ 100 km	0,0454		0,0303	**PP/WOOD**
kg	kg CO2 emission per pallet/100 km	0,1197		0,0799	**66,71%**
	USE				
	TRANSPORT				
liters	Transport - diesel fuel consumption	2 721 212,12		1 815 272,73	**PP/WOOD**
kg	Transport - kg CO2 emission	7 184 000,00		4 792 320,00	**66,71%**
	POOL MAINTENANCE - REPLENISHMENT				
life	RSL's per "pool pallet"	3		0,375	
pallets	number of pallets withdrawn	1 000 000		**0**	
pallets	numbers of pallets repaired	0	**0,00%**	0	
pallets	number of pallets remade	0		0	**100,00%**
pallets	number of pallets replaced with new pallets	1 000 000,00		0,00	
pallets	number of pallets wasted	1 000 000,00		0,00	
kg					
	REMAKE				
1 kWh	energy			0,00	
kg	CO2 emission			0,00	
	REPLACE				
1 kWh	energy	56 477 777,78			
kg	CO2 emission	43 674 265,56			
	SUBTOTAL				**PP/WOOD**
kg	CO2 emission	72 695 398,33		97 956 604,13	**134,75%**
	WASTE				
kg	wood	25 000 000,00			
kg	CO2 wood decomposition	40 000 000,00			
kg	plastic recycled to be used in other products or industries			0,00	
	CO2 plastic decomposition				
kg	nails	380 000,00			
kg	CO2 nails decomposition				
	TOTAL				**PP/WOOD**
kg	CO2 emission	112 695 398,33		97 956 604,13	**86,92%**

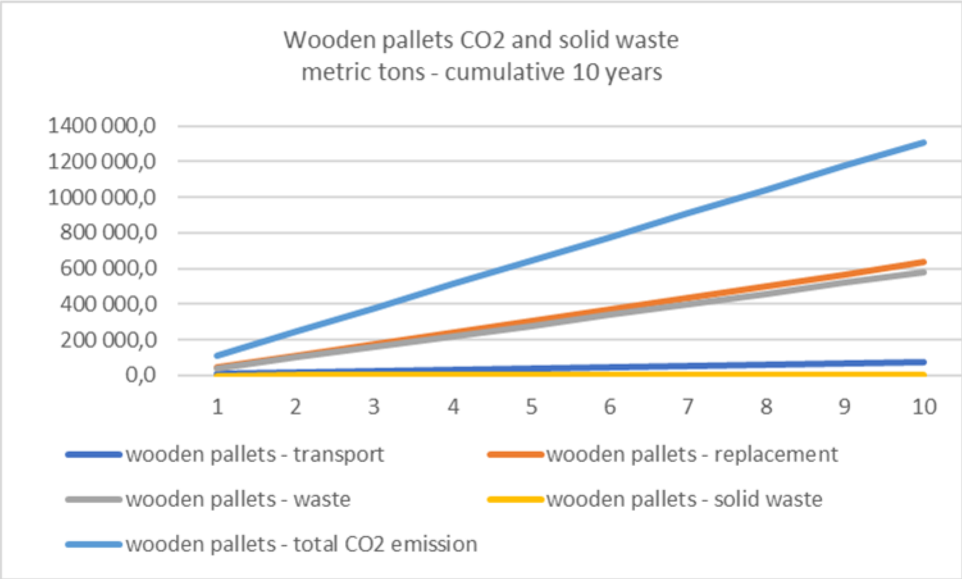
Source: own research

5. Discussion

5.1. Functional Unit: 15.000.000 trips / 500.000 pallets / years 1-10

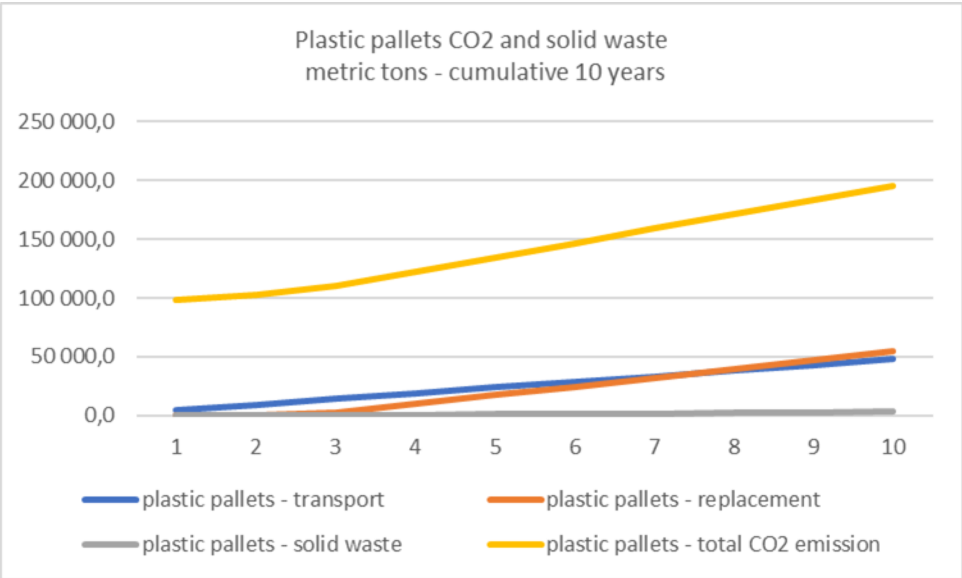
With the exception of initial fabrication, the incremental value of each use and renewal parameter is significantly higher for wooden pallets. It's already the first year-end showing environmental advantage of using plastic pallets agains wooden pallets.

