



ASSOCIAZIONE  
RETE ITALIANA LCA

# ATTI

X Convegno dell'Associazione Rete Italiana LCA  
*XV Convegno della Rete Italiana LCA*

# INNOVAZIONE E CIRCOLARITÀ

Il contributo del *Life Cycle Thinking*  
nel Green Deal per la neutralità climatica



**22-24 settembre 2021**

**Università Mediterranea  
di Reggio Calabria**

Via dell'Università, 25  
Reggio Calabria



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# Simplified Life Cycle Assessment (LCA) of a semi-finished aluminium product

Paolo Di Giorgio<sup>1,2</sup>, Ioannis Arzoumanidis<sup>1</sup>, Andrea Raggi<sup>1</sup>, Luigia Petti<sup>1</sup>

*Abstract:* In the field of aluminium architectural windows and doors, Life Cycle Assessment (LCA) implementations have been carried out, although these do not explicitly concern the analysis of semi-finished products, except for a small number of case studies in the framework of EPDs. For this article, a simplified LCA of a semi-finished aluminium product was carried out and a comparison with an equivalent product was proposed. The results showed that some production steps such as pre-treatment and painting seem to be the most impacting for all environmental impact categories considered, due to the chemicals used. In addition to mitigation measures towards limiting these impacts, the challenge for the near future will be to find alternative solutions that ensure both production efficiency and sustainability.

## 1. Introduction

The Italian economy began showing the first signs of weakness ever since 2008, following the explosion of the economic and financial crisis that began in the United States during the previous year (Di Quirico, 2010). In this context, the construction sector has witnessed a progressive collapse in investment, which has brought it to the levels of the mid-1970s (ANCE, 2012). It was not until 2016 that there were the first signs of recovery, culminating in a growth spike in 2018. However, the sector had to suffer a new setback due to the COVID-19 health emergency. As for the window and door sector, a process of radical change in the market shares of the three most used materials (aluminium, wood and PVC) has been underway since 2014. The market share of aluminium has shown a fair held by 2019 despite the growth of PVC, thanks to investments in new residential construction. Even though 2020 was a particularly complicated year for the construction sector, more comforting forecasts contrast with this scenario for 2021. The windows and doors markets should be driven by tax incentives that will support investment spending and the opening of new construction sites for public works (UNICMI, 2021).

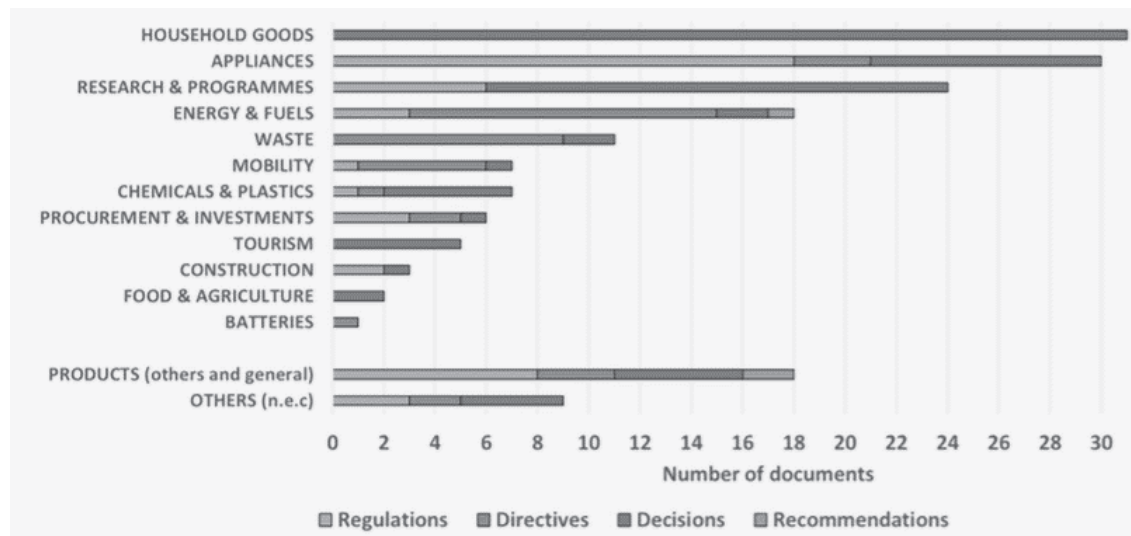
Over the past 30 years, Life Cycle Thinking (LCT) and Assessment has moved from academic implementation to wider applications in society (Sala *et al.*, 2021). The European Union with an increasing number of legal acts and communications, has recognised LCT, LCA, Life Cycle Costing (LCC), and environmental footprinting (the European Environmental Footprint of Products and Organisations PEF/OEF), as useful approaches to support environmental impact assessment, implementation measures and monitoring needs (Figure 1). From the Ecolabel Regulation in 1992, to the Green Deal in 2019, life cycle considerations have been of particular interest in the EU (Sala *et al.*, 2021).

