

## Article

# Pallet Use and Transport in Italy: Comparing the Carbon Footprints of Standard Exchange and Nolpal's Alternative Strategy

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**Abstract:** As global trade continues to intensify, the role of pallets becomes increasingly crucial, as they are essential for the movement of goods worldwide. Wooden pallets are the most common packaging type in Italy and Europe, and their widespread use in distribution and freight transportation means that the relatively minor environmental impact of an individual pallet is greatly magnified by the overall scale of operations. The management of pallets can significantly influence both the emissions and the costs associated with pallet operations. This work presents a case study representative of the emerging trends in sustainable transportation and logistics in Italy, aiming to compare the carbon footprint of the standard pallet exchange system with the system employed by the company Nolpal. Unlike the conventional exchange model, which requires companies to purchase and own EPAL pallets, Nolpal provides leased pallets to the market across Italy, supported by a nationwide network of collection hubs. A comparative life cycle assessment (LCA) between the Nolpal system and the conventional pallet exchange system showed that Nolpal's approach achieves a 35% reduction in CO<sub>2-eq</sub> emissions. These findings highlight how the company's model could serve as a blueprint for future advancements in more sustainable pallet management strategies.

**Keywords:** life cycle assessment; carbon footprint; wooden pallet; pallet supply chain; sustainability



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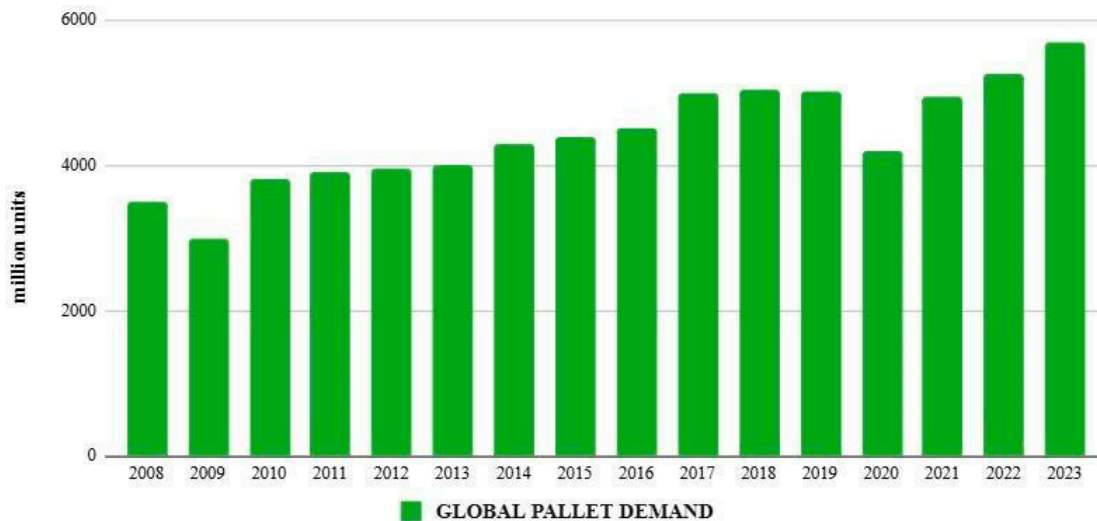
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## 1. Introduction

A broad scientific consensus indicates that environmental impacts resulting from human activities over the past century have significantly contributed to global warming. The exponential rise in industrial activities has the potential to destabilize Earth's ecosystems, leading to adverse impacts on human life on the planet. In the current era, sustainability, encompassing environmental, social, and financial dimensions, has become a critical strategic asset for companies seeking growth and innovation. Advancements in the circular economy are prompting companies to re-evaluate their logistics and production processes, driving the adoption of optimization strategies and eco-sustainable innovations wherever feasible. In today's interconnected world of expanding mobility and burgeoning trade, materials and commodities must be safely transported across various sectors of the economy: from suppliers to manufacturers, manufacturers to warehouses, warehouses to retailers, and ultimately to consumers.

Pallets have played a transformative role in logistics management. Given the profound changes in warehousing and shipping practices globally, pallets have become indispensable in modern shipping operations [1].