Graph 5.1



Source: own research

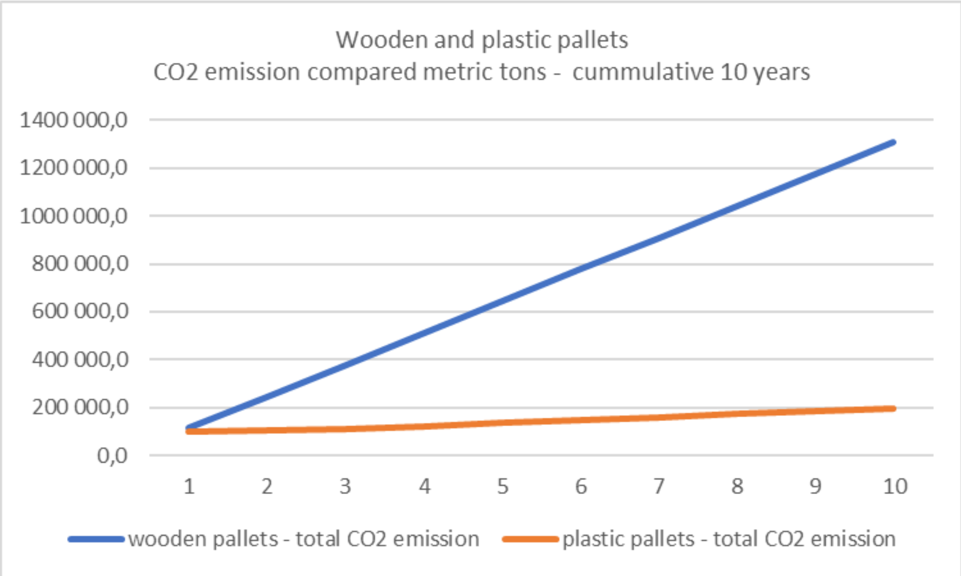
Graph 5.2



Source: own research

In 10 years accumulated CO_2 emissions with wooden pallets will exceed the emissions created by plastic pallets operations by 6 times.

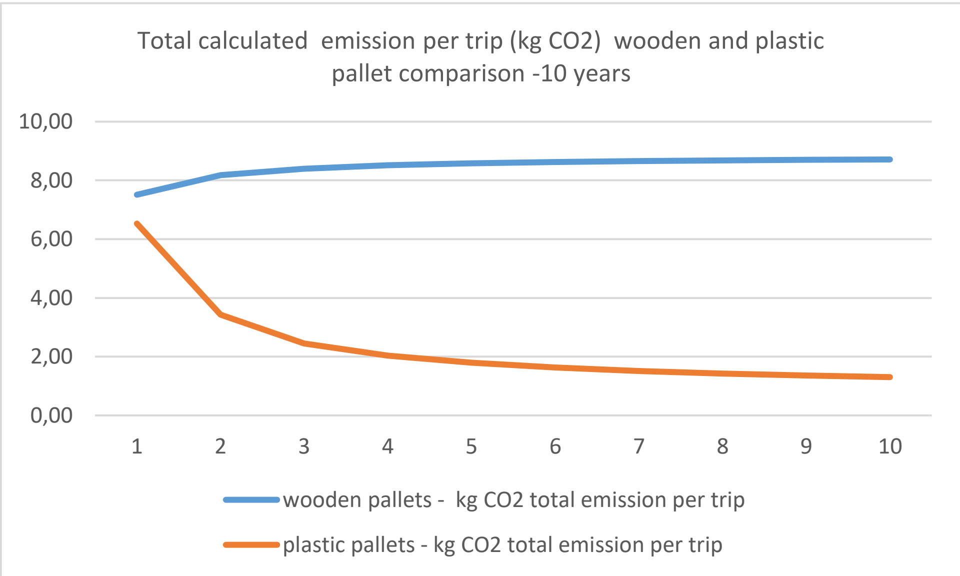
Graph 5.3



Source: own research

In year 10, the gap between single transport CO_2 emissions when we compare plastic and wooden pallets would have reached 85% .

Graph 5.4



Source: own research

6. Conclusions

Plastic pallets have already proven their performance: durability and longevity, when used in the market. Our study shows, that quite contrary to common feeling, they may be a welcomed alternative to wooden pallets in terms of environment as well. Substantially lower carbon footprint and no solid waste generated in comparison to wooden pallets, should at least rise interest and boost research as to wider implementation of plastic pallets. Study shows that multiple use, both the items and material they are being made of, is the key factor in reducing the burden on the environment. The impact of initial production is an important element of the LCA; however, all other elements must be considered as well. Finally, we seem to have far too much "plastics" available, more than we would have wished for, and not that many trees left to cut and take away from our forests.

As mentioned above, we see the results of our work, and the way we share it, as our contribution to paving further activity, which we hope could be agreed upon, aiming at limiting CO2 emissions, and limiting deforestation, due to replacing wood (scarce resource) , with plastic (recycle "waste" in excess, as for now, into raw material). This is the direction of further research and practical implementation of plastic pallets into existing supply chains.

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