<sup>1</sup> Department of Economic Studies, University "G. d'Annunzio", Pescara, Italy

<sup>2</sup> Ponzio Aluminium Frames, Pineto (Teramo), Italy

\* Email: [ioannis.arzoumanidis@unich.it](mailto:ioannis.arzoumanidis@unich.it)

Figure 1: Relative distribution of sectors addressed in the 159 classified policies (Sala et al., 2021)



This has also affected the construction industry when it comes to addressing environmental sustainability issues. Recently, products used in construction, such as windows and doors, have been the subject of LCA studies that assess the environmental and resource efficiency performance of processes and products (Buyle et al., 2013). These tools can guide consumer choices and product supply chains through the knowledge of potential risks.

This study aims at assessing the environmental impact of a semi-finished aluminium product via a simplified LCA implementation. The article is structured as follows: The Goal and Scope is defined in Section 2, whilst the Life Cycle Inventory is illustrated in Section 3. In Section 4, the results are analysed and discussed. Finally, some conclusions are drawn in Section 5.

## 2. Goal and Scope Definition

Ponzio S.r.l. is a B2B company located in Abruzzo, Italy, specialised in the surface treatment, design and production of aluminium systems for architecture. Ponzio S.r.l. markets useful products to produce windows, facades, sliding windows, etc., and one of this is assessed in this study. The product is a semi-finished aluminium profile Frame “Z” (Figure 2) that belongs to the Ponzio aluminium system family called *WindStop*. Semi-finished aluminium products are those “intermediate” products that have undergone an initial industrial process but require further processing in order to define their final use and marketing.

The assessed product is a part of the WS65THI system that allows the production of windows, vasistas, monobloc frames, pivoting windows, door-windows, and doors. *Ponzio Wind-stop* series is marketed in different aesthetic lines using different profiles for design and specific weight but similar in performance and physical characteristics.

The Functional Unit (FU) is an aluminium profile, thermally insulated, powder-coated, 6.5-meter long, of a weight of 9.36 kg. The system boundary (Figure 3) was set as cradle to gate, due to the desire to assess only the potential environmental impacts of the production of the semi-finished product, thus including the following phases: acquisition of raw materials, their transport to the facilities of Ponzio, the production of the semi-finished product and packaging. In order for preliminary results to be obtained, a simplified LCA tool was used for this study, name-

ly CCaLC2 (Manchester University, 2021), which focuses mainly on Global Warming potential, but tackles also other environmental impact categories.

Figure 2: section of Frame “Z” 365701H

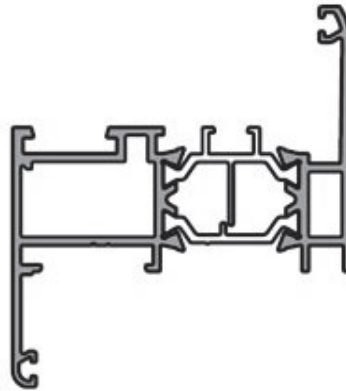
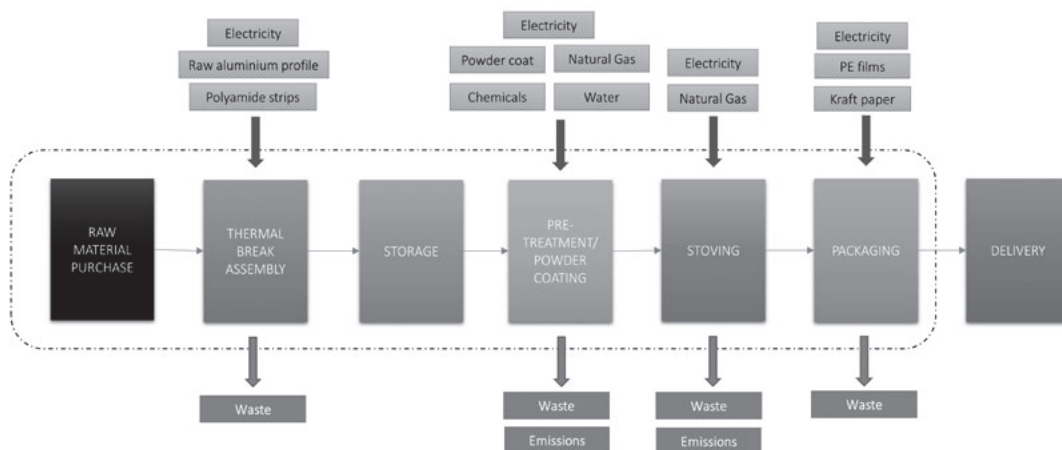