As shown in Figure 1, data from Freedonia indicate the global demand for pallets is constantly growing and is projected to increase by 4.0% annually, reaching nearly 7 billion units, with a market value of USD 83.6 billion by 2028 [2].



**Figure 1.** Global pallet demand from 2008 to 2023 (Freedonia World Pallets).

Given the vast number of pallets in circulation at any given time, they represent a significant investment for many companies and substantially contribute to environmental impacts. The management of pallets can have a considerable effect on both the environmental footprint and the costs associated with their operations.

Founded in 2011, Nolpal was the first Italian company to introduce a nationwide EPAL pallet rental system [3]. Nolpal is continually developing new strategies to minimize impacts during logistic operations, addressing challenges in the current system with the aim of reducing costs and improving environmental sustainability. The Nolpal chain enables the rental of EPAL pallets to customers for goods delivery while managing the most complex aspect of the exchange system: the return process. By optimizing the transportation network through strategically located logistics hubs and distribution centers that minimize travel distances, Nolpal addresses some of the most critical challenges in transportation systems, identified in recent studies and findings [4]. Throughout its lifecycle, the transportation is a critical stage of a pallet's use, meaning that pallets contribute to emissions as they and their cargo move through the supply chain. The main freight transportation methods rely on fossil fuels, and transporting pallets consumes them, leading to increased emissions of carbon dioxide and other pollutants [5].

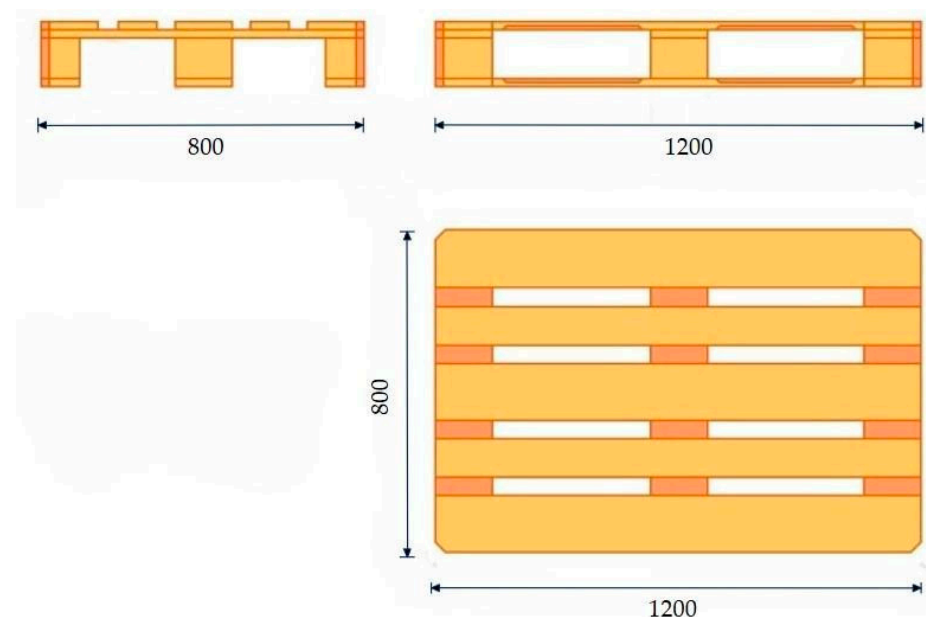
The purpose of this study is to evaluate the environmental impact of Nolpal's EPAL pallet management strategy using the life cycle assessment (LCA) methodology, supported by the openLCA software. The findings indicate that incorporating Nolpal's system into pallet exchange operations significantly enhances the sustainability of the logistics supply chain. Specifically, the results show a marked reduction in carbon dioxide emissions.