Figure 3: Flow chart (system boundary in the dotted line)



### 3. Life Cycle Inventory

An initial quality control is performed, before the raw materials are destined for production. Following this control, the raw aluminium profiles are destined to the assembly process (thermal break assembly), where two profiles are mechanically connected by two strips of polyamide. The raw material of polyamide strip is nylon and glass-fiber (PA 6.6 GF25). Thermal break is an insulation technique used on aluminium frames because it limits condensation and reduces temperature exchange between the outside and inside of the frame. Once the thermal break profile is created, it is sent to the storage warehouse waiting to be picked up for surface treatment. One of the treatments performed in-house is powder coating, which is considered within this study. This is a multi-stage process. The profile to be painted initially undergoes a pre-treatment phase (anti-corrosive treatment) with degreasing and pickling agents, a fundamental step to guarantee the protection of the profile from atmospheric agents and to eliminate any impurity. In this phase, chemicals such as mixtures of acids, bases and a mixture containing chromium trioxide are used.

Subsequently, the pre-treated products are oven-dried (max 100°C), before being coated with synthetic resin-based paint powders. Finally, the coated aluminium profiles are sent to the po-

lymerisation oven, where the previously sprayed powders are melted, thus adhering perfectly to the surface of the profile. The process takes place at a temperature of around 180°-200°C for a duration of around 20-25 minutes. At the end of the coating process, the final quality control takes place with the packaging process.

In this case study, on-site primary data were used, and the corresponding flows and processes were carefully selected from the CCaLC2 tool. During the modelling phase, in the absence of datasets within CCaLC2 that faithfully represent the products used, “proxy” datasets have been identified and chosen that were close to reality. This is the case also of the mixture containing chromium trioxide, which was replaced by a generic process “chromium oxide”.

With regard to the transport of raw materials, in the absence of accurate data and due to the heterogeneity of the means of transport used, following a precautionary approach, it was assumed that suppliers used a diesel-fuelled medium-sized cargo (EURO 5 emission category) to deliver their goods. With regard to air emissions, data representative of the pre-treatment/powder paint process have been reported, based on information obtained from certificates of analysis made available by the organisation and related to periodic sampling by a certified third party. Concerning the packaging phase, raw materials included in this study are kraft paper and polyethylene film.

Finally, with regard to wastes, end-of-life information was recovered from the Waste Identification Form of the company. In these documents, there is an indication of the destination of the waste (Recovery or Disposal) and the recipient. The modelling in CCaLC2 was performed based on existing data and considering two options: landfill for waste destined for disposal and incineration for waste destined for recovery. For both options, the “worst case scenario” was used to describe them, thus maximising the environmental impacts.

#### 4. Life Cycle Impact Assessment and Discussion

The tool provides only the characterised results of the implementation; therefore, only these will be shown and discussed. As aforementioned, CCaLC2 provides *in primis* the results for Global Warming (GW) (Figures 4-5).

Figure 4: Carbon Footprint results – source CCaLC, screenshot.