## 2. Background

### 2.1. Pallet Definition and Characterization

As defined by the SFS-EN ISO 445 standard, pallets are “rigid horizontal platforms of minimum height, compatible with handling by pallet trucks and forklift trucks and other appropriate handling equipment, used as a base for assembling, loading, storing, handling, stacking, transporting, or displaying goods and loads” [5]. Approximately 95% of pallets produced are made of wood, sourced from either hardwood or softwood [6]. The advantages of using wood for pallet production include its rigidity, durability, longevity, rapid availability, and relatively low cost [7]. Pallets can be classified into two main categories based on their material and usage:

- One-way pallets: These are low-cost, low-quality wooden pallets that do not adhere to specific measurement standards. These are non-reusable and are typically discarded after a single use, so there are no requirements for sanitization treatments [8].
- EPAL pallets: These pallets, shown in Figure 2, are certified, high-quality pallets often referred to as ‘standard pallets’ because they must comply with European regulations governing their dimensions, weight, and hygiene. EPAL pallets are made from 11 quality timber boards, nine woodchip or solid wood blocks, and 78 nails. These pallets primarily use wood from sustainable sources and are treated with fumigation processes to enhance their strength and hygiene. EPAL pallets are identified by a stamp marked on the side block.



**Figure 2.** EPAL pallet specifications.

As certified by the European Pallet Association, over 650 million EPAL pallets are in circulation worldwide, playing a crucial role in the industry and logistics sector [9].

- Plastic pallets: These are certified according to European and international standards; plastic pallets are often chosen for their light weight, a potentially indefinite lifecycle, and guaranteed hygiene and safety [10,11]. Unlike wooden pallets, they lack splinters and nails.

This study was carried out using the standard EPAL pallet, a non-reversible, four-way flat pallet weighing 25 kg. It has a safe working load of 1500 kg, and its dimensions are 1200 mm and 800 mm.

## 2.2. The Nolpal Company

This study examines the pallet distribution strategies of Nolpal, the first Italian company to introduce a revolutionary EPAL pallet rental system spanning the entire national territory, including the islands.

Founded in 2011, Nolpal is owned by Casadei Group and was originally established in Emilia Romagna as an experimental management company. After several years of development and shareholder agreements, the company fine-tuned its complex system. In 2015, following rapid advancements in its EPAL pallet management model, Nolpal launched its operational service nationwide.

Nolpal specializes in EPAL standard pallets, which are widely recognized in international logistics due to their standardized design, ensuring compatibility across various systems and countries. Nolpal's system is flexible and advantageous, enabling customers to access high-quality pallets in the desired quantities, anywhere in Italy. This approach reduces costs associated with purchasing, managing, storing, and recovering empty pallets.

Unlike the standard exchange model, which requires companies to purchase and own EPAL pallets, Nolpal positions itself as the pallet owner. It offers pallets to the market as fungible goods for entities within the supply chain. Nolpal's process involves leasing pallets to clients, using them in their supply chains, and ensuring the return of an equivalent quantity and quality of pallets.

The system also supports deferred exchanges. In this scenario, the recipient of the goods issues a pallet voucher, allowing for the later collection of pallets equal in quantity to those received but not immediately exchanged [12].

## 2.3. Pallet Exchange in Italy

In Italy, the standard EPAL pallet exchange system involves two main stakeholders:

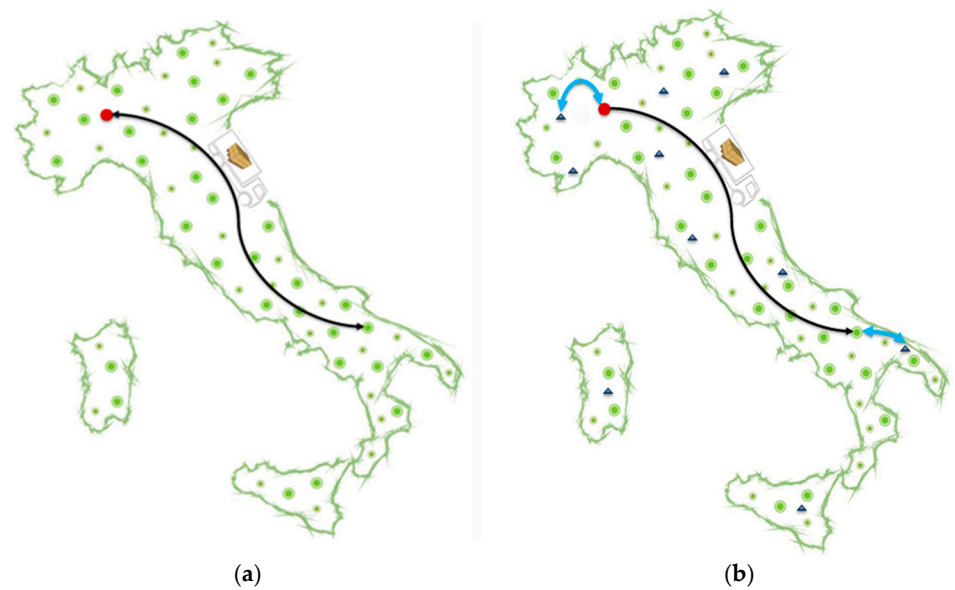
- Trademark industries: these companies purchase and own EPAL pallets, using them to ship branded products to their destinations.
- Large-scale retailers: these are the stores where the products shipped by trademark industries are sold.