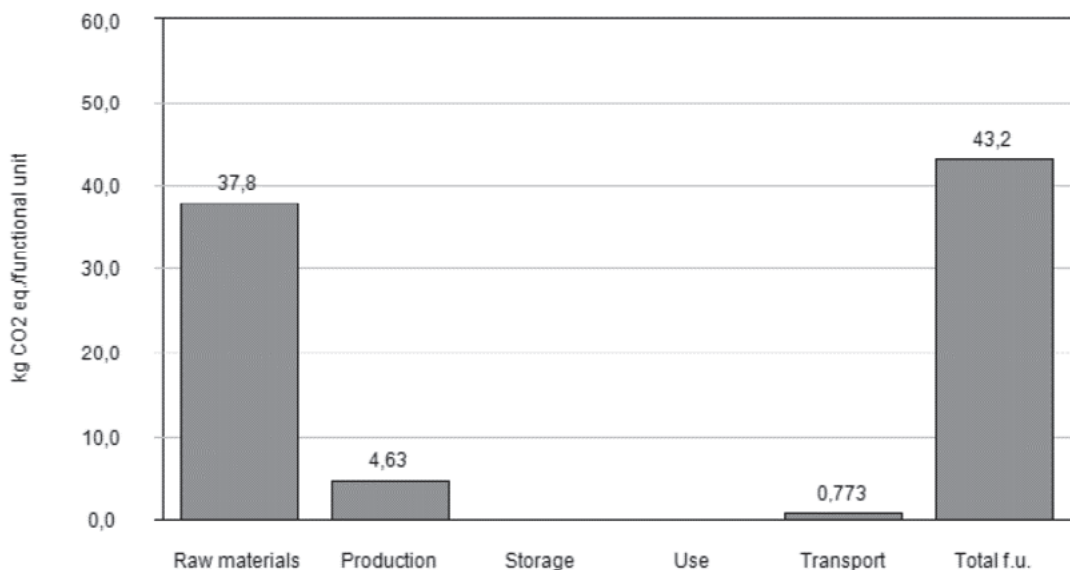
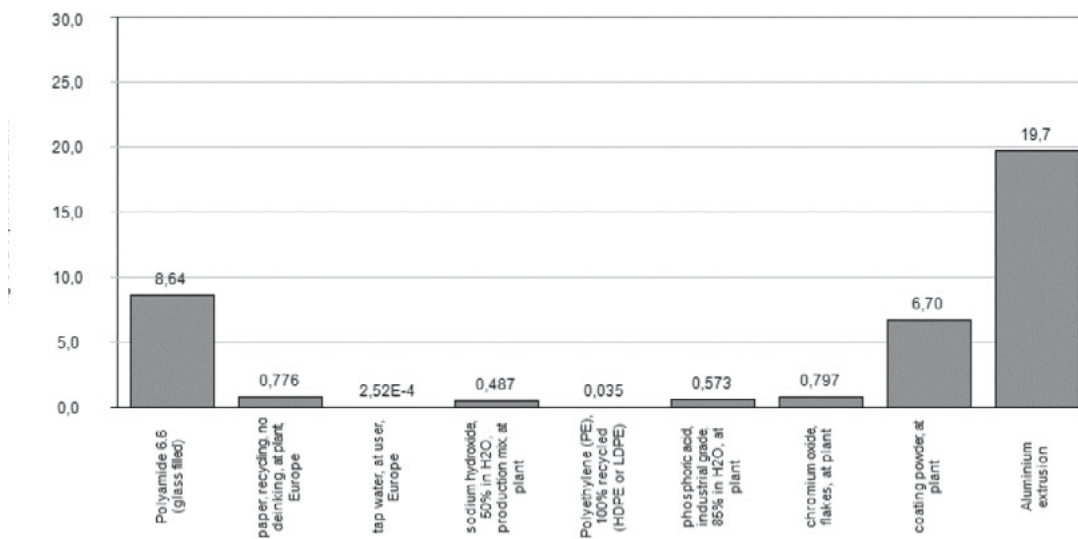


Figure 5: Carbon Footprint results (raw materials) – source CCaLC, screenshot.



The results showed that the use of raw materials was the most impacting, followed by production and transport (Table 1). A more detailed analysis showed that the largest impacts within what CCaLC2 calls “raw materials” were aluminium extrusion, followed by polyamide 6.6 (glass-filled) and coating powder (Figure 4).

Table 1: Characterisation results – source CCaLC, elaborated by the Authors.