Given the distances between these two entities across Italy, the standard exchange model can be logistically challenging and environmentally taxing. Nolpal addresses these issues by acting as the pallet owner and offering a leasing system supported by a national network of over 40 collection sites, known as Nolpal Points. These collection sites serve as distribution hubs, enabling efficient returns and exchanges of pallets. Nolpal Points function as loading and unloading stations, ensuring punctual and precise delivery and collection of rented pallets.

This system enhances logistic efficiency, reduces the distance traveled by trucks transporting goods and pallets, minimizes transportation impacts, and lowers operational costs and pallet wear.

The differences between the two logistics models are depicted in Figure 3, where:

- The red bullet represents the trademark industry under consideration.
- The green bullets represent the retailers associated with it.
- The blue triangles mark the Nolpal points, which are distributed across Italy.
- The blue arrow consists of the distance traveled between the trademark industry and a retailer.
- The cyan arrows depict shorter distances, specifically between one Nolpal points and the retailers and the trademark industry respectively.



**Figure 3.** Representation of: (a) standard EPAL pallet exchange; (b) Nolpal EPAL pallet exchange.

#### 2.4. Pallet Exchange Systems Analyzed

Four distinct pallet exchange systems were evaluated:

- Scenario A (Standard Deferred System): This system involves four trips and two trucks. The first trip delivers goods on pallets from the trademark industry to the large-scale retailer. After delivery, the truck returns empty to the company. A second truck is then dispatched empty to the retailer to collect the pallets and return them to the trademark industry.
- Scenario B (Standard Direct System): This scenario involves two trips using a single truck. Goods are delivered on pallets to the retailer during the first trip, and the same truck returns the unloaded pallets to the trademark industry during the second trip.
- Scenario C (Nolpal Deferred Exchange): This scenario optimizes the process described in Scenario A by involving Nolpal as a third party. After the goods are delivered to the retailer and the truck returns empty, a second empty truck is sent from the nearest Nolpal Point to the retailer. The pallets are collected and routed to the Nolpal Point instead of being returned to the original sender.
- Scenario D (Nolpal Direct Exchange): Similar to Scenario B, this scenario involves two trips with one truck. However, once pallets are delivered and unloaded at the retailer, they are directly routed to a nearby Nolpal Point instead of being returned to the trademark industry.

These scenarios were analyzed using life cycle assessment (LCA) methodology to evaluate and compare their carbon footprints.

### 3. Methodology

Life cycle assessment is widely used to evaluate different pallet types and processes. However, studies specifically analyzing the environmental impacts of pallet lifecycle stages are limited. For instance, Bilbao et al. provided a detailed review of the activities affecting the sustainability of logistics throughout the whole pallet lifecycle [13]. Similarly, Franklin Associates found that pooled pallets impose a lower environmental burden than single-use pallets [14].

Despite these contributions, questions remain about emissions and overall impacts of pallet supply chains, particularly concerning how to improve the sustainability of existing pallet management systems.

This study aims to address these gaps by analyzing the environmental burdens of traditional and innovative pallet management and transportation systems. The LCA results will serve as a framework for providing recommendations to decision-makers in the field.

Like every LCA study, this work will be composed of the following stages: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation of results.

### 3.1. Goal and Scope

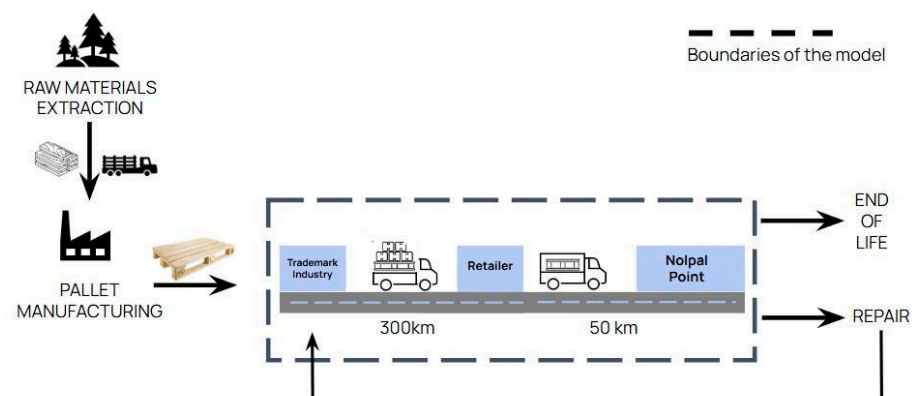
The primary objective of this research is to calculate the carbon footprint of the EPAL pallet management strategy employed by Nolpal in comparison to standard exchange models.

The functional unit, serving as the basis of comparison, is defined as 1000 cycles traveled by lorries. In this context, a “cycle” refers to the trips made within a supply chain, starting from the trademark industry to a specific retailer and to the nearest Nolpal Point. This functional unit, frequently used in similar studies, was selected because it provides a consistent framework for comparing the studied scenarios [15].

The calculations were conducted using the globally recognized IPCC 2021 methodology. The IPCC regularly publishes assessment reports that include emissions metrics for Global Warming Potential. Among the impact categories assessed, this study focuses on the ‘Climate Change, Global Warming Potential (GWP100)’ category, which measures the Global Warming Potential over a 100-year time horizon. This impact category encompasses emissions from biogenic, fossil, and land use sources.

The analysis was conducted by following the requirements stated in the ISO 14040 (EN ISO 14040:2006) and ISO 14044 (EN ISO 14044:2006) [16,17]. The Ecoinvent 3.10 database was used for data input during the calculations.

The lifecycle of EPAL pallets includes the production of hardwood and softwood lumber, pallet manufacturing, sanitary treatment, use and transportation, and end-of-life treatment [18]. However, as shown in Figure 4, this study specifically focuses on the transportation and use phases of pallets’ lifecycle, excluding other stages from the system boundary. This exclusion is primarily justified by the purpose of the LCA, which aims to inform the carbon footprint impacts of pallet management decisions. Additionally, the transport phase represents a significant environmental impact for EPAL pallets. Indeed, even if the use phase of wooden pallets is characterized by high variability and uncertainty, numerous studies, including those conducted by the United States Department of Agriculture, highlight that this phase contributes the most to the overall carbon footprint of a pallet’s life cycle [19]. Moreover, since our study focuses on EPAL pallets rather than one-way pallets, the raw material sourcing and manufacturing phases have a relatively lower impact on the pallet’s lifecycle.



**Figure 4.** Life cycle of EPAL pallet and system boundaries of this study.

The geographical scope of this study is limited to Italy, where the Nolpal network operates.

### 3.2. Life Cycle Inventory

The data used for the analysis were directly provided by Nolpal and covers the period from June to December 2023. The dataset pertains to a single trademark industry managing 7915 shipments to almost 1000 retailers, with subsequent operations carried out at 38 Nolpal Points across Italy. This comprehensive dataset ensures a reliable and robust foundation for modeling environmental impacts.

Due to the large volume of data, weighted average values were calculated for specific parameters, as reported in Table 1.