Impact Category	Unit	Total	Raw materials	Production	Transport
<b>Global Warming</b>	kg CO <sub>2</sub> eq	43.2	37.8	4.63	0.773
<b>Acidification</b>	kg SO <sub>2</sub> eq	0.204	0.142	0.058	0.0037
<b>Eutrophication</b>	kg PO <sub>4</sub> <sup>-3</sup> eq	0.035	0.027	0.0069	0.00097
<b>Ozone Layer Depletion</b>	kg R11 eq	0.0000033	0.000003	0.0000002	0.0000001
<b>Photochemical Smog</b>	kg C <sub>2</sub> H <sub>4</sub> eq	0.011	0.00779	0.00261	0.00012
<b>Human Toxicity</b>	kg C <sub>6</sub> H <sub>4</sub> Cl <sub>2</sub> eq	476	426	49.8	0.172

Regarding other environmental impact categories, CCaLC2 provides the results of the characterisation phase of LCIA, although the software highlighted the fact that a small number of processes were not connected to the environmental impact calculations (please refer to Table 1). For Acidification (AC), Photochemical Smog (PS) and Ozone Layer Depletion (OLD), the use of aluminium in the thermal break assembly phase was found to be the most impacting. On the other hand, for Eutrophication (EU) it was the use of coating powder, and for Human Toxicity (HT) it was the use of chromium oxide (proxy of the mixture containing chromium trioxide), both in the pre-treatment/painting phase, to be the most impacting. Despite the fact that the proxy that was chosen underestimated the impacts with respect to the highly hazardous chromium trioxide, HT still appeared to be greatly affected by it.

In order for more emphasis to be put on the results obtained, it was decided to make a comparison with equivalent semi-finished aluminium products. This was made with a published Environmental Product Declaration (EPD). Although aluminium as a product intended for use

in construction is considered a hot topic in LCA (Klöpffer, 2009), studies conducted so far considering this type of product, have mainly focused on the framework of EPDs. In Italy, Fresia Alluminio was the first European company in the aluminium semi-finished products sector to have its products certified with an Environmental Product Declaration (EPD) (Fresia Alluminio, 2021). It seems that the most recent certified Environmental Product Declarations are 2 for EPD Italy (EPD, 2020a; EPD, 2021a) and 2 at an international level (EPD, 2020b; EPD, 2021c).

All previous EPD-related studies had defined a different system boundary and were therefore not comparable to the case proposed in this study; however, in one case (EPD, 2020), an analysis was made per life-cycle phase, which allowed for a comparison between that and this case study.

Regarding the only comparable EPD (EPD, 2020a), and after adjusting the results to the same FU, it appears that the potentials for all comparable impact categories were higher in this case study than the results reported by the EPD: e.g., GW: 5.28 kg CO<sub>2</sub> eq, AC: 0.0000024 kg SO<sub>2</sub> eq, EU: 0.014 kg PO<sub>4</sub><sup>-3</sup> eq, etc. This can be explained by the fact that the semi-finished aluminium product mentioned in the EPD (2020a) is not 100% primary aluminium, but it contains a percentage of recycled material and because the company in question does not use substances containing hexavalent chromium in the pre-treatment phase, but chromium-free chemicals.

## 5. Conclusions

The results showed that the pre-treatment/painting phases were the most impacting for all environmental impact categories that were considered. Within these, the use of coating powder in the painting phase and chemicals in the pre-treatment phase were found to be the most critical. The results of the analysis were found to be higher than the comparable results of the aforementioned published EPD (EPD 2020a). This result, as described in Section 4, can be justified by the use of chromium-free substances in the pre-treatment process. Future developments may include the implementation of a full LCA, along with a social LCA and Life Cycle Costing, in order to identify key sustainability issues for this product. This study confirmed what has been known for some time, namely the potential impact that chemicals used in pre-treatment, especially hexavalent chromium, have not only on the environment but also on human health. As it is well known, in February 2019, the REACH Committee of the European Chemicals Agency (ECHA) extended the authorisation for companies to use chromium trioxide until 2024. This could provide an impulse for industries to look for alternative coating methodologies. From now until 2024, the challenge will be to find a sustainable, cost-effective and versatile substitute for hexavalent chromium.

At present, Ponzio has been succeeding in mitigating the potential environmental impacts of the use of hexavalent chromium through the management of industrial wastewater in the wastewater treatment plant of the company. This water, once purified, is commonly discharged into the public sewage system. However, in order for the pollutant load that is still present in wastewater to be further reduced and for water to be saved, the company has conducted a major mitigation operation in recent years: the installation of a zero-water emission plant, capable of receiving water from the painting plant, purifying and reusing it in the production process within the company itself.

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