**Table 1.** Parameters' values.

Parameter	Weighted Average Value
Number of pallets per cycle	11
Distance between trademark industry and retailer	300 km
Distance between retailer and Nolpal Point	50 km

The analysis compares the pallet use and transportation phases across the four pallet management systems previously described:

- Scenario A: Standard Deferred Exchange;
- Scenario B: Standard Direct Exchange;
- Scenario C: Nolpal Deferred Exchange;
- Scenario D: Nolpal Direct Exchange.

Since specific data on the types of trucks used for transportation were unavailable, the modeling assumes the use of EURO 6 lorries. As stated by the European Automobile Manufacturers' Association, by 2025, Euro 6 heavy trucks will make up almost 60% of the EU fleet alone, standing as the most widespread type of heavy vehicles used [20]. In addition to this, according to the ANFIA (National Association of the Automotive Industry Supply Chain), heavy-duty vehicles with a weight exceeding 16 tons were by far the most diffused among industrial vehicles in 2023 in Italy, accounting for 83% of the total.

Since our study considers data referring to 2023, EURO 6 lorries within the 16–32 metric tons size class have been selected for the calculations [21].

As previously mentioned, this study focuses on EPAL1 pallets, whose specifications are summarized in Table 2.

**Table 2.** EPAL pallet specifications.

Parameter	Value
Pallet weight	25 kg
Safe working load	1500 kg
Pallet dimensions	1200 × 800 mm

For practical purposes, the systems were divided into virtual subsystems called unit processes, with inputs and outputs identified for each. The four scenarios are composed of either four or two unit processes, depending on the number of trips in each scenario. The unit processes are defined as follows:

- UP1 (Delivery of Goods Supported by Pallet): Common to all scenarios, this unit process involves transporting goods from the trademark industry to the retailer, located 300 km away.

- UP2 (Empty Return Trip of the First Lorry): Included only in Scenarios A and C, this process refers to the return trip of the empty lorry to the company.
- UP3 (Empty Trip of the Second Lorry to Reach the Retailer): Exclusive to Scenarios A and C, this process accounts for the distance traveled by a second lorry to reach the retailer; varying based on the Nolpal Point is part of the system.
- UP4 (Return Trip with Pallets Only on the Lorry): This process differs across scenarios. In Scenarios A and B, pallets are returned to the trademark industry. In Scenarios C and D, the inclusion of Nolpal reduces the trip distance to 50 km, as the pallets are routed to the nearest Nolpal Point.

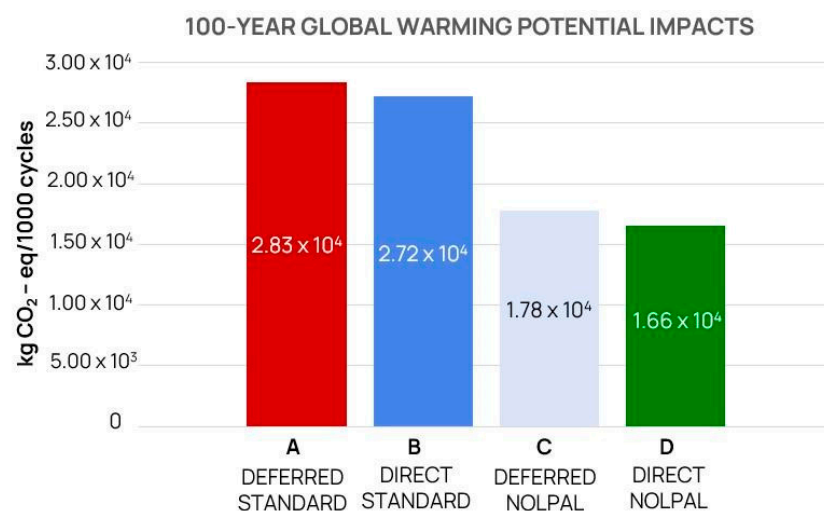
Throughout this study, it was crucial to consider that while the use phase includes transportation segments where pallets are loaded with products—specifically UP1—the emissions impact is limited to those caused by the tare weight of the pallet on that loaded segment. This approach methodology aligns with numerous other studies in the field, which adopt a similar approach when calculating emissions during the use phase [22].

For the final modeling process, specifically the return trip of the lorry, a corrective factor of 0.8 was applied to the calculations. This factor was considered to adjust for the 20% reduction in emissions, typically observed during trips when the truck is unloaded, as compared to fully loaded trips. This corrective factor of 0.8 is derived from findings in several studies and reports, which consistently show that carbon dioxide emission factors for trucks carrying full loads are generally 20% higher than for those running without a load. This distinction is observed because loaded trucks require more energy for the transportation due to their increased weight, leading to higher fuel consumption and, consequently, greater emissions. By applying this factor, this study reflects these patterns in transportation logistics, providing a more accurate model for emission calculations during the use phase of the life cycle [23,24].

The LCA comparison highlights differences in carbon emissions, transportation efficiency, and overall sustainability, shedding light on the advantages of Nolpal's optimized pallet exchange systems over traditional approaches.

### 3.3. Life Cycle Impact Assessment

The results, shown in Figure 5, provide precise values for the GWP 100 category. As depicted, the systems implemented by Nolpal (represented by Scenario C and Scenario D) achieve a significant reduction in CO<sub>2</sub>-eq emissions.



**Figure 5.** Hundred-year Global Warming Potential Impacts for all scenarios.

When focusing on the individual stages of the whole process of pallet transport and use, the most substantial reduction in CO<sub>2</sub> emissions is observed during the return trips carrying only pallets. Figure 6 illustrates this, with CO<sub>2</sub>-eq emissions dropping from 12,500 kg in Scenarios A and B to 2089 kg in Scenarios C and D.

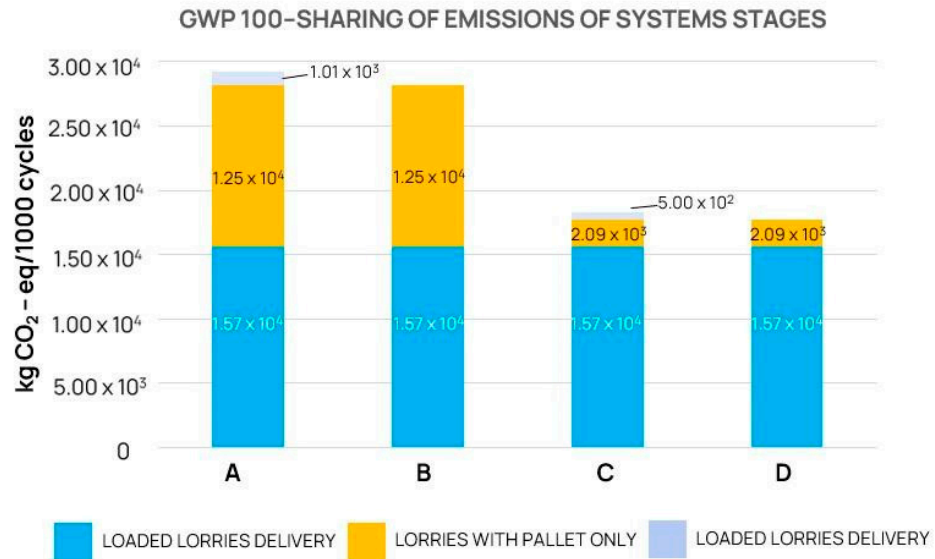


Figure 6. GWP 100—Sharing of emissions of the system stages for all scenarios.

Furthermore, as shown in Figure 7, the contribution of trips carrying only pallets to overall emissions also markedly decreases. In the standard system (Scenarios A and B), these trips account for 44% of total emissions, whereas in the Nolpal system (Scenarios C and D), the figure drops to 11%.

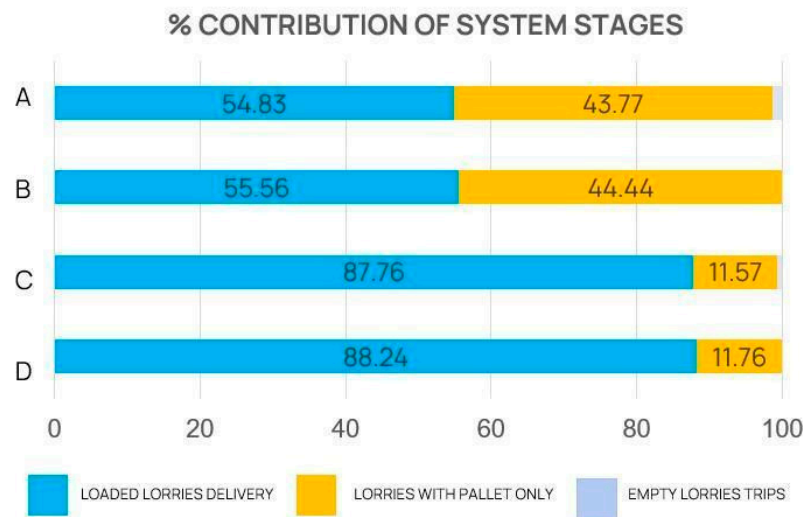


Figure 7. Percentage contribution of the stages of the systems for Scenario A, Scenario B, Scenario C and Scenario D.

#### 4. Interpretation of the Results

The analysis clearly demonstrates that incorporating Nolpal Points into the supply chain significantly enhances the sustainability of both direct and deferred exchange systems. Specifically, Scenarios C and D show a 35% reduction in CO<sub>2</sub>-eq emissions compared to the traditional. This improvement is primarily attributed to Nolpal’s extensive network of collection points across Italy, which enables lorries to travel significantly shorter distances.

The reduced travel distance decreases emissions associated with diesel consumption, lorry maintenance, and other contributors to environmental impact.

It is important to note that emissions cannot be reduced beyond certain limits. For example, during the initial stage of goods delivery from the trademark industry to the retailer, emissions remain constant across all four scenarios. However, other stages of the supply chain show significant reductions, particularly in the return trips for pallet recollection (UP4). These results highlight how Nolpal effectively concentrates most of its emissions in the first stage of the cycle, making the rest of the supply chain substantially more sustainable.

## 5. Discussion and Limitations

The results of this study offer a detailed comparison of traditional pallet exchange systems and those managed by Nolpal. The Nolpal's system addresses one of the key contributors to carbon emissions in logistics: minimizing empty trips and reducing transportation distances. Furthermore, the Nolpal system has significantly enhanced the economic performance of the trademark industry under consideration; by opting for a rental model rather than maintaining an owned pallet fleet, the trademark industry has achieved a reduction in the costs associated with pallet management; the approach proposed by Nolpal offers improved flexibility, allowing the trademark industry to adjust pallet quantities based on fluctuating demand, thereby avoiding overstocking or shortages.

Nonetheless, this study has limitations, such as focusing only on the transportation stage of the pallet lifecycle, excluding production and end-of-life phases. Future studies could expand this scope by incorporating these additional stages to provide a more comprehensive lifecycle analysis of the systems under investigation.

Moreover, the findings suggest that continuous innovation in supply chain management is critical. Logistics stakeholders and policymakers should consider adopting models similar to Nolpal's to achieve ambitious sustainability targets.

## 6. Conclusions

This study emphasizes the significant environmental benefits of Nolpal's innovative pallet management system, demonstrating a 35% reduction in CO<sub>2</sub>-eq emissions compared to traditional exchange models. By leveraging a network of strategically located collection points, the Nolpal system optimizes logistics processes while significantly reducing travel distances. This approach offers a scalable solution for more sustainable supply chain operations.

While emissions during the delivery phase of goods remain consistent across all scenarios, Nolpal's system delivers major improvements in the return phases, mainly due to a reduction in empty trips. These results underscore the potential for systemic innovations to dramatically reduce the environmental impact of logistics. Future research should explore the scalability of similar models in other regions while also incorporating additional lifecycle phases, such as pallet production and end-of-life treatment, to provide a more holistic view of sustainability.

Ultimately, this study underscores the need to transition toward more circular and resource-efficient logistics systems. It also offers a valuable framework for policymakers and business leaders seeking to address the sustainability challenges of international trade.

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